
Draft Report

Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin

Prepared for
USACE, Albuquerque District

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CH2MHILL®

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Acronyms and Abbreviations

AACE-International	Advancement of Cost Engineering International
af	acre-feet
af/mo	acre-feet per month
afy	acre-feet per year
B/C	benefit/cost
cfs	cubic feet per second
Cl-Br	chloride-bromide
Coalition	Rio Grande Salinity Coalition
dS/m	deciSiemens per meter
EBID	Elephant Butte Irrigation District
EC	electrical conductivity
EC	Engineering Circular
EPCWID#1	El Paso County Water Improvement District #1
EPWU	El Paso Water Utility
FWTWPG	Far West Texas Water Planning Group
gpm	gallons per minute
HCCRD#1	Hudspeth County Conservation and Reclamation District #1
HDPE	high density polyethylene
ISC	Interstate Stream Commission
kWh	kilowatt-hour
LVWD	Lower Valley Water District
M&I	municipal and industrial users
mg/L	milligrams per liter
MGD	million gallons per day
NED	national economic development
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPV	net present value
OA	Operating Agreement
P&G	Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies
PEIA	Preliminary Economic Impact Assessment
Program	Rio Grande Basin Salinity Management Program
RO	reverse osmosis
ROD	Record of Decision
SAR	sodium adsorption ratio
SDC	Service during Construction
TDS	total dissolved solids
TM	technical memorandum

tons/yr	tons per year
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WRC	U.S. Water Resources Council
WRCC	Western Region Climate Center
WRDA	Water Resources Development Act
WTP	water treatment plant
WWTP	wastewater treatment plant

Executive Summary

As part of the Rio Grande Basin Salinity Management Program (Program), the U.S. Army Corps of Engineers (USACE), New Mexico Interstate Stream Commission (ISC) and the state of Texas under Section 729 of the Water Resources Development Act (WRDA) 2007 have entered into an agreement to implement projects that study, account for, and ultimately intercept sources of salinity in the Rio Grande Basin. This report was prepared to build on previous watershed studies to identify projects that could be selected for a USACE-led feasibility study and implementation. It is organized to include details that would provide required documentation for a USACE Feasibility Study.

This report describes an economic analysis on the siting, construction, operation, and maintenance of salinity management alternatives to address downstream water quality within the Rio Grande. The Study Area for the project is generally the reach of the Rio Grande between Montoya Drain on the north and Fort Quitman on the south and areas of Texas served by water diverted within this reach.

Four alternatives were formulated and evaluated in this report to determine economic feasibility. Economic benefits for agriculture, municipalities, and industries, as well as potential project costs were developed for the four alternatives under a range of four potential salinity reduction scenarios (16 total modeled scenarios). Benefits were quantified based on salinity reduction outputs using the previously-developed salinity model with some updates. These salinity outputs were used as inputs to the economic model. Salinity and economic model outputs were used to summarize the existing and future-without-project conditions as a baseline for comparison to future-with-project conditions, as well as to conduct a benefit-cost analysis for the construction, maintenance and operation of each alternative.

Modeling Approaches

The project team conducted several interviews, meetings, and site visits to gather information for the economic analysis, including discussions with El Paso Water Utility (EPWU), Lower Valley Water District (LVWD), El Paso County Water Improvement District #1 (EPCWID#1), Hudspeth County Conservation and Reclamation District #1 (HCCRD#1), and Texas AgriLife Extension.

The salinity model simulates average flow and water quality in the Rio Grande and associated canal systems between El Paso and Hudspeth County. Updates to the salinity model included incorporation of additional flow and water quality data, updating the model to reflect future conditions, simulation of total dissolved solids (TDS) instead of chloride to facilitate analysis of economic benefits, and updates to simulate non-irrigation season in addition to irrigation season. The updated model simulates three development conditions, representing years 2010, 2020, and 2050.

The municipal and industrial (M&I) salinity cost component of the economic model is based on economic models from previous studies on the lower Colorado River, Central Arizona, and work completed by Michelson et al. (2009). The models include salinity damages to residential, commercial, public, industrial, landscape, and water utility assets. Most damages are in the form of reduced expected life of water-using residential appliances and facilities. Other damages include bottled water costs and landscape costs that involve the amount of water required for leaching.

The assessment of how salinity affects irrigated agriculture uses is based on a set of well-accepted relationships among irrigation water quality and quantity, root zone salinity, and crop yield. These were incorporated into a model developed to provide preliminary economic assessment of the agricultural costs of Rio Grande salinity (Michelsen et al., 2009). For the current analysis, the relationships were used to create a spreadsheet model to evaluate the impacts of salinity on crop yields and production costs. Recent data on crop acreages, yields, prices, water quality, and costs were used to update the analysis.

Modeled Future-Without-Project Salinity Damages

Urban water demand is forecast to increase significantly over the next four decades, while agricultural demand is forecast to decline somewhat compared to urban uses. Under 2010 conditions, salinity damages associated with residential water use indoors are estimated to be about \$56 million annually. Additional salinity damages for landscape (\$2 million), commercial (\$4 million), and industrial and treatment plants (\$0.1 million) bring total existing municipal and industrial users (M&I) salinity damages to about \$61.5 million, or roughly \$250 per household per year. Salinity damages from irrigation of agricultural crops are estimated to be about \$0.33 million per year.

Alternative Plan Formulation

Based on the sites and management measures presented above, four alternative plans were formulated to meet the project objectives, in addition to the no action alternative (**Table ES-1**). These alternative plans were modeled and assessed as part of the benefit-cost analysis conducted for this report.

Based on discussions with EPWU, the project team identified the potential for joint, multi-purpose alternative plans (B and D) that would address both the water quality objective of the project, contribute to economic benefits for water supply by selling water, and also contribute to regional water treatment capacity. EPWU future water supply planning includes a potential project that would install a new water treatment plant that would remove and de-salt up to 2,700 acre-feet of water from the Montoya Drain, then deliver the treated water to customers (Far West Texas Water Planning Group [FWTWPG], 2012).

None of the Alternative Plans would provide nearly as much new water supply as the FFWTWPG planning document suggests. One option is that the product water could be taken by EPWU over the winter months and the water would be introduced into their distribution system. Since none of the alternative plans provides nearly as much water as EPWU may want and additional treatment costs are unknown, this option is covered in the sensitivity analyses. Water supply from the alternative plans could also be provided to a dedicated water user who is not connected to the EPWU system. This dedicated user would take the new water supply all year.

TABLE ES-1

Formulated Alternative Plans

Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin

Alternative ID	Site	Groundwater Wells	Piping and Outfall Structure	Salinity Treatment	Purpose
No Action	-	-	-	-	<u>No action alternative</u>
A	Site 1	3	Yes	Reverse osmosis (RO) membrane	<u>Single:</u> Water quality
B	Site 1	3	Yes	RO membrane	<u>Multi:</u> Water quality Water supply
C	Site 2	3	Yes	RO membrane	<u>Single:</u> Water quality
D	Site 2	3	Yes	RO membrane	<u>Multi:</u> Water quality Water supply

The salinity scenarios presented in Table ES-1 were applied to each alternative to establish a range of potential salinity reduction outputs.

Economic analysis and results are provided for the single-purpose water quality project, and the multi-purpose, water quality and supply project.

The single-use project alternatives (Alternatives A and C) would be installed in Site 1 or Site 2, respectively. The facility constructed for this project would include a “wall of wells” constructed to maximize removal of the saline groundwater. For each site, this “wall” would include wells distributed throughout the site perpendicular to the flow of the saline groundwater through the aquifer. A pipeline would convey groundwater to the project water treatment plant (WTP) site. The WTP would remove a portion of the salinity from the water through treatment including reverse osmosis (RO) membranes. The RO system would remove salinity from the groundwater, producing a product water stream that would be sold or discharged to the river, and an RO concentrate water stream that would require disposal. The RO concentrate would be disposed of in evaporation ponds that would require ongoing operations and maintenance for disposal of the salt sludge.

The multi-purpose project (Alternatives B and D) would have an additional purpose of providing potable water supply for distribution. The water supply benefit is considered supplementary to the primary objective of reducing salinity in the Rio Grande. Groundwater wells would pull saline water directly from the salinity plume in the aquifer similar to the single-purpose alternatives.

This alternatives analysis report focuses on structural measures to intercept and remove dissolved salts that would otherwise enter the Rio Grande. Non-structural measures have not been specifically evaluated in this report. However, the future-without-project condition or No action Alternative Plan incorporates non-structural measure that water users are implementing to continue to respond to river salinity. Agricultural users would continue to use careful irrigation management, tillage practices, soil amendments, and crop selection to produce crops. Urban users would continue to replace appliances, equipment, fixtures, and pipes sooner, purchase additional soap and water softening supplies, and irrigate landscapes so as to reduce or avoid salt damage. These management activities come at a cost, as estimated in Sections 2.4.2 and 2.4.3. Under the future-without-project condition, all users would continue to bear the costs of responding to current and projected levels of river salinity.

Evaluate Benefits and Costs of Alternative Plans

A brief description of the benefits of each feasible alternative is provided below:

- For single-purpose Alternatives A and C, only benefits to water quality in the Rio Grande were accounted for. Overall, the benefits were substantially less than costs in all cases. Costs ranged from a Net Present Value (NPV) of \$6.7 to \$38.6 million. Project benefits of each alternative plan were about 4 to 17 percent of the costs.
- For multi-purpose Alternatives B and D, benefits to both water quality and water supply sales to a dedicated water user were accounted for. As with single-purpose alternative plans, the benefits were substantially less than costs in all cases. Costs ranged from a NPV of \$7.3 to \$47.6 million. Project benefits of each alternative plan were about 8 to 25 percent of the costs.

These results indicate that none of the alternatives would be economically feasible, and therefore, none would be acceptable to meet federal interests for national economic development (NED). As compared to the single-purpose alternative plans, the multi-purpose alternative plans are more economical even though costs are higher. In all alternative plans, using product water directly as supply, instead of returning it to the river, appears to improve project economics.

Findings and Recommendations

Because salinity reduction benefits from each site are largely independent of the other and should be additive, another alternative that may be considered in the future is to combine groundwater extraction from the two sites into one larger treatment facility to achieve a greater economy of scale. It may be possible to treat source water from two or more locations at one facility by piping the source water. Larger

facilities would appear to improve the cost-effectiveness, but the net effect on project economic performance is unknown.

While there are trade-offs between the two purposes, it is likely that a multi-purpose project would be more economical than two single-purpose projects (one for river water quality, and another for water supply). The water supply purpose is a secondary benefit that may improve the overall cost effectiveness of the project; thus, any additional costs that are solely associated with treatment, operation and maintenance, or distribution for water supply were not included as part of evaluation of effects for the alternative plans. However, the additional water supply benefits could be considered as part of comparison and selection of alternative plans, and may also affect cost sharing.

Section 4.4 provides a description of risks, uncertainties, and sensitivity analysis which illustrate the effect of some key assumptions and data limitations of this economic analysis. While none of the alternative plans would be economically feasible based on the economic analysis conducted for the Distal Mesilla Basin, the Coalition may still desire to pursue a project to address salinity reduction. The federal interest and cost sharing associated with any future project should be re-evaluated to identify potential for additional costs that could be funded locally. Some potential plan improvements for the Coalition and other stakeholders to consider are listed below:

- Economic benefits of longer municipal surface water treatment season
- Combine sites into a larger facility to achieve economies of scale.
- Sell product water to El Paso Water Utilities on a year-round basis.
- Reduce evaporation pond costs using alternative disposal methods.
- Include benefits for future downstream Mexico M&I uses.
- Add more water treatment to achieve more salinity reduction.
- A larger mass of salts than was modeled could possibly be removed during treatment.
- Greater salinity reduction in dry years could occur because flows are low, also longer duration.
- Develop a pilot or demonstration project to clarify costs and benefits.
- Any unplanned surface water treatment plant expansion in response to faster economic growth would increase the benefits.

This report provides an updated framework for economic analysis that could be applied to other project combinations involving single or multi-purpose projects in one or more locations. Given the scale of the overall Rio Grande Salinity Management Program, multiple management measures and projects are needed in combination to have an impact on the overall Rio Grande system.

The Study Area is highly developed and in most cases, previously disturbed by construction. The riparian corridor associated with the Rio Grande is an environmentally sensitive area and should be avoided to minimize environmental impacts and it should also be evaluated for other potential ecological improvements that may improve the benefits of the project.

Evaporation ponds to dispose of concentrated brine were the largest variable in alternative plan costs. Investigating alternatives to evaporation ponds would also affect the feasibility of the alternative plans. Due to the large amount of land that would be required for evaporation ponds, an alternative disposal plan could also further minimize the environmental impact of the project.

SECTION 1

Introduction

Based on previous studies and analysis, the purpose of this report is to conduct a detailed economic analysis for the Distal Mesilla site alternatives as included in the 2013 technical memorandum (TM) titled “Review of Findings of PEIA and Recommendations for Detailed Agricultural Economic Assessment” and in compliance with the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G; U.S. Water Resources Council [WRC], 1983). More specifically, this report includes an assessment of economic benefits for agriculture, municipalities, and industries, as well as proposed project costs for each alternative. Benefits were quantified based on salinity reduction outputs using the previously-developed salinity model, which were used as inputs to the economic model. Salinity and economic model outputs were used to summarize the existing and future without project conditions as a baseline for comparison to future with alternative conditions, as well as to conduct a benefit-cost analysis for the construction, maintenance and operation of each alternative.

1.1 Background

As part of the Rio Grande Basin Salinity Management Program (Program), the U.S. Army Corps of Engineers (USACE), New Mexico Interstate Stream Commission (ISC) and the state of Texas under Section 729 of the Water Resources Development Act (WRDA) 2007 have entered into an agreement to implement projects that study, account for, and ultimately intercept sources of salinity in the Rio Grande Basin. The Program is designed to address highly saline groundwater and surface waters, which have adverse impacts to potable water supplies, crop yields, and soil and groundwater deterioration. The Program includes development and evaluation of numerous water resources management actions, and specifically, potential project sites and salinity reduction approaches. Project implementation is undertaken by various partners and stakeholders based on available resources, occurs in multiple locations, and with various project extents for downstream benefits. As each activity or project is implemented, the cumulative Program benefits are increased. This Program concept is complementary to the concept of “Watershed Studies” as defined in the Engineering Circular “Watershed Plans” (EC 1105-2-411, January 2010), which defines Watershed Studies implemented under Section 729 of WRDA 1986, as amended, as follows:

“Watershed studies are planning initiatives that have a multi-purpose and multi-objective scope and that accommodate flexibility and collaboration in the formulation and evaluation process. Possible areas of investigation for a watershed study include water supply, natural resource preservation, ecosystem restoration, environmental infrastructure, recreation, navigation, flood management activities, and regional economic development. This multi-purpose approach is recommended since numerous entities within the boundaries of any watershed must agree with and support watershed improvement and management initiatives in order to successfully implement effective system-wide solutions.”

Based on the previous studies and analysis, this current report documents detailed economic analysis and benefit-cost evaluation to refine project design concepts based on site-specific details. These concepts were formulated into alternatives to determine the economic feasibility of a salinity reduction project in the Distal Mesilla Basin.

Table 1-1 provides a recent history of studies that have directly led to the work presented in this report. Each study builds on the last to hone in on a specific location for the most cost effective alternatives for salinity reduction projects. Each of these studies includes reference to many other reports, peer-reviewed literature, studies, and information that was used to complete the alternatives analysis. Under Section 729 of WRDA, the USACE gained approval from local sponsors and the Rio Grande Salinity Coalition (Coalition) to

contract with CH2M HILL beginning in 2010. CH2M HILL first assisted with an Alternatives Analysis to identify and screen areas of elevated salinity for further analysis based on salinity reduction potential. A formal decision support process was used to evaluate alternative site locations. The final ranking of sites, based on the attribute-to-cost ratios and further screened according to anticipated non-monetary attributes, yielded the Distal Mesilla Basin, Truth or Consequences, and Fabens as the preferred sites for additional investigations (CH2M HILL, 2011). Distal Mesilla Basin was selected first for further analysis due to the geological conditions, where formations cause highly saline waters to flow toward the surface within a small, confined area. Fabens was found to have a comparably large area for salt capture or interception, and saline flows were smaller at Truth or Consequences.

TABLE 1-1

History of Alternatives Analysis Studies*Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin*

Document	Date	Description
Alternatives Analysis for Rio Grande Salinity Management Program	2011	Used previous studies, characterizations, models, and analyses completed as part of the Program prior to 2007 when the Coalition was formed. Identified and screened salinity management alternatives to address six elevated salinity areas plus one river site, included water treatment options. Study resulted in three prioritized areas based on attribute-to-cost ratios. These three areas were further screened based on hydrogeological conditions and ability to intercept and remove salt from groundwater, including Distal Mesilla, Truth or Consequences, and Fabens.
Conceptual Site Model for Distal Mesilla	2012/2013	Distal Mesilla Basin was selected for further analysis because high saline groundwater could be intercepted in a relatively small, confined area. Two feasible sites were identified within the Distal Mesilla Basin for a potential salinity capture project. Conceptual design and treatment process elements were developed in this report for each site. Both sites were recommended for more detailed groundwater modeling and analysis.
Refinement of Site Screening Criteria	2013	For the two sites identified in the previous report, environmental factors and ranking criteria were developed to screen sites for groundwater extraction, treatment, and disposal.
Review of Findings of PEIA and Recommendations for Detailed Agricultural Economic Assessment	2013	This report provided a review of the previous Preliminary Economic Impact Assessment (PEIA) and a recommended approach to implement updated Economic Assessment for Distal Mesilla site alternatives.
Alternatives Analysis for Distal Mesilla Basin	2014 (current report)	Use modeling to establish existing and future conditions for comparison across project alternatives; establish economic feasibility by comparing benefit-cost ratios.

1.2 Distal Mesilla Project Objectives and Constraints

The objective of the overall Program is to reduce salinity in the Rio Grande, which is also considered to have Federal significance due to the complex multi-State, large-scale geographic reach. Within this Program, the Distal Mesilla Basin was selected for more detailed alternatives analysis to address elevated salinity problems within the Rio Grande Basin, primarily associated with high salinity upwellings from groundwater sources. By implementing salinity reduction measures within the Distal Mesilla Basin, there is an opportunity

to contribute to the overall salinity reduction efforts in the Rio Grande Basin. Two alternative project sites within the Distal Mesilla Basin were identified as having the highest potential for groundwater salinity interception and treatment. Alternative plans are described and evaluated in this report to determine the economic feasibility of implementing a salinity reduction project alternative.

The objective of a potential project within the Distal Mesilla Basin is to reduce downstream salinity in the Rio Grande, based on preliminary project concepts, local groundwater data, and salinity model results. This is in alignment with the Federal objective of water and related land resources project planning to contribute to national economic development (NED). As stated in the P&G,

“Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the Nation. Contributions to NED include increases in the net value of those goods and services that are marketed, and also of those that may not be marketed. A plan that reasonably maximizes net national economic development benefits, consistent with the Federal objective, is to be formulated. This plan is to be identified as the NED plan. (b) Other plans which reduce net NED benefits in order to further address other Federal, State, local, and international concerns not fully addressed by the NED plan should also be formulated.”

While identification of the NED plan is beyond the scope of this report, the analysis was designed to align with the NED principles. Of note, this report includes an evaluation of multi-purpose projects that may result in meeting the project objective, as well as providing a facility that could also accommodate additional water treatment capacity for a local water distribution system utility, El Paso Water Utility (EPWU). It should be noted that any benefits to provide additional water treatment capacity for EPWU are favorable, but were not considered to contribute directly to NED or the Federal project objective of salinity reduction in the Rio Grande. As such, treatment capacity benefits of a multi-purpose project were considered to be incidental and were not included in the economic analysis or the cost-benefit evaluation. An effort was made to describe these indirect benefits in this report. In later phases of this project, they may be considered as part of comparison and selection of the NED and locally preferred alternative plans. Further details regarding this alternative are described Section 3.4.

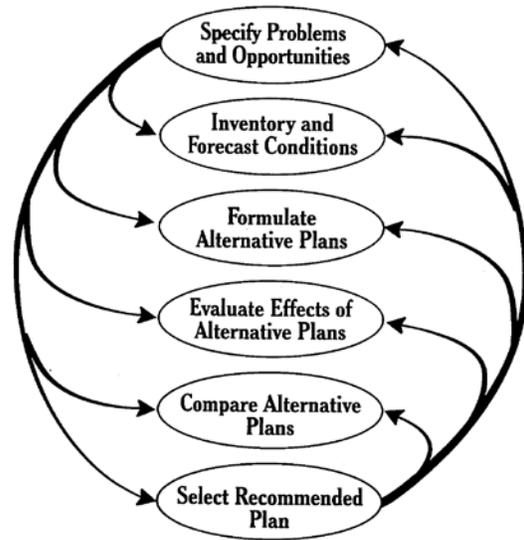
In addition to the project objectives, project constraints were also used to define the project, including the following:

1. Costs associated with additional water supply to local distribution systems will not be included in the federal cost share allocation; any associated water rights would not be addressed by this project.
2. The project should avoid negative source water quality impacts.
3. The project should avoid negative impacts to ecological communities and protected species.
4. The project should avoid negative impacts to municipal, industrial, and agricultural users.

1.3 Report Organization

This report was written to build on previous work and to follow the specific steps in the USACE six-step planning process (**Figure 1-1**), which is primarily to Evaluate Effects of Alternative Plans. All Feasibility Studies led by the USACE follow this six-step planning process, which is expected to be iterative, where steps are often repeated as more project understanding and details are developed.

This report was prepared as a supplement to watershed investigations, in anticipation that a project would be identified for a future feasibility study and implementation. It is organized to include details that would provide required documentation for a USACE Feasibility Study. To complete Feasibility, future phases of this project may include comparing and selecting alternative plans, environmental assessment under the National Environmental Policy Act (NEPA), and involving vertical USACE team members from the District to the Headquarters level in technical and policy reviews, 30-day public notice and comments, and a record of decision (ROD).



A brief description of each section of this report is provided below:

- Section 2 – Inventory and Forecast Conditions. Provides a geographic description of the Study Area, summarizes modeling approach, and presents the modeling results for the existing and future-without-project conditions (years 2020 and 2050) for natural resources, hydrology, and economic markets (i.e., municipal and industrial and agricultural).
- Section 3 – Alternative Plan Formulation. To improve future conditions presented in Section 2, Section 3 identifies locations and measures that could be applied in multiple combinations and under modeled groundwater salinity scenarios. The project team evaluated these locations and measures to formulate alternative plans, which are described at the end of Section 3.
- Section 4 – Effects of Alternative Plans. The approach and results for estimated costs and benefits of each formulated alternative plan are described, followed by the benefit-cost analysis. The analysis is then evaluated against USACE-defined parameters for effectiveness, completeness, efficiency, and acceptability. An analysis of risk, uncertainty, and sensitivity is also concluded.
- Section 5 – Findings and Recommendations. Summarizes results and implications for future decisions.

Inventory and Forecast Conditions

Existing and future-without-project conditions are described in this section, following a brief description of the study area and a summary of the salinity and economic modeling approaches. Further detail for each model is provided in the appendixes.

2.1 Geographic Description of the Study Area

The Study Area for the project is generally the reach of the Rio Grande between Montoya Drain on the north and Fort Quitman on the south and areas of Texas served by water diverted within this reach (**Figure 2-1**). More specifically, the study area includes:

- The Rio Grande itself, including the natural and ecological resources affected by or dependent on it
- Locations of the alternative extraction and treatment facilities
- El Paso gage on the Rio Grande, the upstream boundary of the salinity model
- Urban areas in Texas receiving municipal and industrial water supply from El Paso Water Utilities and Lower Valley Water District
- Agricultural areas in Texas receiving Rio Grande water within El Paso and Hudspeth Counties

Potentially affected urban water use is located within or near the El Paso Texas metropolitan area. All of the urban water use is provided by EPWU, either directly to its retail customers or as wholesale supply provided for municipal and industrial uses in the area. This report does not include any urban water use of Rio Grande water in Mexico.

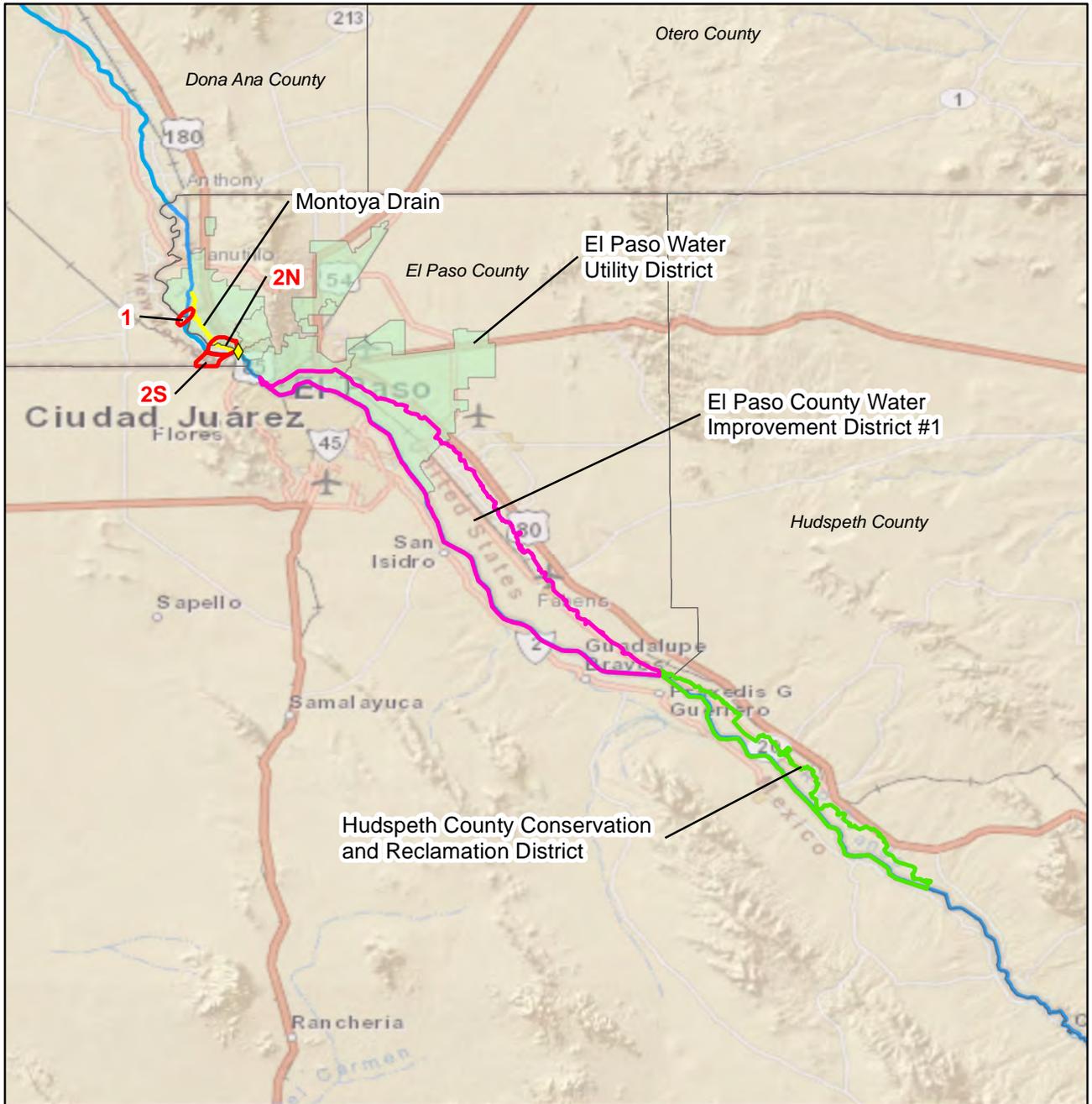
Potentially affected agricultural water uses are located in El Paso and Hudspeth Counties. Rio Grande water is provided to El Paso County agriculture by El Paso County Water Improvement District #1 (EPCWID#1), which has about 69,000 acres of water rights land. It also delivers water to Hudspeth County Conservation and Reclamation District #1 (HCCRD#1), which provides irrigation water to up to about 14,000 acres of irrigated land in Hudspeth County. Other areas of El Paso and Hudspeth Counties that rely solely on groundwater are not included in the Study Area.

2.2 Modeling Approach and Methods

Salinity reduction was evaluated using three models to conduct the alternatives analysis that represents existing and future without project conditions to establish potential damages and project benefits. First, a salinity loading model was used to estimate groundwater patterns and salinity concentrations within the Study Area. Two economic models were used as a basis to establish damages and benefits in monetary terms. These two models applied the outputs from the salinity loading model for (1) municipal and industrial users (M&I) and (2) agricultural users. These models are summarized below and described in more detail in the appendixes.

2.2.1 Selection of Salinity Parameter for Analysis (Total Dissolved Solids)

Levels of and damages associated with salinity were assessed using total dissolved salts in water. In most cases this will be measured in milligrams per liter (mg/L) of total dissolved solids (TDS). For some of the intermediate agricultural damage calculations, a related measurement is used that indicates the electrical conductivity (EC) of the water. EC, measured in deciSiemens per meter (dS/m), is used in most of the reference literature and reports which form the basis of the analysis used here. However, for consistency, mg/L TDS will be used here to report conditions and forecasts of water quality. When conversion between the two units is required, a standard conversion rate is used whereby 1 dS/m is assumed to be the equivalent of approximately 640 mg/L TDS.



VICINITY MAP

LEGEND

- Rio Grande at El Paso Gage
- El Paso Co. Water Improvement District #1 (South)
- Potential Project Site
- Hudspeth Co. Conservation and Reclamation District
- Counties
- Rio Grande
- Montoya Drain
- El Paso Water Utility District

Imagery Source:
ESRI World Imagery, 01/30/2010
ESRI Street Map



FIGURE 2-1
Study Area

Rio Grande Salinity Management Program: Alternatives
Analysis for Distal Mesilla Basin
Rio Grande Salinity Management Program

Other measurements related to water quality are important in specific situations, but were not used in this analysis. For example, most soils and some plants (crops and landscaping) can be adversely affected by sodium ions, so the sodium adsorption ratio (SAR) of irrigation water is an applicable measure. Health hazards of toxic constituents and microorganisms are critical for drinking water, though all alternatives considered will meet health and safety requirements. Still other constituents can affect the cost of treating water for human consumption.

For the purposes of this alternatives analysis, TDS is used for comparison purposes for two reasons. Damages can be caused by a variety of salinity components, so an inclusive measure of salinity such as TDS is appropriate—no single component provides a good measure of an alternative’s effectiveness. Second, none of the alternatives attempt to target reductions in specific components such as sodium. The desalting technology used in the alternatives reduces all constituents. Therefore, the term salinity is used to mean TDS, unless otherwise specified.

2.2.2 Approach for Salinity Loading Model

The primary purpose of the project is to improve water quality for downstream water users. Economic benefits are calculated for each water user based on the reduction of salinity (TDS) due to the project. However, the water users are located downstream, and there are a number of inflows and diversions between the project site and the water users’ diversions that also affect water quality. Accordingly, a reduction in TDS at the downstream diversion locations would also not be the same as the reduction in TDS for the project.

TDS and downstream reductions for existing and future-without-project conditions, as well as each alternative plan, was estimated using an updated version of the salinity model used in the Alternatives Analysis (CH2M HILL, 2011). The model simulates average irrigation season flow and water quality in the Rio Grande and associated canal systems between El Paso and Hudspeth County. A full description of the salinity model, including updates made from the 2011 version, can be found in **Appendix A1**.

In summary, updates to the salinity model included incorporation of additional flow and water quality data, updating the model to reflect future conditions, simulation of TDS instead of chloride to facilitate analysis of economic benefits, and updates to simulate non-irrigation season in addition to irrigation season. The updated model simulates three development conditions, representing years 2010, 2020, and 2050. Current condition (2010) assumptions for return flows (flow rates and water quality) and downstream diversions (flow rates) are based on recent data. Changes to future conditions (2020, 2050) include changes in diversion rates and return flows based on published planning documents and are consistent with water use assumptions used in the economic analysis. Existing and future without project conditions are discussed further in Sections 2.3.1 (existing conditions) and 2.4.1 (future conditions), as well as **Appendix A1**.

Compared to future-without-project conditions, the only salinity model input that is changed to represent future-with-project conditions is the flow and water quality of the Rio Grande at the El Paso gage, located just below the confluence of the Montoya Drain and the Rio Grande (see **Figure 2-1**). To estimate the reduction in TDS for each of the water users, the modeled TDS for future-with-project is subtracted from TDS for future-without-project conditions. The difference in simulated water quality at the diversion locations (which is a flow-weighted average for water users with multiple diversions) between the two conditions is used as the input for the economic model.

2.2.3 Approach for Municipal and Industrial Economic Model

The municipal and industrial salinity cost component of the economic model is based on salinity economic models from previous studies on the lower Colorado River, Central Arizona, and work completed by Michelsen et al. (2009). The models include salinity damages to residential, commercial, public, industrial, landscape, and water utility assets. Most damages are in the form of reduced expected life of water-using residential appliances and facilities. Other damages include use of water softeners, bottled water costs and landscape costs that involve the amount of water required for leaching.

The current salinity cost component of the economic model includes multiple updates to the previous Michelsen et al. (2009) study. New costs included in this analysis are: Soap and detergent use, water softener costs, galvanized pipe costs, and brass fixture costs. Damage functions for these categories were developed in a study for the Los Vaqueros Reservoir (MWH, 2003). Information on the M&I affected environment was updated from the Michelsen et al. (2009) study to show existing conditions and forecast conditions in 2020 and 2050. The 2020 and 2050 forecasts, needed to provide salinity costs over the expected project life, involve population, households, surface water treatment capacity and future mix of water uses and supplies.

All alternatives result in a very small reduction in river flow equal to the volume of water evaporated. The multi-purpose project alternatives require more water rights costs based on the entire amount of water evaporated and provided as water supply. A cost for water rights compensation (\$300 per acre-foot [af]) is based on recent prices paid for water rights (EPWU 2014b) and costs for agricultural water conservation (FWTWPG 2012). The multi-purpose analysis also requires information on the benefits of new water supply. This benefit is the revenue from water sold. A price of \$800 per af is based on recent retail prices and the average cost of alternative supplies.

A full description of the M&I salinity cost economic model is provided in **Appendix B1**.

2.2.4 Approach for Agricultural Economic Model

The assessment of how salinity affects irrigated agriculture uses is based on a set of well-accepted relationships among irrigation water quality and quantity, root zone salinity, and crop yield. These were incorporated into a model developed to provide preliminary economic assessment of the agricultural costs of Rio Grande salinity (Michelsen et al., 2009), called the PEIA. For the current analysis, the relationships in the PEIA were used to create a spreadsheet model to evaluate the impacts of salinity on crop yields and production costs. Recent data on crop acreages, yields, prices, water quality, and costs were used to update the PEIA analysis.

More detail about the agricultural benefit model is provided in **Appendix B1**.

The agriculture model assumes that farmers will apply water and manage salinity in order to achieve the highest net return from crop production. All irrigation water contains salts, and the accumulation of these salts in the root zone of crops can impede growth and yield. Irrigation water with higher concentration of salts, or TDS, must be managed more carefully to avoid or limit damage. Farmers apply enough extra irrigation water (that is, beyond the minimum required by the plants) to move the salts down and out of the root zone. This process is called leaching, and the amount of additional irrigation water required is called the leaching requirement. The leaching requirement is based on both the salt tolerance of the specific crop and the salinity of the irrigation water. The leaching fraction is the actual additional water applied, which may be more or less than the leaching requirement. Inadequate leaching fractions result in the accumulation of salinity and reductions in crop yield. Ayres and Westcott (1985) summarize the relationships among irrigation water, salinity, and crop yield that are widely accepted and used in irrigation management.

The model calculates the level of leaching for each crop that produces the greatest net return, considering the value of crop yield and the cost of the leaching. As the salinity level in irrigation water improves, the crop yield can improve or the leaching water can be reduced, or a combination of both. The model compares the calculated leaching amount for existing and future-without-project conditions to the future-with-project amount for each alternative plan. The value of improved yield and/or avoided leaching cost, summed over all crops and regions, is the annual benefit of the project for each alternative plan.

2.3 Characterization of Existing Conditions

The three models and related, recent data were used to establish existing conditions as a baseline and to quantify the potential economic damages when existing conditions are compared to the future-without-project conditions.

The area receiving benefits includes both urban (M&I) and agricultural areas in El Paso and Hudspeth Counties. Water supplies are a combination of groundwater, pumped from both private wells and district-owned wells, and surface water diverted from the Rio Grande. El Paso County Water Improvement District #1 serves water rights lands in El Paso County, including some lands converted to urban uses that are now within EPWU's service area. Existing water uses potentially benefiting include residential use, industrial and commercial use, landscape irrigation, and commercial crop irrigation.

2.3.1 Existing Hydrologic Conditions

Flow in the Rio Grande through southern New Mexico and Texas is controlled by releases from Caballo Dam, which is part of the U.S. Bureau of Reclamation's Rio Grande Project. A number of historical agreements have been made that allocate water amongst water users in New Mexico, Texas, and Mexico, dating to a treaty between the United States and Mexico in 1906. Project operations have also changed historically, with current operations governed by a 50-year Operating Agreement (OA) between Elephant Butte Irrigation District (EBID), EPCWID#1, and the U.S. Bureau of Reclamation that went into effect in 2008. A good summary of historical changes to operations of the Rio Grande Project can be found in the recent Supplemental Environmental Assessment (U.S. Bureau of Reclamation, 2013a).

Although Rio Grande Project operations have varied historically, an overarching characteristic is that water is only released during the irrigation season, typically March through October, except in flood years when it may be released through the winter. There are typically no releases during the non-irrigation season (November through February), resulting in very little flow in the Rio Grande upstream of El Paso, Texas, during the non-irrigation season. In addition, salinity in the Rio Grande near El Paso is generally lowest during high river flows, and highest during low river flows (Moyer et al., 2009). Accordingly, due to low flows and high salinity, there are few water diversions during the non-irrigation season. Irrigation season and non-irrigation season conditions are summarized below.

2.3.1.1 Existing Irrigation Season Hydrologic Conditions

Current irrigation season flow and water quality are summarized in the model schematic of average conditions (**Figure 2-2**). During the irrigation season, about 80 percent of the Rio Grande flow at the El Paso gage is diverted to the American Canal at the American Dam. Most of the remaining flow is taken as a diversion to Mexico at the International Dam, into the Acequia Madre. Typically, there is very little if any flow in the Rio Grande downstream of the International Dam.

Nearly all water uses in the U.S. come from diversions from the American Canal, and consist of two diversions from the canal to EPWU (Robertson / Umbenhauer Water Treatment Plant (WTP) and Jonathan Rogers WTP), two diversions to EPCWID#1 through the Franklin Canal and the Riverside Canal, and diversions to HCCRD. In addition, there are several return flows into the American Canal, from EPWU wastewater treatment plants and EPCWID#1 agricultural drains.

Salinity increases moving downstream along the Rio Grande and American Canal system during the irrigation season, from about 650 mg/L at the El Paso gage, to about 714 mg/L at the downstream EPCWID#1 diversion. Salinity increases are due primarily to wastewater and irrigation return flows, which typically have higher salinity than water in the Rio Grande and American Canal. Flow rates decrease moving downstream because diversion rates are greater than return flow rates, and tributary inflow is negligible. Water diverted to HCCRD consists primarily of upstream return flows, as HCCRD is not part of the Rio Grande Project.

A key input to the salinity model is the flow rate of the Rio Grande at the El Paso gage, the upstream boundary of the model. Historical Caballo release duration and volume, as compared with average flows at El Paso, are presented in **Figure 2-3**. The figure presents historical data in two categories: before and after the OA went into effect. Historical data suggest that in normal years (Caballo release greater than about 500,000 acre-feet [af]), average irrigation-season flow in the Rio Grande at El Paso is about 50,000 acre-feet (af, about 325,851 gallons) per month (af/mo), with duration ranging between about 180 and 280 days per year. During dry years there is a notable difference between pre-2008 and post-2008 operations.



VICINITY MAP

LEGEND

- El Paso County Water Improvement District #1 Boundary
- Rio Grande
- State Boundary

Imagery Source:
 ESRI World Imagery, 01/30/2010
 ESRI Street Map

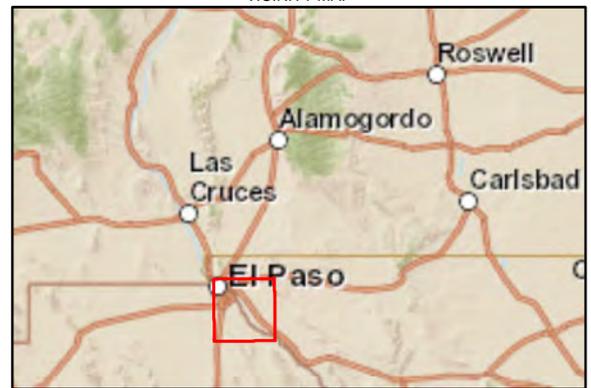
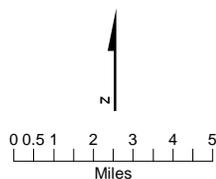
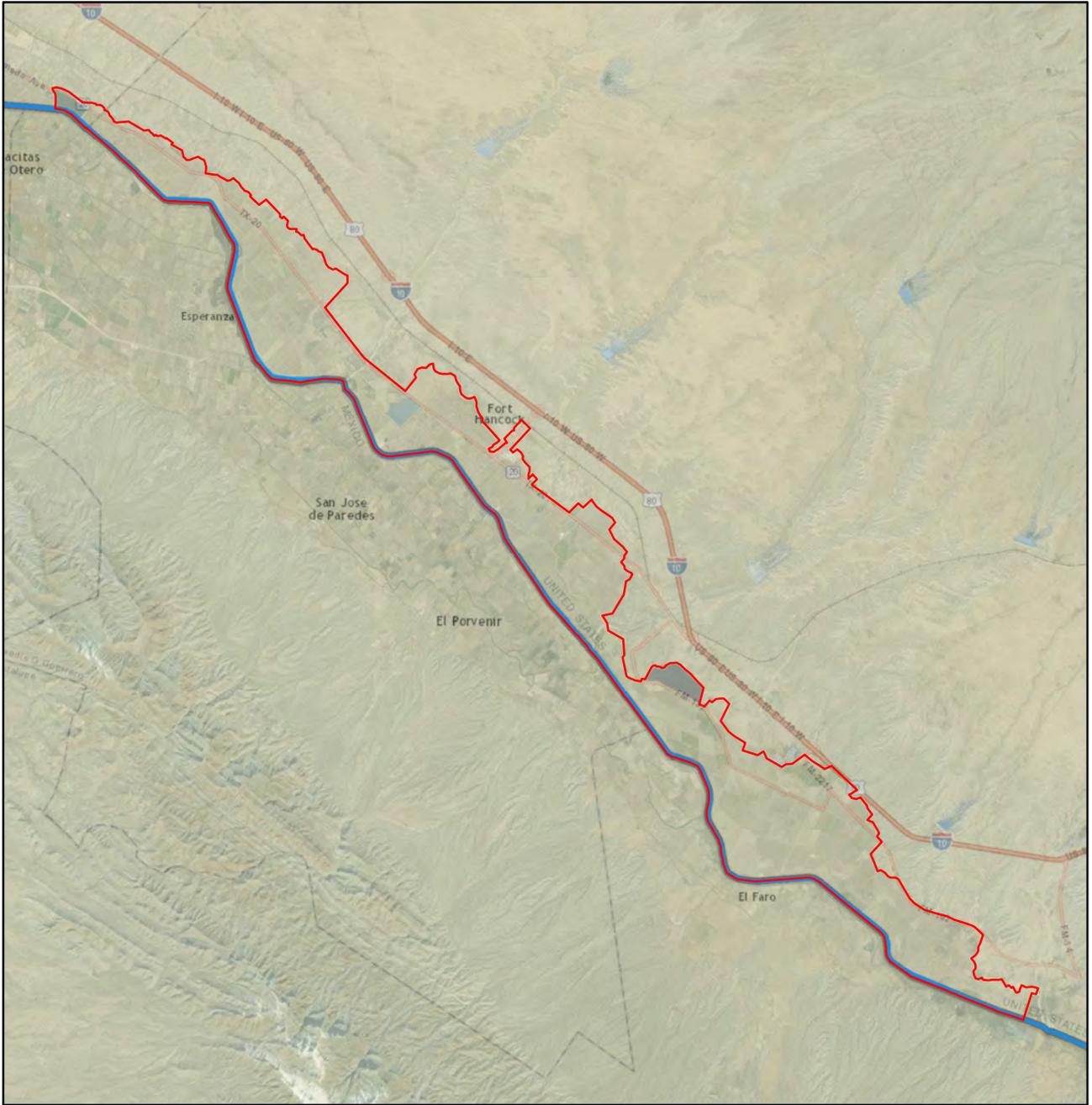


FIGURE 2-2
El Paso County Water Improvement District #1 (South)

Rio Grande Salinity Management Program: Alternatives
 Analysis for Distal Mesilla Basin
Rio Grande Salinity Management Program



VICINITY MAP

LEGEND

-  Hudspeth Co. Conservation and Reclamation District
-  Rio Grande
-  State Boundary

Imagery Source:
 ESRI World Imagery, 01/30/2010
 ESRI Street Map

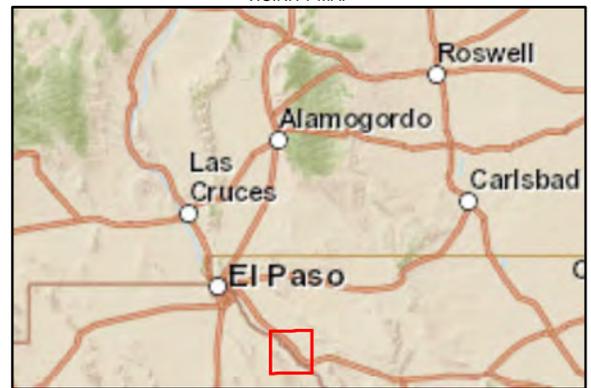
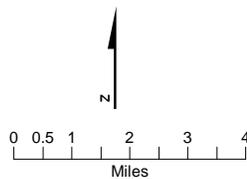


FIGURE 2-3
Hudspeth County Conservation and Reclamation District
 Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin
Rio Grande Salinity Management Program

While prior to 2008, dry year releases from Caballo generally resulted in lower flow rates in the Rio Grande at El Paso, but for longer duration, releases since 2008 have generally been at normal flow rates (approximately 37,000 af/mo to 62,000 af/mo) for reduced durations.

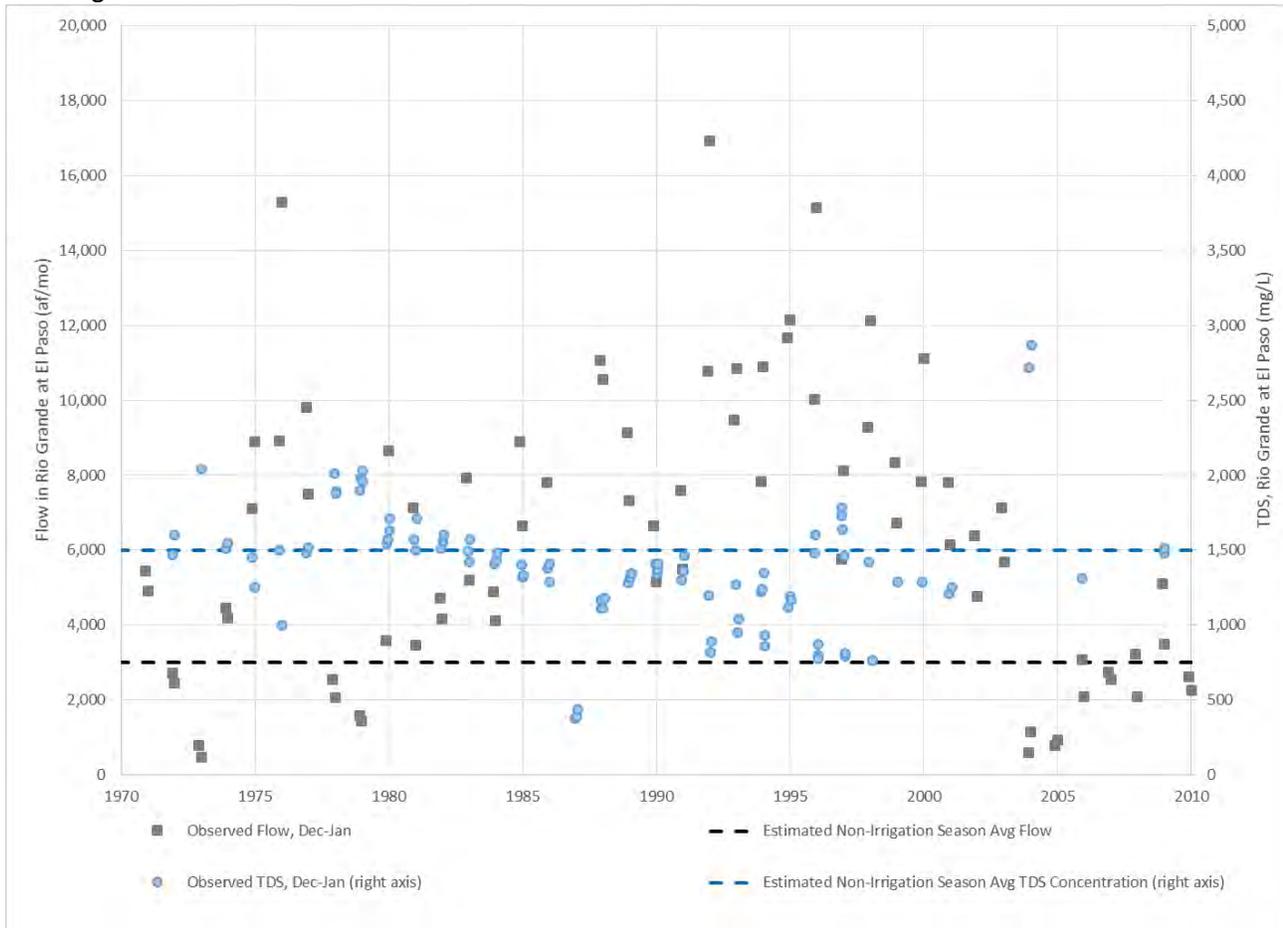
For the purpose of this analysis, it is assumed that current and future irrigation-season flow conditions at El Paso will be the same during dry years, normal years, and wet years, at about 50,000 af/mo, and that the only change in dry years is related to duration of flow. Although the 2008 operating agreement is the subject of litigation and may change in the future, it is understood to represent planned future operations. Description of how assuming lower flow rates in dry years would affect the overall results is presented in Section 4.4.

2.3.1.2 Existing Non-Irrigation Season Hydrologic Conditions

The non-irrigation season is characterized by lower flow and higher salinity in the Rio Grande. Non-irrigation season flow in the Rio Grande at El Paso varies significantly. Non-irrigation season flow 1970-2010 ranges from zero to about 17,000 af/mo, with TDS concentration generally on the order of 1,500 mg/L (Figure 2-4). For the purposes of this analysis, non-irrigation season flows are assumed to be 3,000 af/mo, based on historical data with an emphasis on recent data.

Typically nearly all non-irrigation season Rio Grande flow is diverted to the American Canal for potential irrigation use. Rio Grande flow is supplemented by EPWU’s WWTP effluent. Recent effluent flows total about 4,600 af/mo, and are less variable than the upstream Rio Grande flows. Accordingly, there is generally at least 4,600 af/mo of water available for use downstream of the WWTPs, with water availability exceeding 20,000 af/mo in wetter years when Rio Grande flow is greater.

FIGURE 2-4
Non-Irrigation Season Flow and TDS Estimates



2.3.2 Existing Conditions for Municipal and Industrial Water Uses

Potentially affected urban water use for 2010 is estimated to be 118,167 af. This urban water use estimate is provided by EPWU (2014a) and is also provided in the most recent Far West Texas Regional Water Plan (2012). The urban area included in the model includes EPWU's service area including its wholesale customers. The potentially affected urban water use is estimated to be about 31 percent of all water use (384,484 af) in El Paso County and 86 percent of all non-irrigation use (137,373 af) in the county. The 118,167 af includes all urban use that could be provided by surface water at some time; however, much of this use is provided with groundwater during the winter, and a small amount is normally provided with groundwater all year. Only 42.3 percent of the 118,167 af or about 50,000 af was affected surface water supply in average hydrologic conditions. The 42.3 percent was derived from estimated surface water supply in six different hydrologic conditions, plus information regarding the frequency of these conditions (Reinhart, 2014). The amount of wastewater use, and the average share of wastewater originating as surface water is included.

Table 2-1 summarizes the breakdown of water uses by sector. EPWU directly and indirectly provides water for residential, industrial, commercial and public (schools, churches, government) accounts. PSBEPWU (2014) provides estimated number of accounts and water use by these account types. The total provided for 2010 from this source (103,228 af) does not match the total demand estimate of 118,167, so the estimates from PSBEPWU (2014) are expanded by a factor of 1.145 (118,167/103,228) to obtain the 2010 water use by account type totaling 118,167 af as shown in **Table 2-1**.

These water uses are further disaggregated into indoor and outdoor use. Hermitte and Mace (2012) show that 33 percent of residential use was outdoors. This estimate is applied to residential and commercial accounts. For public accounts, 50 percent of use is assumed to be outdoors.

Table 2-2 shows actual 2010 supplies from the 2011 Far West Texas Regional Water Plan (FWTWPG, 2012) and also published by EPWU (2014a). Current supplies are primarily conjunctive use of groundwater and surface water with a relatively small amount of reclaimed wastewater.

Table 2-3 shows estimates of population and households served. EPWU (2015) provides estimates of population served. In 2010, 637,481 persons were served in the City of El Paso, with an additional 105,955 in Fort Bliss, Vinton, Lower Valley, San Elizario, Socorro, Clint, and elsewhere in El Paso County, for a total of 743,436 potentially affected persons served.

Household estimates are developed from forecasts of population served and recent estimates of persons per household. In 2010, according to the Census, there were 800,647 people and 252,426 households in El Paso County. Population in El Paso City was 649,133 with 216,908 households. From this information, the number of persons per household in the city is 3.0, and persons per household in the remainder of the county is 4.24. These estimates can be used to estimate a total of 238,894 potentially affected households served in 2010.

Based on the M&I model, the existing conditions salinity damages can be quantified in monetary units for comparison with future-with-project and future-without-project conditions. Under 2010 conditions, salinity damages associated with residential water use indoors are estimated to be about \$56 million annually. Additional salinity damages for landscape (\$2 million), commercial (\$4 million), and industrial and treatment plants (\$0.1 million) bring total existing M&I salinity damages to about \$61.5 million, or roughly \$250 per household per year.

TABLE 2-1
Potentially Affected Water Use 2010 Estimated by Sector
*Rio Grande Salinity Management Program: Alternatives Analysis
 for Distal Mesilla Basin*

Sector	Indoor/ Outdoor Shares	Acre-feet
Demand, af, delivered		118,167
Residential		74,662
Residential indoor	67.0%	50,023
Residential outdoor	33.0%	24,638
Commercial		29,519
Commercial indoor	67.0%	19,778
Commercial outdoor	33.0%	9,741
Industrial		815
Public (Schools, churches, government)		13,171
Public indoor	50.0%	6,586
Public outdoor	50.0%	6,586
TOTAL		118,167
Total Outdoor		40,512

TABLE 2-2
EPWU 2010 Supplies from 2012 Far West Texas Regional Water Plan
*Rio Grande Salinity Management Program: Alternatives Analysis for
 Distal Mesilla Basin*

Source	Acre-feet
Existing conjunctive use	125,000
Existing reclaimed	6,000

TABLE 2-3
Potentially Affected Population and Residential Households, 2010
*Rio Grande Salinity Management Program: Alternatives Analysis
 for Distal Mesilla Basin*

Category	Persons
Population served, El Paso City	637,481
Population served, other county	105,955
Population served, total EPWU	743,436
Households served, El Paso City	213,329
Households served, other county	25,564
Households served, total EPWU	238,894

2.3.3 Existing Conditions for Agricultural Water Uses

Agricultural uses are overwhelmingly for irrigation of annual and permanent crops. Some water is used for livestock watering and other miscellaneous uses in farm operations, but these uses are relatively small and not sensitive to the levels of salinity considered here. Irrigated lands receiving water from the Rio Grande are within EPCWID#1 and HCCRD#1.

River Salinity and Crop Irrigation. The vast majority of fields in both El Paso and Hudspeth Counties are flood irrigated. The cost of removing total suspended solids (TSS) from river water by filtration limits the expansion of other forms of irrigation such as drip or microspray. Farmers use river water when it is available because it is much higher in quality (lower in salinity and sodicity) than groundwater, and is lower in cost.

Ideally, farmers only need to apply the specific leaching requirement based on the crop and irrigation water salinity, using the management approaches described in Ayers and Westcott (1985). In practice, the actual leaching fraction applied varies and is not as closely managed as it can be in research studies used to establish crop salinity thresholds. Nevertheless, the Ayers and Westcott (1985) approaches and equations (originally from Mass and Hoffman (1977); Rhoades, 1974; and Rhoades and Merrill, 1976) are used in this study as in the previous PEIA study, as it is still a standard and accepted approach for a feasibility-level analysis.

The duration of river water irrigation is from March to October in a year of full water, but in drought years both the volume of total allocation and the period during which the river flows may be reduced. The typical river salinity during the irrigation period ranges from varies somewhat, but is generally around 650 mg/L TDS, and the local Texas AgriLife Extension agronomist for El Paso County, Dr. Jaime Iglesias, noted that agricultural practices in the region have largely adapted to this level of salinity.

The frequency and depth of irrigation varies based on the soil, the crop, crop stage, water availability, water quality, and preferences of the individual producer. Addressing all of these complexities is beyond the scope of this study. This study focuses on the specific aspects of crop irrigation that could benefit from improved irrigation water quality – avoided leaching water costs and/or improved yields.

Groundwater Salinity and Irrigation. Agricultural producers in both counties rely on groundwater irrigation to supplement Rio Grande supplies. The reliance on groundwater for irrigation increases in drought years, when river allocations decrease. The water quality of groundwater tends to be considerably poorer than the river, with 2500 mg/L TDS and SAR values of up to 15 or more not uncommon. Thus, producers will avoid the use of groundwater as much as possible. It is beyond the scope of this study to address all complexities of supplemental groundwater irrigation. In years when groundwater is used to supplement river water, the analysis assumes that groundwater is the avoided water supply if river water quality improves (and therefore growers can use less for leaching and more to meet evapotranspiration needs).

Crop Acreage. Major crops in EPCWID#1 include cotton, pecans, alfalfa hay, grains, and onions. Total irrigated acreage in EPCWID#1 service area has been as high as about 48,000 acres in recent years, though acreage is reduced during drought years such as 2013 and 2014. Water allocation is 48 inches to each eligible acre in full delivery years, but has fallen to as little as 6 inches per eligible acre in 2013 (EPWU, 2014). As of publication of this report, recent crop acreages were not available directly from EPCWID#1, hence an estimate was made of crop mix and total irrigated acreage using a mix of sources (U.S. Department of Agriculture, 2015; EPWU, 2014; Michelsen et al., 2009; and personal communication, Dr. Jaime Iglesias, Texas Agrilife Extension, January 12, 2015). Dr. Iglesias agreed that, for purposes of analysis in this report, the estimate is a reasonable representation of total acreage and crop mix in EPCWID#1 for a full water supply year (not recent drought years).

Delivered irrigation water in HCCRD#1 has ranged between 10,000 and 40,000 acre-feet, and irrigated acreage has ranged between about 6,000 to 14,000 acres since 2008 (Chavez, 2014). HCCRD#1 acreage is dominated by cotton. **Table 2-4** shows recent crop and acreages for the two districts. Although releases in

2011 were not as great as in 2008 to 2010, it is considered reasonably representative of both irrigated crop mix and extent, and specific acreage data were provided by HCCRD#1.

TABLE 2-4

Existing Crop Acreages and Totals for Districts Delivering Rio Grande Water, El Paso and Hudspeth Counties

Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin

Crop	El Paso County WID #1 ^a	Hudspeth County CRD #1 ^b
Pecans	12,483	
Cotton	30,198	12,040
Alfalfa, Other Hay	2,449	1,785
Grains	2,391	
Onions	202	
Other	288	46
Total	48,010	13,871

^aIrrigated acreage for existing conditions developed from a combination of recent data from U.S. Department of Agriculture (2015), EPWU (2014), Michelsen et al. (2009), and personal communication, Dr. Jaime Iglesias, 1-12-2015

^bIrrigated acreage for 2011 irrigation season. Personal Communication, Danny Chavez, HCCRD#1, 10-18-2014

Crop Water Use and Sensitivity to Salinity. Irrigation water use per acre varies substantially, depending on crop. **Table 2-5** summarizes the estimated evapotranspiration by major crops grown in the study area. Estimates are developed in **Appendix B2**, Crop Water Use Estimates. Crops also vary according to how sensitive their growth and yield are to salt in the soil and irrigation water. Crops are categorized based on their salt sensitivity: sensitive, moderately sensitive, moderately tolerant, and tolerant. This sensitivity rating approach is based on more detailed estimates of salt sensitivity described in Ayers and Westcott (1985), shown in more detail in **Appendix B2**.

TABLE 2-5

Crop Water Use and Soil Salinity Coefficients

Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin

	Pecans	Cotton	Alfalfa	Onions	Chile	Grain	Lettuce	Corn
Actual Evapotranspiration (in.)	43.3	29.5	55.5	38.2	39.2	14.2	22.44	28.4
Salt Sensitivity	Sensitive	Tolerant	Mod. tolerant to mod. sensitive	Sensitive	Mod. sensitive	Mod. tolerant	Mod. sensitive	Mod. sensitive

Sources:

Evapotranspiration: see Appendix B2, Crop Water Use Estimates

Soil salinity sensitivity for all species other than pecans: Ayers and Westcott (1985).

Soil salinity sensitivity for pecans: Miyamoto, 2006.

An important part of the agricultural benefits analysis considers the avoided leaching water that growers require to avoid salt accumulation in the root zone. Crops with greater evapotranspiration and greater sensitivity to salt require larger amounts of leaching water.

Crop Yields and Returns. The analysis also considered the potential cost of reduced crop yield in cases where growers are unable to use adequate leaching to avoid salinity damage. **Table 2-6** summarizes the yield, revenue and variable costs that could be affected by salinity-related effects on crops.

TABLE 2-6

Crop Budgets for Used for El Paso and Hudspeth Counties (per acre measurement)*Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin*

	Pecans	Cotton	Alfalfa	Onions	Chile	Grain	Lettuce	Corn
Unit	lbs	lbs	Tons	Bags	Lbs	Tons	Cartons	bushels
Quantity	1364	Lint 1,326 Seeds 2,122	7.5	650	4000	70	750	100
\$/unit	\$2.25	\$0.72 Lint \$0.09 Seeds	\$240	\$7	\$0.89	\$7.38	\$8	\$4.4
Revenue	\$3,069	\$1,273	\$1,800	\$4,550	\$3,560	\$517	\$6,000	\$440
Variable Cost	\$699	\$438	\$323	\$3,469	\$590	\$224	\$3,841	\$282
Budget Year	2014	2013	2014	2014	2014	2013	2014	2014

Source: Texas AgriLife Extension Service (2014)

Crop budget data from Texas Crop and Livestock Budgets, District 6 (Texas AgriLife Extension Service, 2013 and 2014) provided crop yields and returns for economic benefit calculations. The most recent budget information for cotton and grain was from 2013; other crop budgets were from 2014. Lettuce and corn budget information from 2014 is used. No corn or lettuce acreage is specifically or separately reported in El Paso or Hudspeth counties in recent years, but budget information was included in **Table 2-6** for completeness and consistency with previous studies (Michelsen et al., 2009).

The agricultural benefits model was used to estimate the value of yield reduction and the cost to growers of additional leaching water needed to avoid yield-damaging salt accumulation in the root zone. Using this approach, salinity damages associated with agricultural water use under existing conditions is estimated to be about \$333,800 per year.

2.3.4 Existing Conditions for Natural Resources

An assessment of existing natural resources conditions was conducted during alternative plan formulation to avoid, minimize, and mitigate for any adverse impacts to natural resources that could potentially occur as a result of the project. Natural resources were found to be mostly consistent across potential alternative sites and concept plans with some exceptions. As a result, natural resources are described, but not included in the economic model or other benefit-cost analysis. Natural resources and environmental permitting should be included in future phases of the project during feasibility prior to implementation. See **Appendix C** for details.

The Study Area is highly developed and in most cases, previously disturbed by construction. The riparian corridor associated with the Rio Grande is an environmentally sensitive area. If the project moves to a feasibility study, natural resources should be carefully evaluated for both impacts and potential for ecological improvements.

Four dominant macro-level land covers are found within the study area and include warm semi-desert scrub and grassland; warm Mediterranean and desert riparian, flooded, and swamp forest; herbaceous agricultural vegetation; and developed and urban (**Appendix C**).

Based on a review of National Wetlands Inventory mapping, the study area supports limited potential jurisdictional waters of the United States and potential waters in the states of New Mexico and Texas, including the riparian corridor of the Rio Grande and isolated emergent, scrub-shrub wetlands with adjacent

developed land areas. A wetland delineation of the potential jurisdictional wetland features has not been completed and is recommended to establish a baseline if a project is selected to move to feasibility.

While not likely due to the level of development in the Study Area, there is the potential for suitable habitat for federal- and/or state-listed species, including desert night-blooming cereus and sand prickly pear, Texas horned lizard and spotted bat, and southwestern willow flycatcher, arctic peregrine falcon, common black hawk, Baird's sparrow, bald eagle, American peregrine falcon, interior least tern, Costa's hummingbird, Bell's vireo, and gray vireo. Additional coordination with USFWS and targeted field surveys are recommended if a project moves to feasibility to confirm the presence or absence of suitable habitat and/or the potential occurrence of federal and threatened species within the Study Area.

2.4 Future-without-Project Conditions

Project alternatives would provide reduced salinity in delivered water for an extended period of time. A period of analysis of 30 years was used, which corresponds to a reasonable expected life of capital facilities of the alternative projects. Population, M&I water uses, and irrigated acreage were projected for two points in time, 2020 and 2050, and intervening years were assumed to change in a linear, proportionate way between those two dates.

2.4.1 Future-without-Project Hydrologic Conditions

Assumed future irrigation season hydrology and salinity for years 2020 and 2050 are presented in **Figures 2-5** and **2-6**, respectively. Future conditions were developed for years 2020 and 2050 to be consistent with the economic benefits analysis.

Changes to hydrologic and salinity assumptions in the future are based on available planning documents, and include the following changes from current conditions:

- Increased EPWU irrigation season diversion. Total EPWU diversion increases to about 9,500 af/mo (about 75,000 acre-feet per year (afy) in a normal year) in both 2020 and 2050, from about 7,800 af per month (about 61,000 afy in a normal year) in 2010. The entirety of the increase is assumed to be at Jonathan Rogers WTP.
- Decreased EPCWID irrigation season diversion. Total EPCWID#1 diversion decreases to about 32,200 af/mo (253,000 afy in a normal year) in 2050, from about 34,700 af/mo (274,000 afy in a normal year) in 2010. The decrease is assumed to occur gradually through time, and is applied proportionally amongst EPCWID's diversions.
- Increased wastewater return flows from all EPWU wastewater treatment plants (WWTPs), in both irrigation and non-irrigation seasons. Wastewater flow is forecast to increase at all three EPWU WWTPs. Increases are based on EPWU's Wastewater Facilities Master Plan (EPWU, 2014a), which includes projections for year 2030. Trends were interpolated and extrapolated to obtain 2020 and 2050 conditions, as described in **Appendix A1**. Projected return flow rates are based on projections of demand by service area; therefore, rates of increasing return flows are different at each of the three WWTPs. Total effluent rate is projected to increase to 79 million gallons per day (MGD) in 2020 and 98 MGD in 2050, from 49 MGD in 2013. The greatest percentage increase is in the Northwest Wastewater Treatment Plant, which increases to 18.6 MGD in 2050, from 4.5 MGD in 2013.

As discussed in Section 2.3.1, Rio Grande flow at El Paso is assumed to be 50,000 af/mo during the irrigation season and 3,000 af/mo in the non-irrigation season, in both normal and dry years in the future. The only change during dry years is the duration of flow. It is important to note that this analysis assumes no change in water availability due to climate change. Additional discussion regarding climate change is provided in Section 4.4.

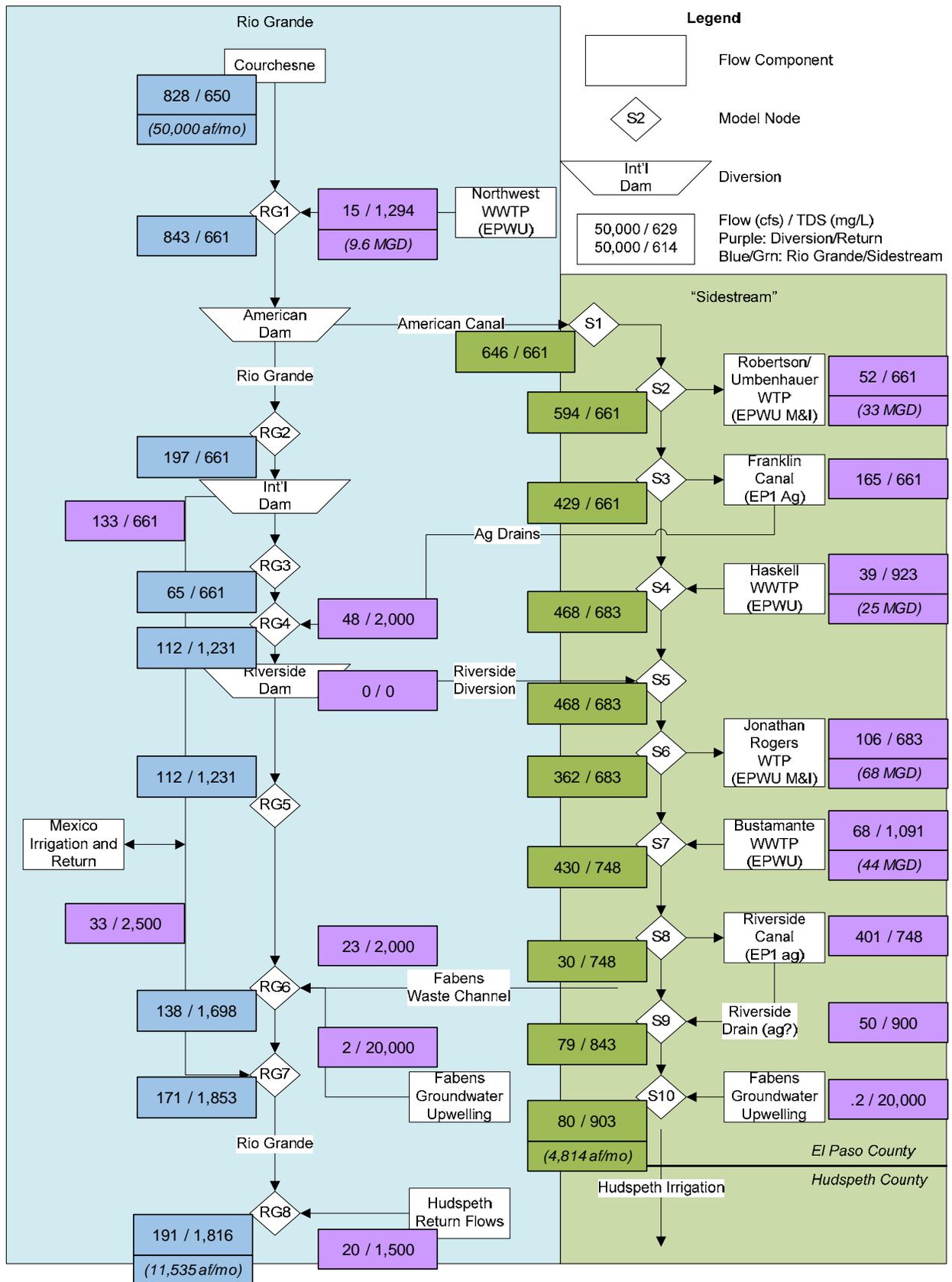


FIGURE 2-5
Model Schematic
Future Conditions (2020)
Rio Grande Salinity Management Program:
Alternatives Analysis for Distal Mesilla Basin

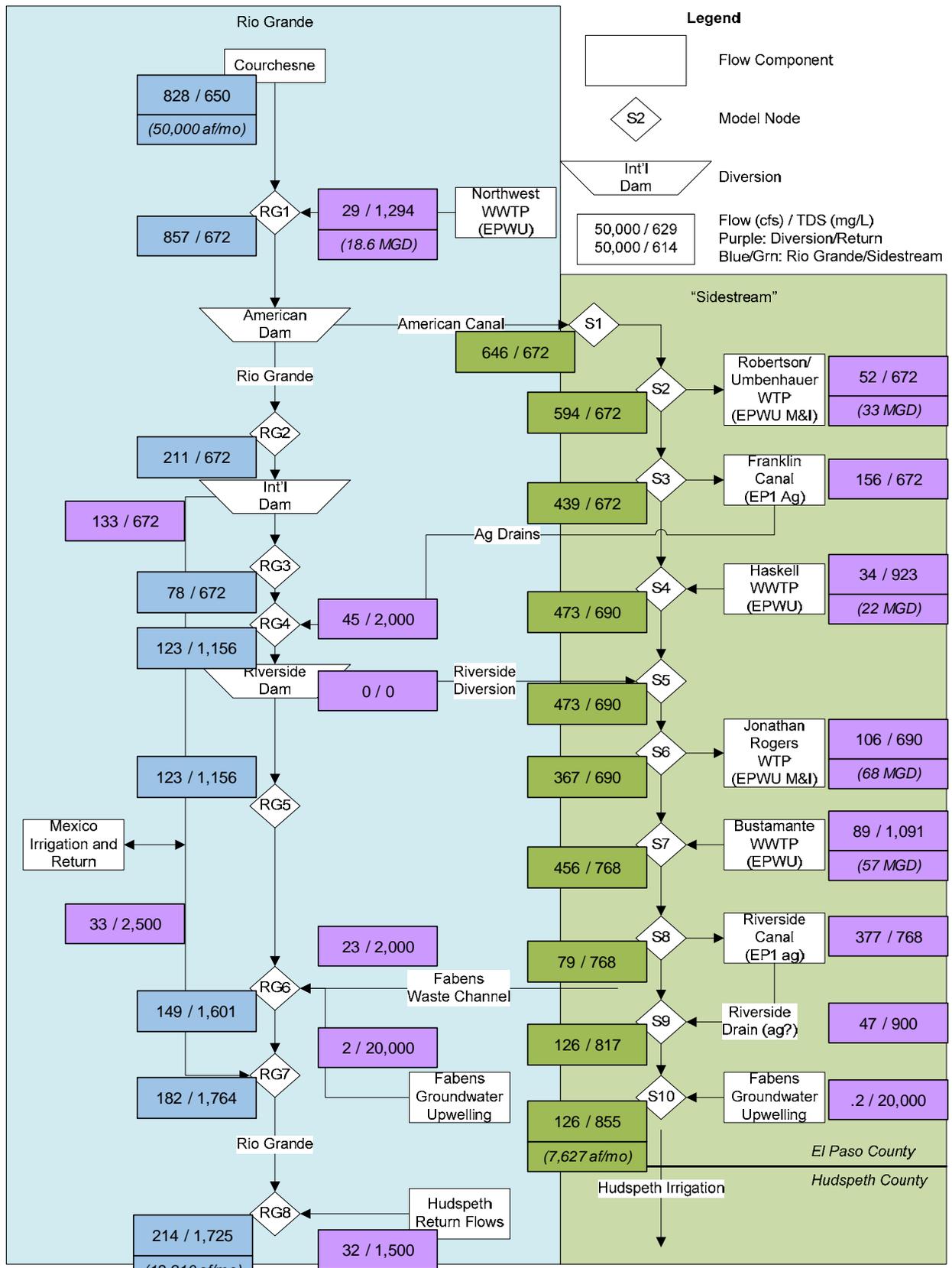


FIGURE 2-6
Model Schematic
Future Conditions (2050)
Rio Grande Salinity Management Program:
Alternatives Analysis for Distal Mesilla Basin

Appendix B1 describes how the economic analysis consider the frequency of different year types and how the amount of surface water use is affected. In dry years, a smaller share of total water use is from surface water. This implies that urban benefits of improved surface water quality will be less in dry years than normal years.

2.4.2 Future-without-Project Conditions for Municipal and Industrial Water Uses

Urban water demand is forecast to increase significantly over the next four decades. **Table 2-7** shows forecast 2020 and 2050 potentially affected urban water demands. These forecast years correspond to the beginning and the end of the assumed period of operation for salinity reduction alternatives evaluated in this report.

In 2020 and 2050, 145,445 and 191,728 af of urban water is potentially affected. There are no forecasts of urban water use by type for these years. The forecasts in Table 2-7 use the estimates of shares of water use by account type in 2014 to estimate 2020 and 2050 shares and amounts (EPWU, 2014b).

These forecasts include all urban use that is provided by surface water sometimes; however, some of this use is met with groundwater. With new surface treatment capacity of 20 MGD expected by 2020, and considering the amount and frequency of potential surface water diversions, 42.0 percent of the 145,445 af or about 61,000 af would be affected surface water supply in average 2020 conditions. By 2050, with no additional surface water treatment capacity, 33.4 percent of the 191,728 af of demand could be met directly or indirectly with surface water.

Table 2-8 shows forecast supplies for 2020 and 2050 from the 2011 Far West Texas Regional Water Plan (FWTWPG, 2012) and also published by EPWU (2014). New water supplies in 2020 include conservation, additional wastewater reclamation, recharge of groundwater with treated surface water, desalination of agricultural drain water, and additional facility construction to expand treatment capacity. By 2050, additional groundwater supply is obtained from the Capitan Reef area and from the Dell City area.

TABLE 2-7

Potentially Affected Municipal and Industrial Water Use, 2020 and 2050 Forecast, by Sector
Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin

	Indoor/ Outdoor Shares	2020	2050
Demand, af, delivered		145,445	191,728
Residential		91,701	120,882
Residential indoor	67.0%	61,440	80,991
Residential outdoor	33.0%	30,261	39,891
Commercial		33,335	43,943
Commercial indoor	67.0%	22,335	29,442
Commercial outdoor	33.0%	11,001	14,501
Industrial		4,373	5,765
Public (Schools, churches, government)		16,036	21,139
Public indoor	50.0%	8,018	10,570
Public outdoor	50.0%	8,018	10,570
TOTAL		145,446	191,729
Total Outdoor		48,946	65,731

TABLE 2-8

EPWU 2010 and Forecast Supplies from 2012 Far West Texas Regional Water Plan, Acre-feet
Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin

Source	2020	2050
Existing conjunctive use	125,000	125,000
Existing reclaimed	6,000	6,000
New conservation	3,000	16,000
New reclamation	2,000	6,000
Recharge GW with treated surface water	5,000	5,000
Desalination of Ag drain water	2,700	2,700
New conjunctive use	5,000	20,000
New groundwater from Capitan Reef		10,000
New groundwater from Dell City		10,000
Total new supply including conservation	148,700	200,700
Total new supply excluding conservation	145,700	184,700
Demand	145,445	191,728
Min (demand or supply)	145,445	184,700
Total reclaimed supply: to surface water use factor	8,000	12,000

For household forecasting, population forecasts from EPWU (2014) are used. These forecasts are shown in **Table 2-9**. Separate forecasts are provided for the City of El Paso City versus all other county urban use. The estimated number of persons per household from 2010 is used to estimate households in 2020 and 2050. The total number of potentially affected households served in 2020 and 2050 is forecast to be 278,833 and 369,577, respectively.

TABLE 2-9

Potentially Affected Population and Residential Households, 2010, 2020 and 2050
Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin

	2020	2050
Population served, El Paso City	717,651	909,384
Population served, other county	160,292	270,464
Population served, total EPWU	877,943	1,179,848
Households served, El Paso City	240,158	304,320
Households served, other county	38,675	65,257
Households served, total EPWU	278,833	369,577

Based on the M&I economic model, the future-without-project conditions can be quantified in monetary units for comparison with benefits of future-with-project alternative plans. The future-without-project conditions are as follows:

- Under 2020 conditions, salinity damages associated with residential water use indoors are estimated to be about \$65 million annually. Additional salinity damages for landscape (\$2.5 million) commercial (\$4.1 million) and industrial and treatment plants (\$0.4 million) bring total existing M&I salinity damages to about \$71.8 million, or roughly \$259 per household per year.
- Under 2050 conditions, salinity damages associated with residential water use indoors are estimated to be about \$68 million annually. Additional salinity damages for landscape (\$2.5 million) commercial (\$4.2 million) and industrial and treatment plants (\$0.4 million) bring total existing M&I salinity damages to about \$75.2 million, or roughly \$205 per household per year. The cost per household declines because no new surface water treatment plant capacity is constructed after 2020.
- For the period of project benefits starting in 2020, annual salinity costs can be estimated by linear interpolation using the 2020 and 2050 estimates. The total net present value (NPV) of M&I salinity damages over 30 years is \$1.37 billion.

2.4.3 Future-without-Project Conditions for Agricultural Water Uses

Crop Acreages. Due to urban encroachment, total irrigated crop acreage is projected to decline in El Paso County (FWTWPG, 2012). Total irrigated acreage in Hudspeth County is not expected to have large decreases from urban growth. For acreage forecasting, irrigation water demand forecasts from EPWU (2014a) are used. Assuming the same level of irrigation efficiency in the 2020 and 2050 future conditions, the percent decrease in irrigated acreage is the same percentage decrease as irrigation water demand from EPWU (2014a).

Neither the local water districts nor the state of Texas prepare official projections of crop mix, and informal discussions with local agricultural experts also did not reveal any clear information about trends in crop mix. So for purposes of this analysis, the current crop mix is assumed to be representative of future conditions. Crop mix percentages from existing conditions are applied to future total acreage projections for 2020 and 2050. **Table 2-10** summarizes the projections of future crop acreages.

TABLE 2-10

Crop Acreages and Totals for El Paso and Hudspeth Counties, 2020 and 2050

Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin

	El Paso County		Hudspeth County	
	2020	2050	2020	2050
Pecans	10,571	9,952		
Cotton	25,574	24,076	11,790	11,072
Alfalfa, Other Hay	2,074	1,952	1,748	1,641
Grains	2,033	1,914		
Onions	171	161		
Other	244	230	45	42
Total	40,666	38,285	13,583	12,756

Crop Water Use. Crop water use and salt sensitivity are assumed to be the same in the future as existing conditions. Although crop varieties may change, leading to different water use or salt sensitivity, these changes are not predictable at this time.

Crop Yields and Returns. For purposes of analysis, current prices, yields, and costs are assumed to hold in the future. Future values are not easily predictable and small changes can have substantial effects on results, so imposing such changes would be speculative.

The agricultural benefits model was used to estimate the value of yield reduction and the cost to growers of additional leaching water needed to avoid yield-damaging salt accumulation in the root zone. Using this approach, the future-without-project conditions are as follows:

- Under 2020 conditions, salinity-related damage to agricultural water uses is about \$324,600 per year.
- Under 2050 conditions, salinity-related damage to agricultural water uses is about \$290,500 per year. The reduction in annual damage relative to 2020 is a result of lower projected future acreage, as shown in **Table 2-10**.
- For the period of project benefits starting in 2020, annual salinity costs can be estimated by linear interpolation using the 2020 and 2050 estimates. The total NPV of agricultural salinity damages over 30 years is \$5.8 million.

2.4.4 Future-without-Project Conditions for Natural Resources

Natural resources conditions in the future were not included in this report. It is assumed that any changes over time to natural resources would be influenced by other environmental variables and impacts due to the project would be important to evaluate as part of a NEPA Environmental Assessment, but differences in environmental impacts amongst the alternative plans would likely be negligible for most categories.

Alternative Plan Formulation

Alternative plans were formulated to meet the project objective of reducing salinity in the Rio Grande. In the Conceptual Site Model for Distal Mesilla (“conceptual model”) (CH2MHILL, 2013), the Distal Mesilla Basin was first screened to identify two potential sites with the highest potential for salinity reduction, known as Sites 1 and 2. Next, management measures were evaluated to address salinity reduction at these sites including installation of one or more groundwater wells, associated piping and outfall structures, and salinity treatment requirements. These elements are described below, followed by a description of each formulated alternative plan, including both single-purpose projects to address water quality in the Rio Grande, but also multi-purpose projects that also provide additional economic benefits associated with selling water for water supply.

3.1 Site Location

3.1.1 Northern Site (Site 1)

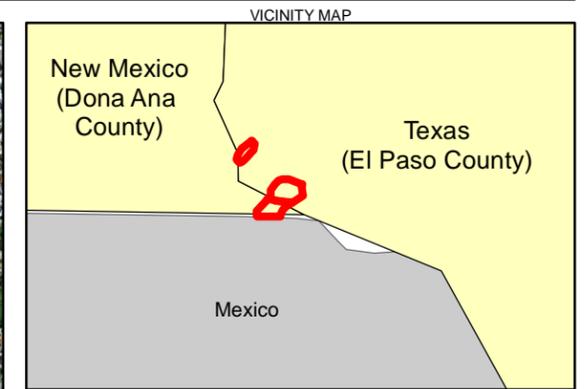
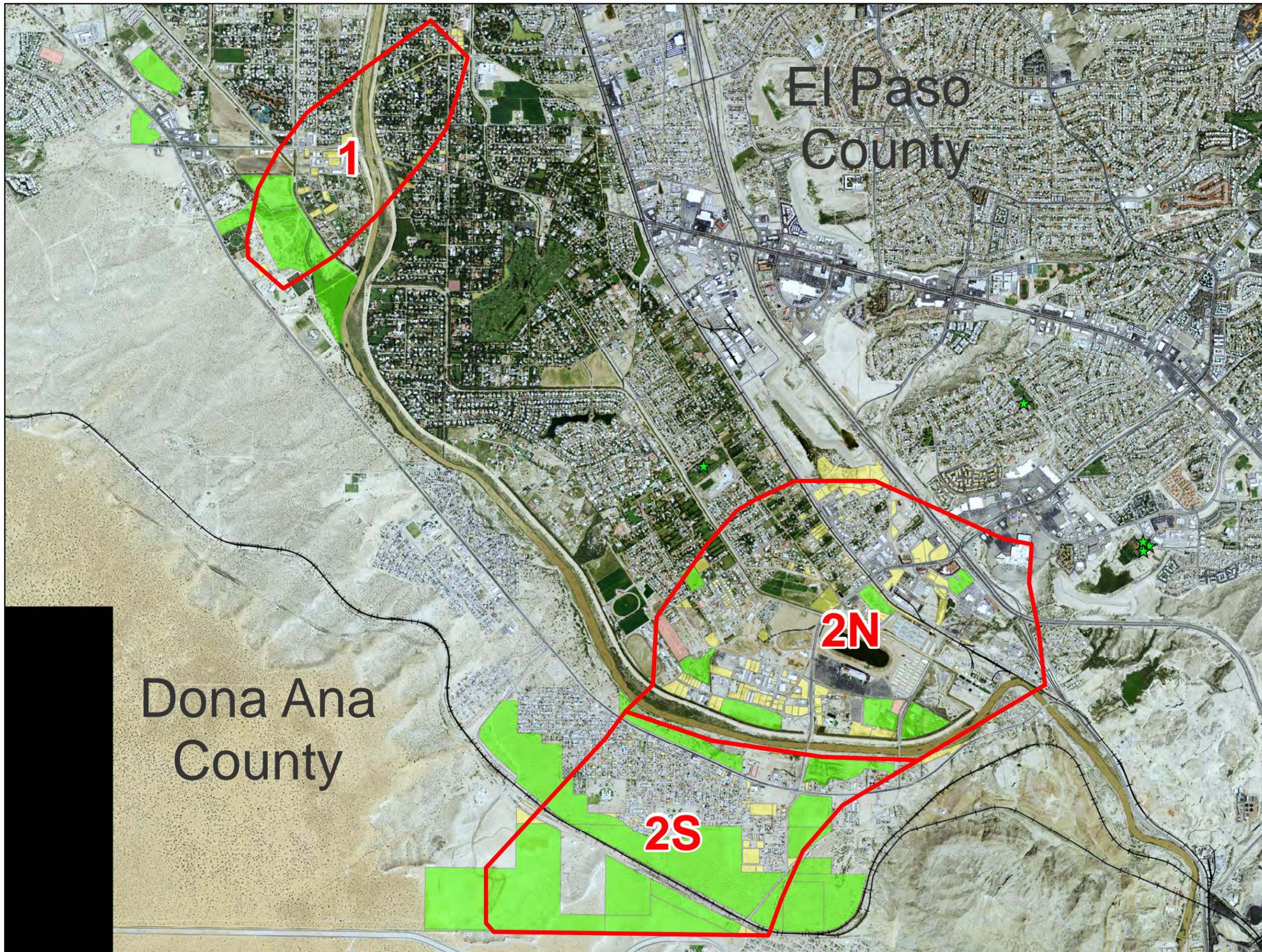
The northern site, Site 1, represents potential upwelling groundwater brines that discharge to the Montoya Drain over a localized area (potentially less than 0.5 mile, but might be up to approximately 2 miles) (**Figure 3-1**). Constraints for Site 1 are illustrated on **Figure 3-2**. Site 1 was selected based on an observed increase in TDS and chloride-bromide (Cl-Br) ratios in the Montoya Drain, as well as simulated flow paths of deep groundwater that converge in this same area. Based on a preliminary mixing model, the chloride load contributed to the drain near Site 1 could have been as high as 5,000 to 7,500 tons/year (tons/yr) in February 2000 (as high as 20,000 tons/yr TDS), but decreased to between 50 and 2,500 tons/yr in February 2013 (about 150 to 7,500 tons/yr TDS). The apparent reduction in saline discharge to the drain could be because of lower groundwater levels in 2013, in response to drought conditions. While both estimates of chloride load are uncertain, the estimate for 2000 is highly uncertain and should be used with caution.

It should be noted that flow rates and concentration of the salinity source at Site 1 cannot be determined with available data. Two general scenarios could be causing the observed salinity increase in the Montoya Drain: (1) a relatively high-flow, deep saline groundwater source with salinity similar to that of water observed in nearby deep wells ISC 5B and ISC 6B (4,000 to 5,000 mg/L TDS), or (2) a localized low-flow, high-salinity source, which could be deep saline brines brought to the surface relatively quickly by faults or hydrothermal systems. However, the localized low-flow is not represented by the model and is not observed in existing groundwater wells. Additional discussion of potential salinity source scenarios is provided in Section 3.2.

3.1.2 Southern Sites (Sites 2N and 2S)

The southern sites, Sites 2N and 2S, have high TDS concentrations observed in groundwater, typically greater than 30,000 mg/L (**Figure 3-1, Appendix A1**). Constraints for Sites 2N and 2S are illustrated on **Figures 3-3 and 3-4**, respectively. Sites 2N and 2S would pull salinity from the same source, so for the purposes of this study they are looked at as a single site, Site 2. Observed surface water flow data (according to U.S. Geological Survey [USGS] seepage studies) and groundwater modeling suggest that groundwater discharges to the Rio Grande near Site 2 at a rate of approximately 500 to 1,000 afy. Preliminary mass balance mixing models suggested that the average TDS concentration of the groundwater discharging to the Rio Grande is approximately 20,000 mg/L, with chloride concentrations approximately 7,000 mg/L, although significant uncertainty is associated with these estimates. These estimates result in mass flux of chloride from groundwater to the Rio Grande of approximately 7,500 tons/yr (22,500 tons/yr TDS). This result is consistent with mass balance modeling of Mills (2003) and an isotopic mixing model (Hogan et al., 2007), which suggested that groundwater near Site 2 appears to contribute approximately 6,500 to 9,750 tons of chloride per year to the Rio Grande. Additional discussion of potential salinity source scenarios is provided in Section 3.2.

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LEGEND

- Public Recreation
- Railroad
- Potential Capture Area
- Vacant Parcels**
- Suitability**
- EVAPORATION POND
- WATER TREATMENT PLANT
- WELL SITE

Notes:

1. Area of interest subject to change.
2. Source: USDA 2012 Agriculture Imagery
3. Sources: El Paso County GIS Department, and the City of El Paso from the University of Texas at El Paso Regional Geospatial Service Center.

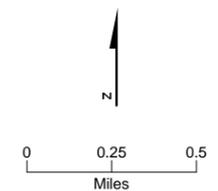
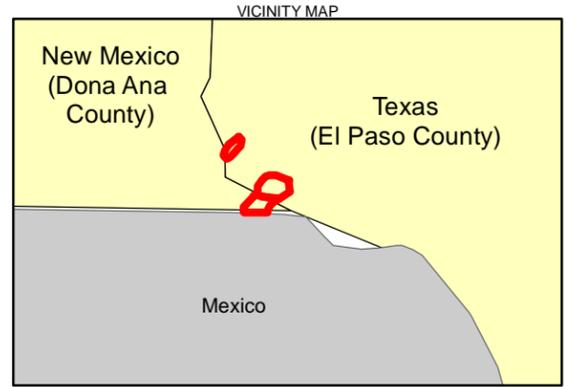
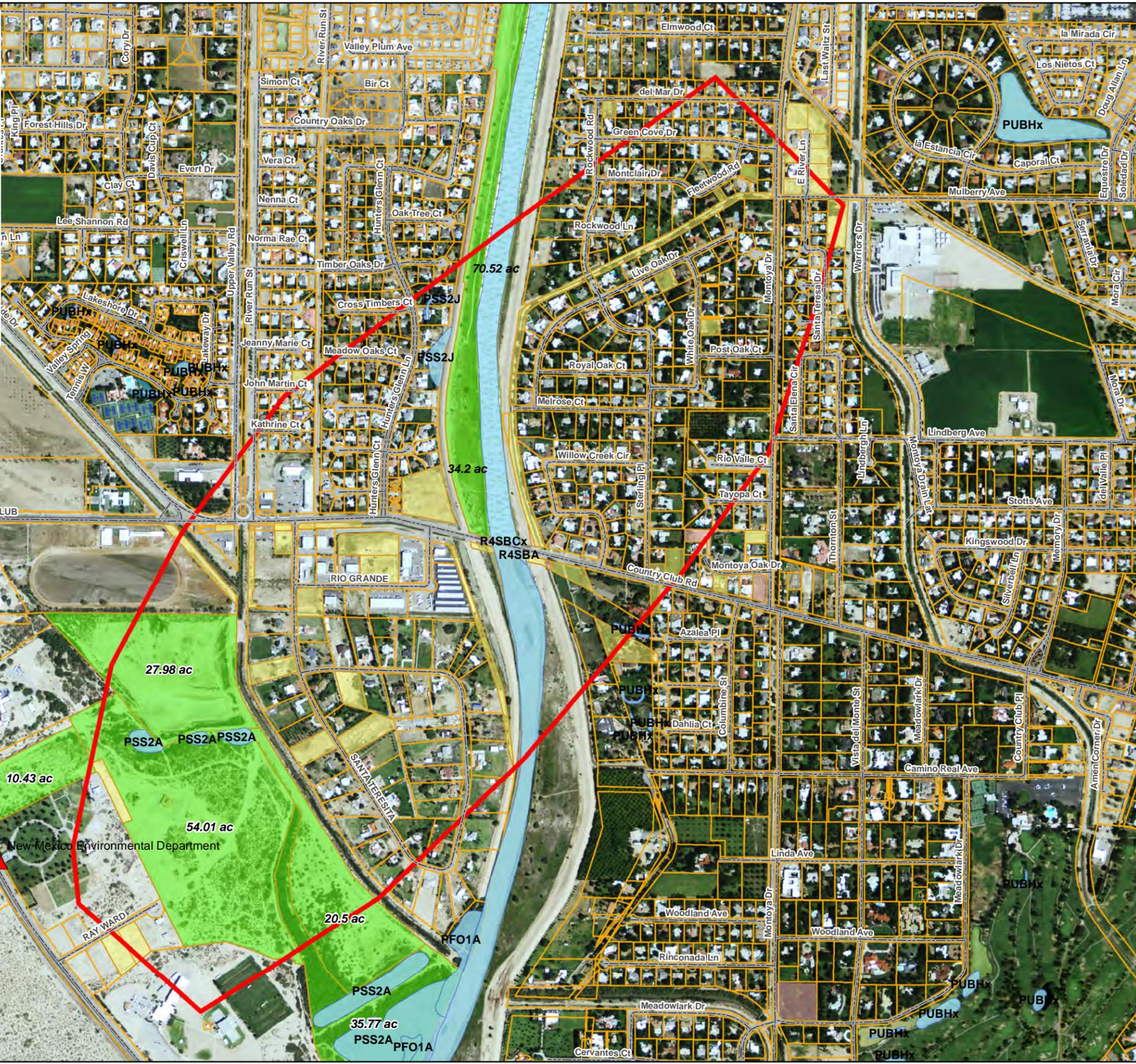


FIGURE 3-1
POTENTIAL PROJECT SITES
 Rio Grande Salinity Management Program: Alternatives
 Analysis for Distal Mesilla Basin
 Rio Grande Salinity Management Program

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Label	Type
L1UBHx	Lake
L2USA	Lake
L2USAh	Lake
PAB3Hx	Freshwater Pond
PEM1A	Freshwater Emergent Wetland
PEM1Ah	Freshwater Emergent Wetland
PEM1Ax	Freshwater Emergent Wetland
PEM1Cx	Freshwater Emergent Wetland
PFO1A	Freshwater Forested/Shrub Wetland
PSS2A	Freshwater Forested/Shrub Wetland
PSS2Ah	Freshwater Forested/Shrub Wetland
PSS2J	Freshwater Forested/Shrub Wetland
PSS2Jh	Freshwater Forested/Shrub Wetland
PUBHx	Freshwater Pond
PUSA	Freshwater Pond
PUSAh	Freshwater Pond
PUSAx	Freshwater Pond
PUSCx	Freshwater Pond
PUSJh	Freshwater Pond
R4SBA	Riverine
R4SBCx	Riverine



LEGEND

- ▲ EPA Brownfield Site
- ▲ Public Housing Development
- ★ Public Recreation
- Railroad
- Local Streets
- Potential Capture Area
- National Wetland Inventory (NWI)
- Industrial Sites
- Parks
- Parcels

Vacant Parcels

Suitability per acres

- WELL SITE (equal to or greater than 0.02 ac)
- WATER TREATMENT PLANT (equal to or greater than 0.123 ac)
- EVAPORATION POND (equal to or greater than 7 ac)
- NOT SUITED

Notes:

1. Area of interest subject to change.
2. Source: USDA 2012 Agriculture Imagery
3. Sources: the City of El Paso from the University of Texas at El Paso Regional Geospatial Service Center, and photointerpretation from the USDA 2012 Agricultural Imagery and Bing Maps.

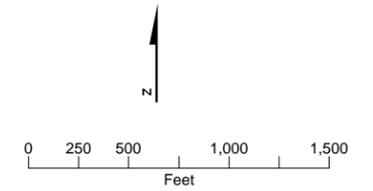
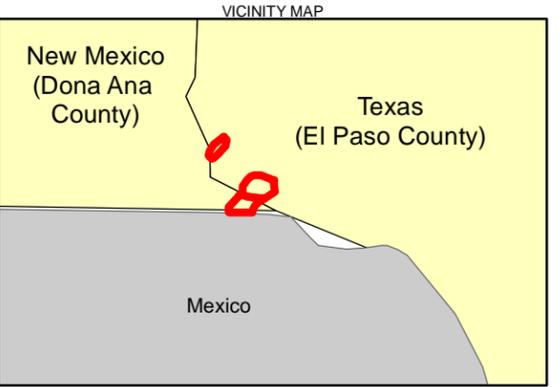
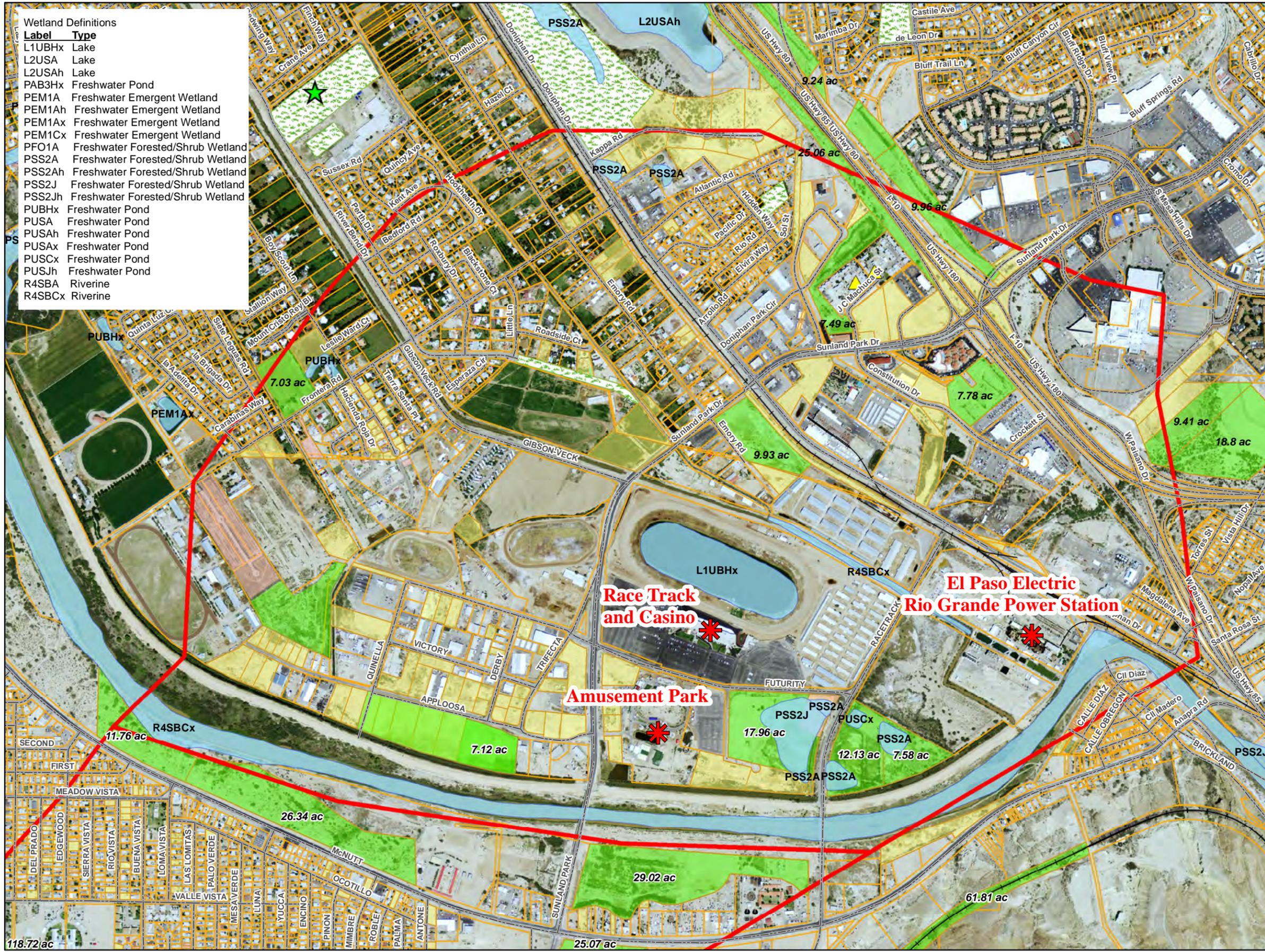


FIGURE 3-2
AVAILABLE AREA AND SELECTED CONSTRAINTS: AREA 1
 Rio Grande Salinity Study Task B
 Rio Grande Salinity Study

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Label	Type
L1UBHx	Lake
L2USA	Lake
L2USAh	Lake
PAB3Hx	Freshwater Pond
PEM1A	Freshwater Emergent Wetland
PEM1Ah	Freshwater Emergent Wetland
PEM1Ax	Freshwater Emergent Wetland
PEM1Cx	Freshwater Emergent Wetland
PFO1A	Freshwater Forested/Shrub Wetland
PSS2A	Freshwater Forested/Shrub Wetland
PSS2Ah	Freshwater Forested/Shrub Wetland
PSS2J	Freshwater Forested/Shrub Wetland
PSS2Jh	Freshwater Forested/Shrub Wetland
PUBHx	Freshwater Pond
PUSA	Freshwater Pond
PUSAh	Freshwater Pond
PUSAx	Freshwater Pond
PUSCx	Freshwater Pond
PUSJh	Freshwater Pond
R4SBA	Riverine
R4SBCx	Riverine



LEGEND

- ▲ EPA Brownfield Site
- ▲ Public Housing Development
- ★ Public Recreation
- ✱ Facilities
- Railroad
- Local Streets
- Potential Capture Area
- National Wetland Inventory (NWI)
- Parks
- Parcels

Vacant Parcels

Suitability per acres

- WELL SITE (equal to or greater than 0.02 ac)
- WATER TREATMENT PLANT (equal to or greater than 0.123 ac)
- EVAPORATION POND (equal to or greater than 7 ac)
- NOT SUITED

- Notes:**
1. Area of interest subject to change.
 2. Source: USDA 2012 Agriculture Imagery
 3. Sources: the City of El Paso from the University of Texas at El Paso Regional Geospatial Service Center, and photointerpretation from the USDA 2012 Agricultural Imagery and Bing Maps.

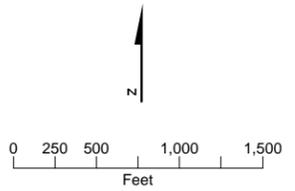


FIGURE 3-3
AVAILABLE AREA AND SELECTED CONSTRAINTS: AREA 2N
 Rio Grande Salinity Study Task B
 Rio Grande Salinity Study

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Wetland Definitions

Label	Type
L1UBHx	Lake
L2USA	Lake
L2USAh	Lake
PAB3Hx	Freshwater Pond
PEM1A	Freshwater Emergent Wetland
PEM1Ah	Freshwater Emergent Wetland
PEM1Ax	Freshwater Emergent Wetland
PEM1Cx	Freshwater Emergent Wetland
PFO1A	Freshwater Forested/Shrub Wetland
PSS2A	Freshwater Forested/Shrub Wetland
PSS2Ah	Freshwater Forested/Shrub Wetland
PSS2J	Freshwater Forested/Shrub Wetland
PSS2Jh	Freshwater Forested/Shrub Wetland
PUBHx	Freshwater Pond
PUSA	Freshwater Pond
PUSAh	Freshwater Pond
PUSAx	Freshwater Pond
PUSCx	Freshwater Pond
PUSJh	Freshwater Pond
R4SBA	Riverine
R4SBCx	Riverine



LEGEND

- ▲ EPA Brownfield Site
- ▲ Public Housing Development
- ★ Public Recreation
- Railroad
- Local Streets
- Potential Capture Area
- National Wetland Inventory (NWI)
- Parks
- Parcels

Vacant Parcels

Suitability per acres

- WELL SITE (equal to or greater than 0.02 ac)
- WATER TREATMENT PLANT (equal to or greater than 0.123 ac)
- EVAPORATION POND (equal to or greater than 7 ac)
- NOT SUITED

- Notes:
1. Area of interest subject to change.
 2. Source: USDA 2012 Agriculture Imagery
 3. Sources: the City of El Paso from the University of Texas at El Paso Regional Geospatial Service Center, and photointerpretation from the USDA 2012 Agricultural Imagery and Bing Maps.

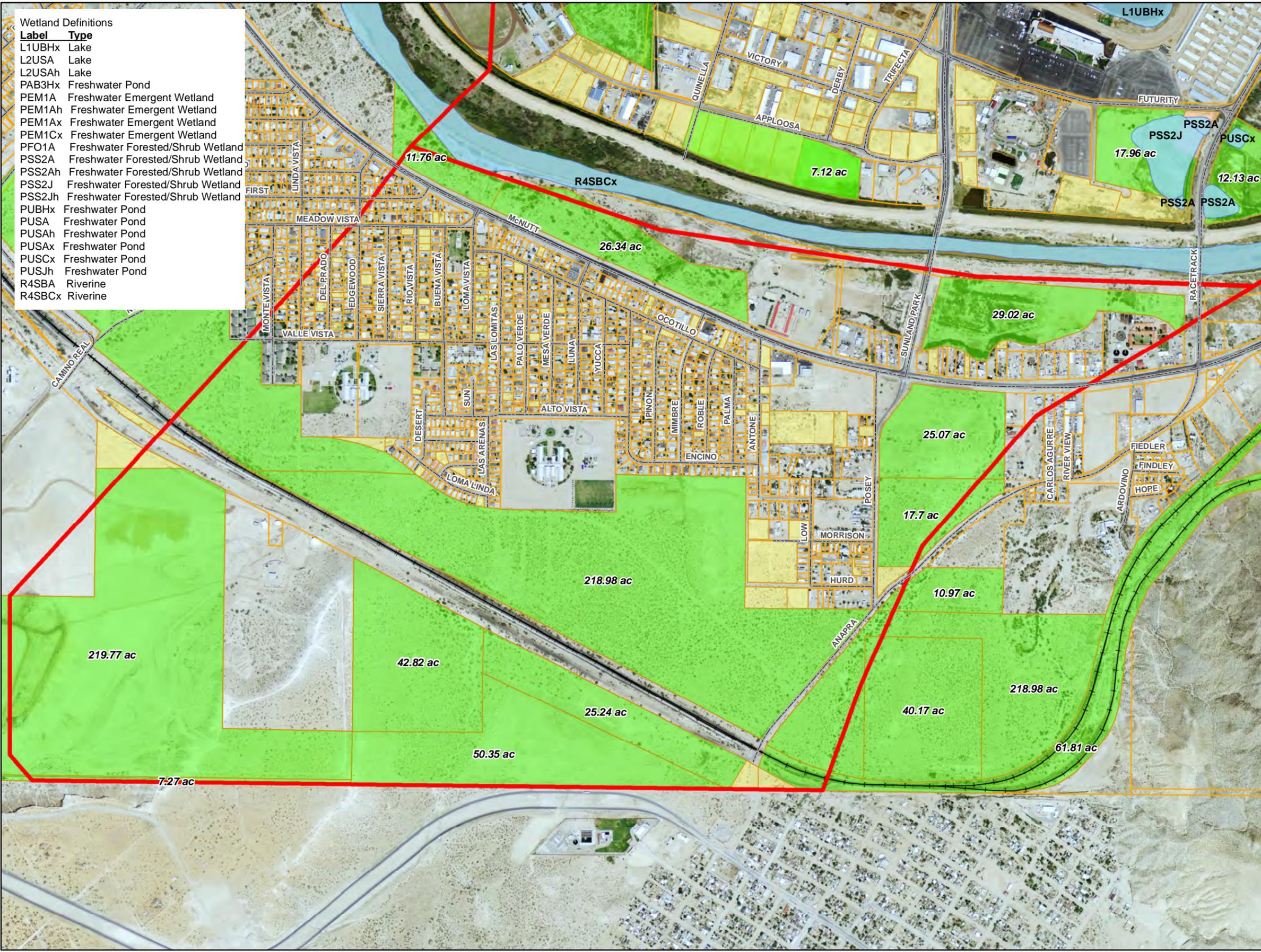
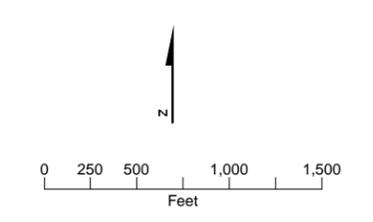


FIGURE 3-4
AVAILABLE AREA AND SELECTED CONSTRAINTS: AREA 2S
 Rio Grande Salinity Study Task B
 Rio Grande Salinity Study

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3.2 Scenarios Used to Establish Range of Potential Salinity Capture

This section summarizes assumptions related to the amount of saline water that could be captured and treated, and the resultant salinity reduction in the Rio Grande near the project site. As described above, the 2013 conceptual model identified two potential sources of salinity that may be targeted for a potential salinity capture project. The conceptual model notes that for both sites, additional investigation would be required to estimate flow rates and salinity of groundwater discharge to the surface waters at the two sites. For the purpose of this analysis, a range of potential salinity capture was assumed at each of the sites, and it was assumed to be the same during irrigation and non-irrigation seasons. For each site, a low TDS mass and high TDS mass scenario was assumed, based on the range of mass estimated in the conceptual model. The low-mass and high-mass scenarios were further subdivided into two assumptions: low-flow, high concentration and high-flow, low concentration, resulting in four scenarios for each site. Assumptions for the scenarios are summarized below, as well as in **Table 3-1**.

Site 1 chloride load to the Rio Grande was estimated to be “as high as 7,500 tons/yr” in year 2000, but between 50 and 2,500 tons/yr in 2013 (CH2M HILL, 2013). Accordingly, to estimate potential effects of a salinity control project, the chloride mass estimate was assumed to be between 500 and 7,500 tons/yr. These estimates translate to an estimated TDS load of about 1,500 tons/yr to about 20,000 tons/yr, based on mass balance calculations in the conceptual model (Tables C-1 and C-2 in CH2M HILL, 2013). Saline source flow rates were assumed to be between 0.1 and 2 cubic feet per second (cfs) (Table 1-1 in CH2M HILL, 2013). These flow rates formed the basis of the low mass / low flow scenario and the high mass / high flow scenario. Flows for low mass / high flow and high mass / low flow were adjusted to maintain reasonable concentrations of groundwater to maintain the load. Concentrations for all scenarios can be found in Table 3-1, and are consistent with TDS concentration estimates of 4,000 to 20,000 mg/L (Table 1-1, CH2M HILL, 2013).

In the conceptual model, Site 2 was assumed to contribute an annual average of 7,500 tons/yr Cl to the Rio Grande. To estimate potential benefits of a salinity control project, the saline mass estimate was assumed to be between about 5,000 tons/yr Cl and 10,000 tons/yr Cl. These estimates translate to an estimated TDS load of about 15,000 to 30,000 tons/yr TDS, based on the ratio of TDS to chloride in the conceptual model mixing calculations (Table C-4, CH2M HILL, 2013).

It is not practical to capture all of the saline source, as that would require installation of numerous wells and would also likely result in substantial capture of relatively clean water that is not part of the saline source. The conceptual model did not provide any additional information about the amount of the saline source that could reasonably be captured. Accordingly, for the purposes of this analysis, it was assumed that 30 percent of the source salinity would be captured, which is based on professional judgment and is the same percentage used in the Alternatives Analysis (CH2M HILL, 2011). Change in the 30 percent capture assumption is evaluated in the Sensitivity section. In addition, it was assumed that the wells would pull in some nearby clean groundwater, such that about 80 percent of the total water pumped is saline water. Resultant flow rate and concentration of water pumped are presented in Section 4.2.

It is important to note that the source of salinity is assumed to continue in the future, at least through the evaluation period (30 years). However, as noted in the conceptual model, future groundwater pumping in the area may reduce or even eliminate saline groundwater discharge to surface water.

TABLE 3-1

Salinity Source Capture Assumptions*Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin*

Salinity Scenario	Site 1: Montoya				Site 2: Rio Grande, ISC-4 Area			
	1	2	3	4	1	2	3	4
	Mass -->	Low	Low	High	High	Low	Low	High
Flow Rate -->	Low	High	Low	High	Low	High	Low	High
Source Characteristics								
Source flow rate (cfs)	0.1	0.3	1	2	0.7	0.9	1	1.5
Cl mass (tons/yr)	500	500	7,500	7,500	5,000	5,000	10,000	10,000
Cl Concentration (mg/L)	5,080	1,693	7,619	3,810	7,257	5,644	10,159	6,773
TDS mass (tons/yr)	1,500	1,500	20,000	20,000	14,813	14,813	29,626	29,626
TDS Concentration (mg/L)	15,239	5,080	20,318	10,159	21,498	16,721	30,097	20,065
Source Capture¹								
Flow Rate (gpm) ¹	17	50	168	337	118	151	168	252
Cl Concentration (mg/L)	4,164	1,455	6,196	3,148	5,905	4,615	8,227	5,518
TDS Concentration (mg/L)	12,491	4,364	16,555	8,427	17,499	13,677	24,378	16,352

Notes:

¹Capture flow rate assumes that 80% of total well pumping is the saline source (with remaining 20% clean groundwater with TDS concentration of 1,500 mg/L and Cl concentration of 500 mg/L, based on nearby wells), and that 30% of the source is captured.

3.3 Management Measures

This section presents a brief description of each management measure that may be applied to the alternative plans.

3.3.1 Groundwater Wells

It is assumed that each site would have three relatively low flow wells installed such that they form a “wall of wells” perpendicular to the flow of saline groundwater through the aquifer to maximize the capture of salinity from the aquifer. For Site 1, these wells would be approximately 400 feet deep. For Sites 2A and 2B, these wells would be approximately 250 feet in depth.

3.3.2 Piping and Outfall Structures

Each site would require approximately one mile of pipeline to connect the wells to the water treatment plant, and up to 1 mile of pipeline to either discharge product water to the river or convey it to a customer for use. It was assumed that a reservoir with 12 hours of treated product water storage would be located at the water treatment plant site. An outfall structure would be constructed for discharge to the river if that option were selected.

3.3.3 Salinity Treatment

Groundwater would pass through a cartridge filter to remove solids and then receive treatment through reverse osmosis (RO) membranes. The groundwater quality would determine the type of RO membranes and percent recovery of product water that would be achieved. For example, water with significant concentrations of silica, barium, iron, manganese, and/or aluminum can present challenges for RO treatment that effect the chemical addition required for treatment and cleaning of the membranes along with the percent of product water recovered from the flow stream. The RO concentrate would be discharged to an evaporation pond, concentrated by evaporation, and manually removed for disposal.

3.4 Formulated Alternative Plans

Based on the sites and management measures presented above, five alternative plans were formulated to meet the project objectives, in addition to the no action alternative (**Table 3-2**). These alternative plans were modeled and assessed as part of the benefit-cost analysis conducted for this report.

TABLE 3-2
Formulated Alternative Plans

Alternative ID	Site	Groundwater Wells	Piping and Outfall Structure	Salinity Treatment	Purpose
No action	-	-	-	-	<u>No action alternative</u>
A	Site 1	3	Yes	RO membrane	<u>Single:</u> Water quality
B	Site 1	3	Yes	RO membrane	<u>Multi:</u> Water quality Water supply
C	Site 2	3	Yes	RO membrane	<u>Single:</u> Water quality
D	Site 2	3	Yes	RO membrane	<u>Multi:</u> Water quality Water supply

The salinity scenarios presented in **Table 3-1** were applied to each alternative to establish a range of potential salinity capture outputs and subsequent benefits and costs.

The project team conducted several interviews, meetings, and site visits to gather information for the economic analysis, including discussions with EPWU (**Appendix B1**). Based on discussions with EPWU, the project team identified the potential for a joint project that would address both the water quality objective of the project, contribute to economic benefits for water supply by selling water, and also contribute to the regional water treatment capacity. EPWU has stated that their future water supply plan includes a proposal to install a new water treatment plant that would remove and de-salt 2,700 acre-feet of water from the Montoya Drain, then deliver the treated water to customers (FWTWPG, 2012).

There are two general options involving the water supply purpose. EPWU has expressed a general interest in new winter water supplies from a desalination facility in the future (FWTWPG, 2012), but none of the Alternative Plans would provide nearly as much new water supply as EPWU might need.¹ One option assumes that the product water could be taken by EPWU over the winter months and the water would be introduced into their distribution system. Since none of the Alternative Plans provide nearly as much water as EPWU might want, and additional treatment costs are unknown, this option is covered in the sensitivity analyses.

In the second option, water supply from the Alternative Plans would be provided to a dedicated water user who is not connected to the EPWU system. The product water could be provided year-round. However, under existing water rights, because the water diverted for desalination would otherwise flow to and contribute water to the river, any new M&I use of product water would require that existing water rights be compensated for the irrigation-season reduction in Rio Grande flows. This requirement is handled as an additional water supply cost in the analysis.

¹ EPWU might take as much as 2,700 afy, from Table 4-3, the alternatives could only provide between 22 and 435 afy if they provided water supply all year.

While there are trade-offs between the two purposes, it is possible that such a multi-purpose project would be more economical than two single-purpose projects. The water supply purpose is an indirect benefit that may improve the overall cost effectiveness of the project; thus, any costs that are primarily associated with treatment, operation and maintenance, or distribution for EPWU's water supply were not be evaluated as part of evaluation of effects for the alternative plans. However, these indirect benefits would be considered as part of comparison and selection of alternative plans, and may affect cost sharing.

Economic analysis and results are provided for the single-purpose water quality project, and the multi-purpose, water quality and supply project.

3.4.1 Description of No Action Alternative Plan

This report focuses on structural measures to intercept and remove dissolved salts that would otherwise enter the Rio Grande. Non-structural measures have not been specifically evaluated in this report. However, the future-without-project condition or no-action alternative plan incorporates non-structural measure that water users are implementing to continue to respond to river salinity. Agricultural users would continue to use careful irrigation management, tillage practices, soil amendments, and crop selection to produce crops. Urban users would continue to replace appliances, equipment, fixtures, and pipes sooner, purchase additional soap and water softening supplies, and irrigate landscapes so as to reduce or avoid salt damage. These management activities come at a cost, as estimated in Sections 2.4.2 and 2.4.3. Under the Future-Without-project condition, all users would continue to bear the costs of responding to current and projected levels of river salinity.

3.4.2 Description of Single- and Multi-Purpose Alternative Plans

The single-use project alternatives (Alternatives A and C) would be installed in Site 1 or Site 2, respectively. The facility constructed for this project would include a "wall of wells" constructed to maximize removal of the saline groundwater. For each site this "wall" would include wells distributed throughout the site perpendicular to the flow of the saline groundwater through the aquifer. A pipeline would convey groundwater to the WTP site. The WTP would remove a portion of the salinity from the water through treatment including RO membranes. The RO system will remove salinity from the groundwater, producing a product water stream that can be used or discharged to the river, and an RO concentrate water stream that requires disposal. RO concentrate would be disposed of in evaporation ponds that would require ongoing operations and maintenance for disposal of the salt sludge.

The multi-purpose project (Alternatives B and D) would have an additional purpose of providing potable water supply for distribution. The water supply benefit is considered supplementary to the primary objective of reducing salinity in the Rio Grande. Groundwater wells would pull saline water directly from the salinity plume in the aquifer similar to the single-purpose alternatives.

If EPWU or another water user elect to participate in using the treatment facility for additional water treatment, the source would likely be from surface water based on discussions with EPWU. These two sources (groundwater and surface water) have significantly different water quality that would require different types of treatment. The surface water from the Montoya drain diversion would require pretreatment to remove inorganic solids (i.e., sand, clay, silt) and organic solids (i.e., leaves) from the water prior to RO treatment. The surface water would have significantly lower salinity concentrations than the well water and would consequently require lower levels of RO treatment, with most likely a single pass of RO membranes. The saline water from the wells would require minimal pre-treatment for solids removal; however, the greater salinity concentrations may require treatment through two passes of RO membranes with additional chemical requirements. Consequently, treatment of these two source waters would most likely occur through two separate water treatment plants that could be co-located to gain efficiencies with materials, operations, and maintenance. Costs associated with a separate RO treatment plan specifically for surface water have not been included in this report.

The groundwater source portion of the project described in Alternatives B and D would look nearly identical to the projects described in Alternatives A and C. Cost savings would most likely be seen in the shared building and operations costs, and shared RO concentrate disposal facilities. This larger facility would require RO concentrate disposal through a mechanism other than evaporation ponds, because the size of the evaporation ponds required would be prohibitively large for the project. As an alternative to evaporation ponds, the project may include deep well injection similar to those currently utilized at EPWU's existing Kay Bailey Hutchison Desalination Plant provided concentrate quality is suitable for injection. This could represent a significant advantage to the multi-use facility, as construction and O&M costs for the evaporation ponds represent a significant portion of the overall project cost.

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Evaluate Effects of Alternative Plans

This section describes the cost estimates and estimated benefits provided by each alternative plan for comparison and evaluation of future-with-project conditions in terms of economic feasibility through a benefit-cost analysis. Each future-with-project condition will describe the same critical variables included in the future-without-project condition developed in Section 2.

4.1 Construction and Operation Costs of Alternatives

Construction and operation costs were estimated based on site configuration for each alternative, current market value of land in the surrounding area, and range of treatment parameters identified through the salinity model. Cost estimates include installation of three wells at each site, a pipeline connecting the wells to a RO WTP, a reservoir with 12 hours of product water storage, and an evaporation pond for RO concentrate disposal. A 30-year NPV was prepared to coincide with an equipment start date of 2020 and benefits evaluation through 2050 with no inflation.

The cost estimate presented in this study is a "Class 5" estimate, as defined by the Association for the Advancement of Cost Engineering International (AACE-International). It is normally expected that an estimate of this type would be accurate within plus 100 percent or minus 50 percent. This range implies that there is a high probability that the final project cost will fall within the range.

A 30 percent contingency has been included in this cost estimate as a provision for unforeseeable, additional costs within the general bounds of the project scope; particularly where previous experience has shown that unforeseeable events and/or conditions that will increase costs are likely to occur. The contingency is used as a means to reduce the risk of possible cost overruns. The contingency in this estimate consists of two components: Bid Contingency and Scope Contingency. Bid Contingency covers the unknown costs associated with constructing a given project scope, such as adverse weather conditions, strikes by material suppliers, geotechnical unknowns, and unfavorable market conditions for a particular project scope. Scope Contingency covers scope changes that invariably occur during final design and implementation.

The cost estimate has been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate, as required for any USACE-led evaluations. Should a project be selected to continue into feasibility and then implementation, this cost estimate would be refined and updated at multiple milestones. The final cost for the project will depend on such criteria as actual labor and material costs, competitive market conditions, actual site conditions, final project scope, and other variables. As a result, the final project cost will vary from this estimate. The proximity to actual costs will depend on how close the assumptions of this estimate match final project conditions. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help assure proper project evaluation and adequate funding.

Approach. To estimate the cost of infrastructure, the same approach was assumed for Sites 1 and 2. A "wall of wells" would be constructed to maximize removal of the saline source water. For each site this "wall" would include three wells distributed throughout the site perpendicular to the flow of the saline water through the aquifer. Each site was assumed to have a total of one mile of pipeline installed between the wells and the WTP site. Wells in Site 1 were assumed to be 400 feet deep, while wells in Site 2 were assumed to be 250 feet deep. The WTP was assumed to include a cartridge filters, acid and antiscalant addition, high pressure pumps, and RO membranes. The RO system will remove approximately 95 percent of the TDS from the feed water, producing a product stream that can be used by industry, municipalities, or agriculture and RO concentrate stream that requires disposal. It is assumed that the turbidity and organics are sufficiently low in the aquifer where coagulation and/or granular media or membrane filtration are not required as pretreatment. The flow of saline water into the WTP was assumed to be 17 to 337 gallons per

minute (gpm) for Site 1, and 151 to 252 gpm for Sites 2A and 2B. Saline water quality was assumed to range from a TDS of 4,363 to 16,555 mg/L for Site 1, and 13,677 to 24,378 mg/L for Sites 2A and 2B (Table 3-1). Given that no specific water quality data was available for these scenarios, the recovery rate for the RO was assumed based on treating the range of feed TDS (calculated) and producing a RO concentrate stream of 50,000 mg/L. This results in RO recoveries of between 51 to 85 percent. Actual RO recovery will be determined by the presence and concentration of sparingly soluble salts in the aquifer, including calcium carbonate, calcium fluoride, calcium phosphate, calcium sulfate, iron, manganese, aluminum, barium sulfate, strontium sulfate, and silica. The product water from the RO would be stored in a reservoir and/or tank sized for 12 hours of storage. Product water would be distributed to customers or discharged to the river through a non-metallic pipe (to avoid the need for additional chemicals to prevent corrosion) that was assumed to be up to 1 mile in length. It was assumed that the RO concentrate will be pumped to evaporation ponds, also in non-metallic pipe. The following assumptions were used to size the evaporation ponds:

- Pan evaporation rates for Caballo Reservoir published by the Western Region Climate Center (WRCC)
- Precipitation data from National Oceanic and Atmospheric Administration (NOAA)
- Two to four evaporation ponds to accommodate periodic salt removal
- Maximum water depth of 5 feet with 2 feet of freeboard (total pond depth of 7 feet)
- High density polyethylene (HDPE) liner and double lined leak detection system
- Gravel road access between and around ponds with 12-foot road width
- Exclusion of turbomisters or use of enhanced evaporation systems

For the purposes of this estimate, it was assumed that construction would begin in January 2019, with operation beginning a year later; however, the cost estimate is in 2014 dollars and assumes no inflation. The following non-construction costs were assumed based on the total construction cost with markups and escalation:

- Design cost = 10 percent
- Permitting cost = 3 percent
- Services during Construction (SDCs) = 7 percent

The cost of land for project infrastructure was estimated by completing a survey of local land currently available for sale via online vendors. Approximately 25 properties were surveyed in the project area. Properties greater than 7 acres were evaluated as potential evaporation pond sites. The average property value for each of the properties surveyed was used to calculate the following average land values by area and use:

- Land for Well and treatment plant = \$281,000 per acre
 - Santa Teresa = \$142,000
 - East Bank = \$264,000
 - Country Club = \$589,000
 - River Bend / Sunset = \$262,000
 - Sunland Park Racetrack = \$174,000
 - Sunland Park West Bank = \$253,000
- Land for evaporation ponds = \$80,000 per acre

The land required for each well was assumed to be 0.2 acres. It was assumed that the WTP would be co-located with one of the wells on a 0.2 acre lot. The evaporation pond size was assumed to be 4 to 52 acres depending on the WTP influent flow, influent water quality, and recovery rate.

The estimate for the cost of operations includes operation, maintenance, and power costs. Equipment maintenance would include service for the well pumps, chemical cleaning of the RO membranes and periodic cartridge filter and RO membrane replacement for the RO system in the WTP, and RO concentrate

sludge removal and hauling from the evaporation pond at \$14.50 per cubic yard to haul and \$75 per cubic yard tipping fee. The power cost was estimated based on a unit price of \$0.01 per kilowatt-hour (kWh).

Interest during construction (IDC) was estimated assuming that construction costs in year 0 are carried for, on average, half a year, so the IDC is one half of the construction cost times the discount rate. The 30-year NPV at start of operation was calculated using an annual discount rate of 3.375 percent, annual inflation rate of 0.0 percent, and 30 year project life cycle.

Results. **Table 4-1** presents Class 5 cost estimates for each site that illustrate the range of costs for this project depending on the flow and water quality characteristics of the groundwater source at the two sites. These estimates assume operation during the entire year. For Alternatives A and C, in which the facilities are only operated during the irrigation season, O&M costs would be reduced proportionately.

O&M costs in **Table 4-1** would be required for the multiple purpose facility that would operate all year. The single-purpose facility would not require O&M costs for one-third of the year. This reduces the NPV of costs. The Class 5 NPV for a single-purpose facility in Site 1 ranged from \$7,649,000 to \$38,730,000 and \$25,401,000 to \$45,616,000 for Site 2.

TABLE 4-1

Summary of Class 5 Cost Estimates for High/Low Mass and High/Low Flow Scenarios

Mass Flow Rate	Site 1: Montoya				Site 2: Rio Grande, ISC-4 Area			
	Low	Low	High	High	Low	Low	High	High
	Low	High	Low	High	Low	High	Low	High
Design Parameter	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4
WTP Feed TDS Concentration (mg/L)	12,491	4,364	16,555	8,427	17,499	13,677	24,378	16,352
Estimated RO Recovery	75%	85%	67%	83%	65%	73%	51%	67%
Product Water TDS Concentration (mg/L) (Estimated)	625	218	828	421	875	684	1219	818
WTP Feed Flow Rate (gpm)	17	50	168	337	118	151	168	252
Product Water Flow Rate (gpm)	13	43	113	280	77	110	86	170
RO Concentrate Water Flow Rate (gpm)	4	8	56	57	41	41	82	83
Project Cost Estimate								
Wells	\$618,000	\$618,000	\$618,000	\$618,000	\$1,080,000	\$1,080,000	\$1,080,000	\$1,080,000
Pipelines (Groundwater and Product Water)	\$510,000	\$510,000	\$510,000	\$510,000	\$510,000	\$510,000	\$510,000	\$510,000
RO System	\$967,000	\$1,011,000	\$1,097,000	\$1,500,000	\$1,050,000	\$1,093,000	\$1,069,000	\$1,300,000
Product Water Storage	\$10,000	\$31,000	\$82,000	\$202,000	\$56,000	\$80,000	\$63,000	\$123,000
Evaporation Pond Cost	\$400,000	\$641,000	\$3,826,000	\$3,826,000	\$2,830,000	\$2,830,000	\$5,468,000	\$5,468,000
Project Costs Subtotal	\$2,505,000	\$2,811,000	\$6,133,000	\$6,656,000	\$5,526,000	\$5,593,000	\$8,190,000	\$8,481,000
Additional Project Costs	\$629,000	\$705,000	\$1,534,000	\$1,666,000	\$1,383,000	\$1,399,000	\$2,049,000	\$2,123,000
<i>Construction Costs (Includes Contractor Markups)</i>	\$4,944,000	\$5,546,000	\$12,089,000	\$13,123,000	\$10,893,000	\$11,026,000	\$16,145,000	\$16,721,000
<i>Non-Construction Costs (Design, Permitting, SDCs)</i>	\$1,479,600	\$1,791,600	\$5,499,600	\$5,706,600	\$4,508,600	\$4,534,600	\$7,559,600	\$7,674,600
<i>Total Capital Cost</i>	\$6,423,600	\$7,337,600	\$17,588,600	\$18,829,600	\$15,401,600	\$15,560,600	\$23,704,600	\$24,395,600
<i>Interest During Construction</i>	\$108,398	\$123,822	\$296,808	\$317,750	\$259,902	\$262,585	\$400,015	\$411,676
O&M Cost Estimate								
Wells	\$2,099	\$12,171	\$83,551	\$253,278	\$47,218	\$70,589	\$83,551	\$159,844
RO System	\$29,050	\$56,050	\$122,000	\$258,300	\$91,400	\$118,650	\$101,300	\$167,250
Evaporation Ponds	\$40,000	\$80,000	\$570,000	\$570,000	\$410,000	\$410,000	\$830,000	\$830,000
Annual O&M Costs	\$71,149	\$148,221	\$775,551	\$1,081,578	\$548,618	\$599,239	\$1,014,851	\$1,157,094
Project Life Cycle Cost Estimate								
Net Present Value (NPV)	\$7,649,000	\$9,988,000	\$31,792,000	\$38,730,000	\$25,401,000	\$26,503,000	\$42,279,000	\$45,616,000

NOTE: The cost estimate presented in this study is a "Class 5" estimate, as defined by the Association for the Advancement of Cost Engineering International (AACE-International). It is normally expected that an estimate of this type would be accurate within plus 100 percent or minus 50 percent. This range implies that there is a high probability that the final project cost will fall within the range.

4.2 Water Quality Benefits of Alternative Plans

TDS reductions to provide irrigation season water quality benefits for each alternative plan for the range of salinity scenarios are summarized in **Table 4-2** for modeled locations used to quantify economic benefits. Complete salinity model results for all scenarios can be found in **Appendix A2**. TDS reductions are a function of the amount of mass removed by the alternative plan, so the scenarios with the greatest mass removal result in the greatest downstream TDS reductions. TDS reductions range from about 0.5 mg/L in the Alternative A low mass scenario to over 10 mg/L in the Alternative D high mass scenario.

Salinity reductions are generally greatest for El Paso municipal and agricultural uses. Hudspeth County TDS reductions are small, primarily due to the fact that most of HCCRD's water comes from agricultural and municipal return flows, rather than upstream Rio Grande flows.

Flow rate of the Rio Grande is the biggest driver for salinity reductions. The project is assumed to remove a constant amount of mass from the system, so salinity reduction due to the project would be greater with lower Rio Grande flow rates. As discussed in the approach section, a single Rio Grande flow rate was assumed for all future conditions, with only the duration of flow changing in dry years. Changes to diversion and return flow rates in the future appear to have a small effect on the reduction of TDS in the future compared with assumptions of future flow rates of the Rio Grande. Accordingly, salinity reductions are generally similar between the two future condition years. Additional evaluation of how Rio Grande flow assumptions would affect results is presented in Section 4.4.

Non-irrigation season water quality benefits for the scenario with the greatest mass removal (D.3) are presented in **Table 4-3**. TDS reduction in year 2020 is estimated to be about 60 mg/L at EPWU's Jonathan Rogers WTP, and about 51 mg/L for agricultural users. TDS reduction decreases in 2050, due to additional treated wastewater effluent diluting the effect of the project. Water availability for agricultural users increases because of additional wastewater effluent to 12,150 af/mo in 2050, from 10,300 af/mo in 2020. Complete non-irrigation season results can be found in **Appendix A2**.

TABLE 4-2

TDS Reductions for Economic Benefit Locations (see Table 3-1 for Salinity Scenario Definitions)

Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin

Project Type	Modeled Location	Year	TDS (mg/L), no project	TDS Reduction (mg/L), with Project							
				Site 1				Site 2			
Salinity Scenario				1	2	3	4	1	2	3	4
Single Purpose (Alternatives A and C)	Rio Grande, El Paso Gage	2010	650.00	0.54	0.55	7.15	7.22	5.29	5.30	10.61	10.59
		2020	650.00	0.54	0.55	7.15	7.22	5.29	5.30	10.61	10.59
		2050	650.00	0.54	0.55	7.15	7.22	5.29	5.30	10.61	10.59
	El Paso Municipal	2010	664.59	0.53	0.55	7.09	7.16	5.25	5.26	10.53	10.51
		2020	675.87	0.52	0.54	6.95	7.01	5.15	5.15	10.32	10.29
		2050	683.92	0.51	0.53	6.82	6.88	5.05	5.05	10.12	10.10
	El Paso Ag	2010	697.27	0.53	0.55	7.09	7.16	5.25	5.25	10.53	10.50
		2020	722.46	0.51	0.53	6.78	6.84	5.02	5.02	10.07	10.04
		2050	739.85	0.49	0.50	6.51	6.57	4.82	4.83	9.67	9.65
	Hudspeth Ag	2010	945.42	0.09	0.10	1.24	1.25	0.92	0.92	1.84	1.84
		2020	903.13	0.19	0.19	2.49	2.52	1.85	1.85	3.70	3.69
		2050	854.99	0.30	0.31	3.97	4.01	2.94	2.95	5.90	5.89

TABLE 4-2

TDS Reductions for Economic Benefit Locations (see Table 3-1 for Salinity Scenario Definitions)

Project Type	Location	Year	TDS (mg/L), no project	TDS Reduction (mg/L), with Project							
				Site 1				Site 2			
Salinity Scenario				1	2	3	4	1	2	3	4
Multi-Purpose (Alternatives B and D)	Rio Grande, El Paso Gage	2010	650.00	0.54	0.50	7.20	7.05	5.34	5.31	10.75	10.67
		2020	650.00	0.54	0.50	7.20	7.05	5.34	5.31	10.75	10.67
		2050	650.00	0.54	0.50	7.20	7.05	5.34	5.31	10.75	10.67
	El Paso Municipal	2010	664.59	0.53	0.50	7.14	6.98	5.30	5.27	10.66	10.58
		2020	675.87	0.52	0.49	7.00	6.83	5.19	5.15	10.44	10.36
		2050	683.92	0.51	0.48	6.86	6.70	5.09	5.05	10.24	10.16
	El Paso Ag	2010	697.27	0.53	0.50	7.13	6.96	5.29	5.25	10.65	10.56
		2020	722.46	0.51	0.47	6.81	6.64	5.05	5.02	10.18	10.09
		2050	739.85	0.49	0.45	6.54	6.37	4.85	4.82	9.78	9.69
	Hudspeth Ag	2010	945.42	0.10	0.11	1.30	1.36	0.96	0.97	1.90	1.93
		2020	903.13	0.19	0.19	2.55	2.55	1.89	1.89	3.78	3.78
		2050	854.99	0.30	0.28	4.00	3.91	2.97	2.95	5.97	5.93

TABLE 4-3

Non-Irrigation Season Flow-Weighted Average TDS Reduction, Scenario D.3

Location	Year	Available Water (af/mo)	TDS (mg/L), no Project	TDS (mg/L), with Project	TDS reduction (mg/L), with Project
El Paso Municipal (JRWTP)	2020		1,164	1,103	61
	2050		1,190	1,131	59
El Paso and Hudspeth Ag	2020	10,300	1,189	1,138	51
	2050	12,150	1,192	1,149	43

4.3 Economic Benefit-Cost Analysis

The benefit-cost analysis compares benefits and costs of each alternative plan. For each alternative plan, two purposes for possible uses of product water are considered. In the single-purpose alternative plans (A and C), the product water is returned to the river. For the multi-purpose plan (B and D), the product water is provided as water supply for a dedicated water user.

4.3.1 Single Purpose and Multi-Purpose Alternative Plan Analysis

First, Alternatives A and C were analyzed as a single-purpose facility for the purpose of river water quality only. In this option, the product water is returned to the river. For some salinity scenarios, the product water quality, though much better than the source quality in the drain or groundwater, is still worse than the river water quality. For these alternatives (from **Table 4-4**, the “Product TDS mg/L” row, Alternative Plan A or B, scenario 3, or any of Plan C or D, river water quality is degraded slightly by returning it to the river, but this effect is small relative to the large improvement caused by diversion, desalination and evaporation of saline

drain and groundwater. That is, the salinity of the product water is much less than that of the saline drain water or groundwater that is kept out of the river.

The multi-purpose Alternatives B and D assume the product water is provided to a dedicated water user. The benefit of this supply is based on retail water prices and alternative costs of water supplies in the region (**Appendix B1**).

4.3.2 Net Present Value Analysis

The analysis uses the 2020 and 2050 benefits estimates to develop a NPV benefits analysis for 30 years. It is assumed that the project would operate for 30 years (2020 through 2049) beginning in 2020. Annual benefits in all years except 2020 are estimated by linear interpolation from the 2020 and 2050 estimates. These annual benefits are discounted to 2020 using the federal approved discount rate for water projects of 3.375 percent (U.S. Department of Treasury, 2015).

4.3.3 Results

Table 4-4 displays results of the economic analysis for the single-purpose Alternatives A and C. The only benefits for the single-purpose alternative plans result from improved river water quality.

The single-purpose alternative plan economic analysis suggests that none of the alternative plans are economical. The river water quality benefits in NPV terms range from about \$305,000 for Alternative A to about \$6million for Alternative C. These benefits amount to 4 to 17 percent of the NPV of project costs. The two alternative plans at Montoya that have low mass removal appear to be less economical, as measured by benefit/cost (B/C) ratios, than the other plans. Project costs reflect some economies of scale that tend to favor the larger facilities.

The river water quality benefits reflect a very small improvement in salinity of the river ranging from 1 mg/L for Alternative A to 11 mg/L for Alternative C. With a baseline of 650 mg/L, the river water quality improvements are all less than 2 percent of the baseline.

The NPV of M&I salinity costs under 2020 to 2049 conditions was estimated to be about \$1. 37 billion (Section 2.4.2), so the reduction in M&I salinity costs caused by the projects (\$305,000 to \$6 million) is a small fraction of the level of salinity damages.

Table 4-4 also displays results of the economic analysis for the multiple-purpose Alternatives B and D. Even with water supply benefits included, the analysis suggests that none of the alternatives are economical. The benefits of improved river water quality and water supply are substantially less than costs in all cases. The river water quality benefits plus the water supply benefits in NPV terms range from about \$630,000 for Alternative B at the lowest end of the range to about \$11 million for Alternatives B and D at the maximum end of the range. Benefits range from 8 to 25percent of project costs. At best, benefits only cover one-quarter of costs. Alternative B appears to be most economical. The two alternative plans at Montoya that have low mass removal appear to be less economical, as measured by B/C ratios, than the other plans.

As compared to the single-purpose alternative plans, the multi-purpose alternative plans are more economical even though costs are higher. In all alternative plans, using product water directly as supply, instead of returning it to the river, appears to improve project economics. If the product TDS is lower (better quality) than the river, then river water quality benefits are increased by returning it to the river. However, this economic benefit is far less than the water supply benefit obtained by selling the water.

M&I water quality benefits constitute the large majority of total benefits for the both the single-purpose and multi-purpose project alternatives. Agricultural benefits would be less than 2 percent of total benefits for single-purpose alternatives, and less than 1 percent for the multi-purpose alternatives. In each alternative and scenario, the greatest water quality benefit would occur in the residential sector, followed by commercial/public, water treatment plants, landscape, and industrial water use sectors. Residential use is the only category in which annual benefits would grow between 2020 and 2050.

TABLE 4-4

Benefit-Cost Analysis Summary (see Table 3-1 for Salinity Scenarios Definitions)*Rio Grande Salinity Management Program: Alternatives Analysis for Distal Mesilla Basin*

Single-Purpose Project Economic Analysis Results (2014 \$ in thousands)								
Alternative Plan Salinity Scenario	Site 1: Montoya				Site 2: Rio Grande, ISC-4			
	A				C			
	1	2	3	4	1	2	3	4
NPV River WQ Benefits	\$305.0	\$314.7	\$3,440.3	\$4,061.4	\$3,007.7	\$3,010.3	\$6,031.2	\$6,017.6
NPV Project Costs	\$6,655.0	\$8,531.0	\$26,600.0	\$31,652.0	\$21,587.0	\$22,375.0	\$35,694.0	\$38,151.0
af/Yr Removed from River	4.5	8.2	60.0	61.1	44.4	44.6	88.3	88.8
Water rights cost (\$300/af/Yr)	\$1.4	\$2.4	\$18.0	\$18.3	\$13.3	\$13.4	\$26.5	\$26.7
NPV water rights cost	\$25.4	\$45.7	\$336.1	\$342.2	\$248.7	\$249.9	\$495.0	\$498.0
Total NPV costs	\$6,680.4	\$8,576.7	\$26,936.1	\$31,994.2	\$21,835.7	\$22,624.9	\$36,189.0	\$38,649.0
B/C ratio Single-Purpose Alternative Plans	0.046	0.037	0.128	0.127	0.138	0.133	0.167	0.156
Multi-Purpose Project Economic Analysis Results (2014 \$ in thousands)								
Alternative Plan Salinity Scenario	Site 1: Montoya				Site 2: Rio Grande, ISC-4			
	B				D			
	1	2	3	4	1	2	3	4
NPV River WQ Benefits	\$304.0	\$284.5	\$4,088.3	\$3,992.5	\$3,031.3	\$3,012.0	\$6,103.9	\$6,056.4
af/Yr Water Sold	21.7	65.2	217.3	434.7	152.1	195.6	217.3	326.0
Product TDS mg/L	625.0	218.0	828.0	421.0	875.0	684.0	1219.0	818.0
Annual water sales benefit (\$800/af)	\$17.4	\$52.2	\$173.9	\$347.7	\$121.7	\$156.5	\$173.9	\$260.8
NPV water sales benefit	\$324.9	\$974.6	\$3,248.5	\$6,497.0	\$2,274.0	\$2,923.7	\$3,248.5	\$4,872.8
Total NPV Benefit	\$628.8	\$1,259.1	\$7,336.8	\$10,489.6	\$5,305.2	\$5,935.7	\$9,352.4	\$10,929.2
NPV Project Costs	\$7,649.0	\$9,988.0	\$31,792.0	\$38,730.0	\$25,401.0	\$26,503.0	\$42,279.0	\$45,616.0
af/Yr Water Removed from River	27.2	81.5	271.7	543.3	190.2	244.5	271.7	407.5
Annual water rights cost (\$300/af)	\$8.2	\$24.5	\$81.5	\$163.0	\$57.1	\$73.4	\$81.5	\$122.3
NPV water rights cost	\$152.3	\$456.8	\$1,522.7	\$3,045.5	\$1,065.9	\$1,370.5	\$1,522.7	\$2,284.1
Total NPV costs	\$7,801.3	\$10,444.8	\$33,314.7	\$41,775.5	\$26,466.9	\$27,873.5	\$43,801.7	\$47,900.1
B/C ratio Multi-Purpose Alternative Plans	0.081	0.121	0.220	0.251	0.200	0.213	0.214	0.228

The multi-purpose alternatives all provide similar river water quality benefits as the single purpose alternatives, and they provide an additional water supply benefit. In the multi-purpose alternatives, the river water quality benefits are reduced (compared to the single purpose plan) for alternative plans where the product water quality is better than the river water quality (In **Table 4-4**, Alternative Plan B, scenario 2 or 4). This is because, by using the product water for water supply, the river dilution caused by the better product water is lost. In cases where the product water quality is worse than the river water (primarily Alternative Plan D), the diversion of product water from the river for water supply provides an additional river water quality benefit. However, any additional costs that might be required to induce the dedicated water user to take this lower-quality water are not included. That is, the analysis has not associated any benefits or costs with the different water qualities of the product water. The potential economic benefits associated with better product water quality in salinity scenarios 1, 2 and 4 for Alternatives A and B are discussed in Section 4.4.

The water supply benefits under the multi-purpose alternatives are generally a similar amount in dollars as the river water quality benefit. In one case (Alternative Plan B Scenario 2) the water supply benefit (\$974.6) is much more than the water quality benefit (\$284.5). In Alternative Plan B Scenario 4, water supply accounts for about two-thirds of the total benefit. In Alternative Plan D Scenario 3, the water quality benefit accounts for more than 60 percent of the total benefit.

Costs for the multi-purpose alternative plans are more than the single-purpose alternative plans because O&M costs are incurred for the entire year, not just during the irrigation season. These incremental costs appear to be far less than the incremental benefit of the water supply. However, no costs have been included to account for any additional facilities, distribution or treatment required to prepare the water supply for M&I use.

4.4 Risk, Uncertainty and Sensitivity Analysis

The following items have been identified as possible factors that might affect the benefits or costs of the project. The list is not exhaustive, but includes issues and uncertainties that have been identified during the planning process. Some could improve the potential economic performance (increase benefits or reduce costs), some could reduce the potential performance, and some simply represent uncertainties that could either improve or reduce performance.

4.4.1 Combine sites into a larger facility to achieve economies of scale

The costs developed for this project suggest that the cost per unit of water treated declines as the scale of the desalination facility increases. It might be possible to treat source water from two or more locations at one facility by piping the source water. Larger facilities would appear to improve the cost-effectiveness, but the net effect on project economic performance is unknown.

4.4.2 Project costs are preliminary

Costs estimated for extraction, treatment, and disposal are highly uncertain, due to a number of factors. Costs could be as much as 100 percent higher or 50 percent lower than shown.

4.4.3 Sell product water to El Paso Water Utilities

The main multi-purpose alternative plan analysis shown above assumed that the product water would be obtained by a dedicated user. As an alternative, winter water supply could be provided to EPWU for the November through February period, or one third of the year. The product water in the summer (March through October) would have limited value for EPWU as long as excess capacity is available at its expanded surface water treatment plants, because the product water could have been diverted into that treatment plant anyway. This is especially true of the product water has higher TDS than the river water because EPWU would prefer to have the product water diluted by the river.

The option to provide water to EPWU would require an interconnection with the EPWU distribution system, so it would be physically possible to take the product water all year. For three out of eight salinity scenarios

applied to multi-purpose alternative plans, the product water is of better quality than the river water. For these three scenarios it can be assumed that the product water could be directly used by EPWU all year. EPWU would receive economic benefit from the better-quality product water. This benefit is estimated using the M&I economic model by substituting the product water for an equal quantity of river water. The incremental water quality benefit for the three alternative plans where the product water is of better quality than the river water is very small and has little effect on the multi-purpose plan economics.

4.4.4 Some incremental costs required for use of product water are not included

Costs to connect to and deliver the product water to a user have not been included, because the potential user's location is unknown. Including these costs would reduce the economic performance of any multi-purpose alternative. Nearby potential users are shown on **Figure 4-1**.

4.4.5 Assume salt from desalination is sold to offset evaporation pond costs

The costs of constructing and operating brine evaporation costs are a large share of total project costs. For the lower end of the B/C ratio range using salinity scenarios 1 and 2, evaporation pond costs account for 26 to 35 percent of all costs. For other alternative plans in the middle or upper end of the salinity reduction range, evaporation pond costs range from 58 to 76 percent of all costs. Reducing brine disposal costs could substantially improve economics of the alternative plans.

It is possible that an alternative means of brine disposal would be more cost-effective. One possible means to reduce disposal cost would include the sale of salt products to a willing buyer. No market analysis has been done to document demand for salt products from this project. Other disposal means, such as using brine in oil and gas well operations, might be less expensive but have not been investigated.

4.4.6 Include benefits for future Mexico M&I uses

Mexico is planning to use Rio Grande surface water for M&I purposes in the near future. Improved Rio Grande river water quality would also benefit Mexico, but such benefits have not been included in this benefit-cost analysis. If Mexico contributed to project costs, the remaining costs to be paid by the United States and its citizens would be less.

The potential use of water is similar in size to the existing use of Rio Grande water by EPWU. If included, benefits could increase by as much as 100 percent, though the alternative plans would still not be economical.

4.4.7 Expand the modeling to include urban salinity costs for excluded items

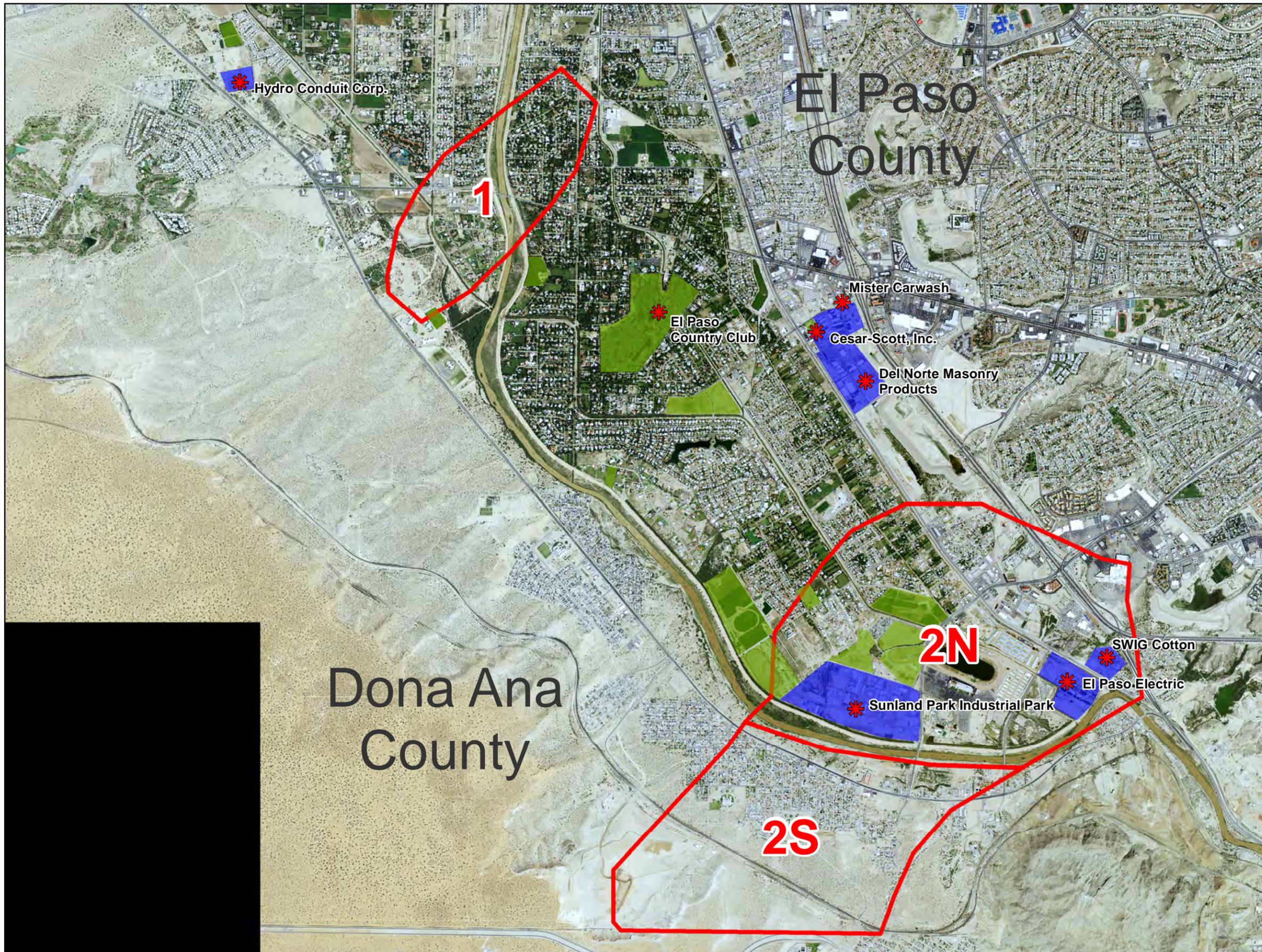
The M&I economic model is based largely on the expected life of water-using fixtures and home appliances. The model includes water heaters, faucets, garbage disposals, clothes washers, dish washers, evaporative coolers, and water and wastewater pipes. The model does not include landscape irrigation equipment, ice-makers, refrigerators with water filters, or coffee makers, to name a few. Including the expected life of these products as a function of salinity would increase the benefits of river salinity reduction. The potential increase in benefits is unknown. Additional studies would be required to establish such cost relationships.

4.4.8 Add more water treatment to achieve more salinity reduction

The value of product water might be improved at additional cost by adding more water treatment. It is unclear whether or not the additional benefit would be worth the cost, and the net effect is likely to be small.

4.4.9 A larger mass of salts could be removed during treatment

Mass removal estimates assume that the treatment process captures and removes 30 percent of the mass load of salt. It is possible that a greater percentage could be captured and if that could be accomplished at little or no additional cost, benefits would increase somewhat. Quantitative analysis has not been performed.



- LEGEND**
- * Potential Users
 - Potential Industrial Use Areas
 - Potential Agricultural Use Areas
 - Potential Capture Area

- Notes:**
1. Area of interest subject to change.
 2. Source: USDA 2012 Agriculture Imagery

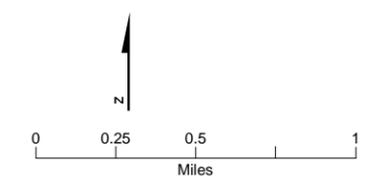


FIGURE 4-1
SITE MAP WITH POTENTIAL USERS
 Rio Grande Salinity Management Program: Alternatives
 Analysis for Distal Mesilla Basin
 Rio Grande Salinity Management Program

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4.4.10 Include greater salinity reduction in dry years because flows are low

The salinity model does not count the full benefit of salinity reduction in dry years when river flows are lower than average. The mass load reduction would be the same but applied to a smaller total flow. If the salinity improvement in dry years were estimated and included in the analysis, benefits would increase but the effect is likely to be small.

4.4.11 Assume lower flows but longer duration in dry years

In the primary analysis, dry year flows are assumed to be at similar rates but shorter duration than normal year flows, based on operations since 2008. However, future operations are uncertain, and dry year flows could differ from recent operations. If future dry year flows were of longer duration and lower flow, there would be a greater reduction in TDS concentration in the surface water system. Effects on overall project net benefits is likely to be small.

4.4.12 Changes in agricultural crop mix or revenue in the future are unlikely to affect results

There may be some potential for additional agricultural benefits related to future agricultural water use. The agricultural benefits are a small share of all benefits due to the very small changes in delivered water quality, and any additional benefits from changing agricultural land uses and revenues are believed to be very small. In addition, the changes in delivered water quality are far too small to affect crop selection. This issue was discussed with local Agrilife Extension experts, water district staff, and growers; the consensus was that the range of salinity reductions considered here is much too small to affect crop selection.

4.4.13 Any unplanned surface water treatment plant expansion in response to faster economic growth would increase the benefits

The M&I benefits are closely related to the share of EPWU water supplies that are drawn from the river. Unplanned population growth or additional surface water treatment capacity, beyond the increases already included, would increase benefits, but the effect would be small.

4.4.14 Add replacement costs and increase project life

The analysis assumed a 30-year project life from 2020 through 2049. The availability of source water past that time is unclear. Also, additional costs for project components that would wear out beyond 30 years would be required. If source water is available, the addition of benefits beyond 30 years might exceed the replacement costs. The net effect on total benefits and costs is unknown but likely to be small.

4.4.15 Potential effects of climate change

Climate change could improve or decrease the economic feasibility of the alternative plans. A recent study suggests that climate change may result in decreasing water availability in the future (Reclamation, 2013b). A smaller surface water use share for EPWU would decrease M&I benefits. On the other hand, salt load reduction resulting from the project improves the concentration in the smaller river flow by a larger percent. In addition, climate change could affect the volume and quality of source water for the project in some unknown way. Therefore the net effect of climate change on project performance is uncertain.

4.4.16 Reduced availability of source water

Potential reduction in future discharge of saline water to the Rio Grande and/or Montoya drain, in response to increased aquifer pumping in Santa Teresa, Sunland Park, Mexico, and elsewhere, was not considered. Rather, it was assumed that the saline source will continue into the future. If available source water declined to the point where the treatment facilities could not be used as designed, project useful life could be shortened and benefits would decline.

4.4.17 Potential additional benefits during shoulder and non-irrigation seasons

The analysis presented in Sections 4.2 and 4.3 focused on water diverted from the river for urban and agricultural purposes during the primary irrigation season, defined as the period during which water

released from Caballo Reservoir is being diverted in El Paso County. Local agencies may also divert water outside the primary irrigation season, even though the river quality is substantially poorer and flow is much less. Further, the periods when releases from Caballo are increasing or declining (the shoulder seasons) have transitions in water quality that affect the water's usability for urban purposes.

This situation suggests two additional opportunities for benefits from the proposed desalting facilities:

1. Removal of salts during the shoulder seasons can allow additional time during which the river water has acceptable quality for use by EPWU.
2. Removal of salts during the off-season provides benefits for any water being diverted during that time.

These potential benefits were not included in the main analysis because of greater uncertainty in the amount, timing, and quality of potential off-season and shoulder season diversions, uncertainty in associated benefits, and the potential implications on water rights. In addition, the large majority of diversions occur during the primary irrigation season, and the main analysis accounts for those benefits. This sensitivity analysis evaluates the potential magnitude of off-season and shoulder season benefits using some additional assumptions and modeling results. Shoulder season benefits could result from additional days or hours during which river water quality is acceptable for urban use, allowing EPWU to avoid costs of alternative supplies including groundwater depletion. Off-season benefits could result because of the salinity reductions provided by a desalting facility to any water diverted during that time.

4.4.17.1 Calculation of benefits from extending surface water treatment season into the shoulder season

When upstream water releases begin from Caballo at the beginning of the irrigation season, flow in the Rio Grande at El Paso typically increases gradually over a period of several weeks to a month, during which time water quality gradually improves due to dilution. A similar process happens in reverse in the fall after Caballo releases. These two periods are commonly referred to as the "shoulder seasons."

EPWU uses water quality criteria to determine when to start and stop diversions during the shoulder seasons. Sulfate is the primary criteria, followed by chloride then TDS. Because the project would improve water quality in the Rio Grande and American Canal, EPWU may be able to begin diversions earlier in the spring shoulder season, and continue diversions later in the fall shoulder season, providing an economic benefit to EPWU. Duration of additional diversion was estimated to be between 0.1 day and 1.7 days, depending on the project alternative (**Appendix A2**).

4.4.17.2 Potential economic benefits from extending surface water treatment season into the shoulder season

Better water quality might allow EPWU to extend their surface water treatment season. The extended treatment season allows more water to be diverted. The benefit of this change is estimated as the cost savings from treating surface water as opposed to groundwater.

The analysis estimated that, as soon as 2020, 57,940 af of surface water per year can be treated on average. This is 271 af per day for the 7-month irrigation season. However, if the available water is provided for a shorter period and the treatment facility operates at capacity of 120 MGD, then the plant could treat 368 af per day.

The benefit of this additional surface water supply is the alternative cost saved, less the cost required for surface water diversion and treatment. The alternative is presumed to be groundwater pumping. In both cases, variable costs should certainly be counted; the amount of groundwater and surface water capacity and fixed cost is unaffected in the short term.

For groundwater, variable costs are pumping costs, and, for some wells, treatment costs. For surface water treatment, Caroom and Maxwell (2003) cite a cost of \$300 per af in 2003. With inflation, this would be about \$350 currently. Hutchison (2009) cites an operations cost of \$150 per af for groundwater and \$300 per af for surface water.

If these are the only costs to consider, then the extension of the surface water treatment season would appear to have a negative net benefit. However, it must be recognized that one of the main benefits of surface water treatment is to extend the life of existing groundwater resources and to avoid future capital costs that might be required if aquifers are depleted. The long-term cost savings from the additional surface water supply should be included. This cost savings is likely to involve delayed future costs of implementing more costly water supply alternatives; for example, brackish groundwater desalination. No information is available and a range was assumed.

One end of the range assumes that the net benefit of treating surface water instead of groundwater is \$100 per af. The other end of the range assumes \$400. The range of af/day was 271 to 368, so the range of annual benefit per day is \$27,100 to \$147,000 annually. These annual benefits from 2020 to 2069 are worth from \$636,000 and \$3,455,000, in present value (NPV) terms. Rounding, the benefit per day of additional treatment is likely to be \$1 million to \$3 million in present value terms. **Table 4-5** shows the additional diversion time for each alternative and the estimated NPV of benefits assuming this range.

TABLE 4-5

Additional Diversion Time during Shoulder Season

Alternative Plan	Site 1: Montoya				Site 2: Rio Grande, ISC-4			
	A, B				C, D			
	1	2	3	4	1	2	3	4
Salinity Scenario								
Additional diversion (days) ²	0.1	0.1	1.3	1.3	0.9	0.9	1.7	1.7
Potential range of NPV, \$1,000	\$100- \$300	\$100- \$300	\$1,300 - \$3,900	\$1,300 - \$3,900	\$900- \$2,700	\$900- \$2,700	\$7,100- \$5,100	\$7,100- \$5,100

Compared to results presented earlier in Table 4-3, this benefit could be an important share of all benefits for the single-purpose alternatives. For the low end of the benefit range (\$100 per AF), the B/C ratios of the single-purpose alternative increase by 0.01 to 0.05. For the Montoya site, using the \$400 per AF benefit, the benefit-cost ratios might double, but the B/Cs are still below 0.10 for alternative 1 or 2 and about 0.27 and 0.25 for alternative 3 or 4, respectively. For the Rio Grande site, the B/C ratios for alternatives 1 and 2 could approximately double to about 0.25 to 0.26, and for 3 and 4, they could almost double; for alternative 3, to almost 0.31, at the high end of the range (\$400 per AF).

The additional benefits would be a smaller fraction of benefits for the multi-purpose alternatives. For the Montoya site, again assuming the \$400 net benefit per AF, the benefit-cost ratios could reach 0.11 and 0.15 for alternative 1 or 2 and 0.34 for alternative 3 or 4. For the Rio Grande site, the B/C ratios increase by about 0.10. For alternatives 1 and 2 reaching about 0.30 to 0.31, and for 3 and 4, about 0.33. These improvements in the B/C ratios are uncertain primarily because the net benefit to assign to use of surface water instead of groundwater is uncertain.

4.4.17.3 Use of River Water Diverted During the Non-Irrigation Season for Urban Uses

One potential benefit of the project is that EPWU could divert water during the non-irrigation season if water quality improvements were sufficient. Baseflow in the Rio Grande at El Paso during the non-irrigation season is estimated to be on the order of 3,000 af/mo (Section 2.3.1), which over several months could yield upwards of 10,000 af. However, non-irrigation season salinity model results show TDS concentrations greater than 1,300 mg/L at the American Canal heading for the best-case project alternative, which would not be suitable for urban uses with current water treatment facilities. The conclusion that fewer than two days of additional diversion would be obtained in the shoulder season also suggests that water quality improvements would not be sufficient to allow non-irrigation season diversions.

4.4.17.4 Use of River Water Diverted During the Non-Irrigation Season for Agricultural Uses

The analysis of irrigation benefits of salinity reduction is based on the total delivery to users reported or estimated by the two districts, EPCWID#1 and HCCRD#1. The TDS of the delivered water, both without project and for the alternatives, is based on salinity model results for the primary irrigation season, defined as the period during which water released from Caballo Reservoir is being diverted by EPCWID#1 for irrigation purposes in El Paso County. A more detailed, separate accounting of non-irrigation season diversion would consider the following:

- The large majority of crop irrigation demand occurs during the primary irrigation season.
- If a portion of the water delivered by EPCWID#1 were diverted outside of the primary irrigation season, the river would generally be at lower flow and higher salinity. The mass load reduction provided by an alternative would remain the same during such times, and so would provide a larger reduction in TDS, all else equal. However, the reduction in TDS would be relative to a higher TDS in the river during that time.

In order to assess the potential importance of separate accounting of non-irrigation season diversions for crop irrigation, we re-evaluated scenario 2.3 with an additional 3 months of diversion by the two irrigation districts occurring outside of the primary irrigation season. Available flow was 10,300 af/mo in 2020 and 12,130 af/mo in 2050. For purposes of analysis, the available flow was split between EPCWID#1 and HCCRD#1. The estimated available flow and salinity are summarized in **Table 4-6** and **Appendix A1**. These assumptions are intended simply to illustrate the general magnitude of effect on potential benefits and project benefit/cost.

TABLE 4-6

Assumptions for Sensitivity Analysis Using Additional Winter Irrigation Diversions

	EPCWID#1		HCCRD#1	
	Without Project	Rio Grande Scenario 3	Without Project	Rio Grande Scenario 3
2020 Off-Season Diversions				
Monthly Volume Diverted	8,000	8,000	2,300	2,300
TDS reduction		51 mg/l		51 mg/l
2050 Off-Season Diversions				
Monthly Volume Diverted	9,000	9,000	3,150	3,150
TDS reduction		43 mg/l		43 mg/l

The agricultural economic model was used to evaluate the benefits of Alternative 2.3 under these conditions of additional diversion of higher salinity water. The additional benefits from salt removal during these non-season diversions above what Alternative 2.3 would already provide is about \$27 thousand in NPV over the life of the project. The overall effect on the B/C ratio of Alternative 2.3 is insignificant, and a similar conclusion is expected if other alternatives were evaluated.

SECTION 5

Findings and Recommendations

The alternatives analysis for the Distal Mesilla Basin evaluated four alternative plans for benefits compared to future-without-project conditions. A brief description of the benefits of each feasible alternative is provided below:

- For single-purpose Alternatives A and C, only benefits to water quality in the Rio Grande were accounted for. Overall, the benefits were substantially less than costs in all cases, which ranged from a NPV of \$6.7 to \$38.6 million. Project benefits of each alternative plan were about 4 to 17 percent of the costs.
- For multi-purpose Alternatives B and D, benefits to both water quality and water supply sales to a dedicated water user were accounted for. As with single-purpose alternative plans, the benefits were substantially less than costs in all cases, which ranged from a NPV of \$7.3 to \$47.6 million. Project benefits of each alternative plan were about 8 to 25 percent of the costs.

These results indicate that none of the alternatives would be economically feasible, and therefore, none would be acceptable to meet federal interests for NED. As compared to the single-purpose alternative plans, the multi-purpose alternative plans are more economical even though costs are higher. In all alternative plans, using product water directly as supply, instead of returning it to the river, appears to improve project economics.

Because there was not a substantial difference in B/C ratio between the two potential sites, another alternative that may be considered in the future is to combine groundwater extraction from the two sites into one larger treatment facility to achieve a greater economy of scale. It may be possible to treat source water from two or more locations at one facility by piping the source water. Larger facilities would appear to improve the cost-effectiveness, but the net effect on project economic performance is unknown.

Section 4.4 provides a description of risks, uncertainties, and sensitivity analysis which illustrate the effect of some key assumptions and data limitations of this economic analysis. While none of the alternative plans would be economically feasible based on the economic analysis conducted for the Distal Mesilla Basin, the Coalition may still desire to pursue a project to address salinity reduction. The federal interest and cost sharing associated with any future project should be evaluated to identify potential for additional costs that could be funded locally. Some potential plan improvements for the Coalition and other stakeholders to consider are listed below (further detail is included in Section 4.4):

- Economic benefits of longer municipal surface water treatment season
- Combine sites into a larger facility to achieve economies of scale.
- Sell product water to El Paso Water Utilities on a year-round basis.
- Reduce evaporation pond costs using alternative disposal methods.
- Include benefits for future downstream Mexico M&I uses.
- Add more water treatment to achieve more salinity reduction.
- A larger mass of salts than was modeled could still possibly be removed during treatment.
- Greater salinity reduction in dry years could occur because flows are low, also longer duration.
- Develop pilot or demonstration project to clarify costs and benefits.
- Any unplanned surface water treatment plant expansion in response to faster economic growth would increase the benefits.

This report provides an updated framework for economic analysis that could be applied to other project combinations involving single or multi-purpose projects in one or more locations. Given the scale of the overall Rio Grande Salinity Management Program, multiple management measures and projects are needed in combination to have an impact on the overall Rio Grande system.

The Study Area is highly developed and in most cases, previously disturbed by construction. The riparian corridor associated with the Rio Grande is an environmentally sensitive area and should be avoided to minimize environmental impacts and it should also be evaluated for other potential ecological improvements that may improve the benefits of the project.

Evaporation ponds to dispose of concentrated brine were found to be the largest share of some alternative plan costs. Investigating alternatives to evaporation ponds could improve the feasibility of the alternative plans. These alternatives might include sale of salt products to help offset costs. Due to the large amount of land that would be required for evaporation ponds, an alternative disposal plan could also further minimize the environmental impact of the project.

SECTION 6

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Appendix A1
Salinity Model Updates and Results

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Salinity Model Updates and Results, Distal Mesilla Basin

PREPARED FOR: USACE, Albuquerque District
PREPARED BY: CH2M HILL
DATE: April 3, 2015

Introduction

This appendix summarizes the salinity model that was used for estimating salinity reduction downstream of the project site. This appendix is divided into three sections, covering model updates, model limitations, and model results.

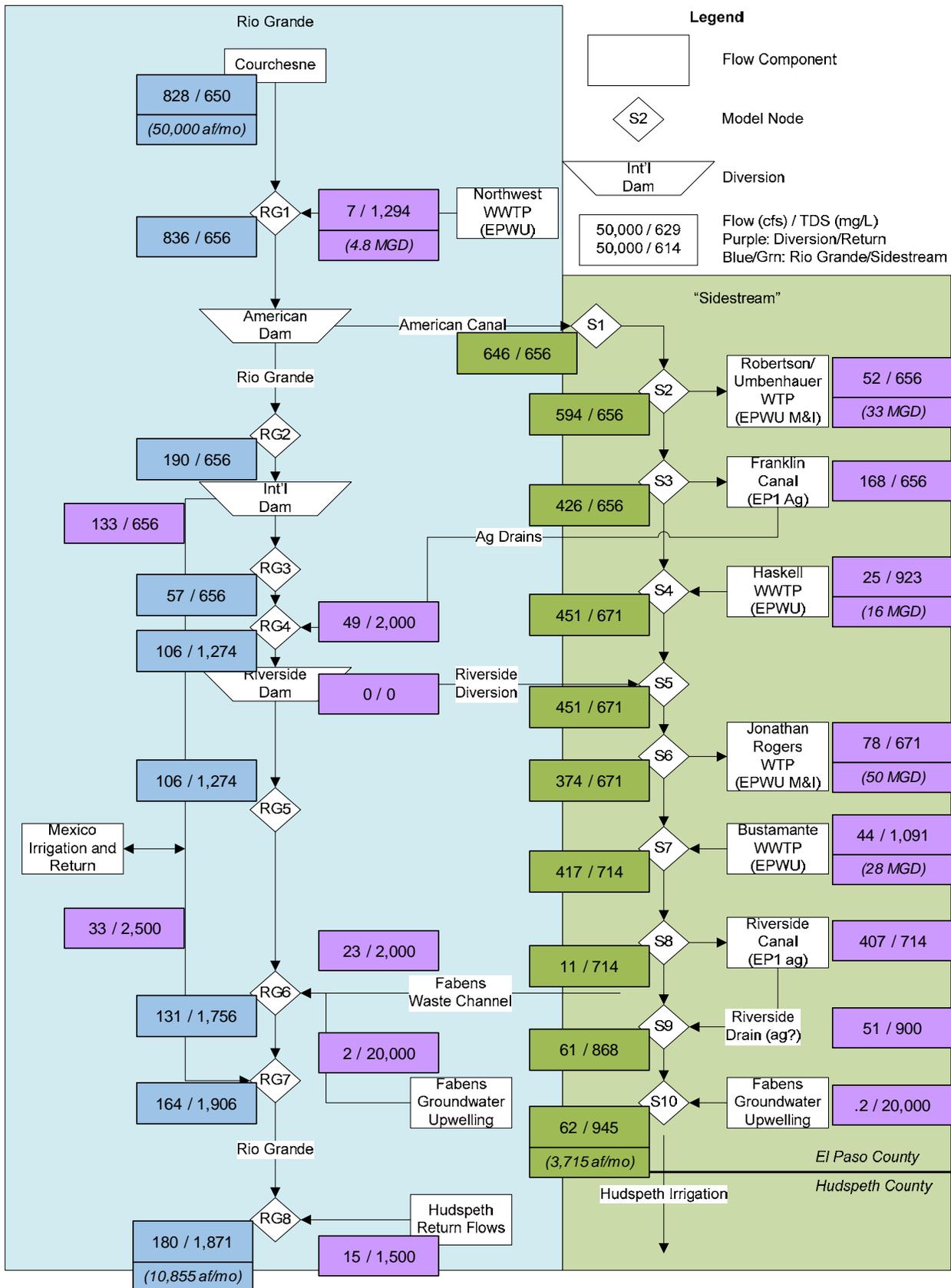
The purpose of salinity modeling for this project is to provide a reasonable representation of how salinity reduction at a potential salinity control project site propagates downstream to locations where the water is used. Model results used for subsequent evaluation include the change in salinity for each of the three water users in response to a potential salinity control project in the Distal Mesilla area.

The model used in the Alternatives Analysis (“2011 model,” CH2M HILL, 2011) was updated with additional information, updated to simulate future conditions, updated to simulate TDS instead of chloride, and updated to simulate both irrigation and non-irrigation seasons. The evaluation approach remains the same as the 2011 model, with the model simulating average-condition flow and water quality between El Paso and Hudspeth County.

A schematic of this reach is provided in **Figure 1**. In the upper part of the reach, a significant portion of the Rio Grande (about 80 percent) is diverted from the Rio Grande via the American Canal. The American Canal is the beginning of a “sidestream” of flow that has numerous inflows and outflows. All of the primary water usage in the U.S. along this reach is diverted from the sidestream. The downstream extent of the sidestream is Hudspeth County irrigation.

The majority of the water remaining in the Rio Grande downstream of the American Canal is diverted to Mexico from the International Diversion Dam. Accordingly, flow in the Rio Grande is limited along this reach, and the sidestream is the primary focus of the model.

FIGURE 1
Current Conditions Model



Model Updates

The model was updated to address key data gaps and to simulate future conditions. The following sections discuss the additional data used, followed by updates to diversions and return flows for current irrigation season conditions, a description of future irrigation season condition assumptions, and a summary of non-irrigation season updates. All irrigation season model updates are summarized in **Table 1**.

Summary of Available Data

This section summarizes new sources of data that were used in the update of the model. One of the key data gaps in the 2011 model was availability of flow and water quality data at Hudspeth County. While flow and water quality measurements are still not available, discussion with HCCRD representatives suggest that they receive about 30,000 acre-feet per year (afy) of water with TDS concentration of about 800 milligrams per liter (mg/L) (Chavez, 2014). Because Hudspeth County forms the downstream end of the model, information on flow and water quality was used to constrain upstream diversions and return flows.

In addition, a dataset was obtained from NM ISC that contained time-series of flow rates for a number of key locations, which was used in support of development and extension of the Upper Rio Grande Water Operations Model (URGWOM) (NM ISC, 2014a). Specifically, data that were used included the following:

- Franklin Canal
- Riverside Canal
- Ascarate Wasteway

NM ISC also provided a schematic of a preliminary flow model that will be used to simulate this reach (**Figure 2**). The schematic was helpful in confirming understanding of the flow routing in the system.

Lastly, additional data were collected for El Paso Water Utility (EPWU) wastewater flows. Data collected include wastewater effluent flow rates, wastewater water quality data (EPWU, 2013), and projections of future wastewater effluent flow rates (EPWU, 2014a).

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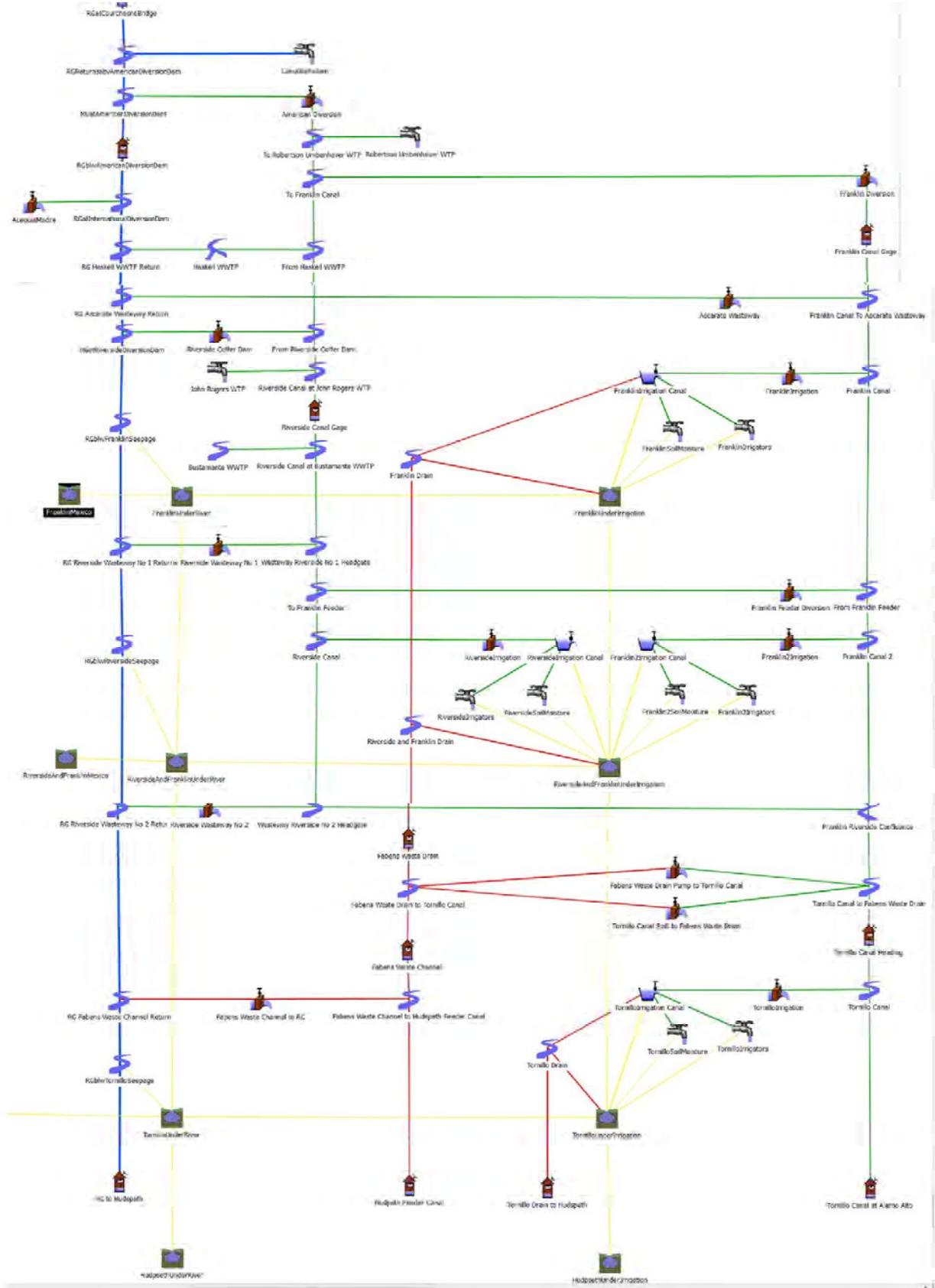
Table 1

Summary of Irrigation Season Model Updates

Model Node	Description	Flow Rate (af/mo)	TDS (mg/L)	Description of Changes From 2011 Model	Flow Rate (af/mo)	Flow Rate (af/mo)	Future Conditions Basis
Rio Grande							
Input	Courchesne	50,000	650	based on historical analysis of flow			
RG1	NW WWTP	446	1,294	Flow average 2006-2010, water quality average 2007-2010. Both are filtered for times that EPWU was diverting surface water. Also implemented a feedback loop for scenarios.	897	1,738	EPWU Draft Wastewater Master Plan (EPWU, 2014a) and projected indoor demand. See Table X).
S1/RG2	American Diversion	39,000	656	Changed to 78% of Courchesne Bridge flow, to facilitate potential changes in Courchesne Flow. Based on historical data and calibration.	<i>(no change)</i>		
RG3	International Diversion	8,000	656	Changed to 16% of Courchesne Bridge flow, to facilitate potential changes in Courchesne Flow. Based on historical data and calibration.	<i>(no change)</i>		
RG4	Ascarate Wasteway	2,930	2,000	Changed to 29% of Franklin Canal (Node S3 below), to facilitate potential changes in Courchesne Flow. Based on historical data and calibration. Water quality data not readily available (note that water quality here does not affect results in this report).	<i>(no change)</i>		
S5/RG5	Riverside	0	0	<i>(no change)</i>			
RG6	Fabens groundwater upwelling, to Hudspeth Ponds	150	20,000	Flow unchanged from 2011 model. Concentration reduced to 20,000 mg/L to match upwelling to sidestream.	<i>(no change)</i>		
RG6	Waste Channels	1,400	2,000	No change to flow from 2011 model; TDS estimated at 2,000 mg/L (note that water quality here does not affect results in this report).	<i>(no change)</i>		
RG7	Return flow from Mexico (ag plus sewage)	2,000	2,500	Changed to 25% of International Diversion to facilitate change in upstream flow.	<i>(no change)</i>		
RG8	Return flow from Hudspeth	929	1,500	Changed to 25% of Hudspeth Diversion to facilitate change in upstream flow.	<i>(no change)</i>		
Sidestream							
S2	Robertson/Umbenhauer WTP	3,120	656	Flow estimated to be 8% of American Diversion, based on total EPWU diversion of 60,000 afy and ratio of capacity between two plants.	<i>(no change)</i>		
S3	Irrigation: Franklin Canal	10,140	656	Flow estimated to be 26% of American Diversion. Based on historical data and calibration, along with Riverside Canal, to match reported total diversion to EPCWID#1	9,980	9,396	Decrease to match projected EPCWID#1 water use
S4	Haskell WWTP	1,512	923	Average 2007-2010, filtered for times that EPWU was diverting surface water. Also implemented a feedback loop for scenarios.	2,332	2,078	EPWU Draft Wastewater Master Plan (EPWU, 2014a) and projected indoor demand. See Table X).
S6	JRWTP	4,680	671	Flow estimated to be 12% of American Diversion, based on total EPWU diversion of 60,000 afy and ratio of capacity between two plants.	6,385	6,385	increase to match projected diversions, based on expansion of plant
S7	Bustamante WWTP	2,632	1,091	Average 2007-2010, filtered for times that EPWU was diverting surface water. Also implemented a feedback loop for scenarios.	4,119	5,361	EPWU Draft Wastewater Master Plan (EPWU, 2014a) and projected indoor demand. See Table X).
S8	Irrigation: Riverside Canal	24,570	714	Flow estimated to be 63% of American Diversion. Based on historical data and calibration, along with Riverside Canal, to match reported total diversion to EPCWID#1	24,183	22,767	Decrease to match projected EPCWID#1 water use
S9	Riverside Drain, to Hudspeth Ponds	3,065	900	Changed to 10% of Franklin Feeder (Node S8 above) + 6% of Franklin (Node S3), to facilitate potential changes in Courchesne Flow. Based on historical data and calibration. TDS estimated to be 900 mg/L based on reported water quality for HCCRD.	<i>(no change)</i>		
S10	Fabens groundwater upwelling, to Hudspeth Ponds	15	20,000	Flow reduced to half of 2011 model, and TDS concentration adjusted to match reported water quality at HCCRD.	<i>(no change)</i>		

Input data Model-calculated value Uncertain input data

FIGURE 2
Draft URGWOM Schematic (NM ISC, 2014b)



Current Irrigation Season Conditions Updates

The model structure remains the same as the 2011 model. No model nodes were added or removed; however, flow and water quality were updated for most nodes. A schematic of the current conditions model is presented in **Figure 1**. In addition, **Table 1** summarizes all changes made to the model from the 2011 version. This section summarizes current condition flow and water quality assumptions for all nodes in the model. It is broken out into subsections of diversions and return flows.

Diversions: Current Conditions

The model was updated to simulate diversion rates as a percentage of flow at El Paso, as opposed to constant diversion rates used in the 2011 model. Using percentages facilitates changing the upstream boundary flow conditions to simulate higher or lower flow rates, to support sensitivity analysis. For diversions, the model only requires flow rates as an input; water quality of diversions is calculated in the model based on upstream flows.

Diversions at the American and International Dams were estimated based on historical data. Historical annual diversions at each dam, compared with flow at El Paso, are presented in **Figure 3**. The same diversions are presented as percentage of annual flow in the Rio Grande at El Paso in **Figure 4**, for normal flows only (i.e., excluding flood and dry years). It can be seen from Figure A-4 that diversions have been relatively constant as a percent of flow at El Paso, with American Canal diversions equal to about 80 percent of El Paso flow, and International diversions equal to about 16 percent of El Paso flow. These values formed the basis of the model inputs, although American Canal diversions were adjusted down slightly during calibration to 78 percent of El Paso flow to better match historical average flow in the American Canal. Historical average flow in the American Canal is about 642 cubic feet per second (cfs) during the irrigation season; using 78 percent of El Paso flow results in simulated flow of 646 cfs in the American Canal.

FIGURE 3
Historical Annual Diversions at American and International Dams

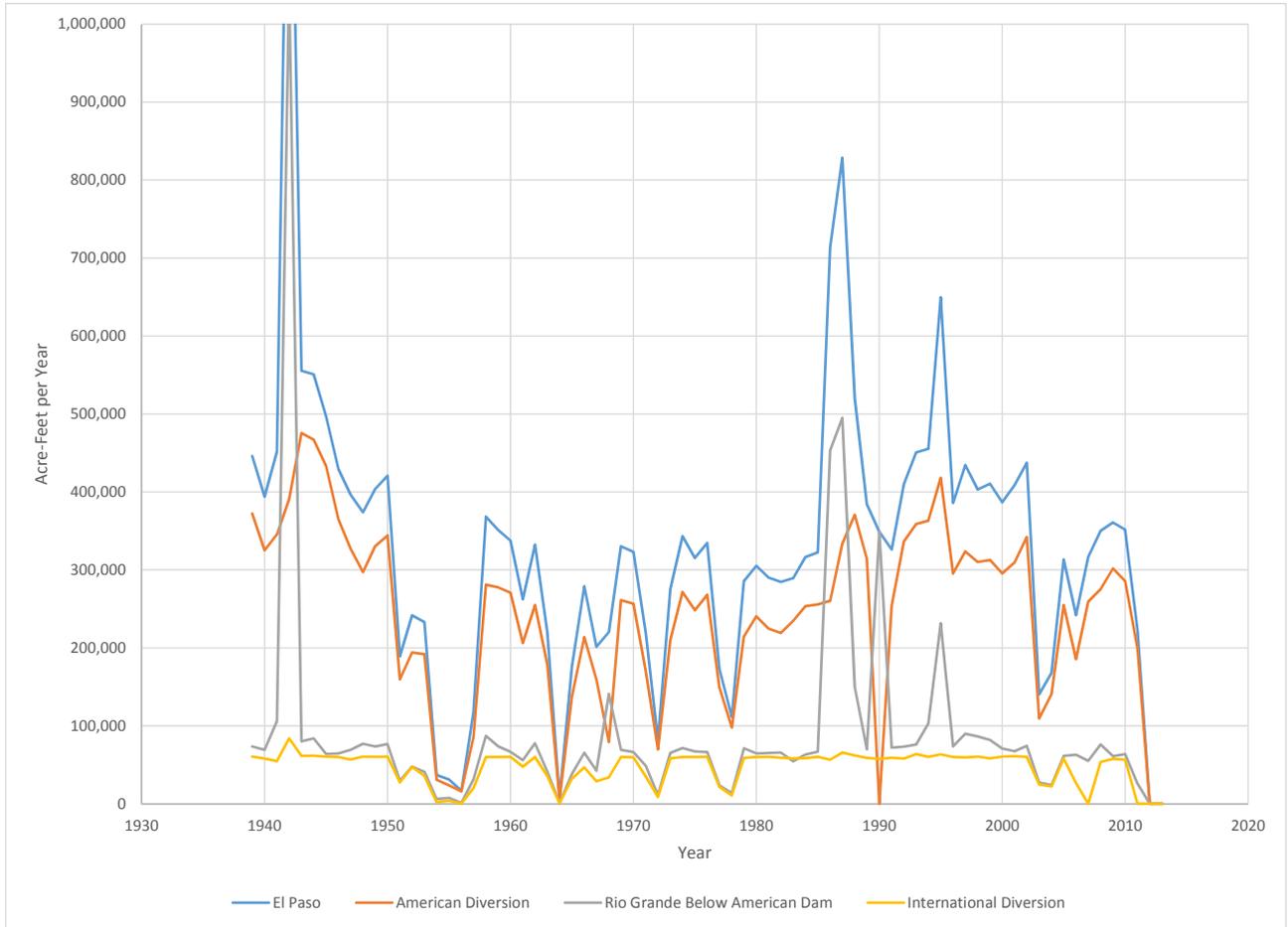
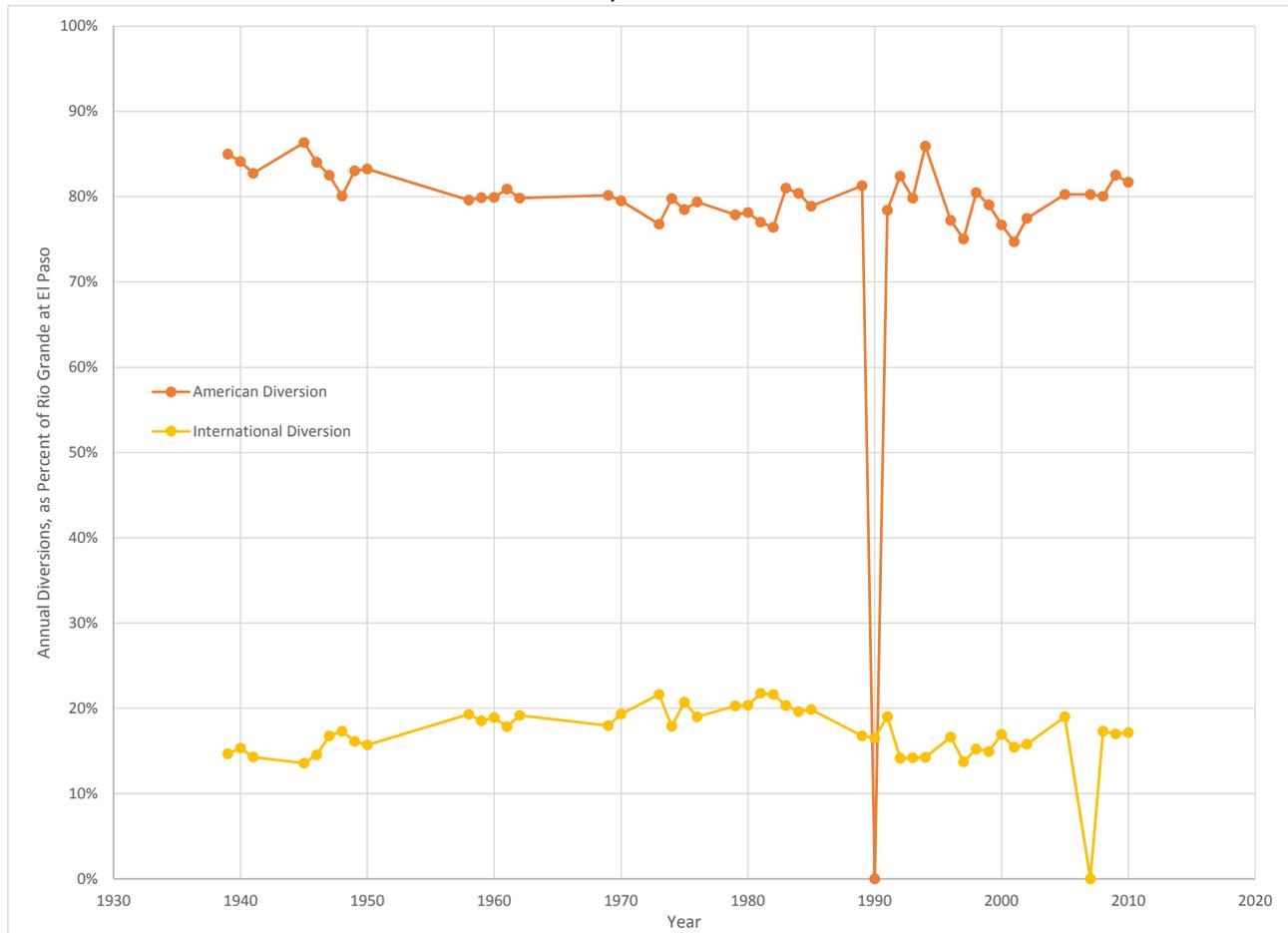


FIGURE 4
Annual Diversions at American and International Dams, as Percent of Rio Grande at El Paso*



*Note: 1990 data point shows 0 diversion at American Canal, which is confirmed by flow below American Dam approximately equal to flow at El Paso. However, flow was “normal” in Riverside Canal, suggesting normal diversion to the U.S. In addition, downstream flow at Fort Quitman was “normal,” which together with “normal” diversions to Mexico, further suggest normal diversion to the U.S. Location. The rate of diversion was not investigated further, and this data point was ignored in the analysis of average diversions to the American Canal.

Diversions from the American Canal to EPWU and EPCWID#1 were based on historical data, and adjusted to match reported annual diversions in a normal year. EPWU diversions were set at a total of 20 percent of American Canal diversions, which result in total diversions over a full 8-month irrigation season of just over 60,000 af. There was no change from the 2011 model in how the diversions are apportioned between the two plants. 60 percent of total EPWU diversions (12 percent of American Diversion) are to Jonathan Rogers Water Treatment Plant and 40 percent (8 percent of American Diversion) from Robertson/Umbenhauer Water Treatment Plant based on recent production and plant capacities.

Diversions for EPCWID #1 are through the Franklin and Riverside Canals. EPCWID has 69,010 irrigated acres with surface water rights of 4 afy/acre (Reyes, 2014). Accordingly, in a full year, EPCWID#1 receives about 276,040 afy of surface water. Historical diversions as a percent of American Canal diversions are presented in **Figures A-5** and **A-6**. Historical data are broken out into data before and after 1993, when EPWU diversions increased. Franklin Canal diversions have historically been on average of 32 percent of American Canal diversions, decreasing to 21 percent since 1993. Riverside Canal diversions have historically been an average of 65 percent of American Canal diversions, decreasing to 58 percent since 1993. Values used on the model were adjusted to 26 percent (Franklin Canal) and 63 percent (Riverside Canal), which are in the

middle of the range of historical values and result in about 274,000 afy of simulated total diversions over a full 8-month irrigation season.

It should be noted that the sum of EPWU and EPCWID#1 diversions from the American Canal exceed the total American Canal diversions. This is due to additional available water in the American Canal from EPWU wastewater treatment plant return flows, which get reused downstream for agricultural purposes.

FIGURE 5
Historical Franklin Canal Diversions, as Function of American Canal Diversions

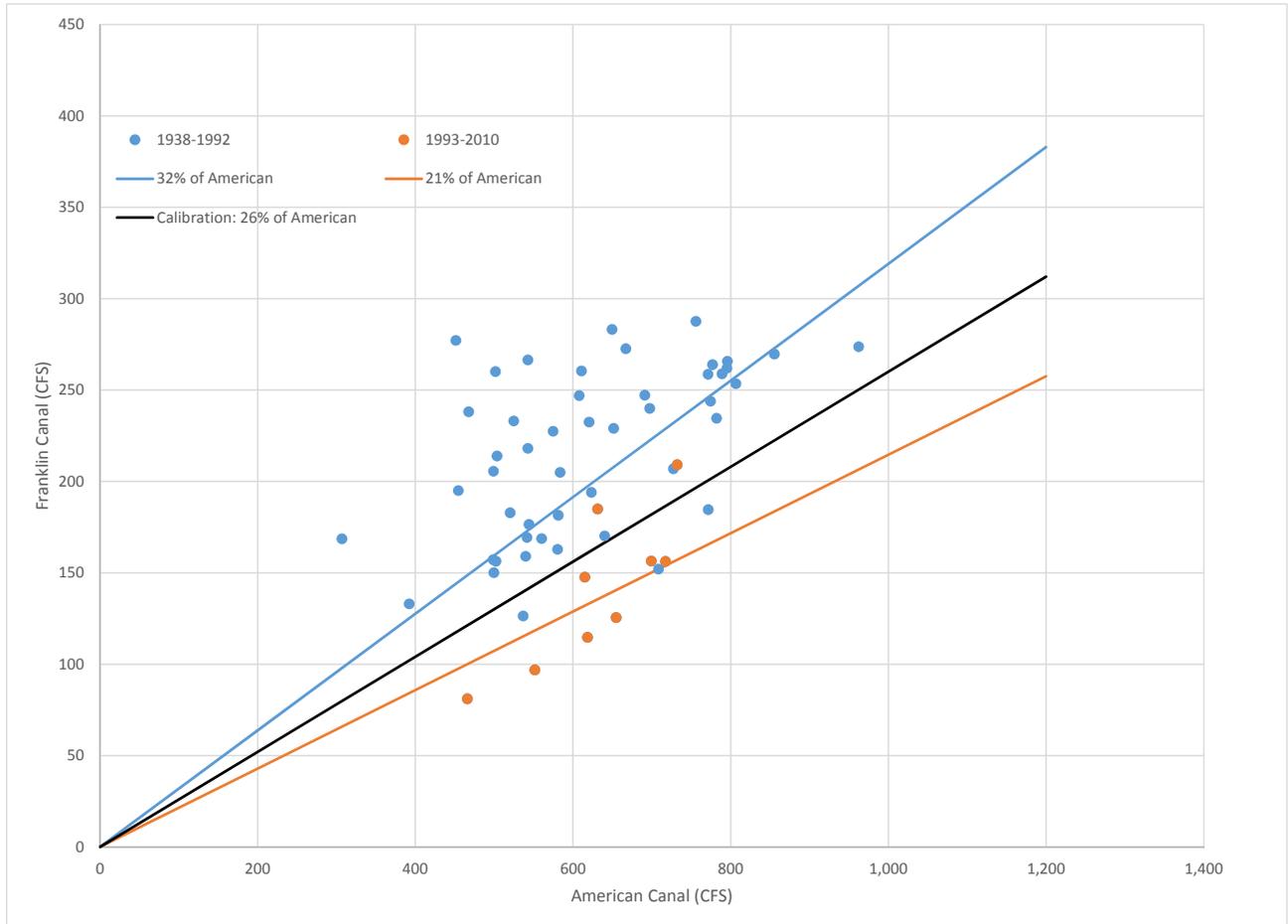
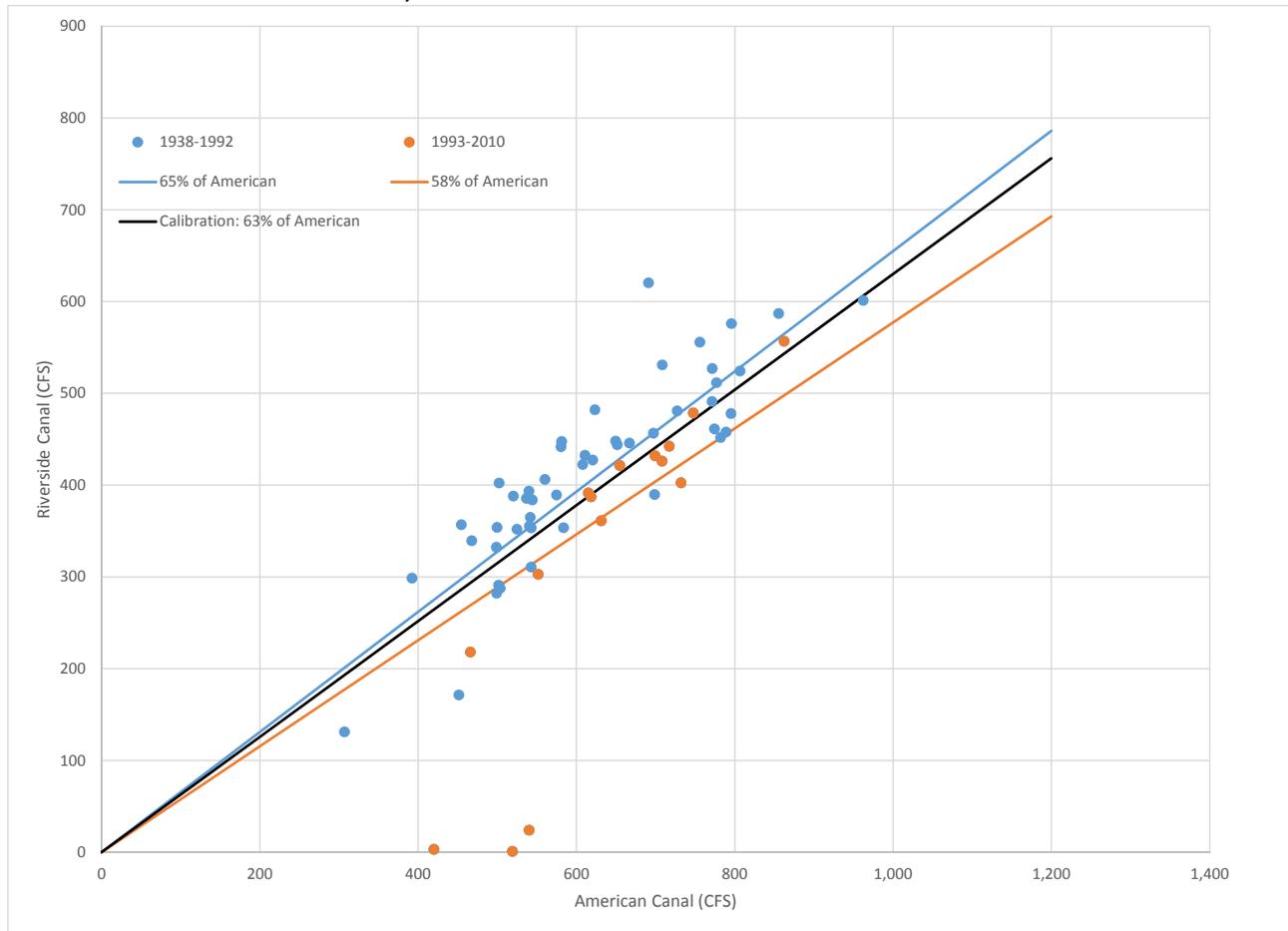


FIGURE 6
Historical Riverside Canal Diversions, as Function of American Canal Diversions

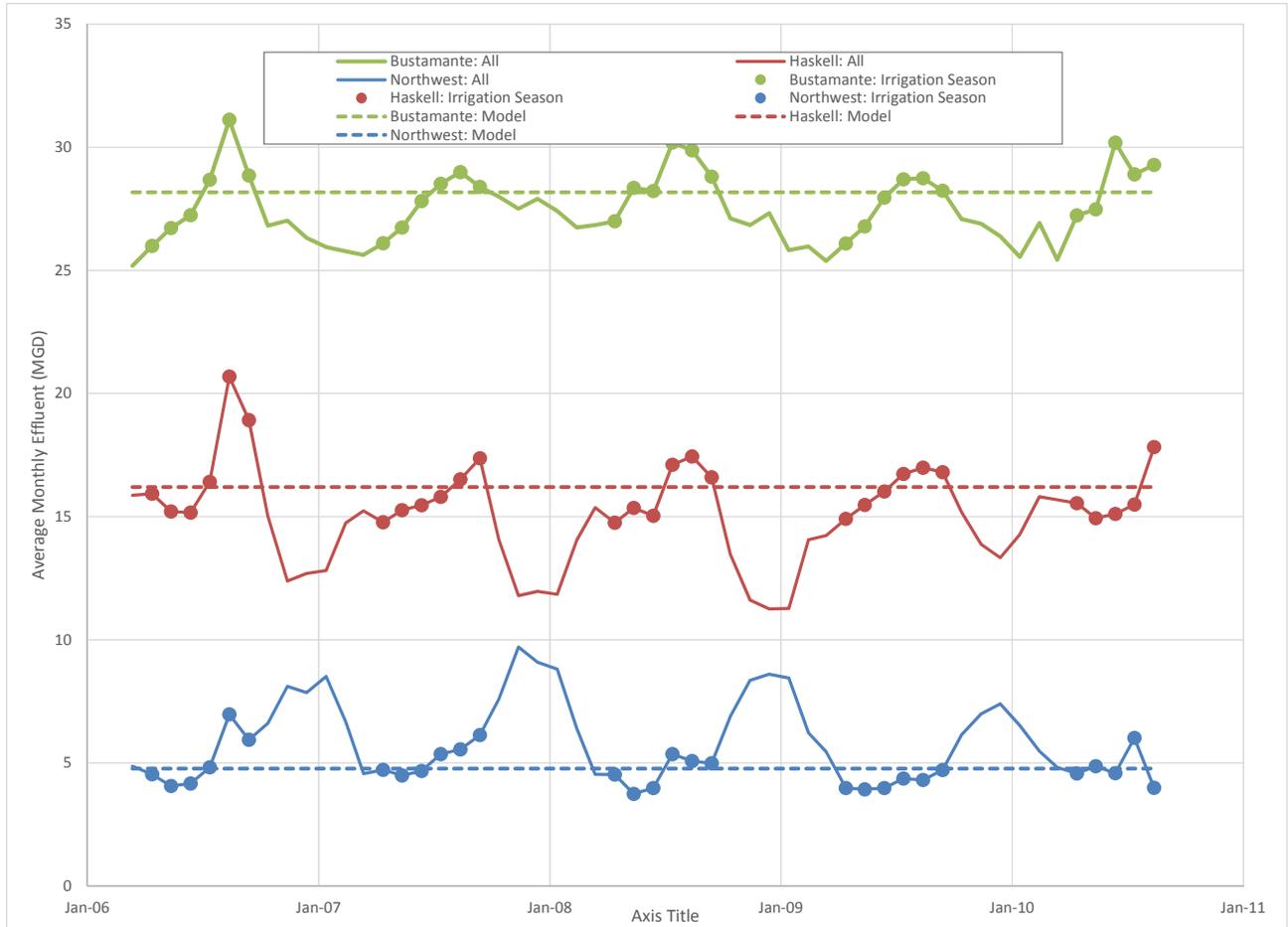


Return Flows: Current Conditions

Two primary types of return flows are simulated by the model: wastewater treatment plant effluent, and irrigation return flows. Each are discussed below.

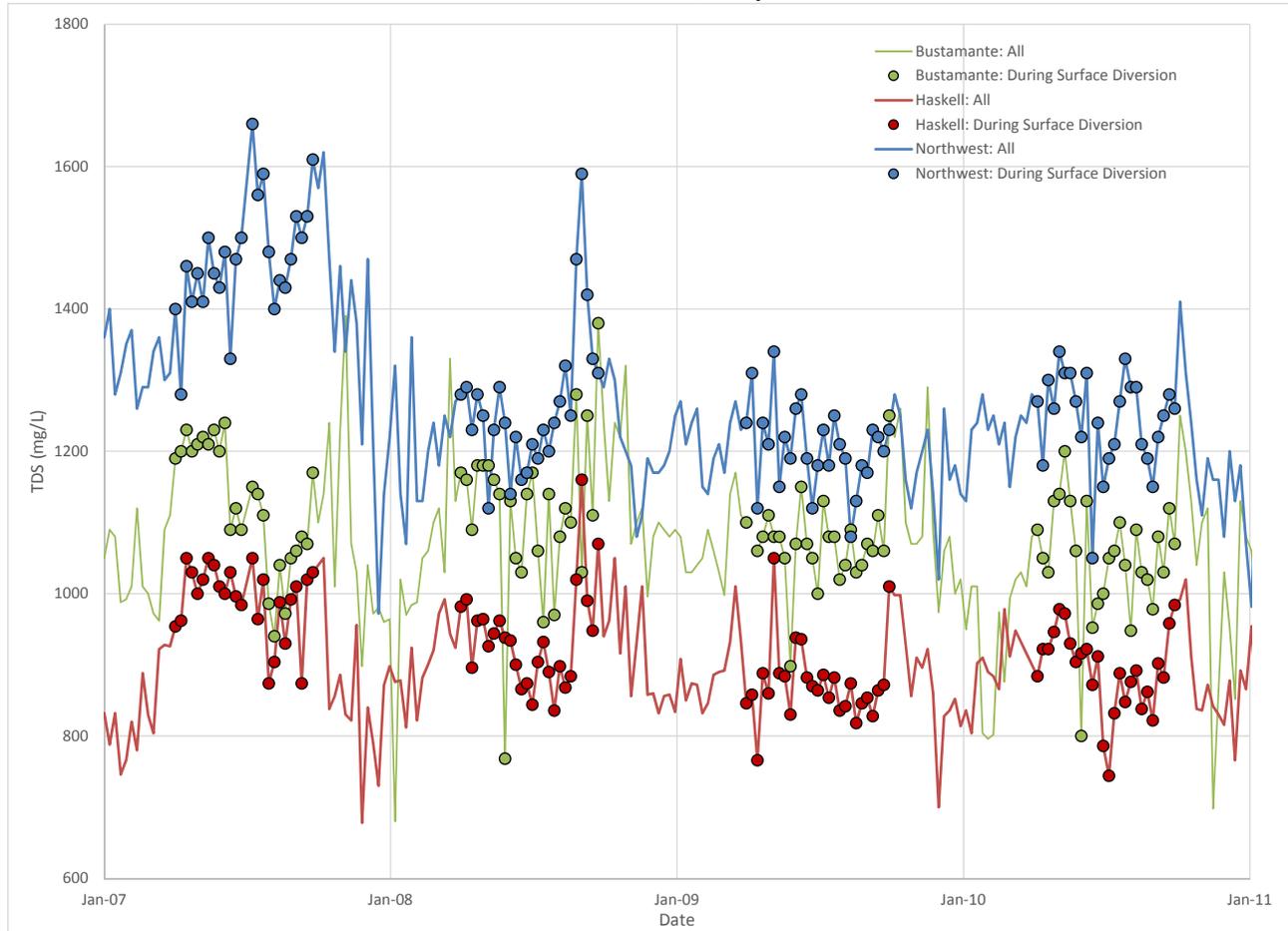
Wastewater return flow rates and water quality were estimated based on historical data (EPWU, 2013). Simulated wastewater effluent rates were based on observed effluent rates for the period 2006-2010 (**Figure 7**). Average irrigation season effluent rates used in the model are 4.77 MGD (7.4 cfs) for Northwest WWTP, 16.19 MGD (25.1 cfs) for Haskell WWTP, and 28.18 MGD (43.6 cfs) for Bustamante WWTP.

FIGURE 7
Historical EPWU Wastewater Treatment Plant Effluent Rates



Water quality for wastewater effluent was evaluated for the period 2007-2010. Data were filtered for periods during which surface water was being diverted, to represent model conditions. Average TDS 2007-2010 was used in the model: 1,294 mg/L for Northwest, 923 mg/L for Haskell, and 1,091 mg/L for Bustamante (Figure 8).

FIGURE 8
Historical EPWU Wastewater Treatment Plant Effluent Water Quality



Along the sidestream, there are additional agricultural drains that ultimately supply Hudspeth County with water. Due to uncertainty associated with the routing of these drains, they were lumped together in the model as the “Riverside Drain,” although this may include other drains such as Fabens Intercepting Drain. Data for these drains are sparse. Accordingly, the flow and water quality for the drains was estimated during calibration, to match reported water supply of 30,000 afy with TDS about 800 mg/L (Chavez, 2014). Adjusted values can be found in **Table 1**.

It should be noted that water quality of agricultural return flows is not linked to water quality of agricultural diversions. The timing and magnitude of the effect of improved water quality of applied water on water quality of drain water cannot readily be quantified at this time.

Lastly, data for the Ascarate Wasteway were evaluated and used to update return flows from EPCWID#1 irrigation to the Rio Grande. The flow rate was updated to 29 percent of Franklin Canal diversions, consistent with historical data. It should be noted that this water is assumed to discharge to the Rio Grande, not the sidestream (based on available system schematics); accordingly, this change does not affect water quality at any of the economic benefit locations.

Future Irrigation Season Conditions Updates

The model was updated to account for future development conditions consistent with the economic modeling. Diversion rates and wastewater return flow rates were adjusted to reflect changes in future development conditions. Schematics of the future condition model are presented in **Figures 9 and 10**.

FIGURE 9
2020 Conditions Model

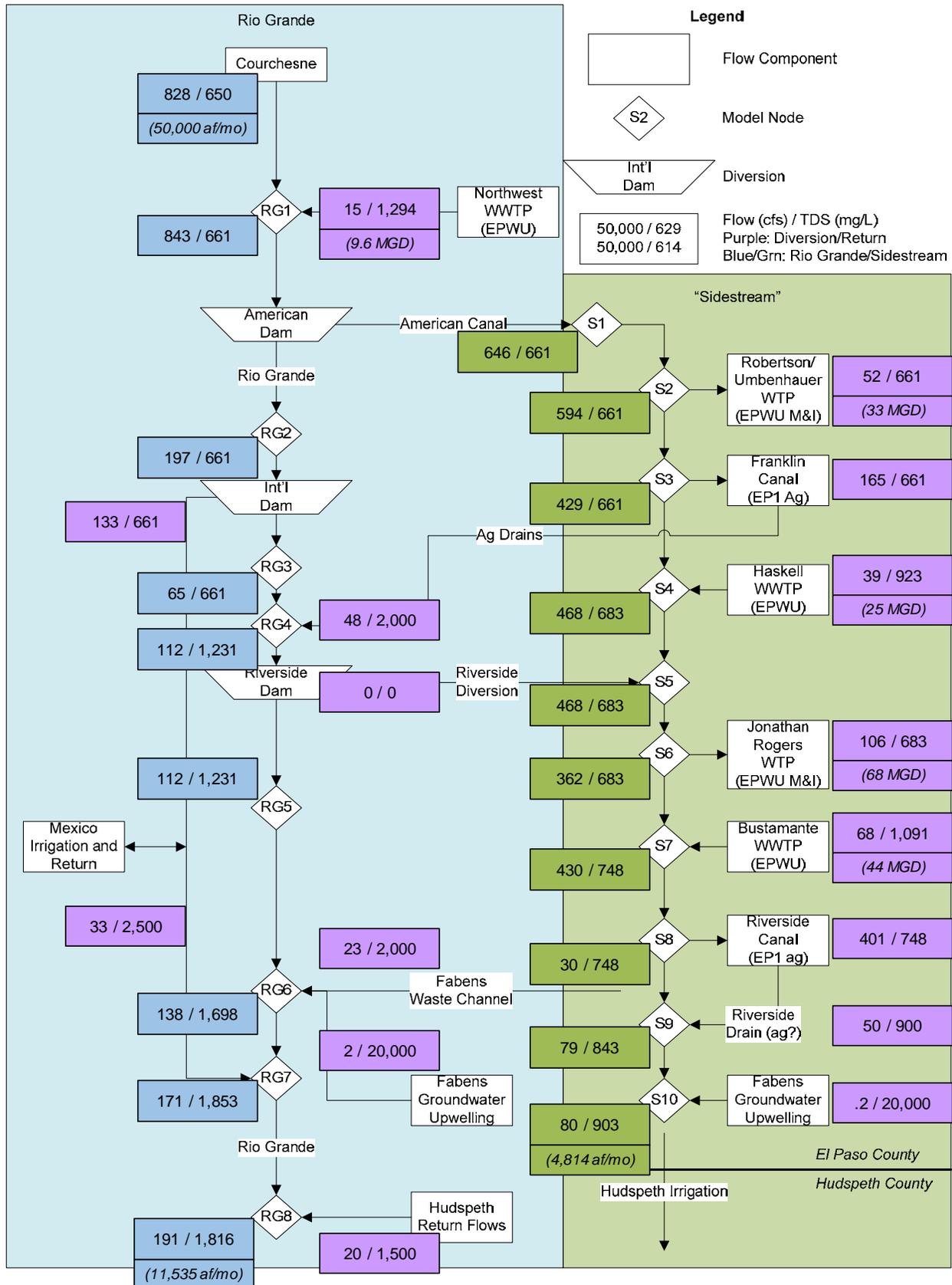
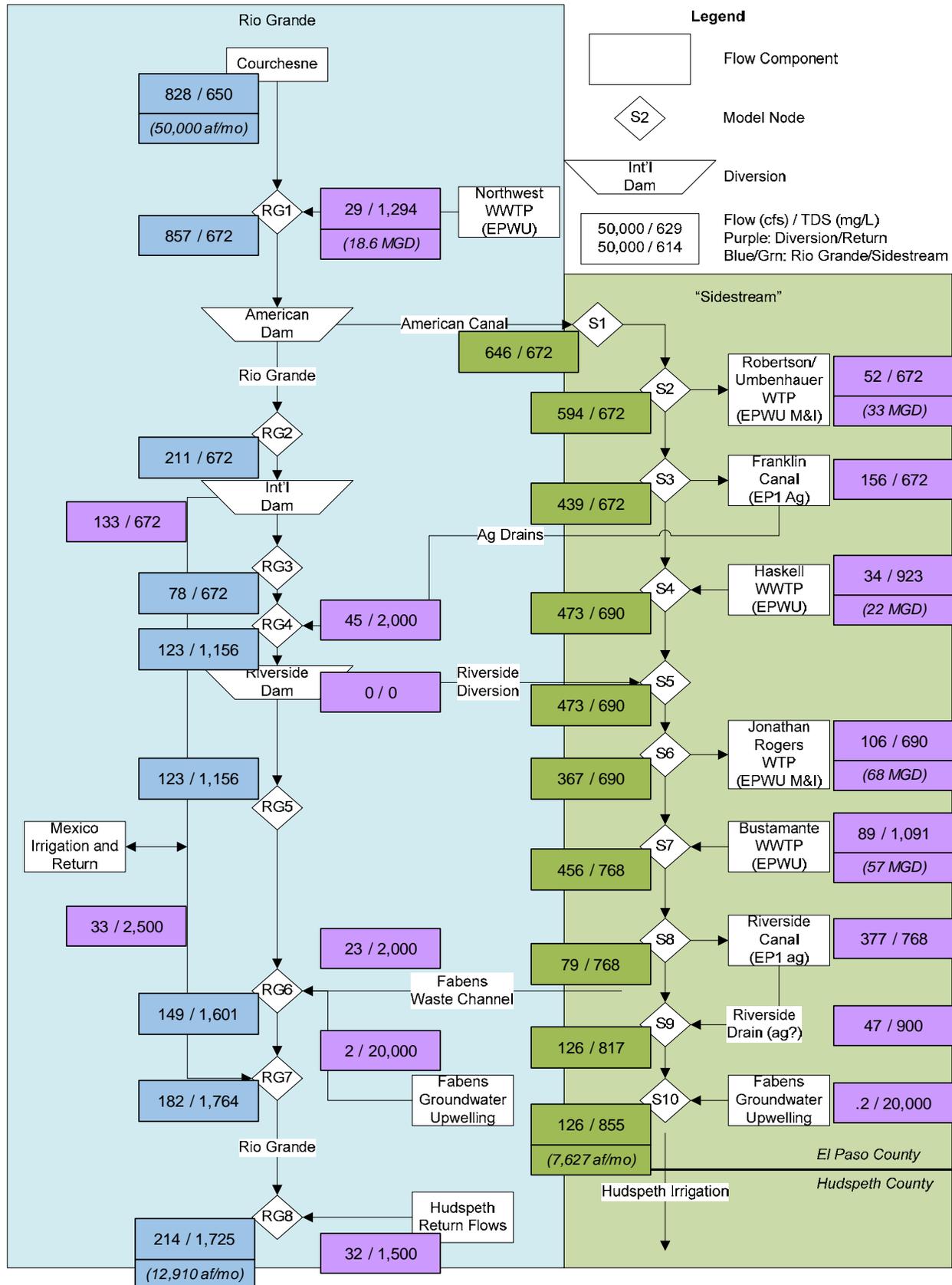


FIGURE 10
2050 Conditions Model



Future Diversions

Total EPWU diversions are assumed to increase to about 9,500 af per month (about 75,000 afy in a normal year) in both 2020 and 2050, from about 7,800 af per month (about 61,000 afy in a normal year) in 2010. The entirety of the increase is assumed to be at Jonathan Rogers WTP. This change is consistent with future surface water use assumptions in the economic benefits evaluation.

Total EPCWID#1 diversions are assumed to decrease to about 32,200 af/mo (253,000 afy in a normal year) in 2050, from about 34,700 af/mo (274,000 afy in a normal year) in 2010. The decrease is applied proportionally amongst EPCWID's diversions. The change in future EPCWID#1 agricultural use is consistent with future surface water use assumptions in the economic benefits evaluation.

Future Return Flows

Future wastewater flow rates were developed based on information in EPWU's Draft Wastewater Master Plan (EPWU, 2014a) and projected total indoor demand described in the M&I future conditions economic model of the main body of this report. The Wastewater Master Plan forecasted current flow rates at each of the four WWTP's, for 2013 and 2030. Future conditions for 2020 and 2050 were interpolated and extrapolated from 2013 and 2030 data, based on a linear growth rate as shown in **Table 2**. The interpolated/extrapolated values were then adjusted to match 2020 and 2050 projected indoor demand for M&I.

TABLE 2

Projected Wastewater Treatment Plant Flow Rates

Treatment Plant	Capacity (MGD)	2013	2030	Annual Increase in Flow (MGD) ²	2020 Interpolated (MGD) ³	2020 adjusted (MGD) ⁴	2050 Extrapolated (MGD) ³	2050 Adjusted (MGD) ⁴
		Average Daily Flow (MGD) ¹	Average Daily Flow (MGD) ¹					
Northwest	17.5	4.5	10.7	0.36	7.1	9.6	18.0	18.6
Haskell	27.7	17.6	19.4	0.11	18.3	25.0	21.5	22.2
Bustamante	39	27	40.1	0.77	32.4	44.1	55.5	57.4

¹From Wastewater Master Plan (EPWU, 2014a)

²Calculated, based on linear growth between 2013 and 2030

³Interpolation and Extrapolation based on linear growth rate between 2013 and 2030

⁴Values adjusted by a factor to match total indoor water use consistent with M&I economic model. Factor for 2020 was 1.36, and factor for 2050 was 1.03

Agricultural return flow rates (Ascarate Wasteway and Riverside Drain) are assumed to remain the same percent of irrigation diversions in the future as they are in current/historical conditions. Water quality is also assumed to be the same. It should be noted that because the economic analysis uses the change in water quality due to a potential project, results would not change if the drain water quality was changed.

Other Irrigation Season Model Updates

Simulation of TDS

The model was updated to simulate TDS instead of chloride, because TDS forms the basis of the economic benefits evaluation. The previous model simulated chloride, which behaves conservatively (no chemical reactions, no leaching from or adsorption to riverbed sediments, etc.) and is a common water quality indicator. In the Alternatives Analysis, an equation was used to relate Cl at the diversions to TDS, for estimate of relative economic benefits. However, using an equation to relate Cl to TDS is an approximation, and assumes that the Cl-TDS ratio is the same throughout the reach. That, in turn, would only hold true if wastewater return flows have the same Cl-TDS ratio as the Rio Grande. Because they do not have the same ratio, it was assumed that uncertainty associated with potential non-conservative behavior of TDS along this short reach of river is less than the uncertainty associated with converting Cl to TDS. Therefore, the model was updated to simulate TDS instead of Cl.

Wastewater feedback loop

In a project scenario, EPWU would be diverting cleaner water from the American Canal. It is reasonable to assume that some portion of this cleaner water would return to the wastewater treatment plants, thereby reducing the salinity in WWTP effluent discharging to the Rio Grande and American Canal. EPWU estimates that during times of surface water diversions, effectively all of the water at Bustamante and Haskell WWTPs was water that was originally from the Rio Grande. At the Northwest WWTP, about 15 percent of the water was originally from the Rio Grande (EPWU, 2014b). Using the baseline model, these assumptions suggest that about 54 percent of the surface water diverted returns to the wastewater plants, which is consistent with EPWU indoor water use during summer months (EPWU, 2004).

For future conditions, it was assumed that the percent of diverted water that is returned to the wastewater plants remains at about 54 percent. Because total wastewater increases at a faster rate than the use of surface water (increasing demand is met predominantly by other supplies, not the Rio Grande), the portion of each wastewater plants effluent that originated from surface water will decrease in the future. Accordingly, the reduction of salinity at each of the WWTPs due to the project will also decrease in the future. Calculation of salinity at the WWTP's involved two steps. First, the percent of water at each plant that originated as surface water was calculated based on assumed surface water diversion and return of 54 percent of that water returning to the wastewater plants (Table A-3). Second, concentration of wastewater effluent for a project scenario was calculated as:

$$\text{Scenario concentration} = (1 - \text{percent from SW}) * \text{Baseline WW effluent concentration} + (\text{percent from SW}) * (\text{baseline concentration} - \text{difference in mg/L between baseline diversion and scenario diversion})$$

The result is that total mass at the WWTP's is reduced in a scenario by an amount equal to about 55 percent of the reduced mass diverted from the river.

TABLE 3
Projected Percent of Wastewater Originally From Surface Water

Year	WWTP Effluent flow rate (af/mo)			Percent of effluent originally from surface water			Total wastewater originally from surface water	Total diverted	Percent of diverted water returning to WWTPs
	Northwest	Haskell	Bustamante	Northwest	Haskell	Bustamante			
2010	446	1,512	2,632	15%	100%	100%	4,211	7,800	54%
2020	897	2,332	4,119	12%	78%	78%	5,137	9,505	54%
2050	1,738	2,078	5,361	10%	67%	67%	5,159	9,505	54%

Non-Irrigation Season Model Updates

During the non-irrigation season, Rio Grande flow is much lower than during the irrigation season. However, EPWU continues to discharge treated wastewater into the Rio Grande and the American Canal, providing a potential source of water to EPCWID#1 and HCCRD. Accordingly, the model was updated to simulate estimated non-irrigation season conditions.

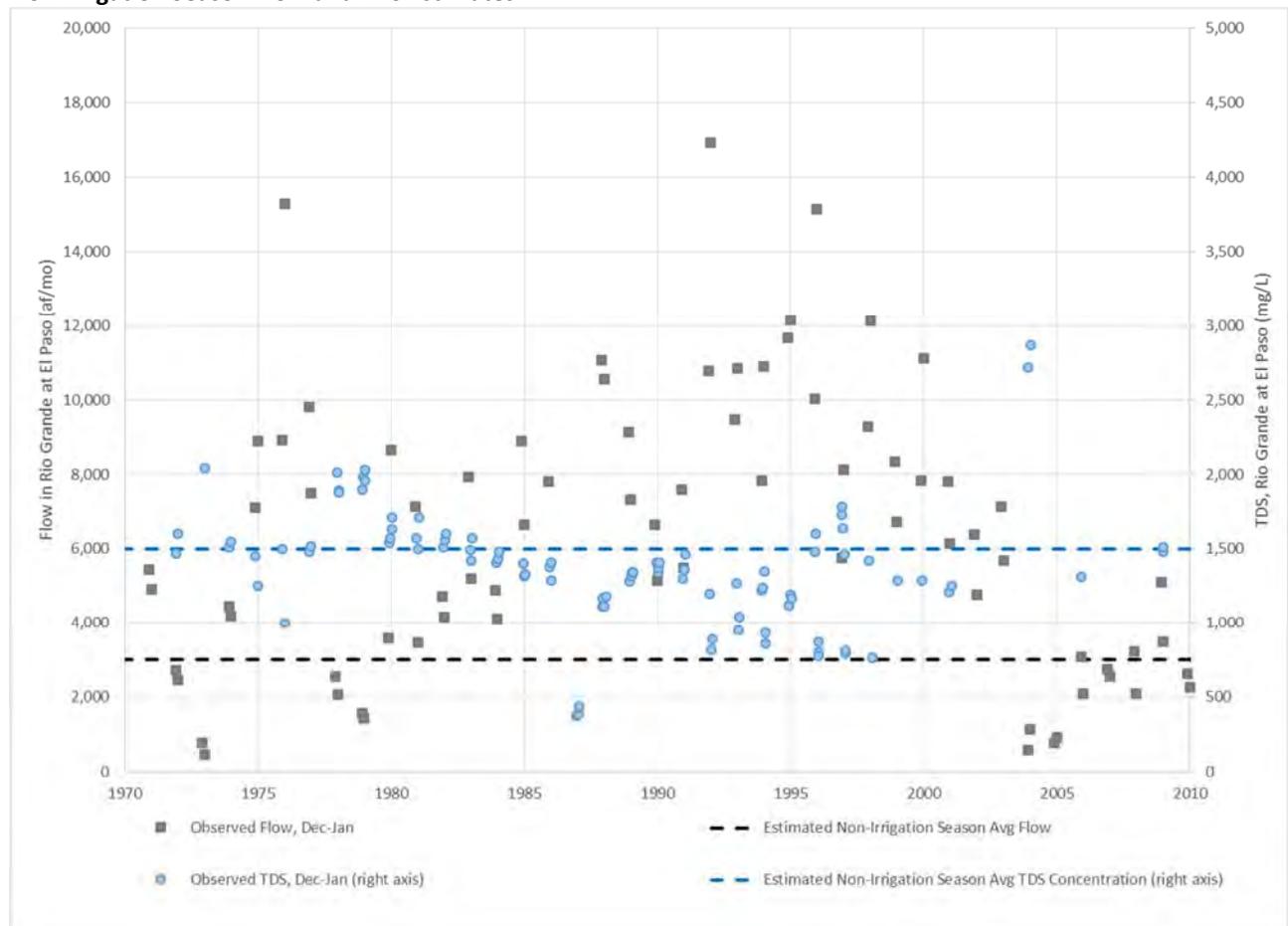
Changes to the non-irrigation season model from the irrigation season model are as follows:

1. Upstream Rio Grande flow and water quality updated to 3,000 af/mo with TDS concentration of 1,500 mg/L, based on approximate average of observed data (**Figure 11**).
2. American Diversion was assumed to divert all of the water in the Rio Grande during the non-irrigation season.
3. No improvements made to WWTP effluent because EPWU is not diverting surface water during the non-irrigation season. WWTP effluent rates were kept the same as during the irrigation season.

4. Franklin Canal and Riverside Canal diversions were updated to reflect full use of available water, which is estimated to be 10,300 af per month in 2020 and 12,150 af per month in 2050 (based on 3,000 af per month in the Rio Grande, plus WWTP effluent). Non-irrigation season agricultural water use is not well quantified at this time. Accordingly, it was assumed that diversions to the Franklin Canal and Riverside Canal both equal 50 percent of flow in the American Canal. In addition, diversions at the Riverside Canal include a portion of the wastewater effluent that discharges to the American Canal. The Riverside Canal diversion was adjusted to match the flow assumptions used in the agricultural non-irrigation season benefit analysis (in year 2020: 8,000 af per month total to EPCWID, and 2,300 af per month to HCCRD; in year 2050: 9,000 af per month total to EPCWID, and 3,150 af per month to HCCRD).

The purpose of the non-irrigation season model is to support analysis of potential agricultural and M&I benefits during the non-irrigation season. Because of uncertainty associated with non-irrigation season flow routing and rates, the model was only run for the scenario with the greatest TDS mass removal, Scenario D.3. Results are then used in Section 4.4 of the main body to characterize potential for non-irrigation season benefits. It should be noted that the non-irrigation model was not refined and may not accurately reflect the system, particularly with respect to downstream agricultural diversions. However, due to the minimal economic benefit associated with the estimated non-irrigation season water quality improvements, the model was not refined further.

FIGURE 11
Non-Irrigation Season Flow and TDS Estimates



Model Limitations

Some limitations of the model are as follows:

- Simulated HCCRD diversion increases in the future due to American Canal, EPWU, and EPCWID#1 diversions all being fixed percentages of Rio Grande flow, while wastewater return flow increases in the future. However, it is likely that EPCWID#1 will be using most of the EPWU return flows, not HCCRD. Due to the limited contribution of agricultural benefits to total benefits, it is assumed that the effect on results is minor.
- There is currently no feedback loop incorporating improved water quality in EPCWID#1 drain water in response to improved diversion water quality. Timing of drain water improvement, and propagation of salt through the subsurface cannot be readily quantified at this time. Incorporation of a feedback loop would only change water quality for HCCRD, which makes up a minor component of the overall benefit.
- Diversions from American and International Dams are currently a function of flows in the Rio Grande at El Paso. However, EPWU's Northwest WWTP returns water to the river between the El Paso gage and the American Canal diversion. Accordingly, in the irrigation season model, that flow continues past both diversions, unused. This is believed to have only a minor effect on results, given that the wastewater effluent flow rate is small compared with water in the river. In the non-irrigation season model, all of the Northwest WWTP effluent is assumed to be diverted at the American Canal.
- There is uncertainty associated with future flow conditions, and allocation of water amongst users during dry years. It is currently assumed that any shortages will be shared equally amongst EPWU and EP1, but that was not confirmed during this evaluation. During dry years there is less economic benefit due to less water use, so this assumption is unlikely to significantly affect results.
- Non-irrigation season water use was not well quantified as part of this work.

Model Results

Complete irrigation-season model results are summarized in **Table 5**, and **Figures 12 through 43**.

Non-irrigation season results are summarized in **Table 6** and **Figures 44 through 45**.

TABLE 5

Irrigation Season TDS Reductions at Economic Benefit Locations (see Table 3-1 for Salinity Scenario Definitions)

Project Type	Modeled Location	Year	TDS (mg/L), no project	TDS Reduction (mg/L), with Project							
				Site 1				Site 2			
Salinity Scenario				1	2	3	4	1	2	3	4
Single Purpose (Alternatives A and C)	Rio Grande, El Paso Gage	2010	650.00	0.54	0.55	7.15	7.22	5.29	5.30	10.61	10.59
		2020	650.00	0.54	0.55	7.15	7.22	5.29	5.30	10.61	10.59
		2050	650.00	0.54	0.55	7.15	7.22	5.29	5.30	10.61	10.59
	El Paso Municipal	2010	664.59	0.53	0.55	7.09	7.16	5.25	5.26	10.53	10.51
		2020	675.87	0.52	0.54	6.95	7.01	5.15	5.15	10.32	10.29
		2050	683.92	0.51	0.53	6.82	6.88	5.05	5.05	10.12	10.10
	El Paso Ag	2010	697.27	0.53	0.55	7.09	7.16	5.25	5.25	10.53	10.50
		2020	722.46	0.51	0.53	6.78	6.84	5.02	5.02	10.07	10.04
		2050	739.85	0.49	0.50	6.51	6.57	4.82	4.83	9.67	9.65

TABLE 5

Irrigation Season TDS Reductions at Economic Benefit Locations (see Table 3-1 for Salinity Scenario Definitions)

Project Type	Modeled Location	Year	TDS (mg/L), no project	TDS Reduction (mg/L), with Project							
				Site 1				Site 2			
				1	2	3	4	1	2	3	4
Salinity Scenario				1	2	3	4	1	2	3	4
Single Purpose (Alternatives A and C) cont.	Hudspeth Ag	2010	945.42	0.09	0.10	1.24	1.25	0.92	0.92	1.84	1.84
		2020	903.13	0.19	0.19	2.49	2.52	1.85	1.85	3.70	3.69
		2050	854.99	0.30	0.31	3.97	4.01	2.94	2.95	5.90	5.89
Multi-Purpose (Alternatives B and D)	Rio Grande, El Paso Gage	2010	650.00	0.54	0.50	7.20	7.05	5.34	5.31	10.75	10.67
		2020	650.00	0.54	0.50	7.20	7.05	5.34	5.31	10.75	10.67
		2050	650.00	0.54	0.50	7.20	7.05	5.34	5.31	10.75	10.67
	El Paso Municipal	2010	664.59	0.53	0.50	7.14	6.98	5.30	5.27	10.66	10.58
		2020	675.87	0.52	0.49	7.00	6.83	5.19	5.15	10.44	10.36
		2050	683.92	0.51	0.48	6.86	6.70	5.09	5.05	10.24	10.16
	El Paso Ag	2010	697.27	0.53	0.50	7.13	6.96	5.29	5.25	10.65	10.56
		2020	722.46	0.51	0.47	6.81	6.64	5.05	5.02	10.18	10.09
		2050	739.85	0.49	0.45	6.54	6.37	4.85	4.82	9.78	9.69
	Hudspeth Ag	2010	945.42	0.10	0.11	1.30	1.36	0.96	0.97	1.90	1.93
		2020	903.13	0.19	0.19	2.55	2.55	1.89	1.89	3.78	3.78
		2050	854.99	0.30	0.28	4.00	3.91	2.97	2.95	5.97	5.93

TABLE 6

Non-Irrigation Season Flow-Weighted Average TDS Reduction, Scenario D.3

Location	Year	Available Water (af/mo)	TDS (mg/L), no Project	TDS (mg/L), with Project	TDS reduction (mg/L), with Project
El Paso Municipal (JRWTP)	2020		1,164	1,103	61
	2050		1,190	1,131	59
El Paso and Hudspeth Ag	2020	10,300	1,189	1,138	51
	2050	12,150	1,192	1,149	43

FIGURE 12
Salinity Model Simulation, Scenario C.1 Single-Purpose, 2020 Irrigation Season

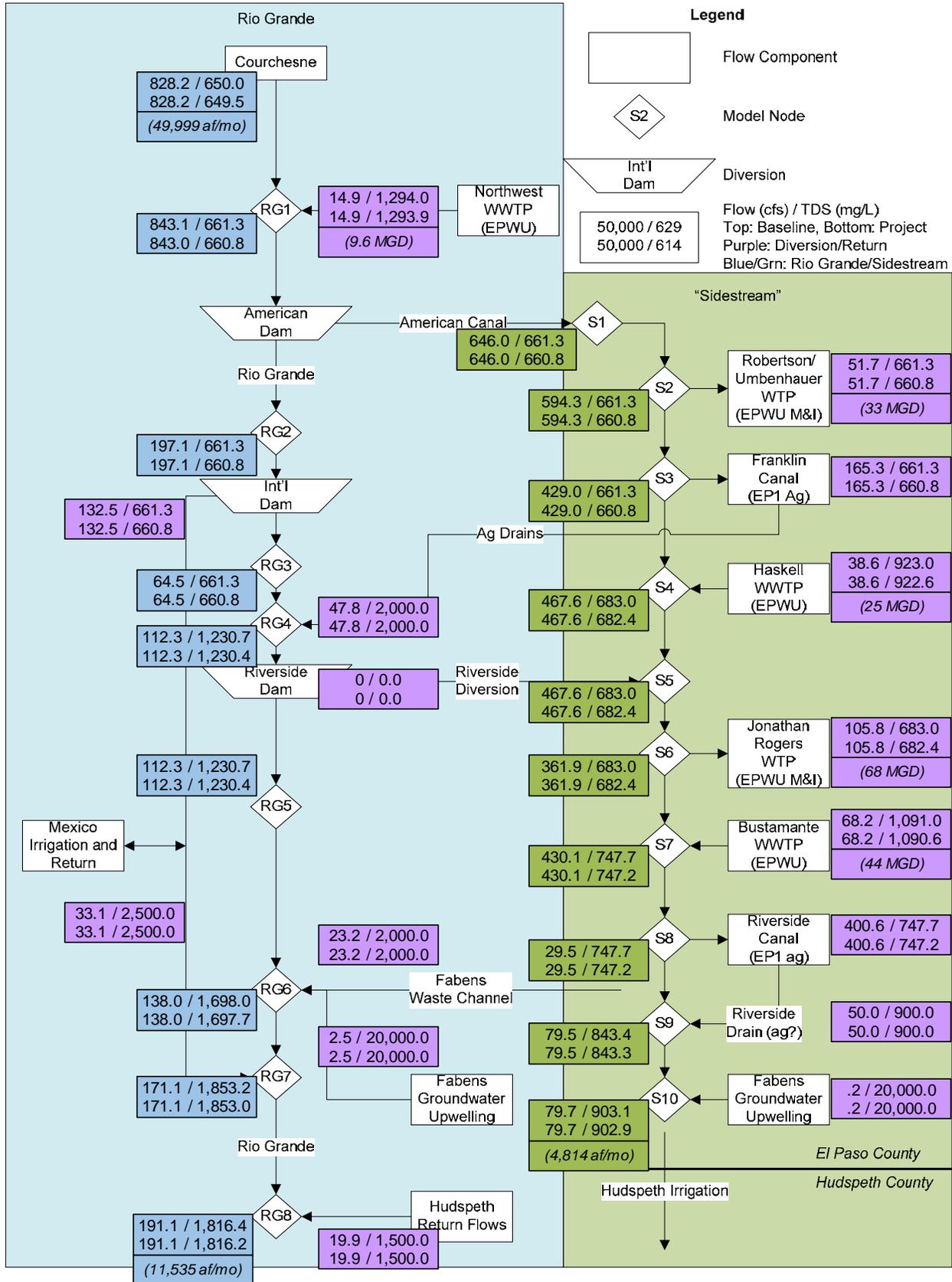


FIGURE 13
Salinity Model Simulation, Scenario C.1 Single-Purpose, 2050 Irrigation Season

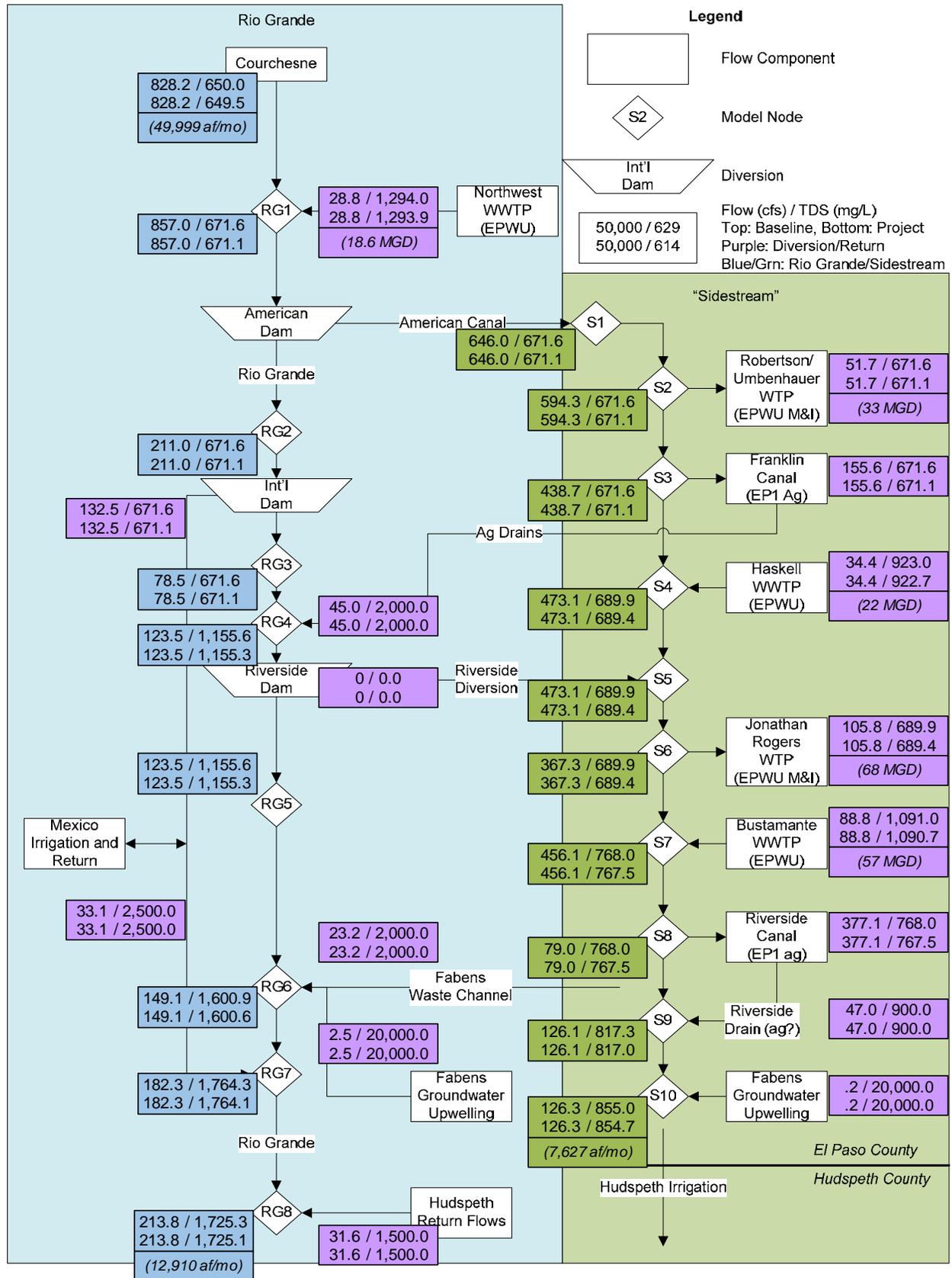


FIGURE 15
Salinity Model Simulation, Scenario C.2 Single-Purpose, 2050 Irrigation Season

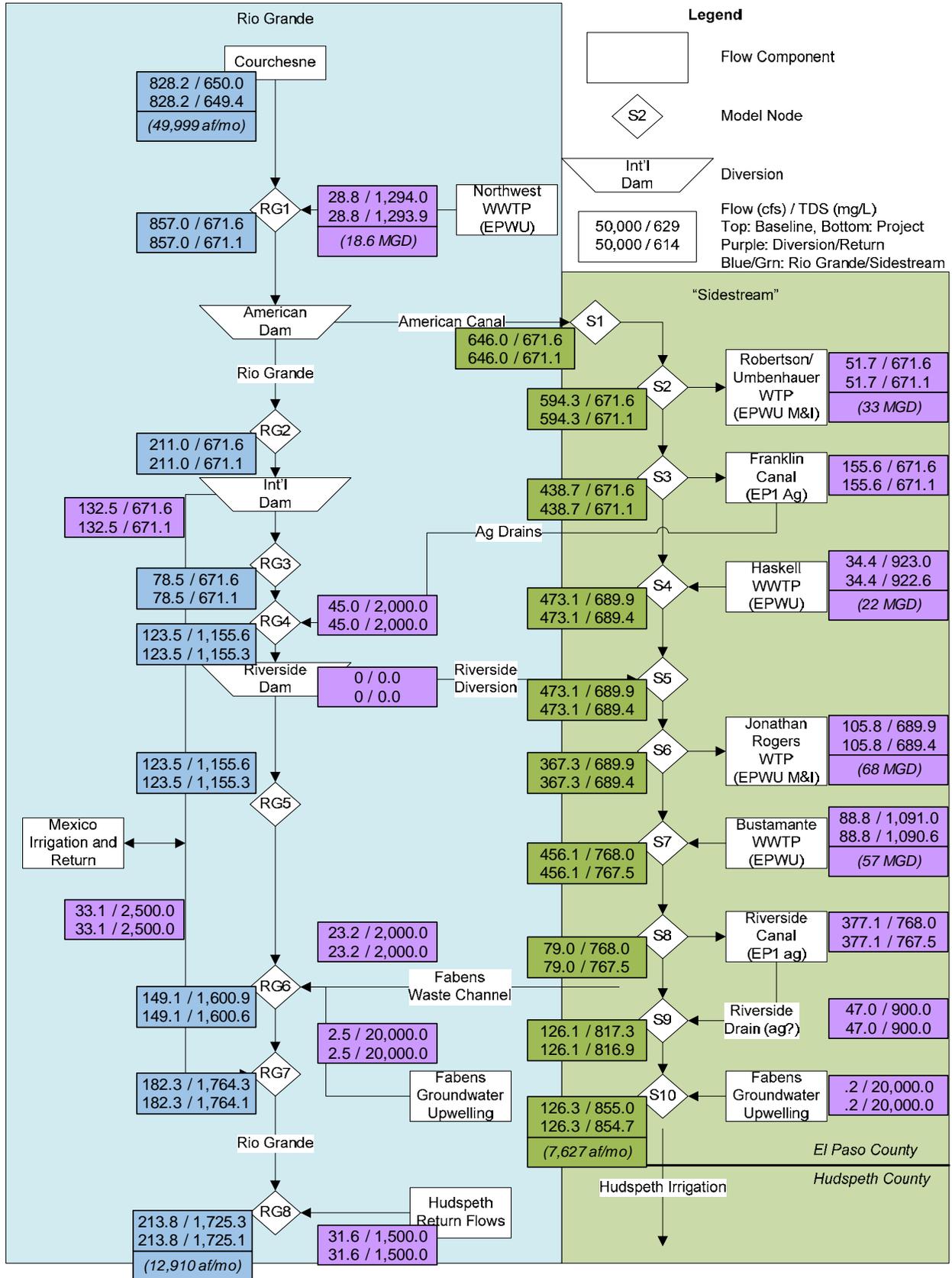


FIGURE 16
Salinity Model Simulation, Scenario C.3 Single-Purpose, 2020 Irrigation Season

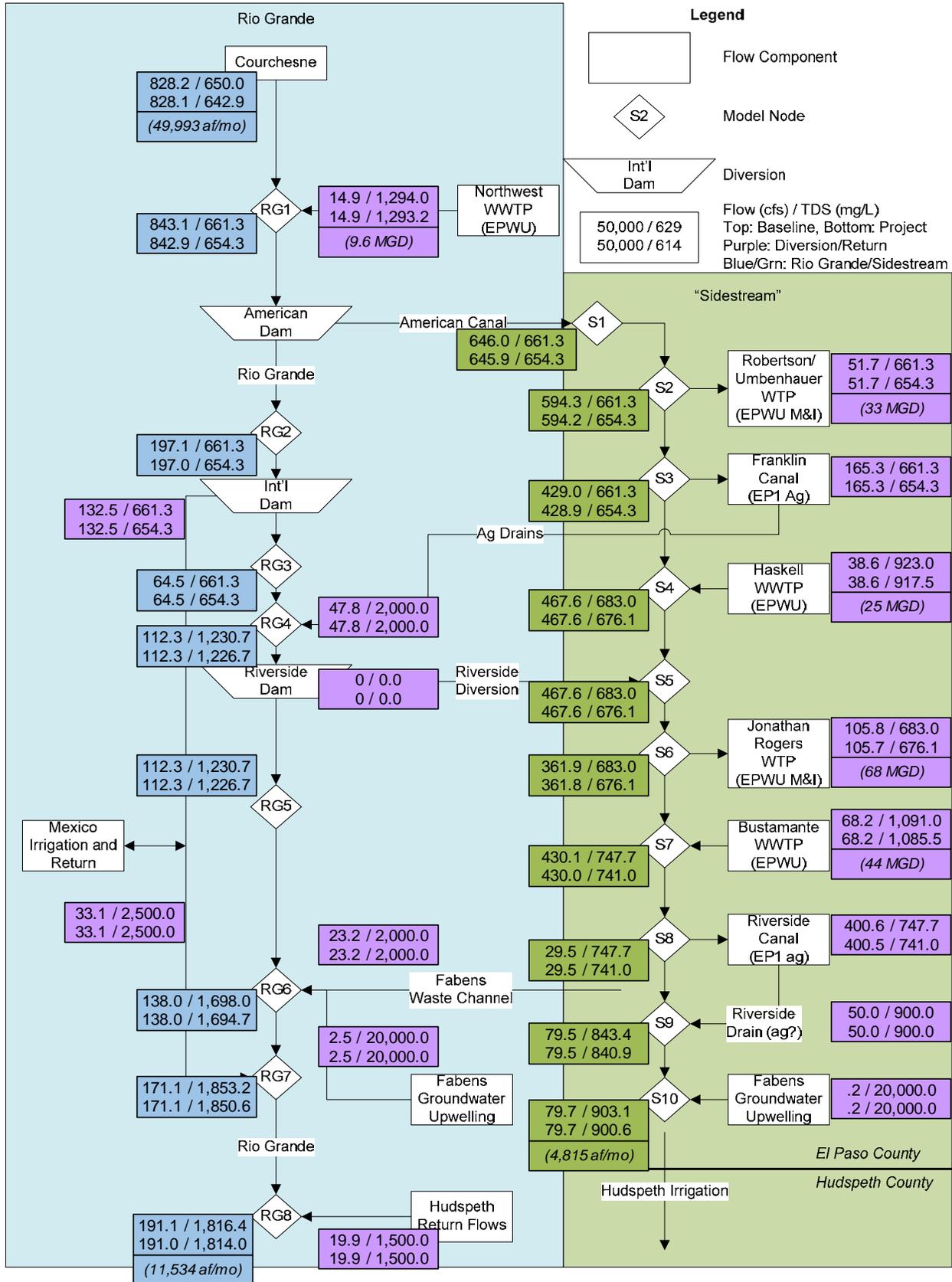


FIGURE A-17
Salinity Model Simulation, Scenario C.3 Single-Purpose, 2005 Irrigation Season

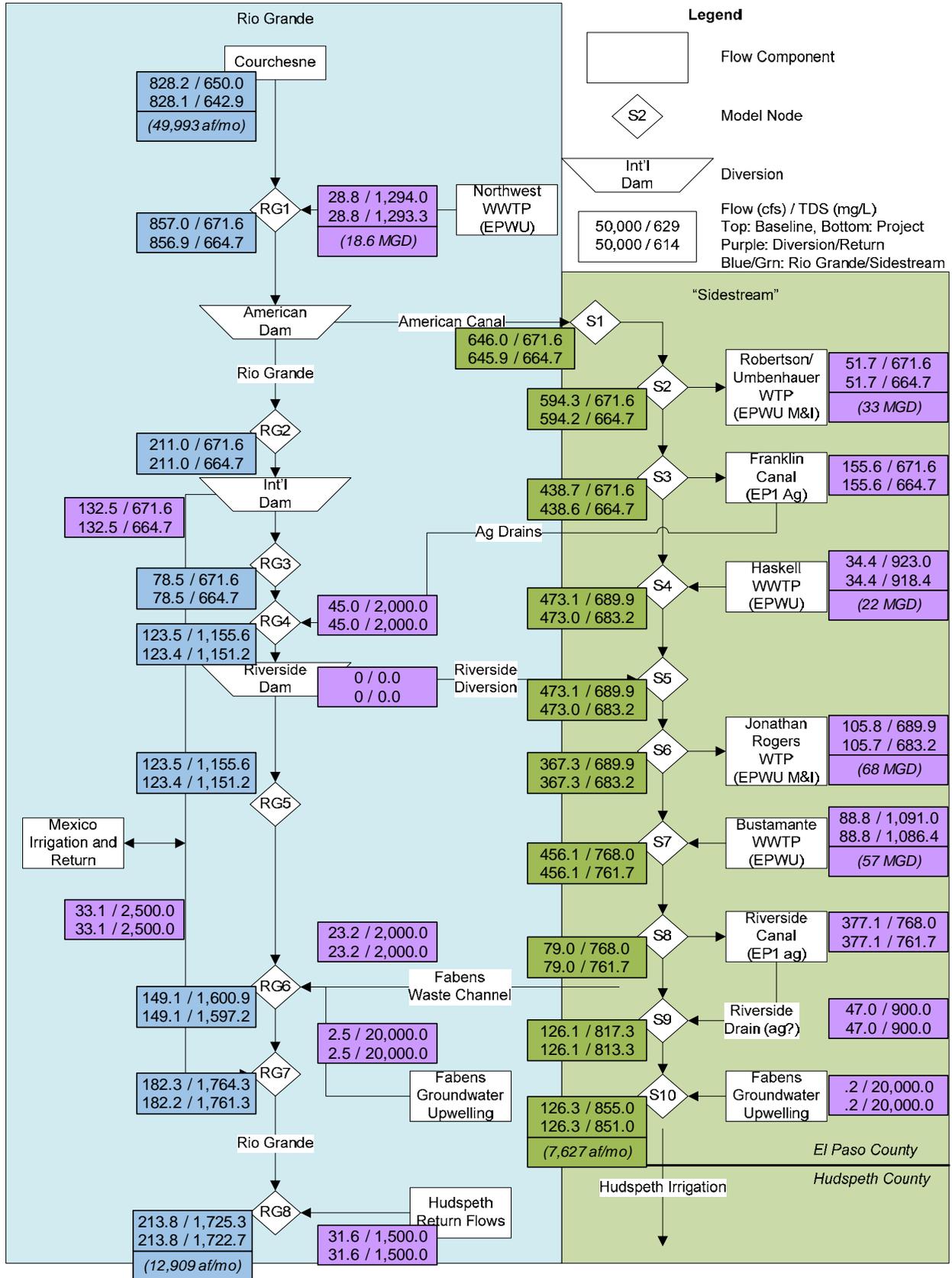


FIGURE 18
Salinity Model Simulation, Scenario C.4 Single-Purpose, 2020 Irrigation Season

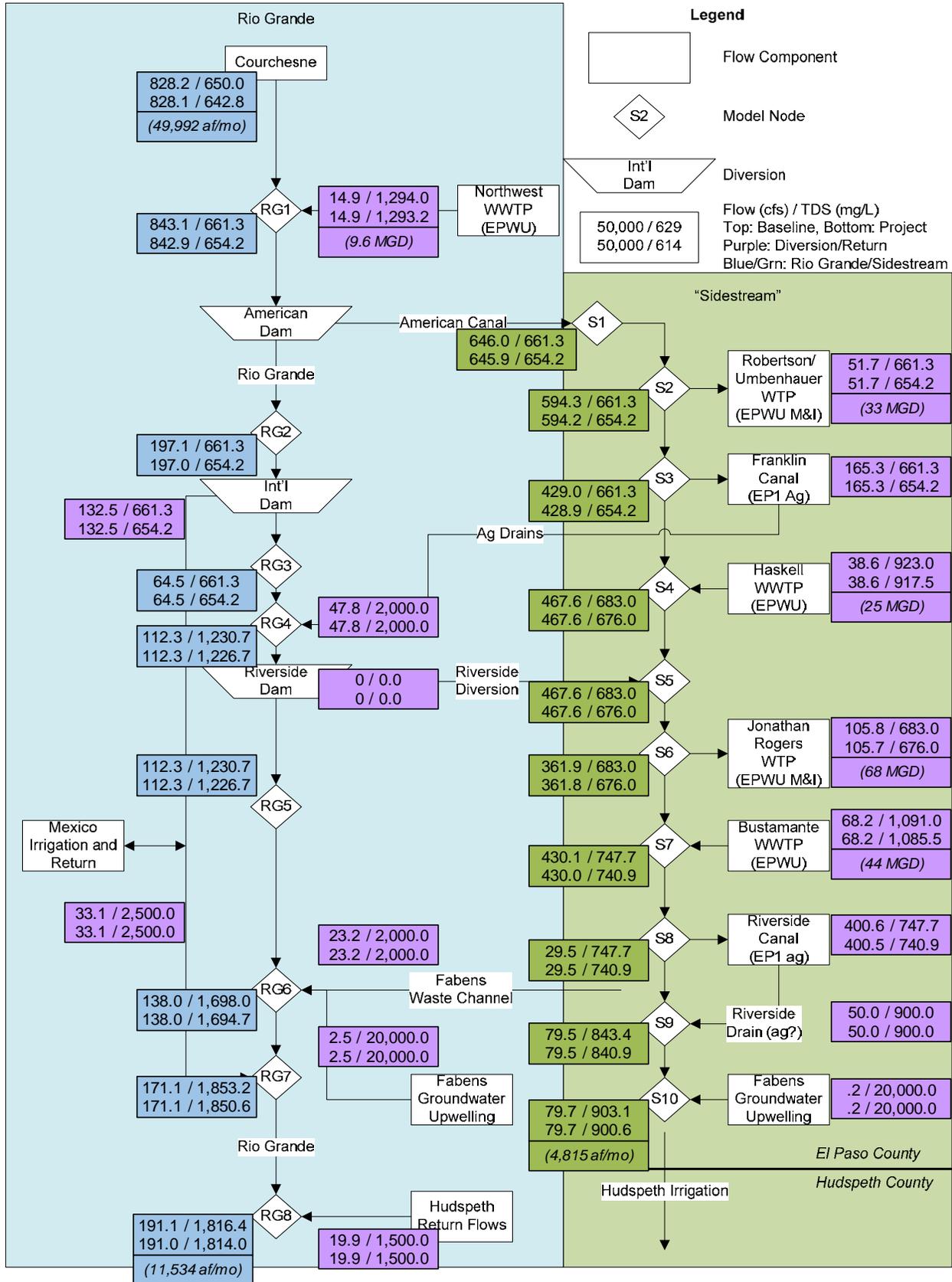


FIGURE 19
Salinity Model Simulation, Scenario C.4 Single-Purpose, 2050 Irrigation Season

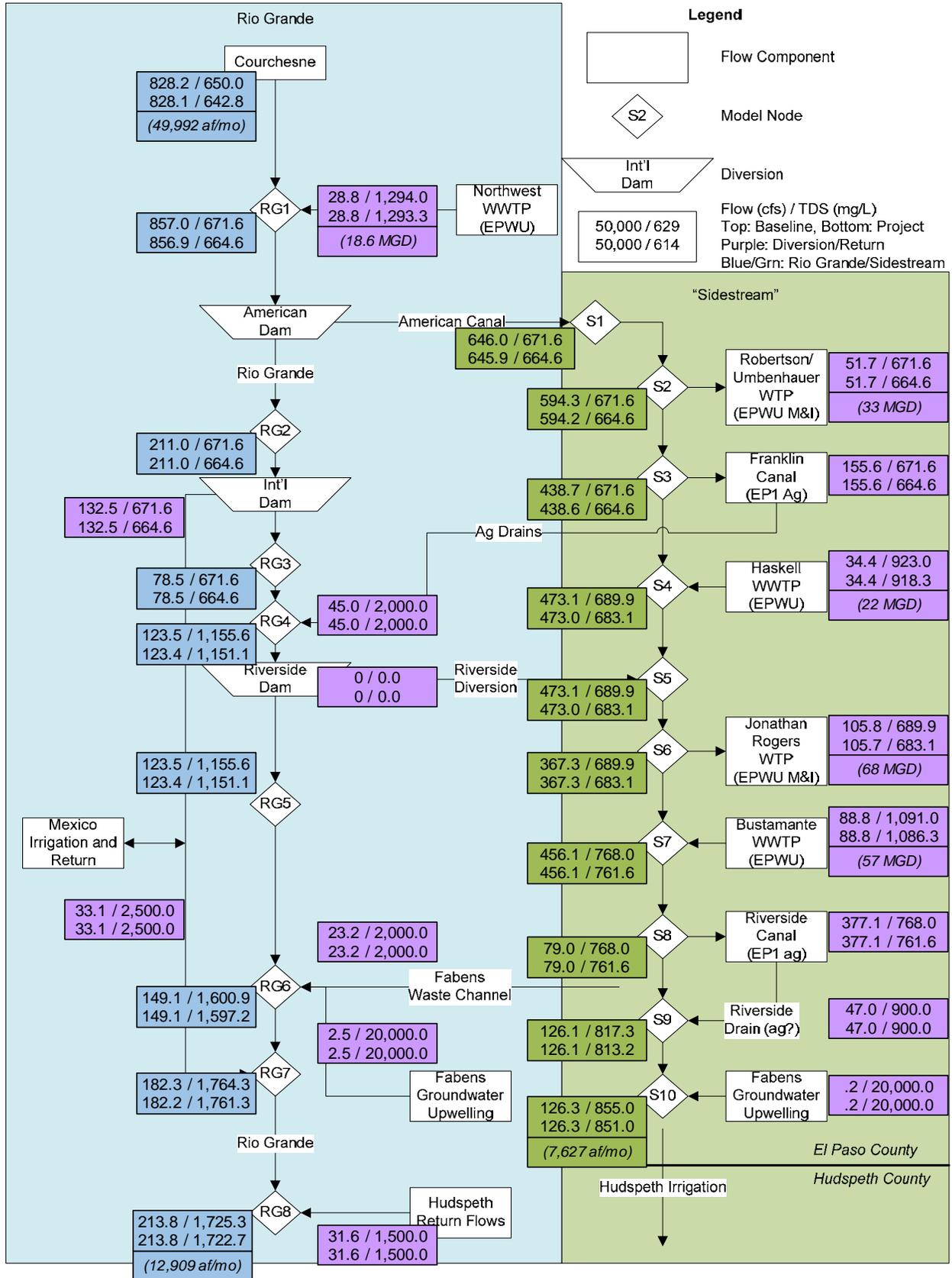


FIGURE 20
Salinity Model Simulation, Scenario D.1 Single-Purpose, 2020 Irrigation Season

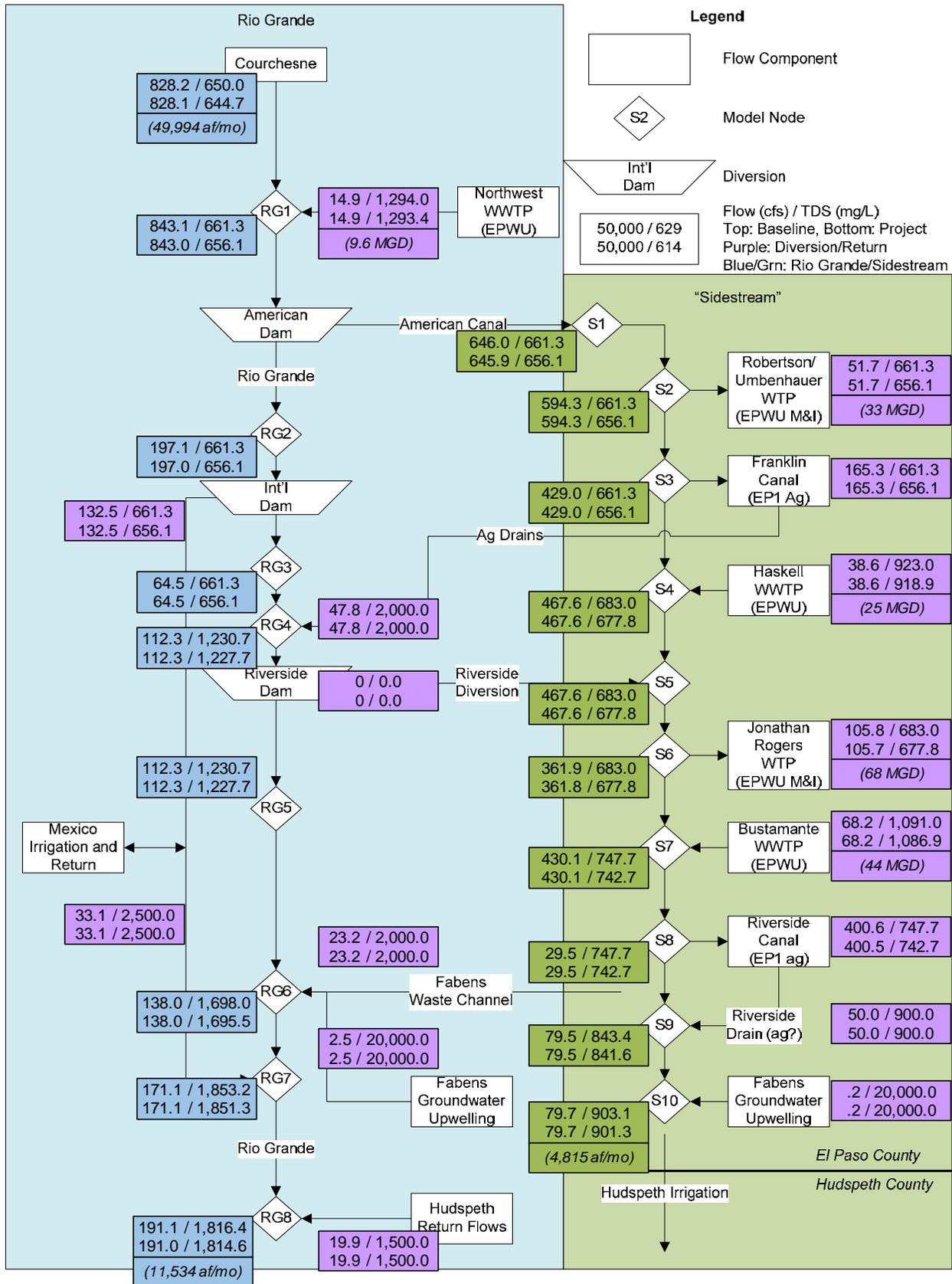


FIGURE 21
Salinity Model Simulation, Scenario D.1 Single-Purpose, 2050 Irrigation Season

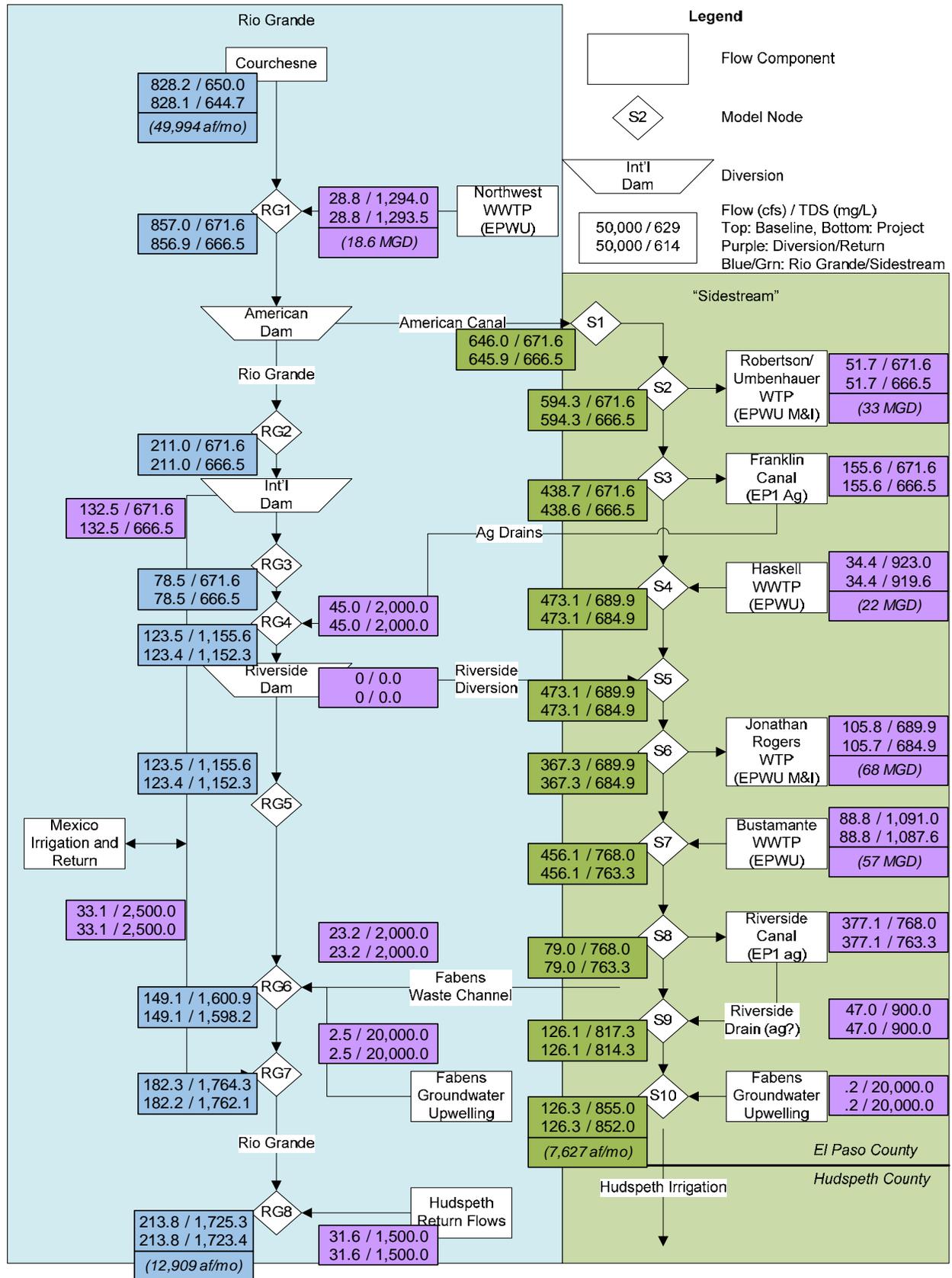


FIGURE 22
Salinity Model Simulation, Scenario D.2 Single-Purpose, 2020 Irrigation Season

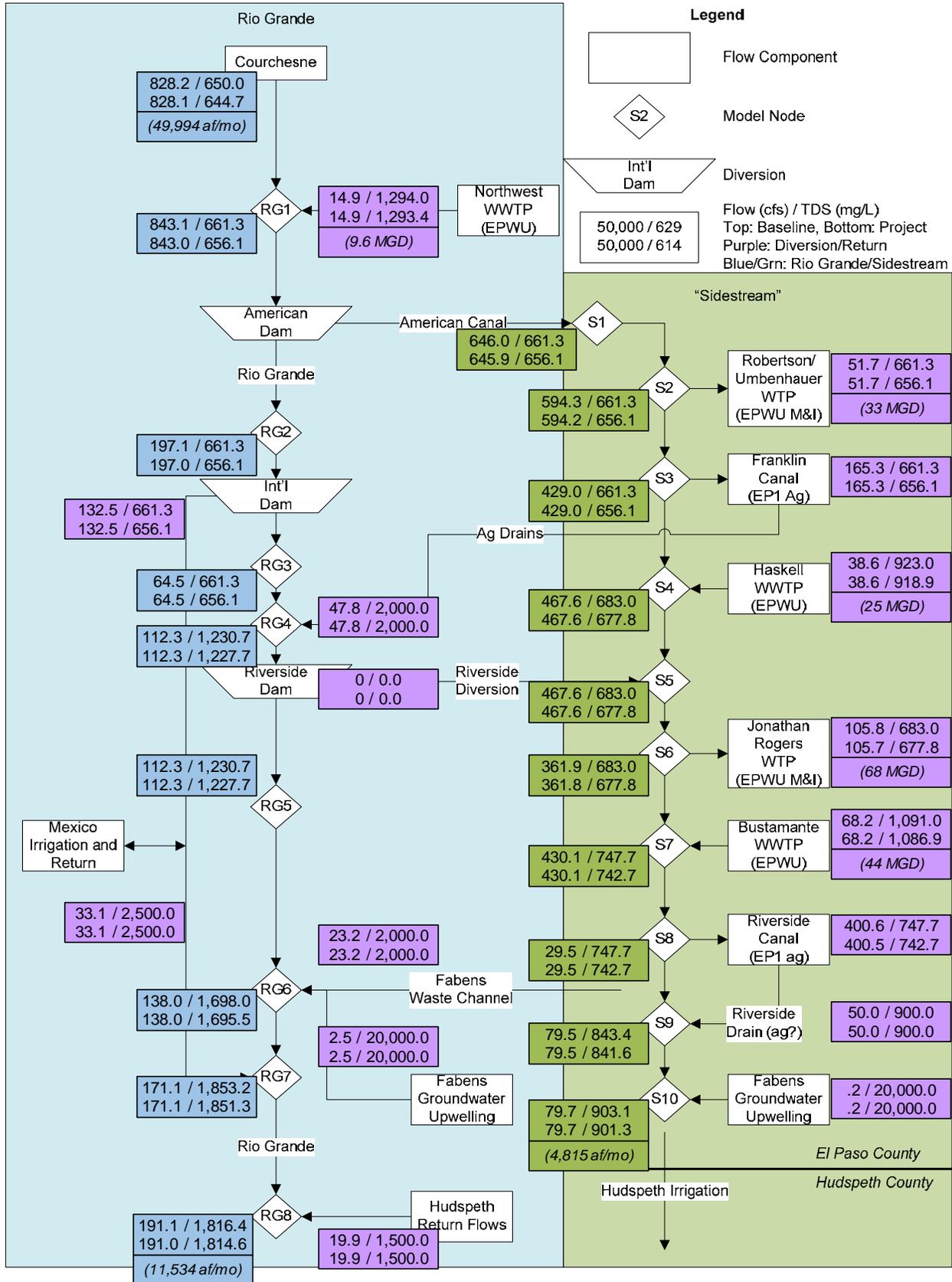


FIGURE 23
Salinity Model Simulation, Scenario D.2 Single-Purpose, 2050 Irrigation Season

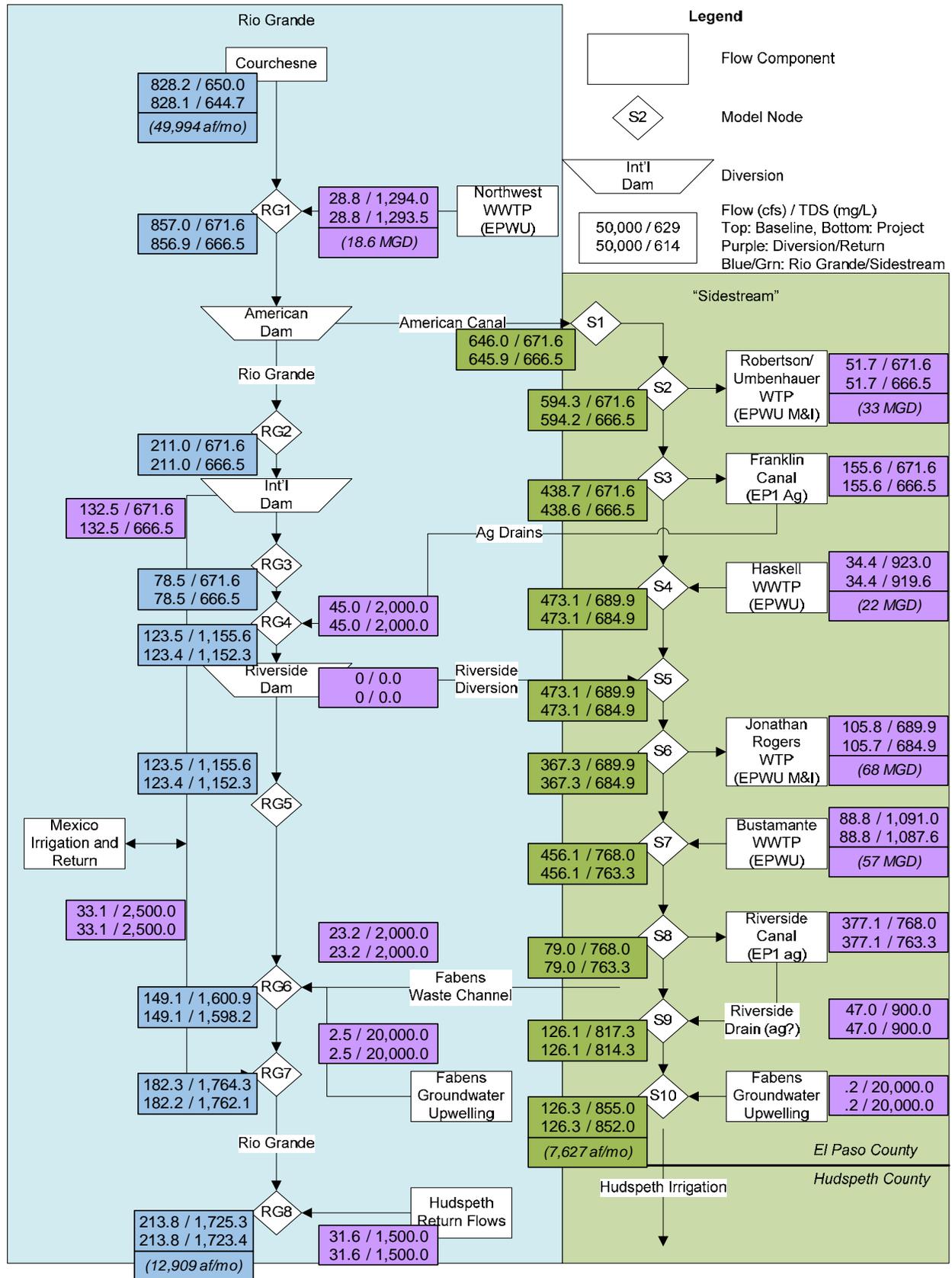


FIGURE 24
Salinity Model Simulation, Scenario D.3 Single-Purpose, 2020 Irrigation Season

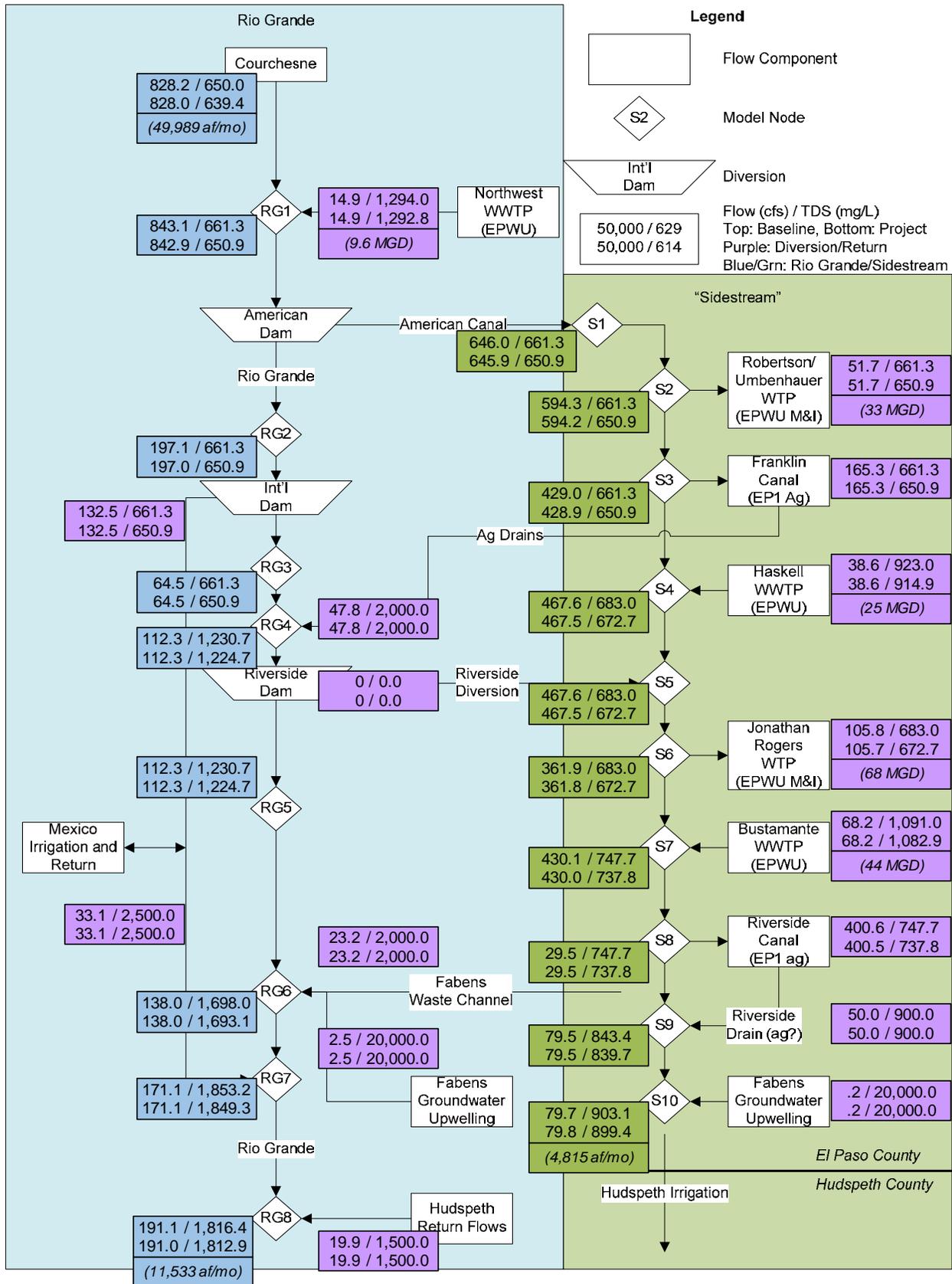


FIGURE 25
Salinity Model Simulation, Scenario D.3 Single-Purpose, 2050 Irrigation Season

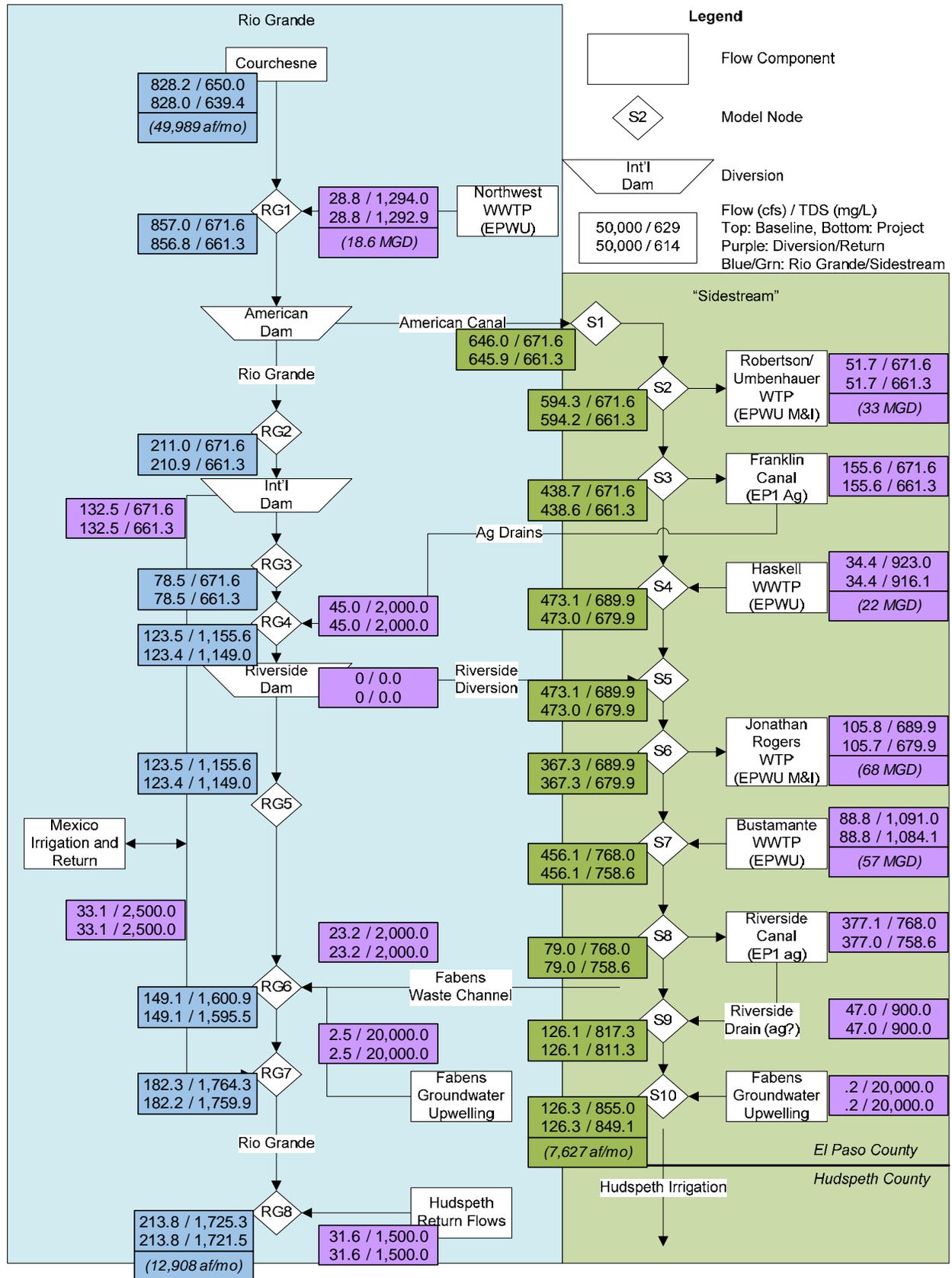


FIGURE 26
Salinity Model Simulation, Scenario D.4 Single-Purpose, 2020 Irrigation Season

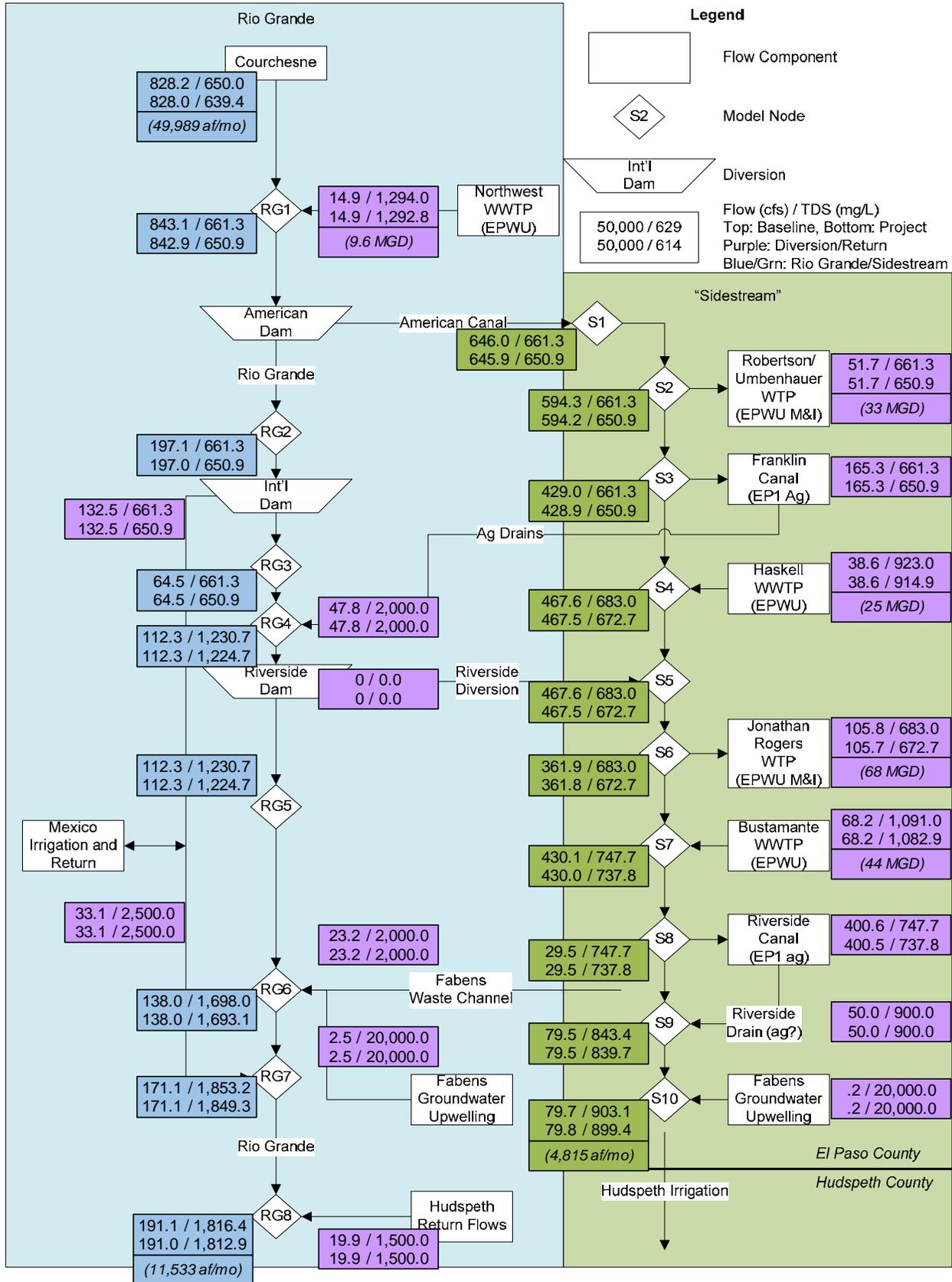


FIGURE 28
Salinity Model Simulation, Scenario C.1 Multi-Purpose, 2020 Irrigation Season

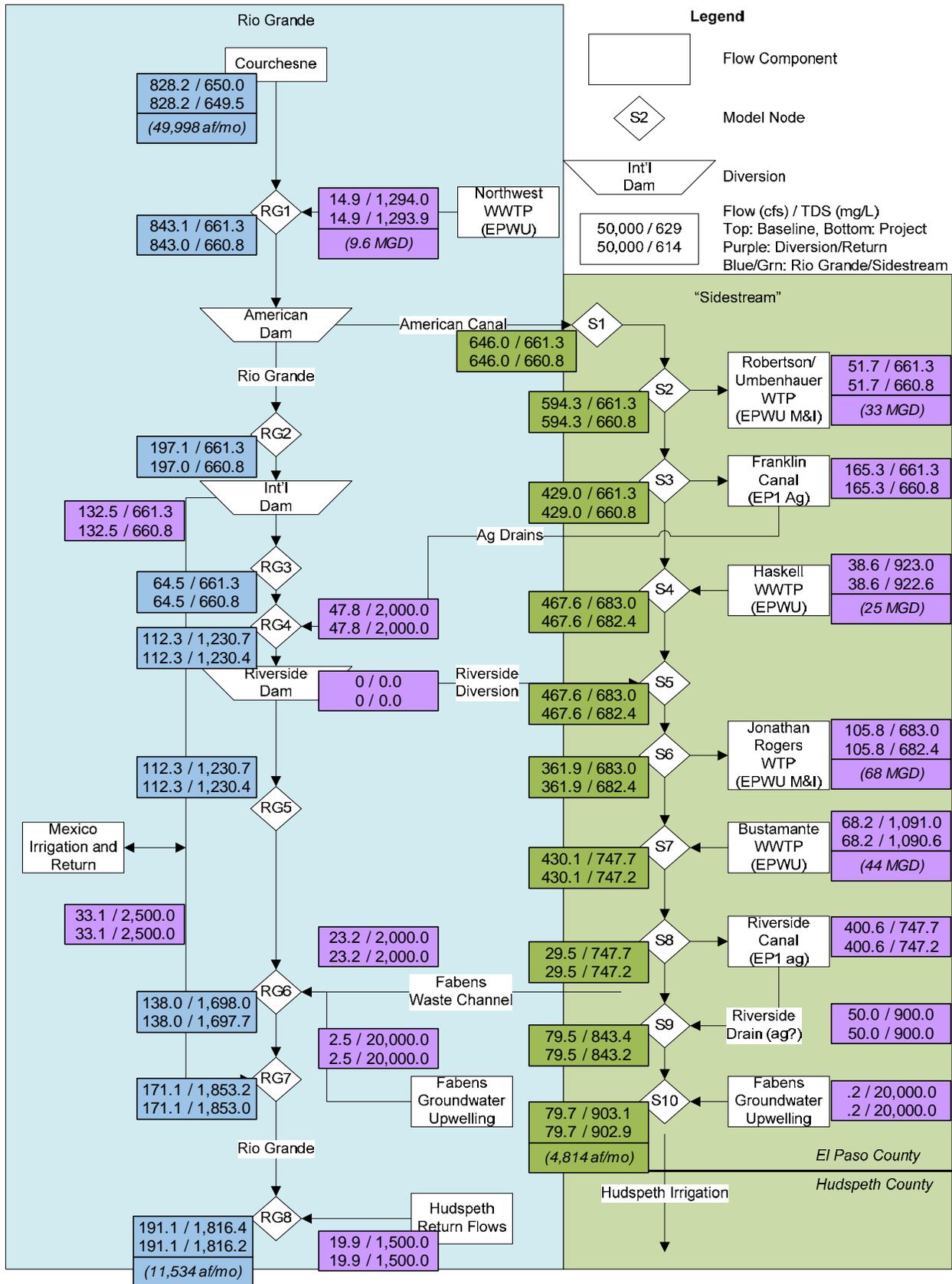


FIGURE 29
Salinity Model Simulation, Scenario C.1 Multi-Purpose, 2050 Irrigation Season

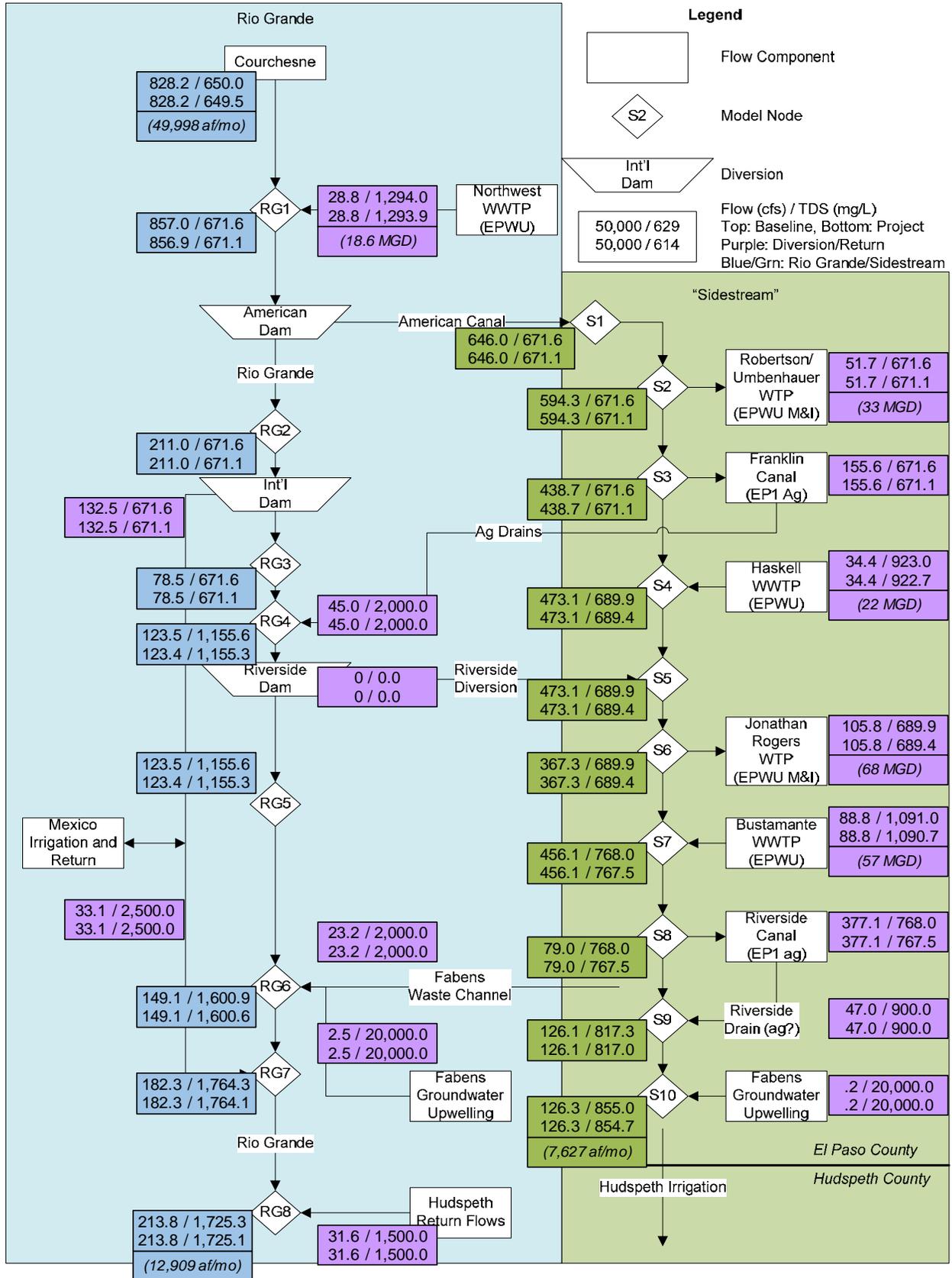


FIGURE 30
Salinity Model Simulation, Scenario C.2 Multi-Purpose, 2020 Irrigation Season

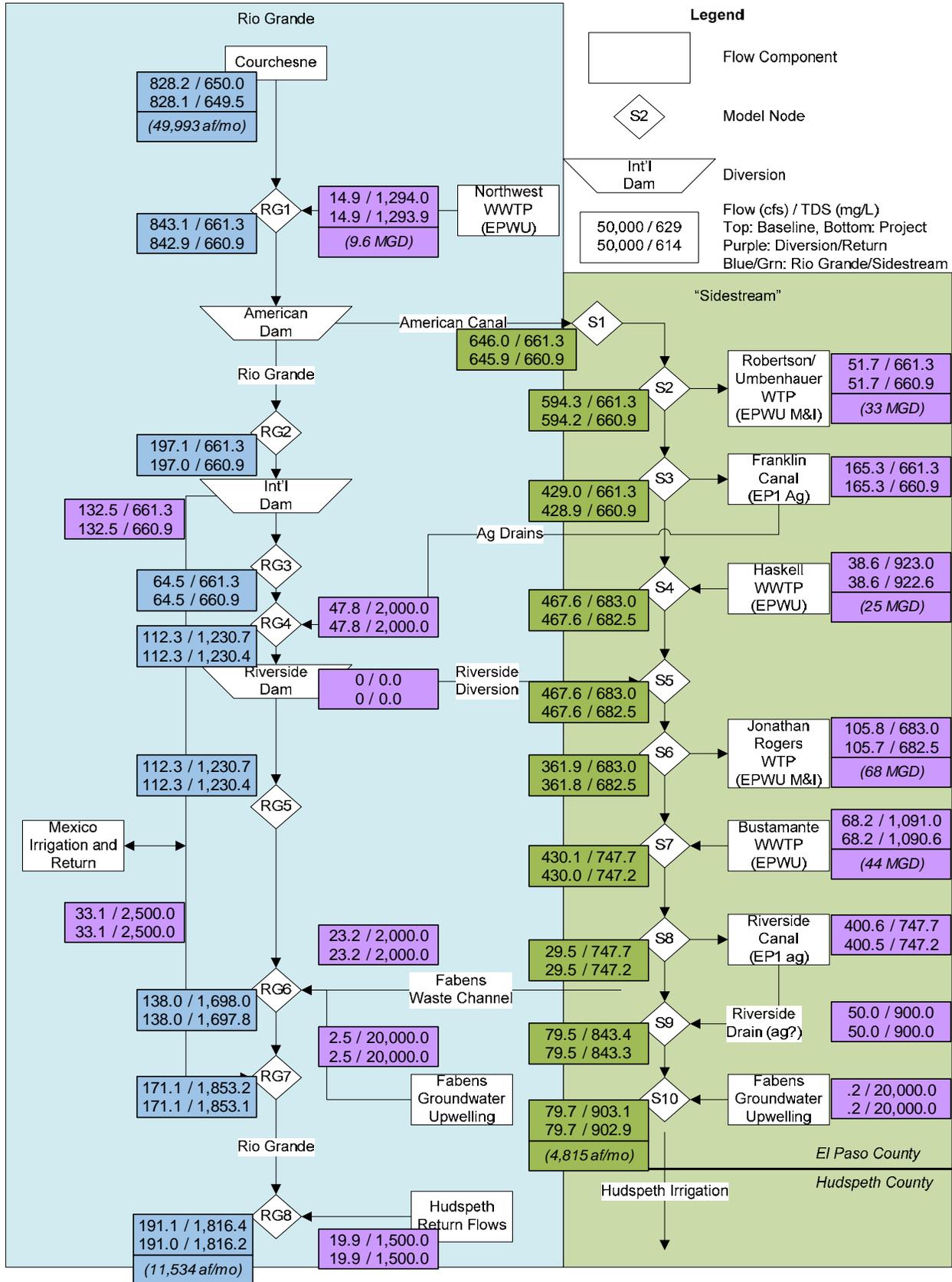


FIGURE 31
Salinity Model Simulation, Scenario C.2 Multi-Purpose, 2050 Irrigation Season

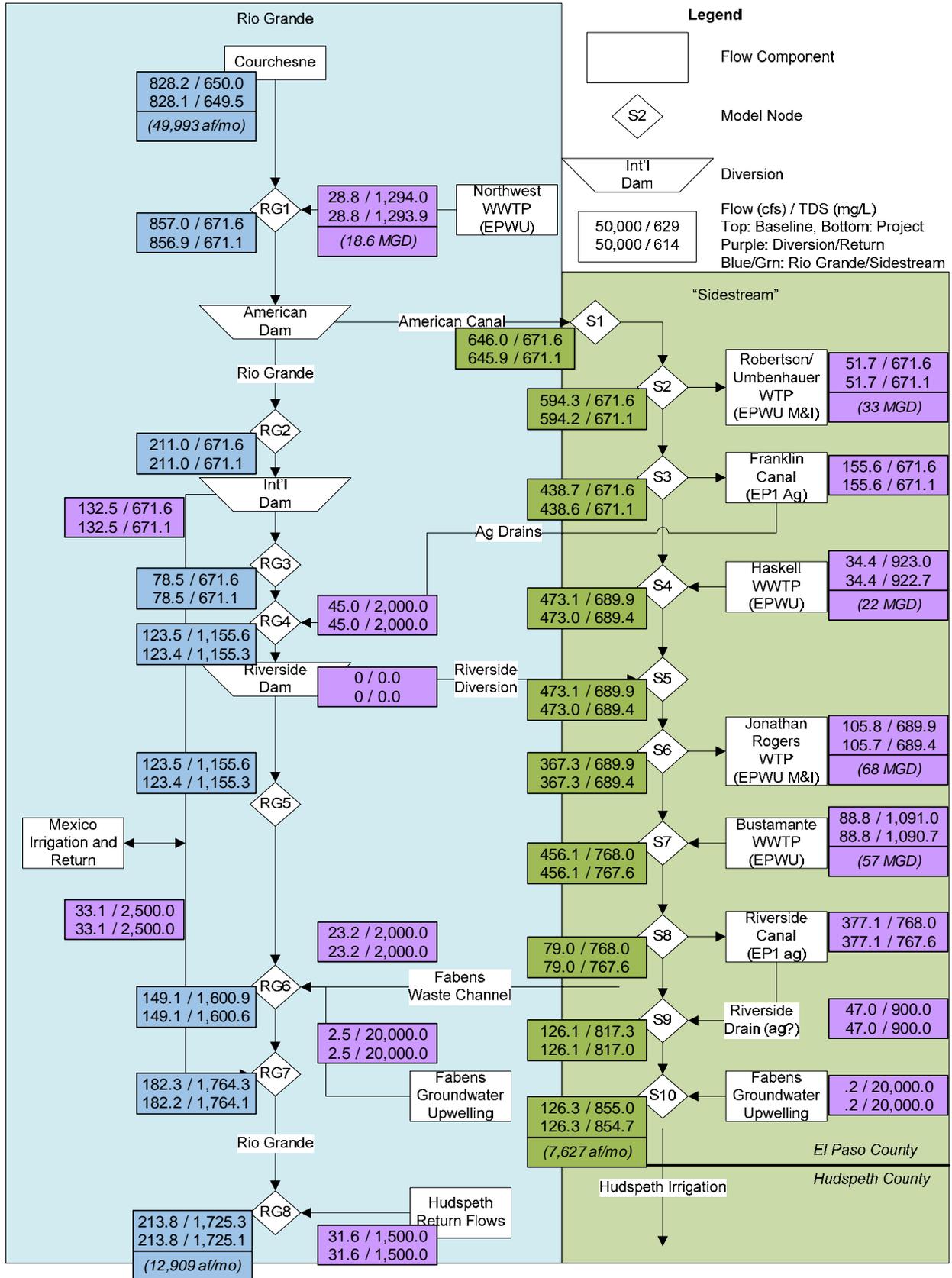


FIGURE 32

Salinity Model Simulation, Scenario C.3 Multi-Purpose, 2020 Irrigation Season

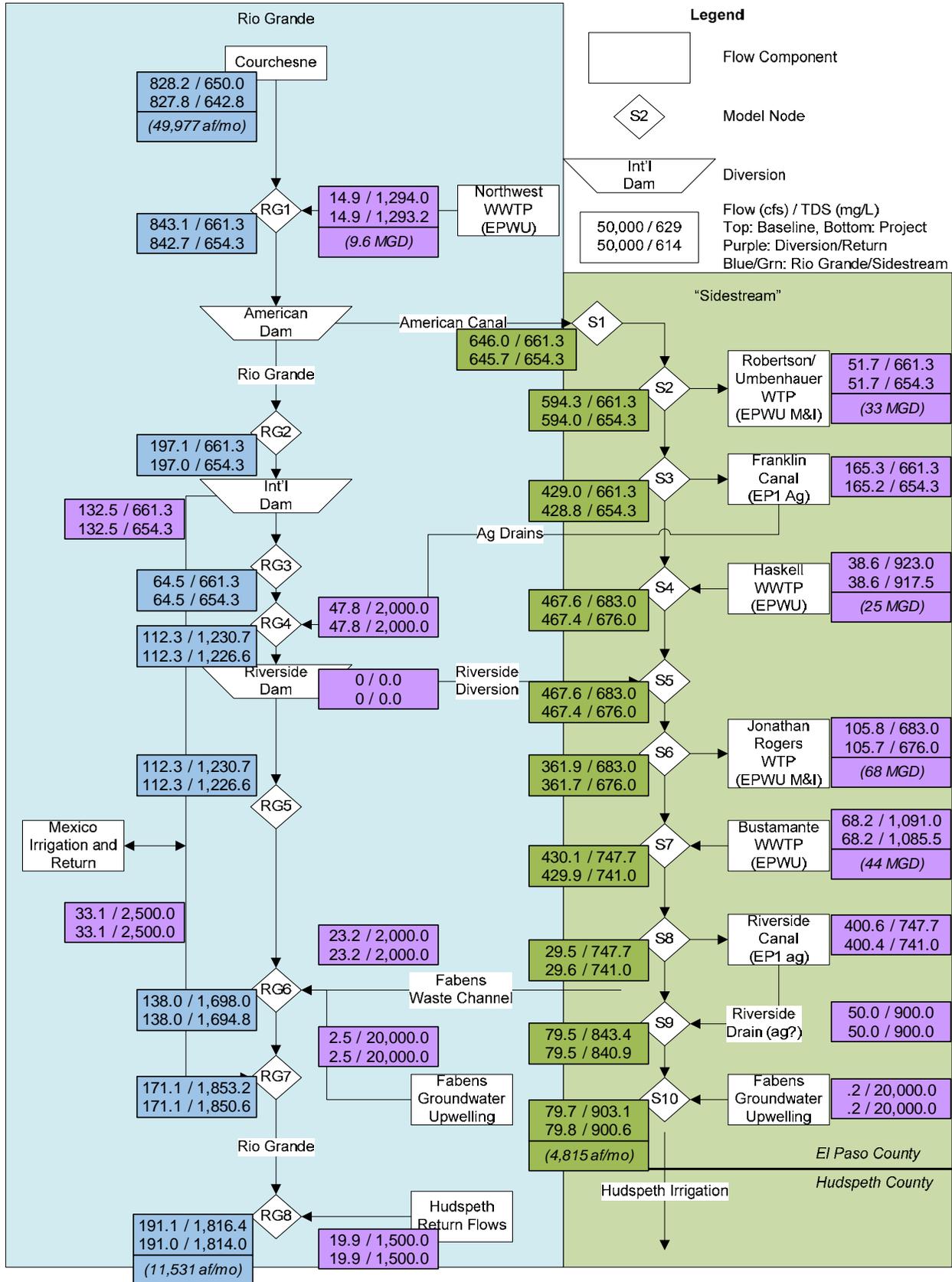


FIGURE 33
Salinity Model Simulation, Scenario C.3 Multi-Purpose, 2050 Irrigation Season

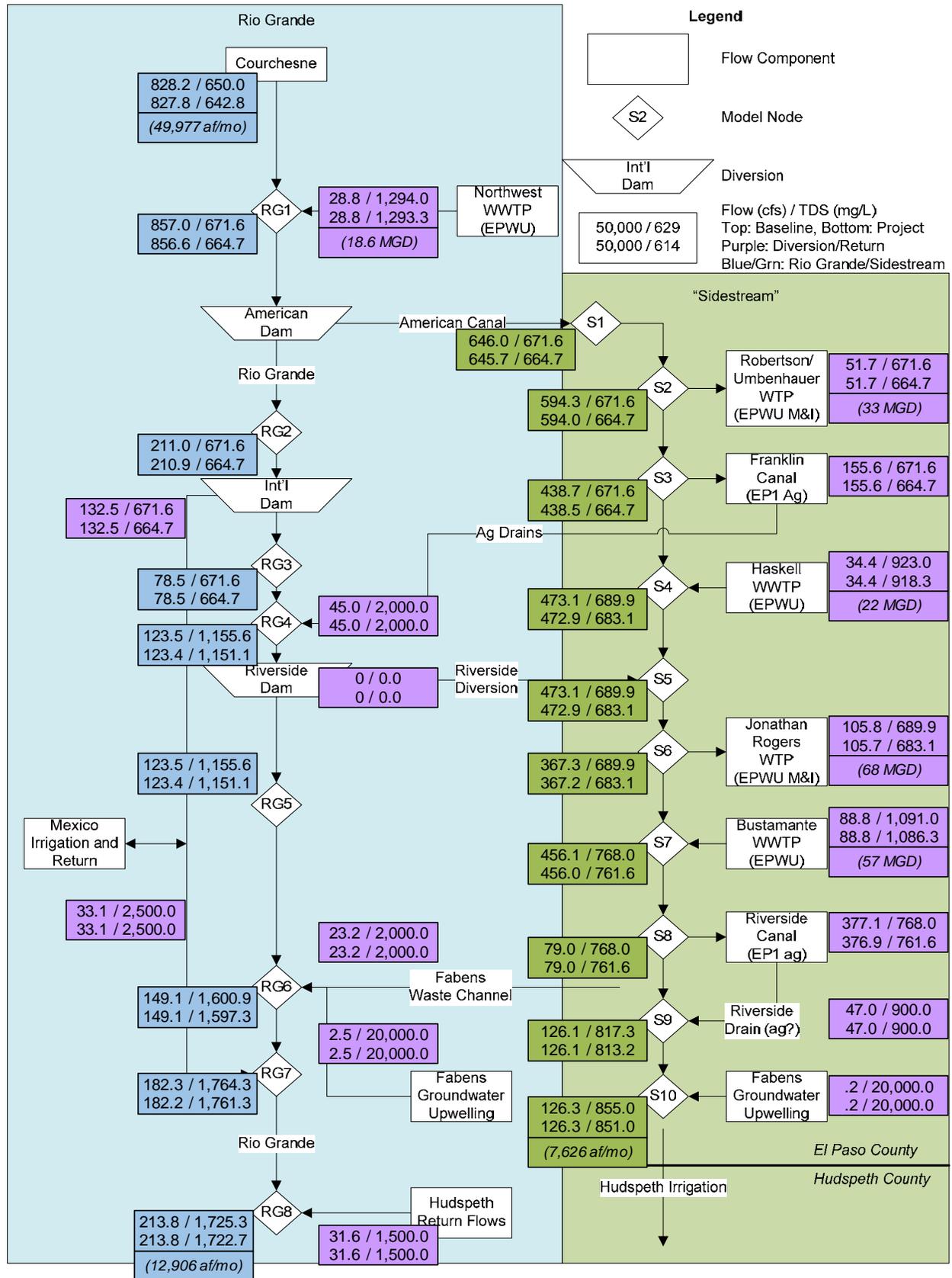


FIGURE 34
Salinity Model Simulation, Scenario C.4 Multi-Purpose, 2020 Irrigation Season

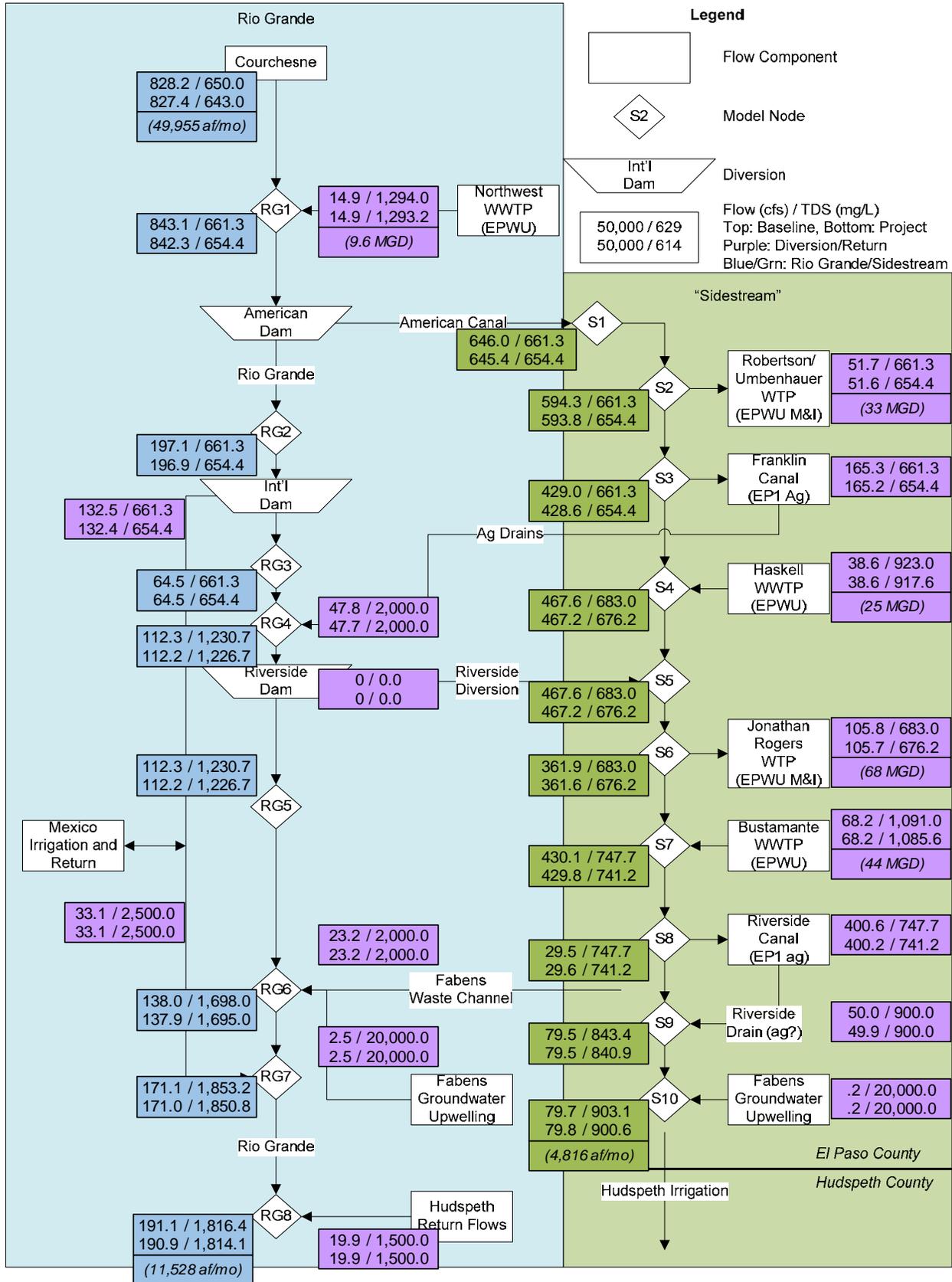


FIGURE 35
Salinity Model Simulation, Scenario C.4 Multi-Purpose, 2050 Irrigation Season

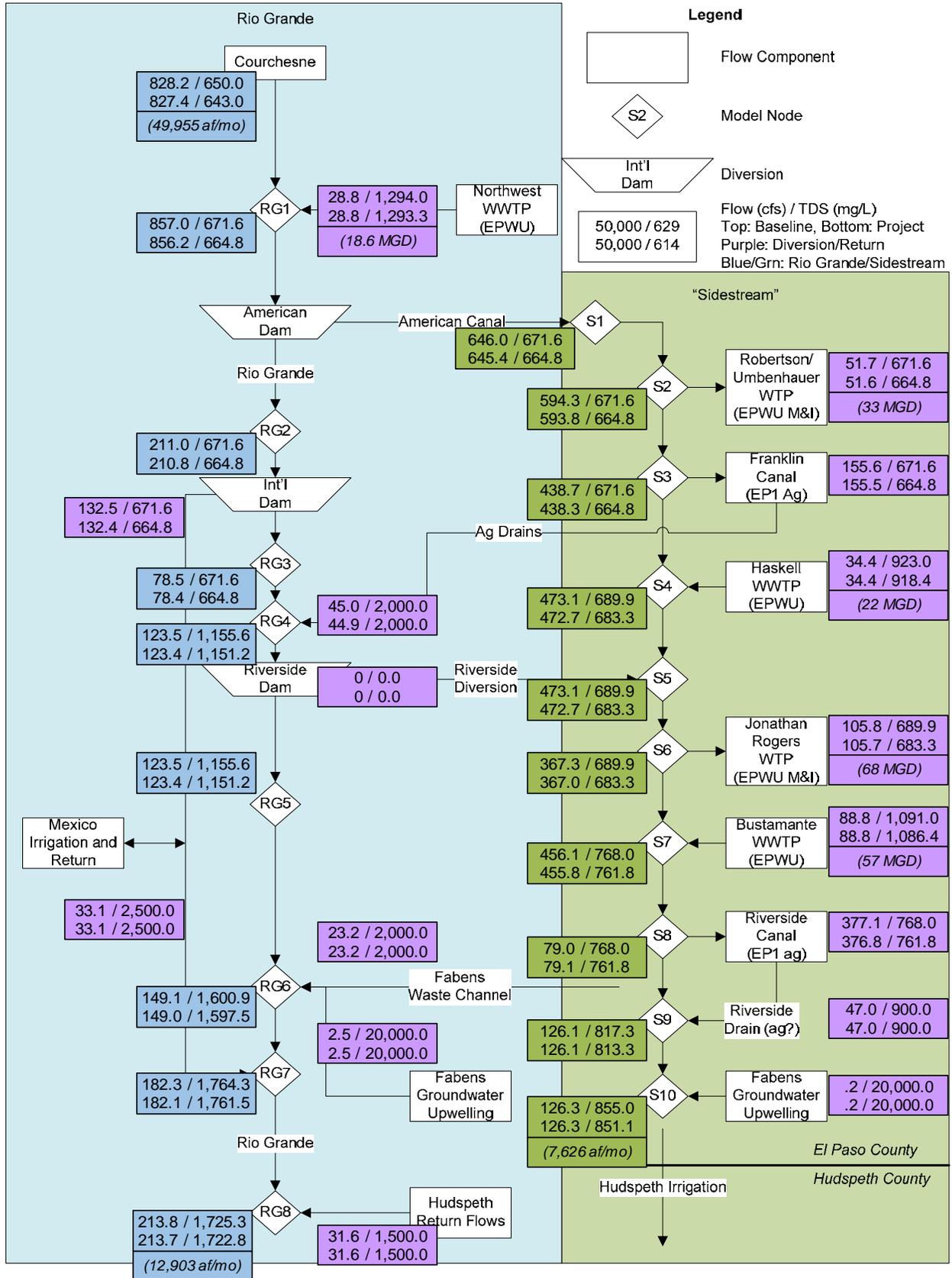


FIGURE 36
Salinity Model Simulation, Scenario D.1 Multi-Purpose, 2020 Irrigation Season

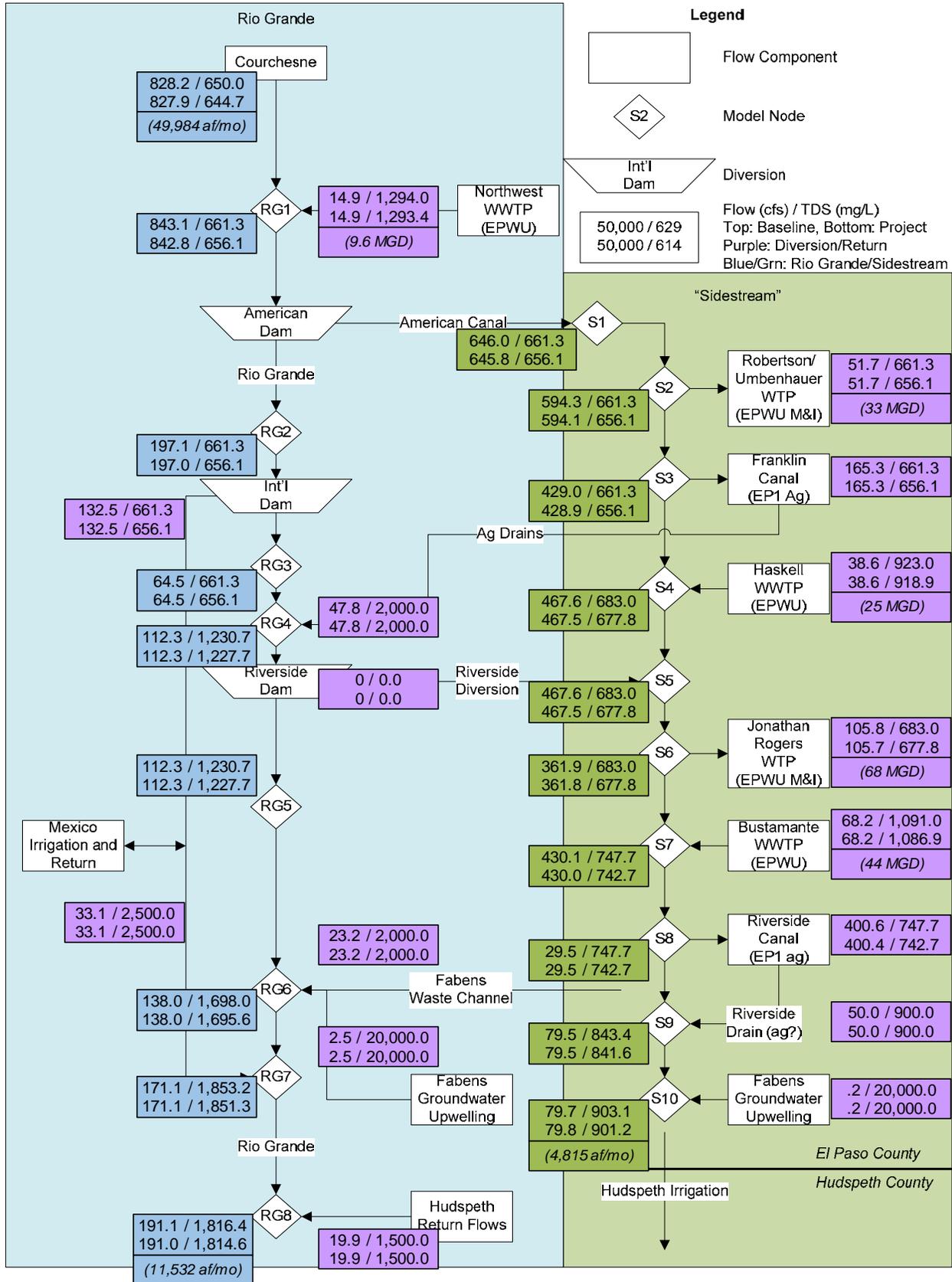


FIGURE 37
Salinity Model Simulation, Scenario D.1 Multi-Purpose, 2050 Irrigation Season

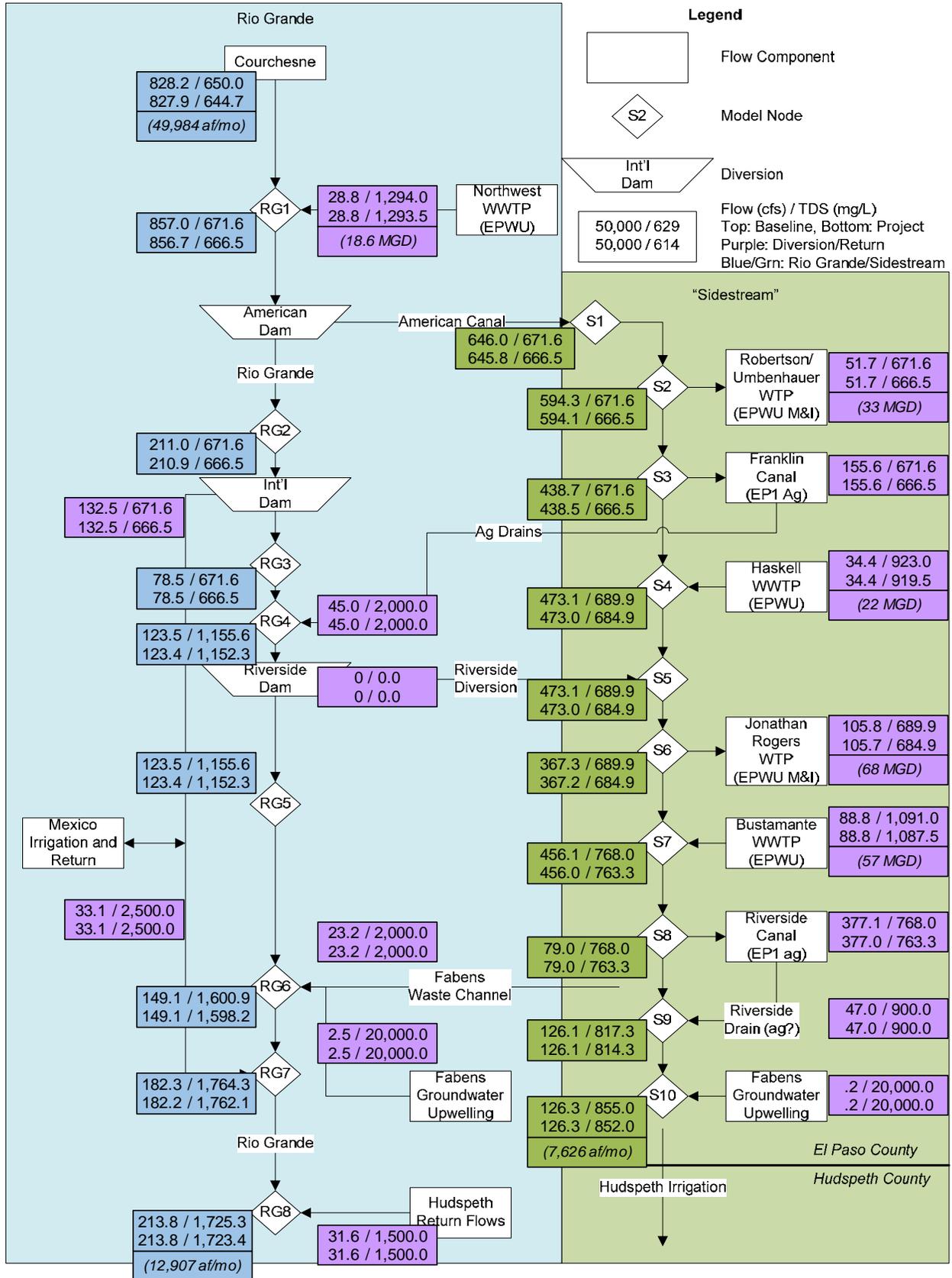


FIGURE 38
Salinity Model Simulation, Scenario D.2 Multi-Purpose, 2020 Irrigation Season

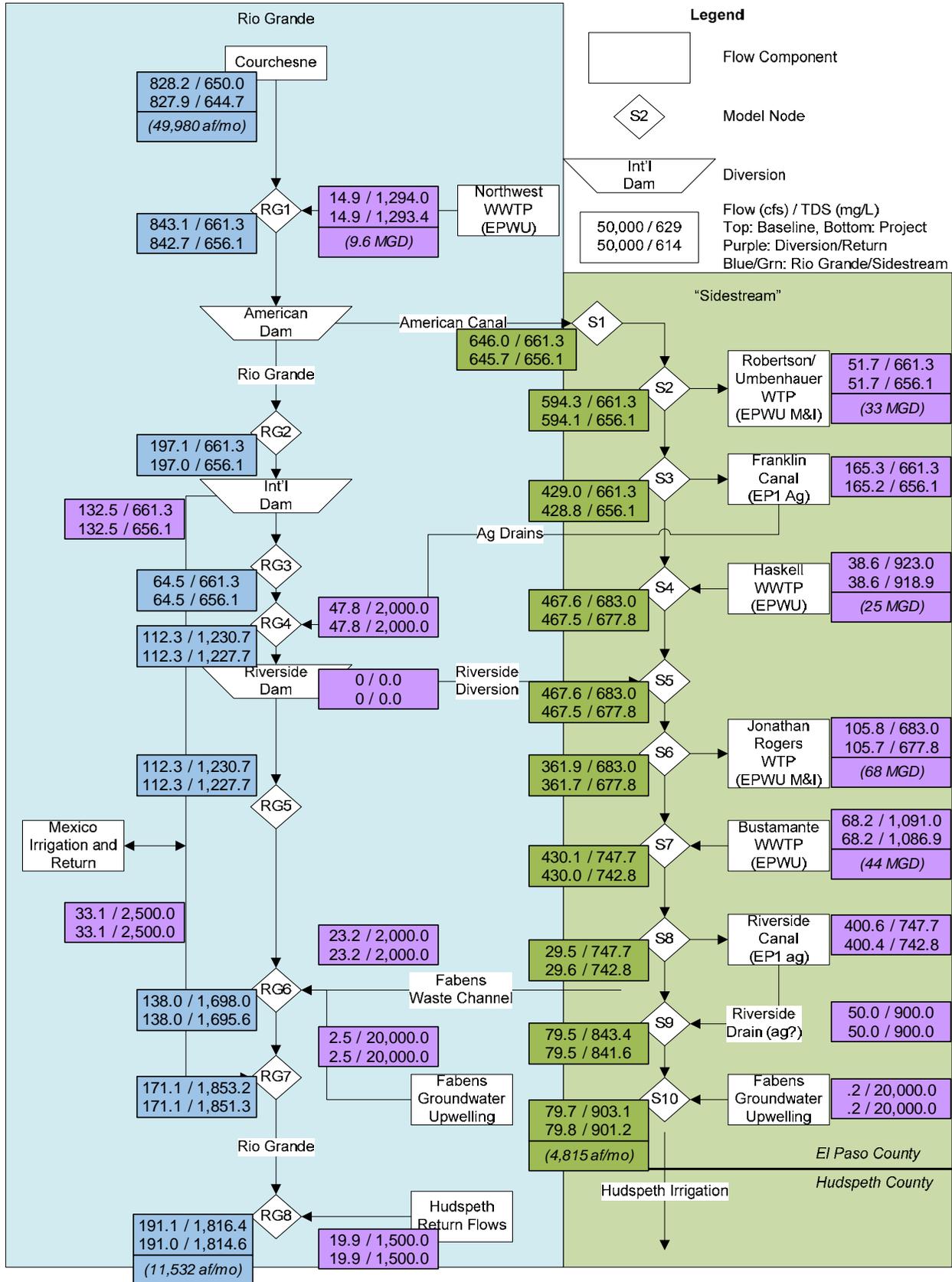


FIGURE 39
Salinity Model Simulation, Scenario D.2 Multi-Purpose, 2050 Irrigation Season

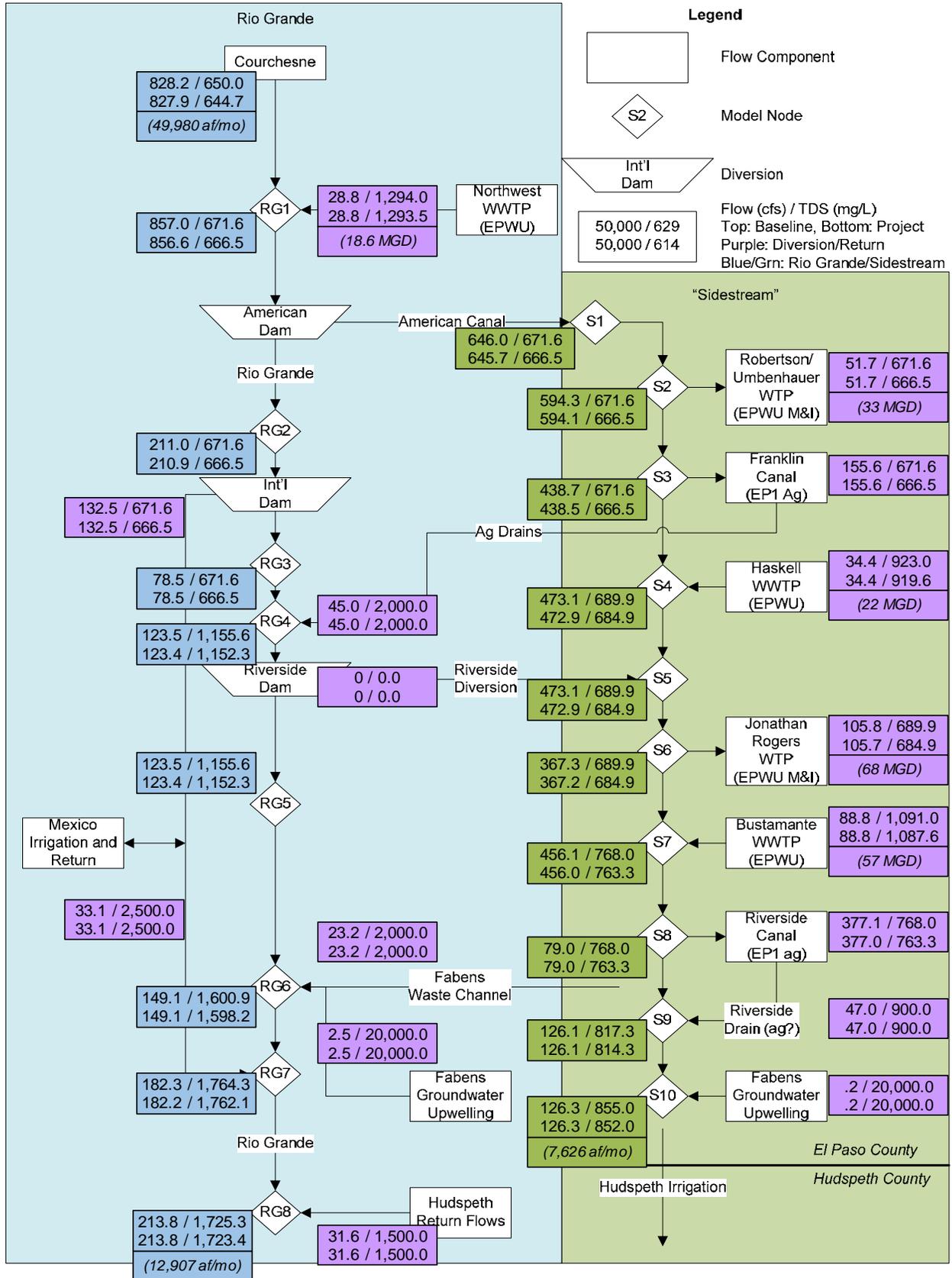


FIGURE 40
Salinity Model Simulation, Scenario D.3 Multi-Purpose, 2020 Irrigation Season

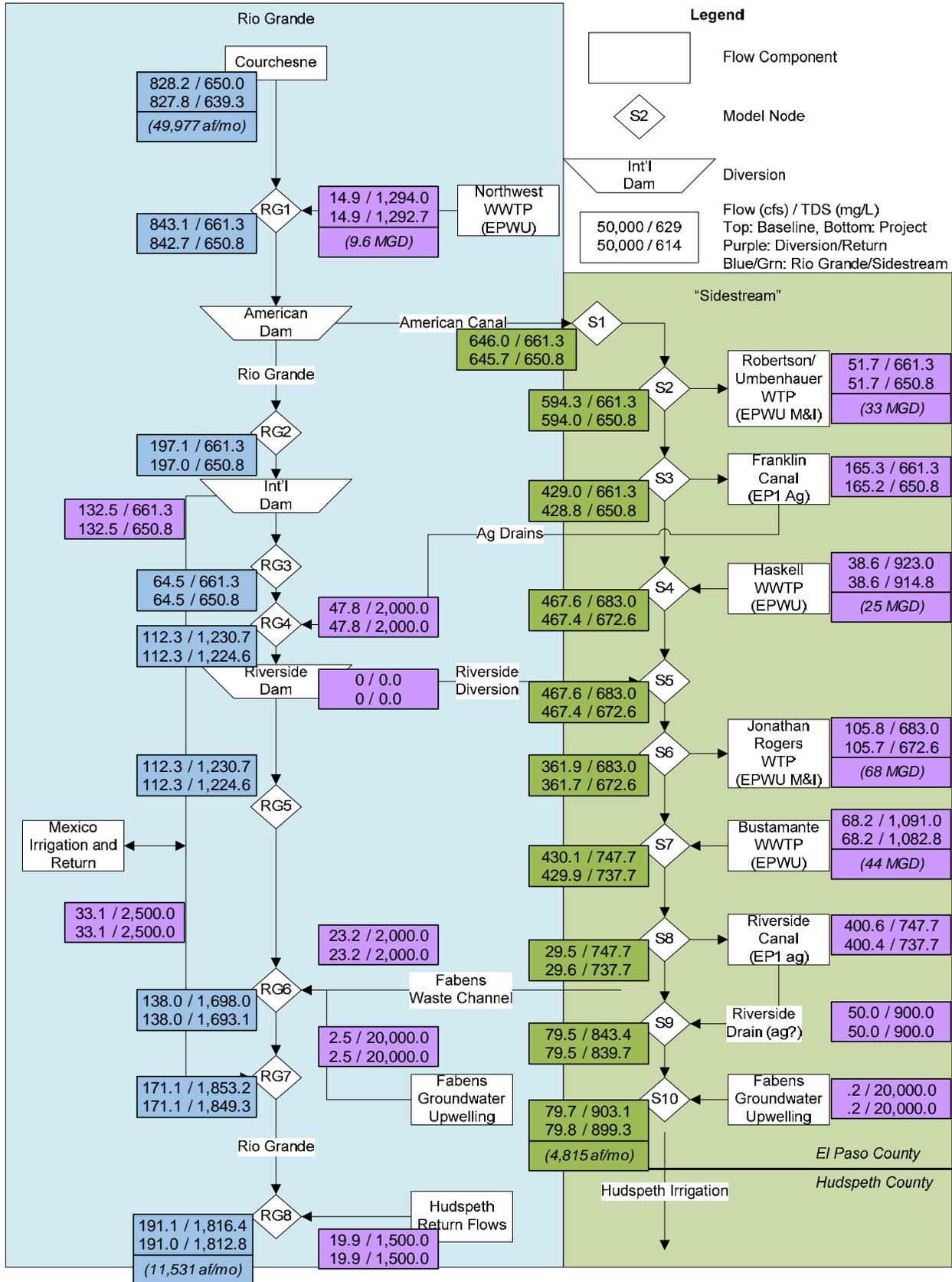


FIGURE 41
Salinity Model Simulation, Scenario D.3 Multi-Purpose, 2050 Irrigation Season

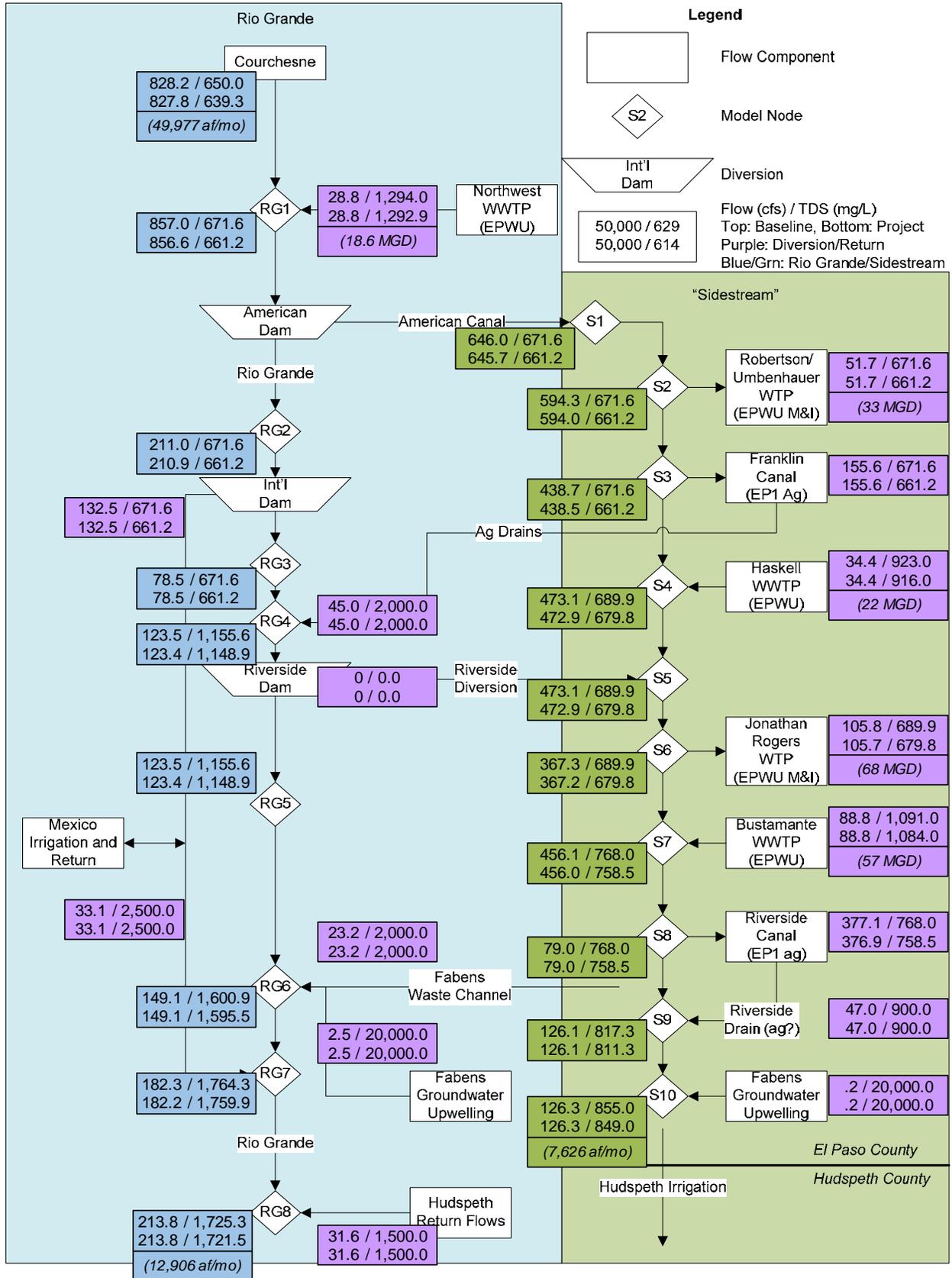


FIGURE 42
Salinity Model Simulation, Scenario D.4 Multi-Purpose, 2020 Irrigation Season

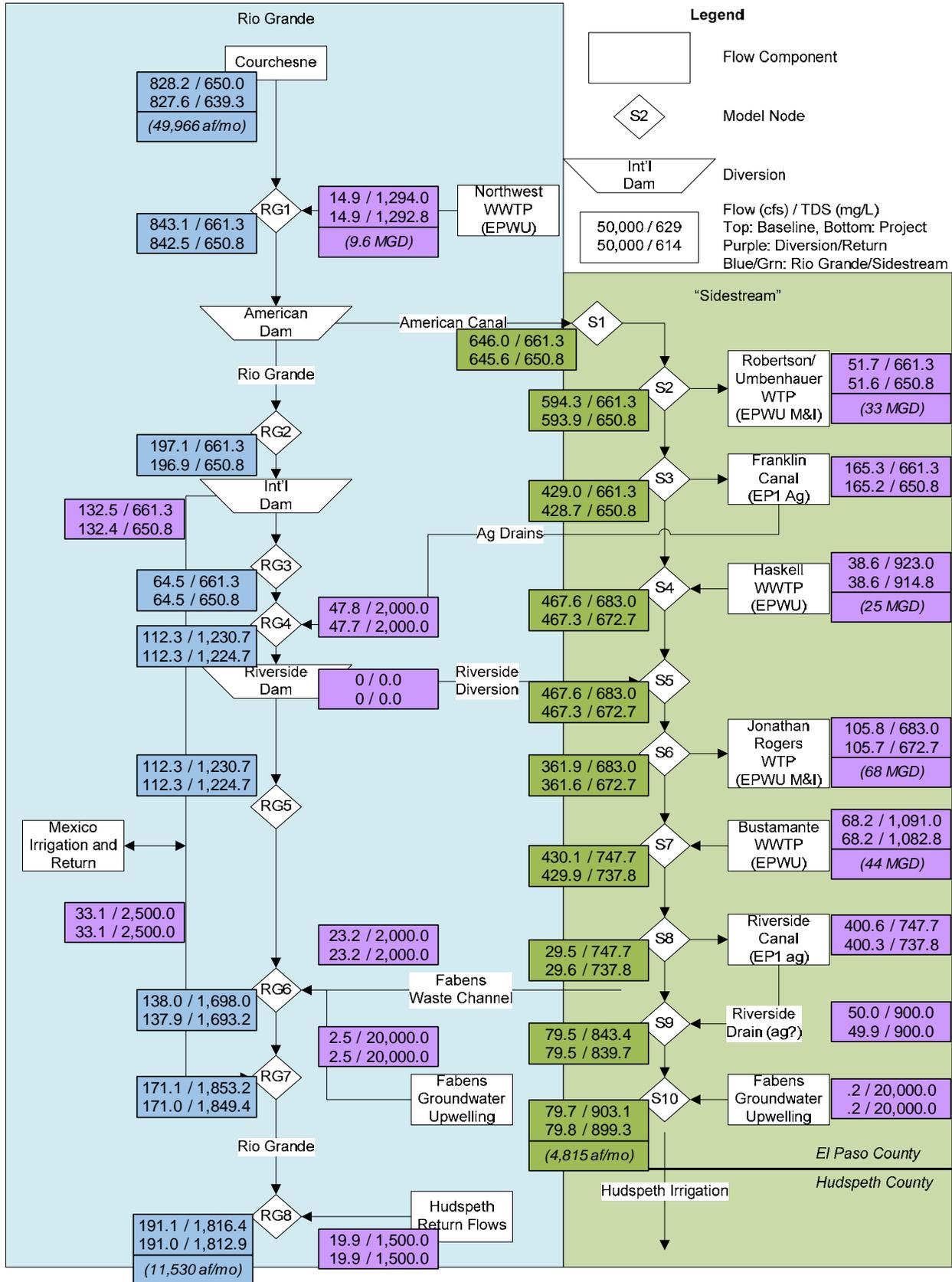


FIGURE 43
Salinity Model Simulation, Scenario D.4 Multi-Purpose, 2050 Irrigation Season

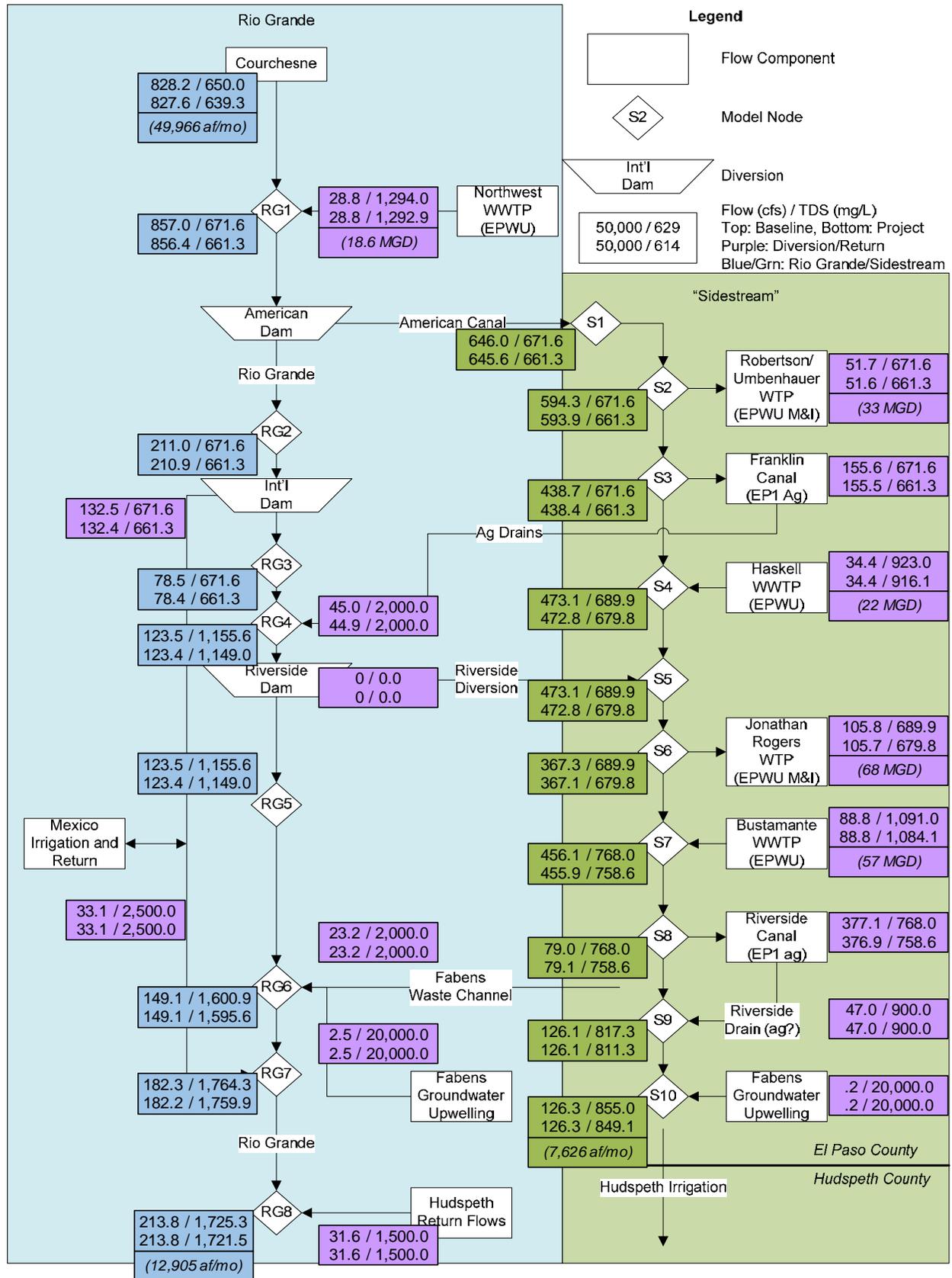


FIGURE 44
Salinity Model Simulation, Scenario D.3 Multi-Purpose, 2020 Non-irrigation Season

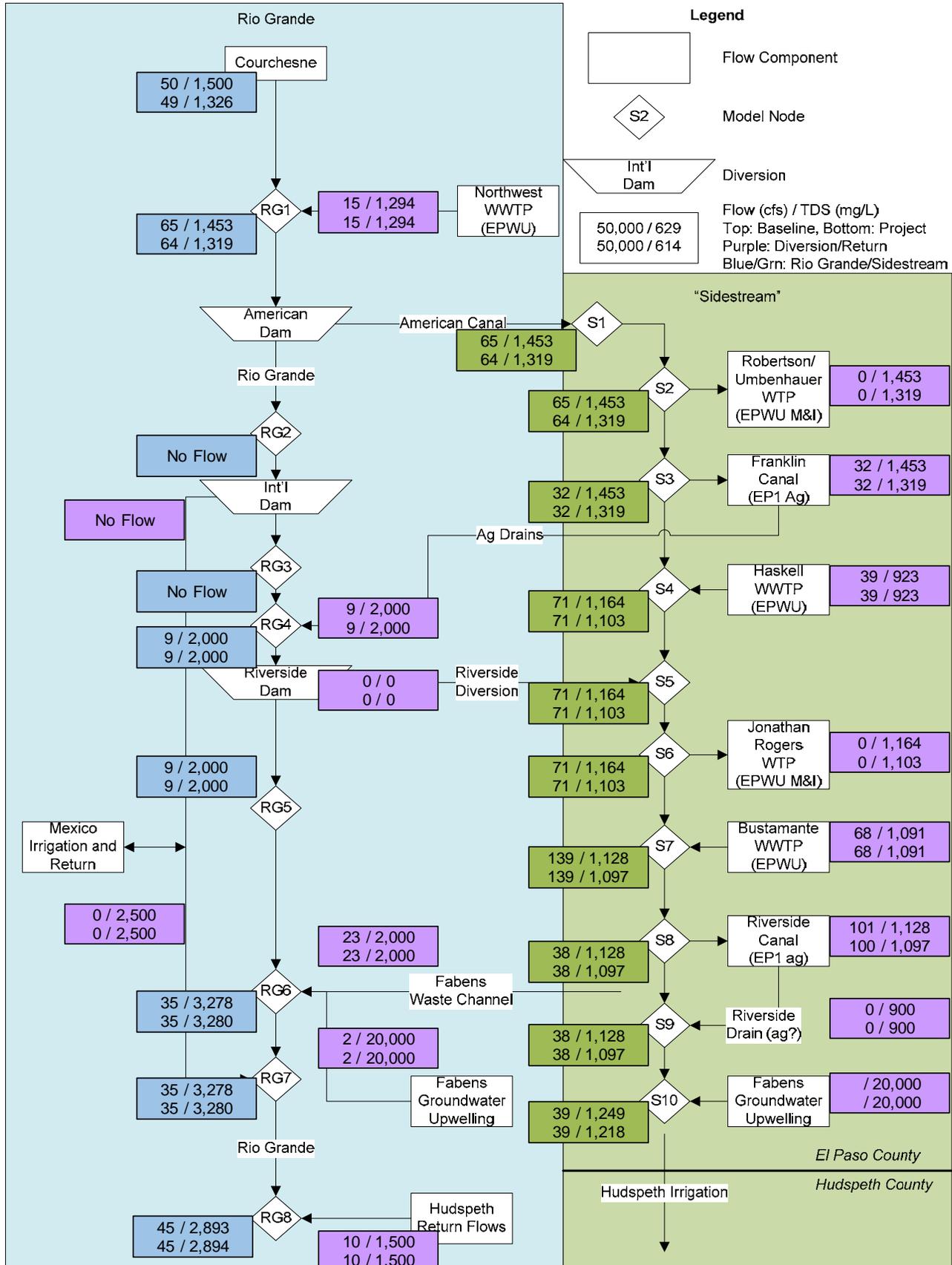
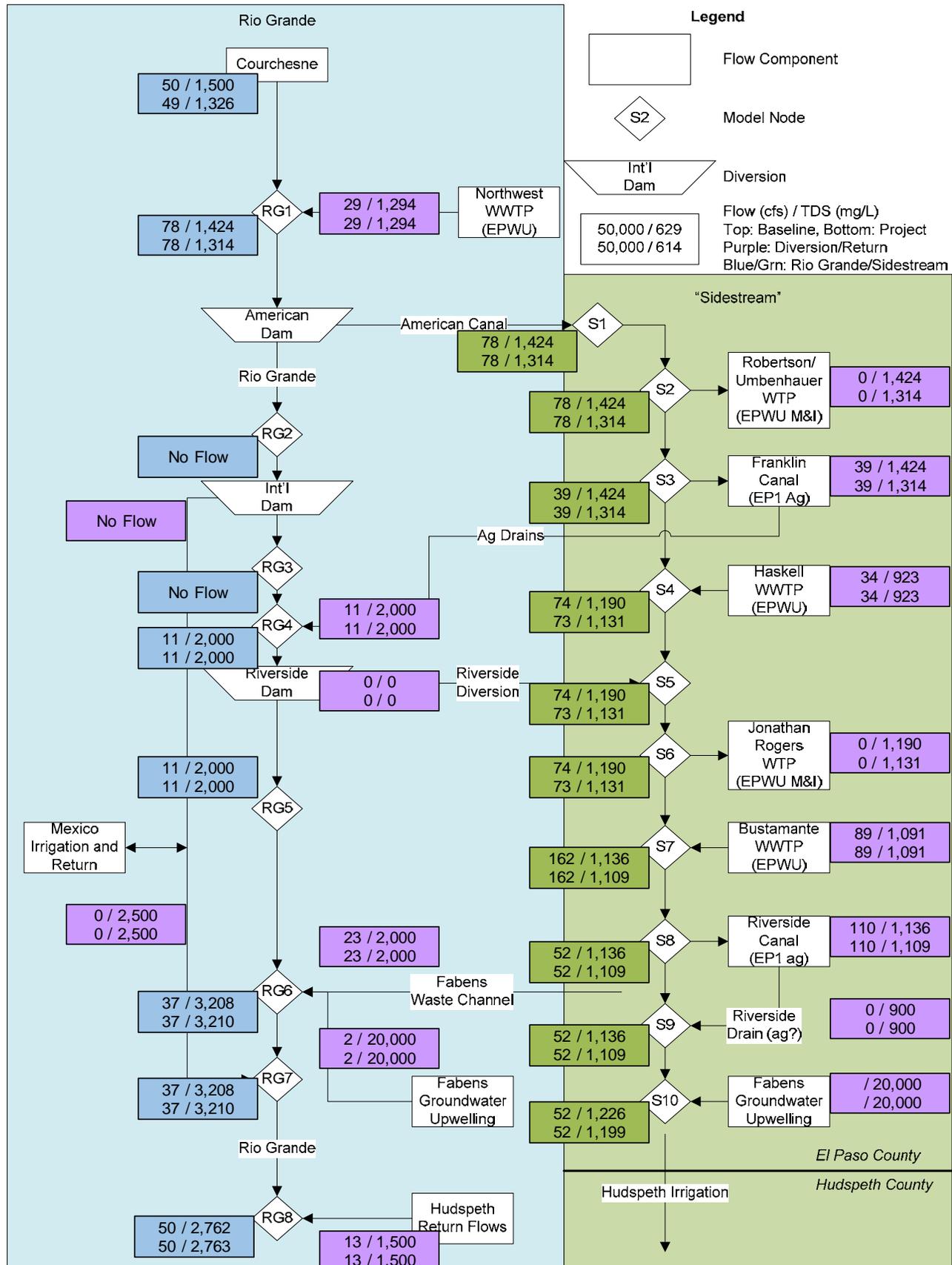


FIGURE 45
Salinity Model Simulation, Scenario D.3 Multi-Purpose, 2050 Non-irrigation Season



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Appendix A2
Potential Water Quality Benefits during
Shoulder and Non-irrigation Season

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Estimation of Potential Water Quality Benefits during Shoulder and Non-irrigation Season

PREPARED FOR: USACE, Albuquerque District

PREPARED BY: CH2M HILL

DATE: April 3, 2015

This technical memorandum provides additional details regarding water quality estimates used in the sensitivity analysis for shoulder and non-irrigation season benefits.

The best available time-series data for shoulder season water quality are chloride concentrations at EPWU's raw water intake (at Robertson/Umbenhaur Water Treatment Plant [WTP]). Sulfate and total dissolved solids (TDS) data were not readily available at sufficient time resolution to perform this analysis. Observed chloride in the spring shoulder season is presented in the solid lines on Figure 1, for years 2008 to 2010. Chloride concentrations decreased as flow increased, over a period of about 1 month.

Figure 1 also shows calculated chloride concentrations (dashed lines) if Alternative 3 at Site 2 were in place (the alternative with the greatest potential chloride reduction). It can be seen from Figure 1 that if chloride were the primary criterion for diversions, diversions could start about 1 day earlier under this alternative. Assuming a similar period of time for the fall shoulder season would result in about 2 days of additional diversion under Alternative 3 at Site 2, if chloride were the primary criterion.

However, because sulfate is the primary criterion, a method was developed to estimate the effect on sulfate based on the relative concentrations of sulfate and chloride. Observed decline in chloride concentration is approximately linear during the spring shoulder season (Figure 1). Water quality improvement due to the project results in a shift of that line downward. However, the increased diversion is a function of how much the downward shift of the line results in an apparent lateral shift of the line (to the left). The apparent lateral shift is a function of a) the magnitude of water quality improvement and b) the slope of the line. For example, for the same water quality improvement, a steep-sloped line (large difference in concentration from low flow periods to high flow periods and/or a short time from low flow to full flow) would result in a lesser lateral shift (lesser increase in the period of diversion) than a flatter-sloped line. If the water quality improvement is assumed to be linear, then the time of additional diversion would be equal to the water quality improvement divided by the slope of the line.¹ The relative difference in these two factors for sulfate as compared with chloride can be used to estimate the duration of additional duration when sulfate concentration is the primary criterion for diversions.

Chloride in the Rio Grande is typically on the order of 250 milligrams per liter (mg/L) during low-flow periods, decreasing to about 80 mg/L during full flow periods (note that the first data point in **Figure 1** occurs after Rio Grande flow has begun to increase, and is therefore less than the 250 mg/L low-flow concentration). Sulfate concentration in the Rio Grande is typically on the order of 500 mg/L during

¹ Based on a trigonometry calculation. If θ represents the angle of the slope of the line, from horizontal, then $\tan(\theta) = (\text{non-irrigation season concentration} - \text{irrigation season concentration}) / (\text{number of days})$. Also $\tan(\theta) = \text{concentration reduction due to project} / \text{time of increased diversion}$. Therefore, $\text{time of increased diversion} = \text{concentration reduction due to project} * (\text{number of days}) / (\text{non-irrigation season concentration} - \text{irrigation season concentration})$

low-flow periods, decreasing to about 200 mg/L during full flow periods. Assuming the same time period to reach equilibrium, the slope of the sulfate concentration curve would be about 1.75 times that of chloride (300 mg/L decrease of sulfate divided by 170 mg/L decrease of chloride).

The relative effect of the project on sulfate concentration in the river was estimated based on the relative concentration of sulfate in groundwater compared with chloride. Observed sulfate concentration in groundwater is generally on the order of 1.5 times chloride concentration. Accordingly, it is assumed that the duration of additional diversion using sulfate as the criteria would be about 85 percent of the increased time of diversion if chloride were the primary criteria (relative water quality improvement of 1.5 divided by relative change in slope of 1.75), or 1.7 days under Alternative 3 at Site 2).

Additional duration of diversion was estimated for the other alternatives based on the relative amount of chloride removal for each of the alternatives. Due to inherent uncertainty in this estimate, separate results for the single- and multi-purpose alternatives were not developed. Resultant additional duration for all alternatives are presented in **Table 1**.

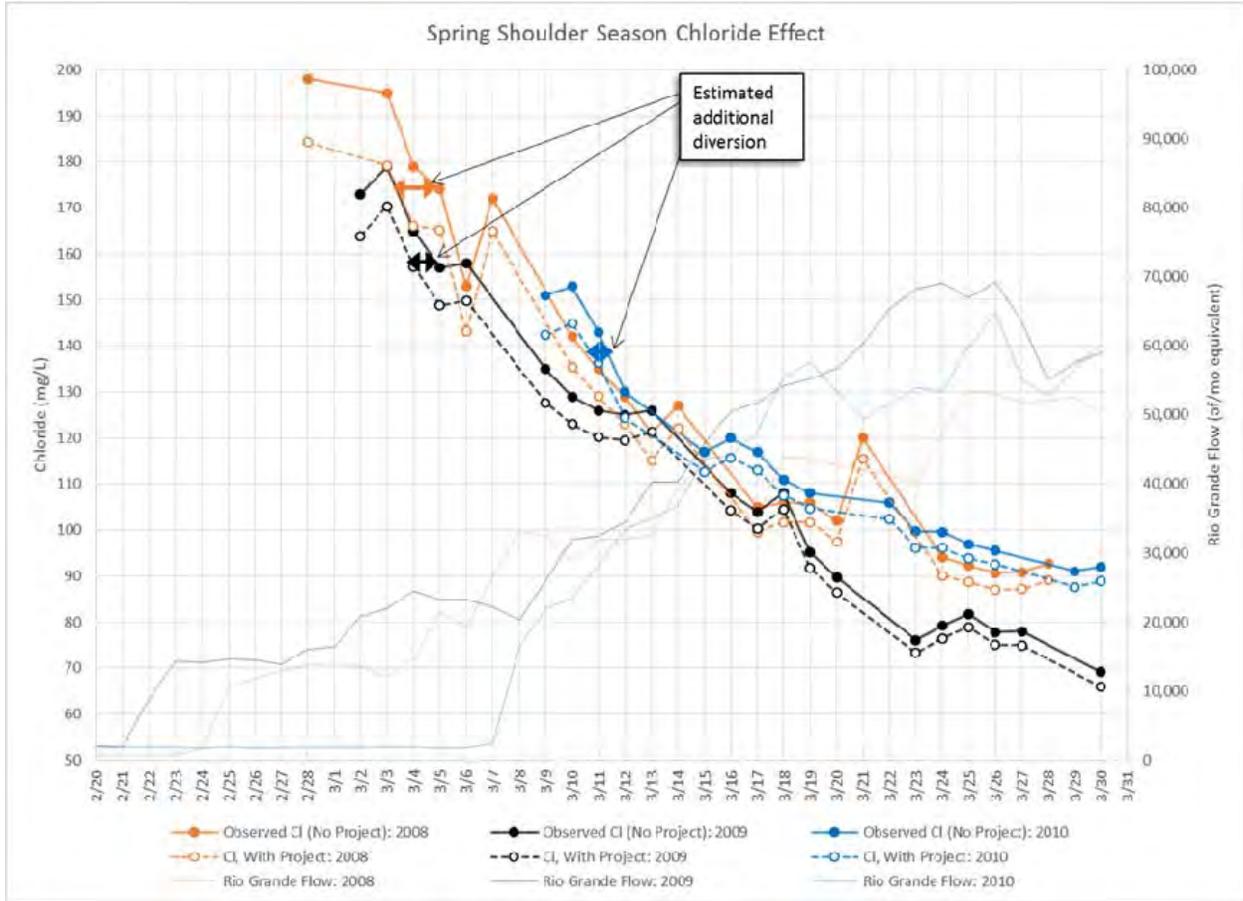
TABLE 1
Estimated Duration of Additional Diversion

Alternative Plan	Site 1: Montoya				Site 2: Rio Grande, ISC-4			
	A, B				C, D			
	1	2	3	4	1	2	3	4
Cl mass removal (tons/mo) ¹	13	13	191	194	127	128	253	255
Cl removal, relative to Alternative C.3	0.1	0.1	0.8	0.8	0.5	0.5	1.0	1.0
Additional diversion (days) ²	0.1	0.1	1.3	1.3	0.9	0.9	1.7	1.7

¹ Mass removal calculation assumes that 80 percent of total well pumping is the saline source (with remaining 20% clean groundwater with Cl concentration of 500 mg/L, based on nearby wells), and that 30 percent of the source is captured.

² Calculated as 1.7 days for C.3 multiplied by Cl removal, relative to Alternative C.3

FIGURE 1
Spring Shoulder Season



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Appendix B1
Economic Benefits Calculations

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Economic Benefits Calculations, Distal Mesilla Basin

PREPARED FOR: USACE, Albuquerque District

PREPARED BY: CH2M HILL

DATE: April 3, 2015

Introduction

Economic benefits of salinity reduction across project alternatives are measured for urban and agricultural users of Rio Grande water. As stated in the main body of the report, the study follows established methodology for calculating benefits from salinity reduction. The analysis uses the 2010, 2020 and 2050 benefits estimates to develop a net present value (NPV) benefits analysis for 50 years using the federal approved discount rate for water projects of 3.5 percent (USDA NRCS 2014). Annual benefits in all years except 2010, 2020 and 2050 are estimated by linear interpolation and extrapolation from the 2010, 2020, and 2050 estimates.

Agricultural Water Use Benefits

Project alternative benefits were estimated as the savings in irrigation water cost plus any increase on the value of crop yield resulting from improved irrigation water salinity. The model simulates farmers' irrigation decisions by choosing the level of leaching that produces the greatest net return. The relationship between leaching and crop yield is based on the established relationships between applied water, water salinity, and soil salinity from Ayers and Westcott (1985). Crop budget data was used to calculate incremental changes in yield value based on irrigation water salinity and leaching fraction.

Below we describe the general approach used to model the effect of irrigation water salinity on soil salinity and crop yield, and how they are affected by water applied for salt leaching. Results of discussions with local experts provide information and perspective on local conditions and how farmers manage irrigation and salinity. Then, a model is described that we used to estimate the costs of salinity to agricultural production and the benefits (reduced costs) of improving salinity conditions in the river.

Transient vs. Steady-state Models of Salinity Impact on Irrigated Crops

The impact of salinity on crop establishment, growth, and yield has been modeled with transient and steady-state tools depending on the study objectives, budget, and available data.

Although soil water content, soil salinity, and crop growth are never really steady state, the steady-state approaches have been considered excellent first approximations (Hoffman, 2009). The overall objective of the steady-state approaches is to evaluate for a given irrigation water quality and a given crop tolerance to salinity, how much additional water (leaching fraction) must be applied to avoid salt accumulation and yield loss (also known as the leaching requirement [Hoffman, 2009]).

The widely cited works of Rhoades (1974), Rhoades and Merrill (1976), Mass and Hoffman (1977) and Ayers and Westcott (1985) and an assumption of steady-state conditions are commonly used to estimate yield impacts of irrigation water salinity and leaching fractions required by different levels of salinity. Leaching fractions were determined for each crop based on the amount of additional water that would be required to maintain 100 percent yield with a given irrigation water salinity.

Two key equations in the steady-state approach are as follows:

$$LR = \frac{EC_w}{(5(EC_e) - EC_w)}$$

(Rhoades, 1974; Rhoades and Merrill, 1976)

Where EC_w is the salinity of the applied water (dS/m), LR is the leaching requirement needed to maintain soil salinity at the given EC_e ; and EC_e is the salinity of the soil saturation extract (deciSiemens per meter [dS/m]). A key assumption inherent in this equation is that crops respond to the average salinity in the root zone (Rhoades and Merrill, 1976).

$$Y = 100 - b(EC_e - a) \text{ (Mass and Hoffman, 1977)}$$

Where Y is the relative crop yield, a is the constant representing the soil salinity threshold value for yield loss, and b is the slope of the yield decline, or the yield loss per unit increase in soil salinity.

Table 1 summarizes the water use and soil salinity parameters used, by crop type. The soil salinity coefficients are also commonly referred to as Maas-Hoffman coefficients.

TABLE 1
Crop Water Use and Soil Salinity Coefficients

	Pecans	Cotton	Alfalfa	Onions	Chile	Grain	Lettuce	Corn
Actual Evapotranspiration (in.)	43.3	29.5	55.5	38.2	39.2	14.2	22.44	28.4
Slope ^b	0.217	0.052	0.071	0.161	0.162	0.071	0.130	0.076
Threshold (100% Yield) (dS/m EC_e)	2.5	7.7	2	1.2	1.61	6	1.3	1.8
0% Yield (dS/m EC_e)	7.0	27	7.3	7.4	7.8	20	9	10

EC_e = Electrical conductivity of the soil saturation extract, which is the standard basis for crop salt tolerance interpretations.

Sources:

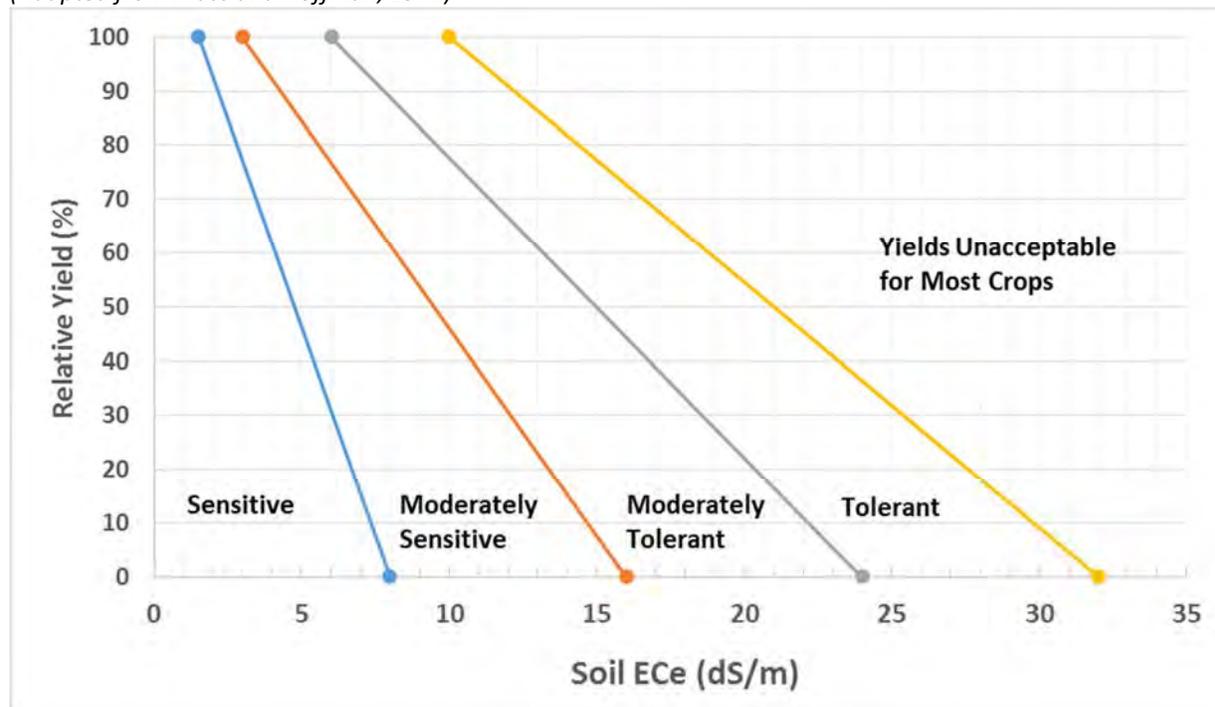
Actual ET: see Appendix 5b.

Soil salinity coefficients for all species other than pecans: Ayers and Westcott (1985), Maas (1996).

Soil salinity coefficients for pecans: Miyamoto 2006

Figure 1 illustrates how the crop responses to soil salinity are classified and the practical application of the Mass and Hoffman (1977) equation. Particularly under experimental conditions where salinity is the only variable, the observed response is no decrease in yield as salinity is increased until a species (and possibly crop variety-specific) threshold is reached. As salinity is further increased, the relative crop yield decreases linearly.

FIGURE 1

Classification of Crop Response to Salinity.*(Adapted from Mass and Hoffman, 1977)*

Transient Models

Transient models that incorporate the effect of time are able to more accurately capture the soil water and salinity dynamics that result from irrigation practices; therefore, these models better represent economic impacts.

Transient models can reflect the reality that a number of important processes affecting crop water use and crop yield change with time. Irrigation water quality may change with time; crop sensitivity may change with crop growth stage; salts precipitate and dissolve; and plant water uptake varies with soil salinity and water content (Hoffman, 2009). For transient models, detailed data are required regarding irrigation amount and frequency, soil physical and chemical properties, and crop evapotranspiration (Hoffman, 2009). Generally, these models use a daily time step for applied water, drainage, and crop evapotranspiration. Example models include Grattan, Corwin, Simunek, SALTMED, SWAGMAN, SDB, and Letey (ENVIRO-GRO) (Hoffman, 2009).

University of California Center for Water Resources Leaching Fraction Workgroup Approach

An update to the steady state approach that has been recommended to regulatory agencies such as the California State Water Resources Control Board is a modified steady-state analysis that corrects for error inherent in the traditional Ayers and Westcott approach (White and White, 2011). The major changes are the use of a water-uptake-weighted average root zone salinity instead of a linear average, and accounting for average annual rainfall. **Table 2** provides the recommended adjusted approach.

TABLE 2
Salinity of Irrigation Source Waters that Can be Applied to Obtain Maximum Yields in Crops with a Salinity Tolerance Threshold of 1.0 dS/m.

Leaching Fraction	Annual Rainfall as Fraction of Total Water Applied						
	0%	10%	15%	20%	25%	30%	35%
	----- dS/m -----						
0.05	0.63	0.70	0.74	0.79	0.84	0.90	0.97
0.1	0.78	0.86	0.91	0.98	1.04	1.11	1.20
0.15	0.9	1.0	1.05	1.12	1.20	1.28	1.38
0.20	1.0	1.11	1.17	1.25	1.33	1.43	1.54
0.25	1.06	1.17	1.25	1.32	1.41	1.51	1.63
0.30	1.18	1.31	1.39	1.48	1.57	1.68	1.81

*Note that values can be scaled on a linear basis for crops with a threshold other than 1.0. For example, if the crop’s salinity threshold for 100% yield is 2.0, values in Table 1 would be double the values shown.

Source: Adapted from White and White, 2011.

Although **Table 1** likely represents the best available science regarding determination of the most appropriate leaching fraction, the approach has not been widely accepted, and is therefore not used in the analysis.

Approach Used in the Model

Despite the many advantages of the transient models in better representing soil processes, it is not practical to apply them in large-scale basin studies, partly because of the lack of data. Liu and Barroll (2011) note that “the available data (i.e., for the lower Rio Grande) on observed groundwater and root zone salinity trends is highly limited.” It is understood that the traditional Ayers and Westcot (1985) approach will show greater yield reductions and/or greater leaching volumes required at a given level of salinity than the **Table 1** approach.

Summary of 2014 Interviews with Local Experts

A series of phone and face-to-face interviews were conducted with local agricultural experts, including agricultural producers, irrigation district staff, and extension service staff, to guide and ground-truth the data, assumptions, and analysis. The following is a list of summary points based on these meetings:

- No one interviewed believed that decreasing river salinity by around 20 mg/L or less would affect the economics of agricultural production or choice of crops. Farmers are well adapted now to river water approaching 1000 mg/L TDS, and are finding ways to continue to grow pecans with 5 to 6 times the salinity that Texas A&M University research (Miyamoto, 2006) says they should have for maximum yield (i.e., 3000 mg/L vs. 500 mg/L). Farmers noted that this requires very good leaching and therefore good drainage. By one local expert’s estimate, the required decrease in river salinity to impact cropping significantly would be roughly 500 to 600 mg/L. (Note: A meaningful improvement can be much less than 500 mg/L in terms of avoided management costs. Significant crop choice improvement may not occur unless the change is several hundred mg/l TDS, or a comparable reduction in sodium.)
- Adequate leaching to maintain steady state salinity conditions (i.e., as in the Rhoades and Mass Hoffman equations) commonly does not occur in drought, when available water volumes are limited and

expensive. Rather than maintaining a constant leaching fraction day by day or even year by year, anything more than partial leaching below the upper root zone tends to be a wet year phenomenon.

- The hydrologic model should show that under current drought conditions, there is essentially no surface drainage back to the river from the system except the Montoya Drain (which is above the agricultural districts in El Paso and Hudspeth Counties). In wetter years, some agricultural drainage returns to the river from Hudspeth County.
- Urban growth is very important near El Paso. Not an issue in Hudspeth County.
- River water quality tends to improve in drought years for the EPWID, as irrigation return flow decreases, but typically the reverse is true for HCCRD, with increased TDS under drought.
- By far the largest concern among agricultural producers is the allocation from the river, as well as the timing and duration.
- Overall salinity (TDS) is a lesser concern than quantity. However, sodicity, the amount of sodium in the water is a significant concern. Elevated sodium has a major adverse impact on soil drainage. If drainage is impeded, salts accumulate. The key concern is the sodium adsorption ratio (SAR), or the amount of sodium relative to the amount of calcium (Ca) and magnesium (Mg).
- Drainage was repeatedly mentioned as a major issue, and is also where economics, soil chemical and physical conditions, and irrigation water salinity intersect. Drainage is critical to allow sufficient leaching and removal of salts from the root zone. When available volumes of irrigation water are limited, agricultural producers cannot keep salts sufficiently leached out of the root zone. Common practices to address drainage and excess sodium issues include deep ripping, complete soil mixing with excavators (limited to pecan establishment), acid (elemental sulfur or sulfuric acid), gypsum applications, and leaching. In addition, some respondents indicated lack of channel maintenance on lower reaches of the river (Hudspeth County and downstream) impedes drainage, and increases the potential for salts to come back toward fields during high river flow, whenever that comes.
- Salts accumulate in the system (soil and shallow groundwater) during drought, and that is followed by an initial 'flush' of salt from the system when a wet year comes.
- Supplemental groundwater irrigation is extremely important to agriculture in the region, especially during drought. Water quality is low, typically 2500 mg/L, along with very high SAR (15 or more).
- Pecans are the primary economic engine for agriculture in the EPWID. In Hudspeth County, cotton is the only major crop that can be sustained under current conditions, and profit margins are very low. If water volume and quality would allow, the most likely crop to increase in acreage would be pecans.
- In high flow years, Hudspeth County can divert directly from the river at several points for irrigation, but this has not occurred for a number of years.
- Essentially all irrigation in the study area is via flood methods. Salinity effects on irrigation hardware is not a major issue.
- Salt tolerant alfalfas (e.g., 'Salado') are common in the area. The threshold for yield decline (2.0 dS/m soil EC_e) is the same as non-salt tolerant alfalfas, but the slope of the yield decline with further increases in soil salinity is flatter, with approximately 25 percent greater yield at levels of salinity beyond the threshold.

Agricultural Benefits Model

The information and relationships described above were used to develop a model to estimate the benefits to agricultural production from changes in irrigation water salinity. The structure of the model is based on a model developed for and described in the Preliminary Economic Impact Assessment (PEIA) prepared by Michelsen et al. (2009). The following principles were used in developing the model:

- Growers adapt their irrigation practices to account for irrigation water salinity so as to maximize net returns. Stated another way, for a given crop or set of crops, growers apply irrigation and leaching water to minimize the total cost of salinity, defined as the cost to leach salts plus the cost in yield reduction caused by soil salinity.
- The relationships between irrigation water salinity, leaching water, and crop yields are defined by the steady-state leaching equations and salinity sensitivity parameters described above.
- Based on discussions with local experts, and considering the relatively small changes in irrigation water salinity that would result from project alternatives, no changes in crop mix were assumed to occur as a result of project implementation. Therefore, the model only needs to consider the trade-off between the cost of additional leaching water and the avoided yield loss from insufficient salt leaching.
- The model calculates salinity-related costs separately by crop and by production region, El Paso County Water Improvement District #1 (EPCWID) versus Hudspeth County Conservation and Reclamation District (HCCRD). It does not attempt to distinguish irrigation decisions or salinity-related costs at any greater level of resolution (for example by individual grower).
- Many growers supplement irrigation water from the river with groundwater pumped from private wells. This can occur in many years, but especially in drought years when river allocation is reduced. For purposes of analysis, the model assumes that the switch to groundwater, if needed, would occur at the end of the river diversion and delivery season. The model calculates leaching fractions and salinity-related costs separately for the surface water application period and the groundwater application period.

The agricultural benefits model is an Excel® spreadsheet that makes use of the software's non-linear solver to select the cost-minimizing mix of leaching water and yield reduction for a given salinity of delivered irrigation water. The model solves for the optimal decisions, by crop and production region, subject to the leaching and salinity sensitivity relationships described above.

The model includes calculations for existing conditions and for 2020 and 2050 projected conditions. Inputs to the model are:

- Acreages by crop are displayed in **Table 3**.
- Yields, revenues per acre, and variable costs per acre are based on recent available crop production budgets prepared by Texas Agrilife Extension Service (2013, 2014). See **Table 4**.
- Surface water salinity, in mg/l TDS, is provided by separate analysis from the salinity loading model. Groundwater salinity is relatively high, and varies across the study area. For the analysis it is assumed to be 2,500 mg/l TDS, based on discussions with local experts.
- For purposes of analysis, the 2011 water delivery was used (more recent years have significantly lower delivery due to drought). The allocation per irrigated acre for EPCWID (2014) was 3.5 feet in 2011, or about 168,000 acre-feet based on estimated acreage; HCCRD (2014a) reported that it delivered about 35,600 acre-feet. Remaining crop water use was assumed to be met by private groundwater pumping, which was calculated within the model as the difference between total applied water demanded minus available district supply.
- Water costs are based on information provided by the districts. Charges per acre-foot vary substantially from year to year based on water available for sale. EPCWID (2014)

charged growers \$15 per acre-foot in 2011 (in addition to its land assessment and service charges). HCCRD per-acre-foot charges have been high the last few years due to reduced delivery. For the analysis, we assumed \$35 per acre-foot. For both districts, the marginal (higher cost and higher salinity) supply is supplemental groundwater. HCCRD (2014b) estimated that variable pumping costs average about \$45 per acre-foot. This value was used for both districts. Because the model assumes that growers must rely to some extent on the higher-cost and higher-salinity groundwater source in many years (including the water supply conditions used for analysis), the cost and leaching requirement of groundwater determines the model's tradeoff between leaching cost and crop yield.

- Future (2020 and 2050) total crop acreage was based on projections in the Far West Texas Water Plan (FWTWP, 2012). Crop mix (percent of total by crop type) was assumed to remain the same. Surface water per irrigated acre delivered by the districts was assumed the same as the 2011 estimates.

TABLE 3

Crop Acreages and Totals for El Paso and Hudspeth Counties, Current, 2020 and 2050

	El Paso County			Hudspeth County		
	Current ^a	2020	2050	Current ^b	2020	2050
Pecans	12,480	10,570	9,950			
Cotton	30,190	25,570	24,080	12,040	11,790	11,072
Alfalfa, Other Hay	2,450	2,070	1,950	1,785	1,748	1,641
Grains	2,400	2,030	1,910			
Onions	200	170	160			
Other	290	240	230	46	45	42
Total	48,010	40,660	38,280	13,871	13,583	12,756

^aIrrigated acreage for current conditions developed from a combination of recent data from USDA, FWTPG, Michelsen et al., and personal communication, Dr. Jaime Iglesias, 1-12-2015.

^bIrrigated acreage for 2011 irrigation season was used to represent current conditions. HCCRD (2014b).

Future condition total acreages are from FWTWP (2012), with crop mix the same as current.

TABLE 4

Crop Budgets Used for El Paso and Hudspeth Counties (per acre measurement)

	Pecans	Cotton	Alfalfa	Onions	Chile	Grain	Lettuce	Corn
Quantity	1364	Lint 1,326 Seeds 2,122	7.5	650	4000	70	750	100
Unit	Lbs	Lbs	Tons	Bags	Lbs	Bu	Cartons	Bu
\$/unit	\$2.25	\$0.72 Lint \$0.09 Seeds	\$240	\$7	\$0.89	\$7.38	\$8	\$4.4
Revenue	\$3,069	\$1,273	\$1,800	\$4,550	\$3,560	\$517	\$6,000	\$440
Variable Cost	\$699	\$438	\$323	\$3,469	\$590	\$224	\$3,841	\$282
Budget Year	2014	2013	2014	2014	2014	2013	2014	2014

Source: Texas AgriLife Extension Service (2013, 2014)

Urban Water Use Benefits

The municipal and industrial salinity cost component of the economic model is based on work completed by Michaelson et al. (2009). That model is itself based on salinity economic models that have been applied to salinity costs on the lower Colorado River and Central Arizona. The model includes salinity damages to residential, commercial, public, industrial, landscape and water utility assets. Most damages are in the form of reduced expected life of water-using residential appliances and facilities. Some damages involve use of water softeners, bottled water, and soaps and detergents, and landscape costs involve the amount of water required for leaching.

Important changes to the Michaelson et al. (2009) analysis are:

- Removing analysis and results based on an improvement to 500 mg/L TDS and adding a capability to include any change in salinity in TDS, mg/L.
- Adding some salinity damage equations from the Bay Area Water Quality Economics Model (BAWQEM), but not included in the Michelsen et al analysis.
- The Michelsen et al. model was based on 2007 to 2008 conditions. For this effort, benefits estimates for future conditions are required. The revised model adopts 2010 actual, and 2020 and 2050 forecast water demands and supplies from El Paso Water Utilities (EPWU) to develop benefits estimates for 3 years.
- A calculation of the share of water provided by surface water is developed for each of the 3 years (2010, 2020 and 2050) to replace the 54 percent assumed by Michelsen et al, which was based on one year.
- A forecast of number of households is included for each of the 3 years.
- A variety of price indices are used to increase the price level of the analysis to 2013 dollars.
- The future annual benefits estimates are used to develop a net present value analysis for the planning horizon 2020 through 2049 using the federal approved discount rate for water projects.
- Information regarding the value of new water supply and the cost of water rights was added for the multiple-purpose project analysis.

Cost Equations Added

The PEIA analysis of municipal and industrial impacts of salinity in El Paso (Michelsen et al., 2009) was based on the Central Arizona Salinity Study, which was itself based on modeling conducted for the Lower Colorado River Salinity Management Study (MWDSC and Reclamation, 1998). Some categories of salinity damage and cost were added or updated for our analysis.

Bay Area Water Quality Economics Model (BAWQEM) was first developed for Los Vaqueros Reservoir benefit studies (MWH, 2003), and developed further for California Department of Water Resources (DWR) and Reclamation benefits studies; most recently it was used in the Franks Tract Project Plan Formulation Report (CH2M HILL, 2013). The equations for household damages are different and include some types of costs that are not included in Michelsen et al. (2009). Table 5 shows the equations from BAWQEM added to the El Paso model.

TABLE 5

Equations for Costs and Life of Household Features as a Function of TDS or Total Hardness (TH), from BAWQEM

Customer Cost Category	Cost Measure	Equation Constant	Parameter on TDS	Parameter on TH	% of Households	Original Cost
Soap and detergent use	1983 \$/hshld	85.00000	NA	0.120000	100 minus % with softeners	NA
Water softener cost	1983 \$ per hshld using	-4.66635	NA	0.111965		Included
Galvanized waste water pipe	Log Life yrs	1.54900	-0.000797	NA	10%	\$1,000
Galvanized water pipe	Life yrs	16.56000	-0.006700	NA	10%	\$1,100
Brass faucets	Log Life yrs	1.30400	-0.000700	NA	10%	\$170 (for 2)

The share of households currently using galvanized water pipe, galvanized wastewater pipe and brass faucets must be included. All of these fixtures are currently being replaced with more modern technologies, but some homes (10 percent is assumed) still have these types of fixtures.

Michelsen et al (2009) assumed that the annual cost per household for water softeners was fixed at \$319 per year and the share of households using water softeners was variable. The revised analysis retains the equation for share of households using softeners, but the cost per year for households using softeners, from BAWQEM, is now around \$35 per year and increases with salinity.

An equation for costs of soaps and detergents recognizes that more soaps and detergents are used with more saline potable water. The share of households that receive this additional benefit is limited to the share that does not use water softeners.

Update to 2010, 2020 and 2050 conditions

The revised analysis calculates salinity benefits for 2010, 2020 or 2050 development conditions. The development condition intends to reflect population, demographics and average water demands, water supply, and supply mix in those years. The 2010 data are based on actual conditions, and the 2020 and 2050 conditions are based on forecast conditions.

The analysis requires a breakdown of water demand by sector because salinity damage estimates are based on sectors. Shares of water provided to each sector are based on data provided by PSBEPWU (2014) and reproduced in **Table 6** below. The 2014 shares are used for 2020 and 2050.

TABLE 6

EPWU Accounts and Use, 2010 and 2014, and Share of Use by Sector

Sector	2014			2010		
	Accounts	AF Use	Share	Accounts	AF Use	Share
Residential	178,211	58,623	54%	165,723	58,219	56%
School	806	3,804	4%	761	3,577	3%
Church	459	370	0%	449	393	0%
Industrial	155	3,244	3%	163	712	1%
Commercial	13,455	21,674	20%	14,205	21,974	21%

TABLE 6
EPWU Accounts and Use, 2010 and 2014, and Share of Use by Sector

Sector	2014			2010		
	Accounts	AF Use	Share	Accounts	AF Use	Share
Government	1,676	7,720	7%	2,599	7,537	7%
Very Large Water Users	6	2,300	2%	8	2,612	3%
Wholesale	20,846	9,392	9%	18,227	7,004	7%
Other	1,821	751	1%	1,130	1,201	1%
Total	217,435	107,876	100%	203,265	103,228	100%

Source: PSBEPWU, 2014, page B-4

Table 3 shows EPWU demand forecasts and allocation among sectors and indoor/outdoor water use. The demand forecasts are from the 2011 Far West Texas Regional Plan (FWTWPG, 2012) and are also published by EPWU (2014a).

For the categories in **Table 7**, it is assumed that all of the “wholesale” use is residential (sales to other retail water providers with largely residential uses), and all “very large water users” and “other” categories are commercial uses. These assumptions can be changed when better information is obtained.

TABLE 7
EPWU 2010 Estimated, and 2020 and 2050 Forecast Demand by Sector

	Indoor/ Outdoor Shares	2010	2020	2050
Demand, AF, delivered		118,167	145,445	191,728
Residential		74,662	91,701	120,882
Residential indoor	67.0%	50,023	61,440	80,991
Residential outdoor	33.0%	24,638	30,261	39,891
Commercial		29,519	33,335	43,943
Commercial indoor	67.0%	19,778	22,335	29,442
Commercial outdoor	33.0%	9,741	11,001	14,501
Industrial		815	4,373	5,765
Public (Schools, churches, government)		13,171	16,036	21,139
Public indoor	50.0%	6,586	8,018	10,570
Public outdoor	50.0%	6,586	8,018	10,570
TOTAL		118,167	145,446	191,729
Total Outdoor		40,512	48,946	65,731

Michelsen et al. (2009) assumed that 50 percent of residential, school, and church use, and 32 percent of commercial use, was outdoor use. Hermitte and Mace (2012) estimate that, for the period of 2004 through 2008, only 33 percent of single-family residential use was outdoor use. The revised analysis allows for one-third of residential and commercial use to be outdoor use. For public uses (government, school and churches), the 50 percent assumption from Michelsen et al (2009) is retained.

Table 8 shows actual 2010 supplies and forecast supplies for 2020 and 2050 from the 2011 Far West Texas Regional Water Plan (FWTWPG, 2012) and also published by EPWU (2014a).

TABLE 8
EPWU Forecast Supplies from 2011 FWTRWP, Acre-feet

Source	2010	2020	2050
Existing conjunctive use	125,000	125,000	125,000
Existing reclaimed	6,000	6,000	6,000
New conservation		3,000	16,000
New reclamation		2,000	6,000
Recharge GW with treated surface water		5,000	5,000
Desalination of Ag drain water		2,700	2,700
New conjunctive use		5,000	20,000
New groundwater from Capitan Reef			10,000
New groundwater from Dell City			10,000
Total new supply including conservation	131,000	148,700	200,700
Total new supply excluding conservation	131,000	145,700	184,700
Demand	118,167	145,445	191,728
Min (demand or supply)	118,167	145,445	184,700
Total reclaimed supply: to surface water use factor	6,000	8,000	12,000

The demand and supply forecasts do not match because some excess supply is available. The amount of future use is assumed to be equal to the minimum of forecast demand or future supply excluding new conservation. For example, in 2050, the demand forecast is 191,728 AF. However, 2050 supplies of 200,700 AF include up to 16,000 AF of new conservation. The 2050 demand can be met using only 7,028 AF of this conservation leaving total water use at 184,700 AF.

Share of Supply from Surface Water

Michelsen et al. state:

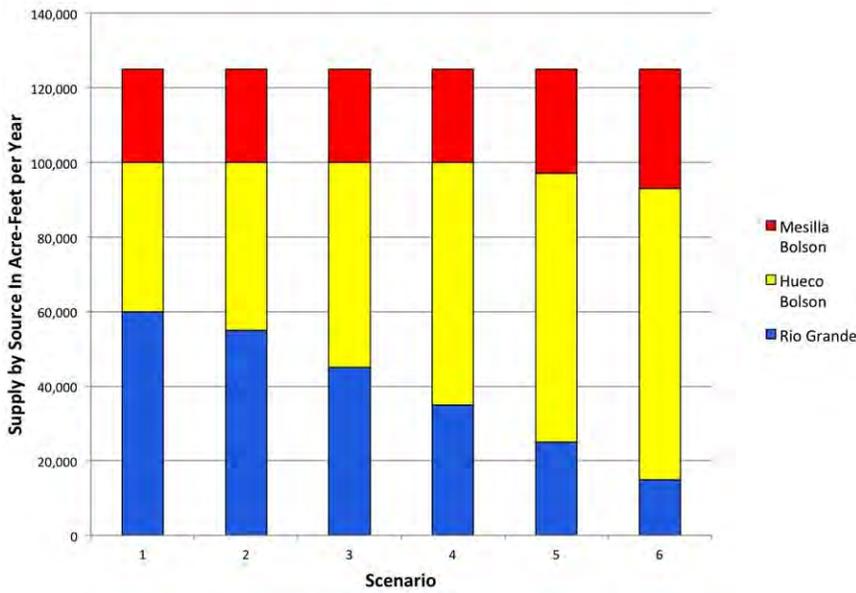
Surface water accounted for 54% of total annual supplies (58,141 acre-feet surface water / 106,684 acre-feet total water delivered, EPWU 2007) to urban users. The annual equivalent supply of surface water would be 54% of the 160,474 residential accounts thus 87,476 of all households were assumed to be supplied Rio Grande surface water on an annual equivalent basis. The same surface water percent was applied to commercial and industrial water use (see page 25).

For the revised analysis, a different share is calculated for each of the three analysis years. Figure 1 below is from EPWU (2014).

EPWU staff was able to associate a frequency with each of the six scenarios (Reinert, 2014). This allows a surface water use adjustment factor to be calculated as shown in **Table 9**.

The calculation weights each Rio Grande delivery amount in **Figure 2** by its frequency, and sums them to obtain a weighted average total. Two adjustments are required. First, new treatment capacity of 20 mgd is planned to be available by 2020. 20 mgd of capacity could provide 13,104 AF of treated supply over the seven month surface water season. It is assumed that this supply will be available according to the share of treatment capacity used in **Figure 1**. In **Figure 1** Scenario 1, for example, all of the 13,104 AF can be used. In Scenario 2, only 55/60 of the 13,104 AF can be taken, and so on.

FIGURE 2
El Paso Water Utilities Conjunctive Use Components



The analysis suggests that, on average, about 10,500 AF of the 13,104 AF of potential will be usable. Second, the analysis needs to include the surface water fraction in reused water. The water reuse amounts are shown in **Table 4**. With these adjustments, the surface water use fraction is estimated to be 42.28, 42.02, and 33.41 percent of all water use in 2010, 2020 and 2050, respectively.

The surface water use adjustment share can and should be recalculated if new information is obtained on the amount and frequency of surface water deliveries.

TABLE 9
Calculating Surface Water Use Adjustment Share

Frequency (Reinert, 2014)	TAF Rio Grande Supply	Product of Frequency and TAF		
		2010	2020 ¹	2050 ¹
27.00%	60	16.20	19.74	19.74
31.00%	55	17.05	20.77	20.77
16.00%	45	7.20	8.77	8.77
13.00%	35	4.55	5.54	5.54
6.00%	25	1.50	1.83	1.83
7.00%	15	1.05	1.28	1.28
TOTAL		47.55	57.94	57.94
Total TAF Demand		118.17	145.45	184.70
Direct SW use as % of demand		40.2%	39.8%	31.4%
Reclaimed water supply, TAF		6	8	12
Rio Grande Supply as % of Demand		42.28%	42.02%	33.41%

¹. Includes 20 mgd new capacity starting 2020

Number of Households

Residential benefits estimates are based on the number of households that have any uses, fixtures, or appliances that are affected by salinity. Michelsen et al. (2009) apparently based the number of households (160,474) on the number of residential accounts reported by EPWU for 2008 (PSBEPWU, 2014). This number understates the number of households as some residential accounts cover multiple households.

Household estimates are developed from forecasts of population served and recent estimates of persons per household. In 2010, according to the Census, there were 800,647 people and 252,426 households in El Paso County (USDC, 2014a). Population in El Paso City was 649,133 with 216,908 households (USDC, 2015). From this information, the number of persons per household in the city is 3.0, and persons per household in the remainder of the county is 4.24.

For household forecasting, population forecasts from EPWU (2014) are used. These forecasts are shown in **Table 10**. Forecasts are provided for El Paso City and all other. The forecast number of persons per household from 2010 are used to estimate households in 2020 and 2050.

TABLE 10
Estimating Residential Households, 2010, 2020 and 2050

	2010	2020	2050
Population served, El Paso City	637,481	717,651	909,384
Population served, other county	105,955	160,292	270,464
Population served, total EPWU	743,436	877,943	1,179,848
Households served, El Paso City	213,329	240,158	304,320
Households served, other county	25,564	38,675	65,257
Households served, total EPWU	238,894	278,833	369,577

Cost Updating

A variety of cost indices are applied to the 2008 Michelsen et al estimates, and the BAWQEM cost estimates must be updated from their original cost basis.

For residential costs, no cost updating is provided for appliance purchase costs. These costs do not appear to be increasing over time in nominal terms. Costs for bottled water, water softeners, and use of soaps and detergents are updated using the Houston Consumer Price Index (USDL 2014a). Bottled water costs are updated from 2008 to 2014. Water softeners, soaps, and detergent costs are increased from 1983, the year of the original BAWQEM equations, to 2014.

For landscape costs, Michelsen et al. (2009) used the middle tier of the three-tier water rate structure, \$3.40 per hundred cubic feet, to represent water cost. The cost of that tier increased to \$3.68 in 2014 (EPWU 2014b). The \$3.68 is now used instead of \$3.40.

For industry, Michelsen et al. used 2002 estimates of employment by industry, water use per employee, and an industrial grouping into six categories of salinity damages based on different cost per mg/l per AF used, to estimate industrial water use and salinity costs. The sum product of employment and water use by industry was then calibrated to total EPWU industrial delivery. For this model, 2010 employment data by industry have been obtained (USDC 2014). However, the method of Michelsen et al (2009) cannot be reproduced because the method of grouping NAICS industries into the six salinity-damage groups is not shown in their report.

The six industrial water use salinity damage groups are: process water demineralization, process water softening, process water minor, cooling towers, boiler feed, and sanitation and Irrigation.

For industrial costs, CH2MHILL (2011) used the average cost per mg/l per AF of industrial supply to reproduce the Michelsen et al. results. For the update, this cost (\$64.16 cents per mg/l per AF) is increased by the increase in the producer price index from 2008 to 2014 for total manufacturing industries (USDL BLS, 2014b). For commercial costs, costs are increased by the increase in the Houston CPI from 2008 to 2014 (USDL BLS, 2014a). For water treatment plant costs, Michelsen et al assumed a replacement cost of \$100 million. This cost is updated by the increase in the producer price index for industrial structures from 2010 through 2014. Data for 2008 and 2009 are not available.

Value of Urban Water Supply and Water Rights

For the multi-purpose project, information about the benefits and incremental costs of water supply are required. The value of the new water supply, and the cost for compensating existing water users must be included.

The region is growing quickly and new sources of water will be needed to meet demands (FWTWPG 2012). The value of new water supply could be valued using the cost of developing supplies by some other means. That is, the cost of other supplies would be avoided because of this project. The FWTRWP (2012) provides cost estimates for a variety of projects and actions for El Paso. These actions include conservation, direct reuse, desalination, conjunctive use, groundwater recharge and imports. Their Table 4-3 (page 4-12) shows unit costs of water varying from \$45 to \$2,553 per AF. With supply estimates from Table 4-2, the average annual cost of these supplies is \$814 per AF.

Another method for valuing municipal water supply uses the price paid by existing water users. The retail price suggests the price that a new user must be willing to pay for water. **Table 11** shows that the average price paid for water during 2012 and 2013 was about \$777 and \$807 dollars per acre-foot, respectively.

A unit benefit of \$800 is used to value water supply in the analysis.

TABLE 11

Average Price Paid by EPWU Customers, 2012 and 2013

Fiscal year, March through February	2013-14	2012-13
February data not included	YTD	YTD
Total water billed, 1000 gallons	32,864,708	34,319,355
Residential water billed, 1000 gallons	17,897,115	18,730,142
Meter Sales to General Customers	\$74,291,798	\$74,840,188
Meter Sales to City	\$2,824,025	\$3,099,724
Meter Sales to LVWDA	\$2,437,766	\$2,220,483
Meter Sales to County of El Paso	\$274,454	\$265,297
Meter Sales to Haciendas del Norte	\$97,279	\$62,090
Meter Sales to Ponderosa	\$52,907	\$52,060
Meter Sales to Mayfair/Nuway	\$57,185	\$8,794
Meter Sales to Gaslight Square	\$51,457	\$51,014
Meter Sales to Paseo Del Este	\$813,454	\$641,755
Meter Sales to Ft. Bliss	\$443,371	\$592,343
Total metered sales	\$81,343,694	\$81,833,748
Average metered charge, \$/AF	\$806.52	\$776.98

Source: EPWU 2014; Revenue Snapshot 1-2014.xls

The economic analysis requires compensation for water rights during summer. EPWU leases water from lands in El Paso County Water Improvement District No. 1. The leasing program is used for parcels less than 2 acres. The program pays all water rights taxes, estimated to be \$30 per acre per year, plus a one-time payment of \$2,500 per acre, for a 75-year lease (EPWU 2014b). If this land can provide 1 AF per acre, the

annualized cost is less than \$150 per AF. EPWU also acquires water from El Paso County Water Improvement District No. 1 made available through management actions within the district. The FWTRWP estimated that El Paso County Water Improvement District No. 1 could make up to 25,000 AF of water available through improvements to district delivery systems at a cost of \$339 per AF per year. Both of these sources suggest that the cost required to acquire water rights needed to divert the product water all year could be as low as \$300 per AF. \$300 per AF is assumed for the analysis.

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Appendix B2
Crop Water Use Estimates

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Crop Water Use Estimates, Distal Mesilla Basin

PREPARED FOR: USACE, Albuquerque District

PREPARED BY: CH2M HILL

DATE: April 3, 2015

Crop water use is an important component of the economic analysis. An effort was made to confirm the crop water use estimates (evapotranspiration or ET) in the Agri-Life 2009 report. The 2009 report that crop water use estimates were based on Sammis et al. (1985). Review of the 1985 study revealed that the study was limited to alfalfa, cotton, sorghum, and corn, and did not include any information on pecan, chile, or winter wheat. The 2009 report did not provide any details of how the Sammis et al. study was used to develop the crop water use estimates, such as what data were used to establish Growing Degree Days (GDD). The 1985 study provides crop coefficient (K_c) equations based on GDD, rather than either crop water use or directly listing crop coefficients.

Approach

The best available data from New Mexico State University (NMSU) and Texas A&M University (TAMU) were used to develop estimates. Essentially all irrigated agricultural land in the study area is in Texas, but TAMU crop water use (crop coefficient) data are very limited, as described on the TAMU web site (<http://texaset.tamu.edu/coefs.php>):

“Crop coefficients vary for different crops, as well as for the region crops are grown in. In addition, they change based on the growing stage of the crop. Unfortunately, for Texas, we only have verified crop coefficients for the North High Plains. These coefficients were developed by the North Plains PET Network Project Team. FAO (Food and Agriculture Organization of the United Nations) has published generalized crop coefficients which are used throughout the world where local values are not available.”

The FAO crop coefficients referenced by TAMU are listed in FAO, 1998.

In contrast, NMSU has established crop coefficient relationships for several major crops found in the region based on GDD. The polynomial equations provided by NMSU’s New Mexico Irrigation Center (<http://aces.nmsu.edu/aes/irrigation/index.html>) are provided in **Table 1**.

TABLE 1

Summary of NMSU’s Growing Degree Day-Based Evapotranspiration Crop Coefficients

Crop	Coefficient	Source
Alfalfa	$K_c = 4.05E-1 + 1.11E-3 * GDD - 4.25E-7 * GDD^2 + 3.56E-11 * GDD^3$	Sammis et al., 1985
Chile	$K_c = 9.8E-2 + 3.33E-5 * GDD + 1.91E-7 * GDD^2 - 3.25E-11 * GDD^3$	Saddiq, M.H. 1983
Corn	$K_c = 1.20E-1 + 1.68E-3 * DGG - 2.46E-7 * GDD^2 - 4.37E-10 * GDD^3$	Sammis et al., 1985
Cotton	$K_c = 4.2E-4 + 1.20E-3 * GDD + 4.62E-7 * GDD^2 - 5.77E-10 * GDD^3$	Sammis et al. 1985
Pecan	$K_c = 3.34E-1 + 4.31E-3 * GDD - 1.08E-5 * GDD^2 + 1.11E-8 * GDD^3 - 3.866E-12 * GDD^4$	Sammis et al., 2004
Winter Wheat	$K_c = 2.70E-1 - 4.8E-4 * GDD + 6.27E-7 * GDD^2 - 1.3E-10 * GDD^3$	Sammis et al., 1979

Potential Evapotranspiration

Crop coefficients are used to modify estimated evapotranspiration of a reference crop, commonly a well-watered short grass under defined conditions. The reference ET value for grass is abbreviated ET_0 . TAMU provides these data for a number of locations in Texas, including El Paso at <http://texaset.tamu.edu/pet.php>. The El Paso average values are based on a 52-year dataset. These data were used with K_c values to estimate crop water use, or ET_c ($ET_c = K_c \times ET_0$).

Growing Degree Days

Growing Degree Days for El Paso for use with NMSU GDD functions were obtained from the Western Regional Climate Center (<http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?tx2797>), and are based on average values for 1947-2012. Growing Degree Day units are computed as the difference between the daily average temperature and the base temperature (daily average temperature - base temperature). One unit is accumulated for each degree the average temperature is above the base temperature. Negative numbers are discarded. The base temperature varies by crop, and some crops have a maximum temperature for inclusion in the daily average temperature calculation.

FAO Crop Coefficients

Generalized crop coefficients from the FAO report were used for the crops that did not have an NMSU GDD equation established. Values from the FAO report are provided for initial K_c ($K_{c\ ini}$), planting to 10 percent ground cover, $K_{c\ mid}$ (mid-season growth, peak ET), and $K_{c\ end}$ (end of season, crop senescence). **Table 2** provides these data.

TABLE 2
Summary of FAO Single Crop Coefficient Values

Crop	$K_{c\ ini}$	$K_{c\ mid}$	$K_{c\ end}$	Note
Alfalfa	0.4	0.95	0.9	Averaged for cutting effects
Cotton	--	1.15-1.20	0.7-0.5	
Corn	--	1.2	0.35	
Lettuce	--	1	0.95	
Onion	--	1.05	0.75	dry
Pecan	0.4	0.9	0.65	Almond, no ground cover
Pepper	--	1.05	0.9	Bell peppers
Pasture - other hay	0.3	0.75	0.75	Pasture - extensive grazing
Wheat	--	1.15	0.25	Spring wheat

Note: $K_{c\ mid}$ and $K_{c\ end}$ are for sub-humid climate with average daytime minimum relative humidity (RH) of 45 percent with calm to moderate winds averaging 2 meters per second.

Summary – Estimates by Crop

The above inputs were used to estimate water demand for the dominant crops in the region, as shown in **Table 3**. This analysis does not include any additional volume to address the required leaching fraction due

to irrigation water salinity and crop salinity tolerance. For reference, values for crop evapotranspiration used in the PEIA study (Michelson et al., 2009) are also provided. Values vary slightly by crop for the two studies.

TABLE 3

Annual Crop Evapotranspiration Estimates (inches per year)

	Cotton	Wheat	Corn	Chile	Onion	Alfalfa	Pecan	Pasture - other hay
This study	29.5	14.2	28.4	39.2	38.2	55.5	43.3	34.2
Michelson et. al. (2009)	31.2	18.0	30.0	39.0	37.4	60.0	45.6	31.2

Note: Alfalfa, cotton, chile, corn, winter wheat, and pecan are based on the NMSU-GDD approach, and El Paso climatic data. Onion and pasture / other hay are based on FAO 56 values. Pasture – other hay ET was reduced by 40% from FAO Kc calculations to allow for only partial irrigation.

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Appendix C
2013 Sensitive Biological and Wetland Resources

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Rio Grande Salinity Management Program—Sensitive Biological and Wetland Resources

PREPARED FOR: United States Army Corps of Engineers

COPY TO: Todd Wang/CH2M HILL

PREPARED BY: CH2M HILL

DATE: November 15, 2013

PROJECT NUMBER: 408366.R2.CM.EF

Introduction

This technical memorandum summarizes the results of a literature review of the sensitive biological and wetland resources that may occur within the Ecosystem Framework Analysis area (study area) for the Distal Mesilla Conceptual Site Model as part of the Rio Grande Salinity Management Program.

The study area is located along the Lower Rio Grande River at the southern end of the Mesilla Valley between the Franklin Mountains and the Santa Teresa range in Doña Ana County, New Mexico, and El Paso County, Texas, adjacent to the border of Ciudad Juarez, Mexico (Figure D-1). The study area is in the Smelertown United States Geologic Survey 7.5 minute quadrangle at 31°50' 49"N, 106°36' 25"W, and ranges at an elevation between 3,700 and 4,100 feet.

Summary

Four dominant macro-level land covers are within the study area: warm semi-desert scrub and grassland; warm Mediterranean and desert riparian, flooded, and swamp forest; herbaceous agricultural vegetation; and developed and urban (USGS, 2011). Each of these macro-level land covers contains several subclasses classified at the ecosystem level within the study area (Figure D-2). According to the Natural Resources Conservation Service (NRCS) Web Soil Survey, the dominant soil types within the study area include Agua variant and Belen variant, Bluepoint loamy sand, and Harkey loam sand (NRCS, 2009; NRCS, 2012; U.C. Davis, 2012).

Based on a review of the literature and previous field surveys (CH2M HILL and Geo-Marine, 2000; USBWC, 2004), the study area supports potential jurisdictional waters of the United States (U.S.) and potential waters in the state, including wetlands (Figure D-3). A wetland delineation of the potential jurisdictional wetland features is recommended to establish a baseline prior to implementation of the Rio Grande Salinity Management Program.

The study area also may support potential habitat for federal- and/or state-listed species including desert night-blooming cereus and sand prickly pear (Table D-1); Texas horned lizard and spotted bat (Table D-2); southwestern willow flycatcher, arctic peregrine falcon, common black hawk, Baird's sparrow, bald eagle, American peregrine falcon, interior least tern, Costa's hummingbird, Bell's vireo, and gray vireo (Table D-3). Field surveys are recommended to confirm the presence or absence of suitable habitat and/or the potential occurrence of federal and threatened species within the study area.

Setting

Climate and Precipitation

The local climate is characterized by cool winters and hot, dry summers. Average temperatures range from a low of 33 degrees Fahrenheit (°F) in December and January to a high of 96°F in June. Based on data from the El Paso,

Texas, weather station (The Weather Channel, 2012), the average annual precipitation is 9.4 inches, with the majority of precipitation occurring between June and September. The potential for changes in climate parameters, temperature, and precipitation that might influence the distribution and abundance of local biota is not addressed in this memorandum.

Soils

According to the NRCS Web Soil Survey, the dominant soil types within the study area include Agua variant and Belen variant, Bluepoint loamy sand, and Harkey loam sand (NRCS, 2009; NRCS, 2012; U.C. Davis, 2012). Each of these soil types totals greater than 10 percent of the soils in the study area.

Agua variant and Belen variant soils within the study area are somewhat poorly drained, coarse, loamy alluvium underlain by mixed sandy and gravelly calcareous alluvium, and occur on floodplains and alluvial fans. Agua variant soil is very slightly saline to moderately saline. The Bluepoint soil series is a somewhat excessively drained, wind-modified, sandy alluvium, and it occurs on gentle slopes of valley sides and alluvium fans. Bluepoint loamy sand soil is nonsaline to slightly saline. The Harkey soil series is well-drained, mixed stratified, coarse-silty, calcareous alluvium, and it occurs on floodplains and stream terraces. Harkey loam sand is nonsaline to very slightly saline.

Vegetation

The Gap Analysis Program for the Southwest Region (USGS, 2011) was accessed electronically and primarily used to identify vegetation types within the study area.

The vegetation types that historically dominated the study area and its vicinity include Trans-Pecos shrub savanna, grama-tobosa desert grasslands, oak-juniper woodlands, and mesquite tarbush desert (CH2M HILL and Geo-Marine, 2000). Livestock overgrazing, urban development, drought, and/or decreases in fire frequency have fragmented plant communities, resulting in disturbance conditions favorable to scrub communities (USGS, 2011) and non-native invasive species such as tamarisk (*Tamarix spp.*).

Four dominant macro-level land covers are within the study area: warm semi-desert scrub and grassland; warm Mediterranean and desert riparian, flooded, and swamp forest; herbaceous agricultural vegetation; and developed and urban (USGS, 2011). Each of these macro-level land covers contains several subclasses classified at the ecosystem level within the study area (Figure D-2); these land covers are described in the following sections.

Warm Semi-desert Scrub and Grassland Communities

Warm semi-desert scrub and grassland communities consist of several dominant warm semi-desert scrub and grassland vegetation subclasses primarily within the western area of the study area, including Apacherian-Chihuahuan mesquite upland scrub, Chihuahuan creosote bush mixed desert and thorn scrub, and Apacherian-Chihuahuan semi-desert grassland and steppe (Figure D-2). Apacherian-Chihuahuan mesquite upland scrub is common in the foothills and plains in the Chihuahuan Desert. The dominant plant species in this subclass are honey mesquite (*Prosopis glandulosa*) and velvet mesquite (*Prosopis velutina*). Other common shrub species in this subclass can include acacias (*Acacia neovernicosa*, *A. constricta*) and junipers (*Juniperus spp.*).

Chihuahuan creosote bush mixed desert and thorn scrub occurs in desert basins and plains, alluvial flats, and lower alluvial fans with finer textured soil, and it is the most common vegetation in the Chihuahuan Desert. The dominant plant species in Chihuahuan creosote bush mixed desert and thorn scrub is creosotebush (*Larrea tridentata*). Other common plant species in this subclass can include tarbush (*Flourensia cernua*), ocotillo (*Fouquieria splendens*), fluff grass (*Erioneuron pulchellum*), black grama (*Bouteloua eriopoda*), alkali sacaton (*Sporobolus airoides*), and bush muhly (*Muhlenbergia porteri*). Grasses are generally sparse in desert shrub communities.

Chihuahuan desert grassland vegetation consists of primarily Apacherian-Chihuahuan semi-desert grassland and steppe (Figure D-2). This vegetation subclass occurs on the gentle slopes of alluvial fans and plains. The desert grassland vegetation can include black grama, mesa dropseed (*Sporobolus flexuosus*), giant sacaton (*S. wrightii*), gypgrass (*S. nealleyi*), alkali sacaton, and curlyleaf muhly (*Muhlenbergia setifolia*). Succulent species such as agave

(*Agave* sp.) and yucca (*Yucca* sp.), as well as shrub and tree species such as acacia, (*Acacia* sp.), mesquite, and various desert oak species (*Quercus* spp.), may be present.

Warm Mediterranean and Desert Riparian, Flooded, and Swamp Forest Types

Freshwater aquatic and riparian habitats within the study area are classified as warm Mediterranean and desert riparian, flooded, and swamp forest. This macro-level land cover consists of mostly North American warm desert riparian woodland and shrubland subclass (Figure D-2). This vegetation subclass is a mixture of riparian woodlands and shrublands along the Rio Grande. Dominant trees in these subclasses typically include poplars (e.g., *Populus angustifolia*, *P. deltoides* ssp. *wislizeni*, and *P. fremontii*), Arizona sycamore (*Platanus wrightii*), Arizona walnut (*Juglans major*), Arizona ash (*Fraxinus velutina*), and wingleaf soapberry (*Sapindus saponaria*). Dominant shrubs typically include narrowleaf willow (*Salix exigua*), Arizona alder (*Alnus oblongifolia*), and mulefat (*Baccharis salicifolia*). The growth and reproduction of these native riparian species is dependent upon the presence of flooding regimes, sediment scour, and/or the rise in the water table (USGS, 2011).

Currently, riparian vegetation is highly regulated through mowing along the Rio Grande within the study area (Photo 1). Non-native invasive species such as Russian thistle (*Salsola kali*) occur along Rio Grande within the study area (Photo 2). Tamarisk, also a non-native invasive species, occurs along the Rio Grande, but mowing controls this species (USIBWC, 2003). Grass species such as native saltgrass (*Distichlis* sp.) and non-native Bermuda grass (*Cynodon dactylon*) are dominant along the Rio Grande with some native and non-native shrub encroachment.

Herbaceous Agricultural Vegetation

Cultivated cropland is a subclass of herbaceous agricultural vegetation, and it occurs primarily along and within the Rio Grande (Figure D-2). Cultivated cropland includes areas used for the production of annual and perennial crops. This subclass also includes actively tilled land (USGS, 2011).

Developed and Urban

Developed and urban includes areas of low- and high-intensity development, such as constructed materials, impervious surfaces, and little to no naturally occurring vegetation.

Sensitive Resources

Potential Waters of the U.S. and Waters in the State

The study area is located within the El Paso-Las Cruces Watershed (HUC unit 1300102) of the northern Chihuahuan Desert. The flow in the Rio Grande study area is almost entirely regulated and is determined by irrigation needs. The Rio Grande has been highly disturbed by channelization and impoundment activities. The levees were engineered to control flood events and to assist in the operation of the network of irrigation canals throughout the Rio Grande floodplain; the levees are currently maintained by the U.S. Section of the International Boundary and Water Commission (USIBWC, 2003).

Methods

The U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) (USFWS, 2012a) was accessed electronically to identify USFWS NWI wetlands that may be (1) subject to the U.S. Army Corps of Engineers (USACE) jurisdiction under Section 404 of the Clean Water Act (CWA) as waters of the U.S., and (2) subject to the review authority of the New Mexico Environment Department's Surface Water Quality Bureau (NMED-SWQB) and the Texas Commission on Environmental Quality for certification under Section 401 of the CWA as waters in the state. Additional sources were reviewed to identify potentially jurisdictional waters of the U.S. and waters in the state, including the El Paso-Las Cruces Regional Sustainable Water Project: Biological Resources Technical Report (CH2M HILL and Geo-Marine, 2000).

Literature Review Results

A literature review of potential jurisdictional waters of the U.S. and waters in the state, including wetlands, within the study area identified lacustrine, palustrine, and riverine wetlands (Figure D-3). The potential jurisdictional waters of the U.S. and waters in the state shown on Figure D-3 are based on the results of the 1999 field surveys (CH2M HILL and Geo-Marine, 2000) and on the current extent of NWI wetlands within the study area (USFWS, 2012a). The potential waters of the U.S. and waters in the state from the 1999 field surveys are identified as “Field Checked Wetlands” on Figure D-3.

A majority of the NWI wetlands identified in the study area were excavated or highly disturbed, as indicated by the “x” classification of the NWI wetlands on Figure D-3. A majority of the Rio Grande was identified as an excavated, seasonally flooded, riverine intermittent streambed. The surface water for the majority of the river is present for extended periods early in the growing season, but surface water is mostly absent at the end of the growing season; the water table fluctuates between saturating the surface to extending well below the soil surface (USFWS, 2012a). Tributaries, artificial canals, and ditches convey flows to the Rio Grande within the study area.

The NWI wetlands identified on Figure D-3 may not meet the wetland definition as defined by USACE (Environmental Laboratory, 1987), or the wetlands may be isolated; therefore, they would not be defined as waters of the U.S. However, these NWI wetlands may be subject to the jurisdiction of the NMED SWQB or the Texas Commission on Environmental Quality. A wetland delineation of the potential jurisdictional wetland features is recommended to establish a baseline prior to implementation of the Rio Grande Salinity Management Program.

Federal- and State-listed Species

Methods

A list of potentially occurring federal- and state-listed (i.e., threatened and endangered) species was prepared for the study area by searching the online databases of the NMRPTC New Mexico Rare Plants (NMRPTC, 1999), the NMDGF Biota Information System of New Mexico (BISON-M) (NMDGF, 2012), the TPWD Nongame and Rare Species Program: Federal/State Threatened and Endangered Species (TPWD, 2012), the USFWS Federal Endangered and Threatened Species List (USFWS, 2012b; USFWS, 2012c), and the New Mexico Avian Conservation Partners Species Accounts (NMACP, 2012). The counties, Doña Ana County, New Mexico, and El Paso County, Texas, were searched in each database as applicable. Online database searches by quadrangle or project-specific location were not possible.

Additional sources were reviewed to identify potential occurrence for federal- and state-listed species within the study area, including the Biological Resources Technical Report (CH2M HILL and Geo-Marine, 2000) and the Draft Environmental Impact Statement (USIBWC et al., 2000) for the El Paso-Las Cruces Regional Sustainable Water Project, as well as the Draft Environmental Impact Statement River Management Alternatives (USIBWC, 2003), Final Environmental Impact Statement River Management Alternatives (USIBWC, 2005), Biological Assessment River Management Alternatives (USIBWC, 2004), and Biological Opinion for the River Management Alternatives for the Rio Grande Canalization Project (USFWS, 2012d).

Tables D-1, D-2, and D-3 list federal- and state-listed species that may occur based on the absence or presence of potential habitat within the study area. Scientific names were included in the discussion below for plant species because the common names of plants can vary. Scientific names for wildlife species are listed only in Tables D-2 and D-3. The results of the literature review and/or previous field surveys follow. Prior to project implementation, field surveys for federal- and state-listed species are recommended to confirm the presence or absence of suitable habitat and/or the potential occurrence of federal and threatened species within the study area.

Literature Review Results

Potentially Occurring Listed Plants

There is no suitable habitat for federal-listed plant species, including Sneed's pincushion cactus (*Coryphantha sneedii* var. *sneedii*), within or adjacent to the Rio Grande in the study area (CH2M HILL and Geo-Marine, 2000; USIBWC, 2004). However, potential habitat for two New Mexico state endangered species (i.e., desert night-blooming cereus and sand prickly pear) occurs in sandy silty areas with mesquite and creosotebush within the study area (NMRPTC, 1999).

Listed plants were not observed during previous surveys conducted along the Rio Grande within the study area in 1999 and 2001 (CH2M HILL and Geo-Marine, 2000; USIBWC, 2004). In general, habitat throughout most of the river corridor has been significantly disturbed by levee construction and floodplain maintenance activities. Listed plant species would not be expected to occur because of the dramatically altered and poor-quality habitat present in the river corridor (CH2M HILL and Geo-Marine, 2000). Although the site surveys are more than 10 years old, the habitat along the Rio Grande remains disturbed, and the presence of suitable habitat likely continues to be absent.

Potentially Occurring Listed Mollusc

There is no suitable habitat for listed mollusk species, including Doña Ana talussnail (federal species under listed status review).

Potentially Occurring Listed Fish

Rio Grande silvery minnow, a locally extirpated listed species (the species occurs farther north in the Middle Rio Grande and is the subject of significant conservation efforts), and Bluntnose shiner, an extinct listed species, historically occurred in Rio Grande and/or canal systems upstream of the study area. There is no suitable habitat for these fish species within the study area. Aquatic surveys were conducted for the El Paso River Management Unit for the Rio Grande Canalization Project Biological Assessment (USIBWC, 2004). The El Paso River Management Unit extends from the New Anthony Road to the American Dam and includes the portion of the study area along the Rio Grande. No suitable habitat for aquatic species was observed during previous surveys in September 2000 and January 2001 for the El Paso River Management Unit. Aquatic species collected during previous surveys within the study area included channel catfish (*Ictalurus punctatus*), longear sunfish (*Lepomis megalotis*), fathead minnow (*Pimephales promelas*), and flathead catfish (*Pylodictis olivaris*).

Potentially Occurring Listed Reptiles

Suitable habitat potentially occurs for Texas horned lizard (Texas state threatened species) in open, arid, and semi-arid areas with sparse vegetation. Previous surveys indicated that one listed herptile, Texas horned lizard, was observed in the river corridor portion of the project area during the spring and summer 1999 field surveys (CH2M HILL and Geo-Marine, 2000). The lizard was observed in a floodplain near Hatch, New Mexico, approximately 83 miles northwest of the study area.

Potentially Occurring Listed Birds

Table D-3 lists federal- and state-listed bird species that have reportedly occurred in Doña Ana County, New Mexico, and El Paso County, Texas, based on the database searches (NMDGF, 2012; USFWS, 2012b; USFWS, 2012c; USFWS, 2012d; NMACP, 2012; TPWD, 2012). Based on a review of the literature and previous field studies, three New Mexico and/or Texas state threatened species with potential habitat have occurred within the study area. These species include bald eagle (New Mexico state threatened species), peregrine falcon (New Mexico and Texas state threatened species), and Bell's vireo (New Mexico state threatened species) (CH2M HILL and Geo-Marine, 2000). The study area may provide potential limited habitat for federal listed species interior least tern within the study area (USIBWC, 2004), and may support potential habitat for New Mexico state threatened species, including gray vireo (New Mexico state threatened species) at Sunland Park (NMDGF, 2012), and common ground dove (New Mexico state endangered species).

These species may be fairly common migrants in the study area, including rare spring-fall migrants, such as Costa's hummingbird (New Mexico state threatened species); very rare winter residents, such as northern goshawk (New Mexico sensitive species), common black hawk (New Mexico state endangered species), and Baird's sparrow (New Mexico state threatened species); or accidental species, such as brown pelican (New Mexico state endangered species) (CH2M HILL and Geo-Marine, 2000). Yellow-billed cuckoo (federal candidate species) was observed along the Rio Grande in Seldon Canyon approximately 60 miles northwest of the study area. Potential habitat for yellow-billed cuckoo was not observed in the study area (CH2M HILL and Geo-Marine, 2000; USIBWC, 2004).

Southwestern willow flycatcher (federal-, New Mexico-, and Texas state endangered species) was observed during the field surveys along Rio Grande in Seldon Canyon (CH2M HILL and Geo-Marine, 2000). According to the USFWS Biological Opinion of southwestern willow flycatcher for the River Management Alternatives for the Rio Grande Canalization Project, Sunland Park within the study area supports migrant flycatchers within approximately 20 miles next to flycatcher habitat. During past surveys, flycatcher territories were detected at the Country Club East and Sunland Park sites within or nearby the study area. Country Club East and Sunland Park are not expected to provide breeding flycatcher habitat following proposed IBWC Rio Grande Canalization Project site restoration. It is unknown whether Country Club East and Sunland Park sites within the study area will become future territories for southwestern willow flycatcher (USFWS, 2012d). USFWS critical habitat is proposed for southwestern willow flycatcher along a 46 mile-segment of the Rio Grande in Sierra and Doña Ana Counties, New Mexico, from Caballo Dam to Leasburg Dam, away from the study area (Federal Register, 2011).

All other potentially occurring federal or state endangered, threatened, and proposed threatened species in Table D-3 were not observed during the previous surveys (CH2M HILL and Geo-Marine, 2000). There is no potential habitat for Mexican spotted owl or northern aplomado falcon within the study area (USIBWC, 2004).

Potentially Occurring Listed Mammals

The study area may support potential habitat for spotted bat (New Mexico state threatened species) at Sunland Park (NMDGF, 2012).

TABLE D-1

Literature Review of Presence/Absence of Suitable Habitat for Potentially Occurring Listed Plant Species in Study Area Reported in Doña Ana County, New Mexico, and El Paso County, Texas

Common Name <i>Scientific Name</i>	USFWS	NMRPTC	TPWD	Habitat Requirements	Within Known Distribution	Potential Habitat Present
mescalero milkwort <i>Polygala rimulicol mescalerorum</i>		E		Crevices in sandy limestone cliffs in montane scrub at 5,700-6,300 feet.	No	No
desert night-blooming cereus <i>Cereus greggii var. greggii</i>		E		Desert flats and washes between 3,000 and 5,000 feet; in sandy to silty gravelly soils, often in the shade of desert shrubs like creosote in Sonoran and Chihuahuan deserts of southern Arizona, east to western Texas, and south to northern Mexico.	No	Yes
Sneed pincushion cactus <i>Coryphantha sneedii sneedii</i>	E	E	E	Interior chaparral, limestone ledges of high hills in desert and in grassland; Franklin Mountains between El Paso and Las Cruces at 4,300 to 5,400 feet.	No	No
sand prickly pear <i>Opuntia arenaria</i>		E		Sandy areas in Chihuahuan desert scrub, often with honey mesquite and sparse grasses; Rio Grande Valley between Las Cruces and El Paso; urbanization.	Yes	Yes

Notes:

E = Endangered

NMRPTC = New Mexico Rare Plant Technical Council

TPWD = Texas Parks and Wildlife Department

USFWS = U.S. Fish and Wildlife Service

Sources: CH2M HILL and Geo-Marine, 2000; USIBWC, 2004; TPWD, 2012; NMRPTC, 1999; USFWS, 2012b; USFWS, 2012c.

TABLE D-2

Literature Review of Presence/Absence of Suitable Habitat for Potentially Occurring Listed Mollusc, Fish, and Reptile Species in the Study Area as Reported in Doña Ana County, New Mexico, and El Paso County, Texas

Common Name <i>Scientific Name</i>	USFWS	NMDGF	TPWD	Habitat Requirements	Within Known Distribution	Potential Habitat Present
MOLLUSC						
Doña Ana talus snail <i>Sonorella todseni</i>	Under Review	T		Found under rocks in desert hills and forested mountains; endemic to Doña Ana Mountains; have been collected at an altitude of 1,600 ft under rocks in igneous calus on Doña Ana Peak; collected in January during hibernation and in August while active after rains, mining, and loss of habitat.	No	No
FISH						
bluntnose shiner <i>Notropis simus</i>			T	Upper Rio Grande (above El Paso); rare; main channels over sand or gravel/reduced water levels in Rio Grande system.	No	No
Rio Grande silvery minnow <i>Hybognathus amarus</i>	E	E	E	Silt substrates in areas of low or moderate velocity. Known to occur in Upper Rio Grande in Sierra County; Bosque Del Apache National Wildlife Refuge; Sevilleta National Wildlife Refuge.	Yes	No
REPTILES						
Chihuahuan desert lyre snake <i>Trimorphodon wilkinsonii</i>			T	Chihuahuan desert in rock and crevice dwelling in limestone-surfaced desert northwest of the Rio Grande from Big Bend to the Franklin Mountains at elevations ranging from at least 2,822 to 6,089 feet, especially in areas with jumbled boulders and rock faults/fissures.	No	No
mountain short-horned lizard <i>Phrynosoma hernandesi</i>			T	Open, shrubby, or openly wooded areas with sparse vegetation at ground level; soil may vary from rocky to sandy; known only from two small isolated populations in the Davis and Guadalupe Mountains.	No	No
Texas horned lizard <i>Phrynosoma cornutum</i>			T	Open, arid, and semi-arid regions with sparse vegetation, including grass, cactus, scattered brush, or scrubby trees; widespread, particularly lower elevations and open country.	Yes	Yes
BATS						
spotted bat <i>Euderma maculatum</i>		T		Streams or ponds; prominent rock features.	Yes	Yes

Notes:

C = Candidate

NMDGF = New Mexico Department of Game and Fish

S = Sensitive (NM)

T = Threatened

TPWD = Texas Parks and Wildlife Department

Sources: CH2M HILL and Geo-Marine, 2000; USIBWC, 2004; TPWD, 2012; NMGF, 2012; USFWS, 2012b; USFWS, 2012c.

TABLE D-3

Literature Review of Presence/Absence of Suitable Habitat for Potentially Occurring Listed Bird Species in the Study Area as Reported in Doña Ana County, New Mexico and El Paso County, Texas

Common Name <i>Scientific Name</i>	Designation or Status			Habitat Requirements	Within Known Distribution	Potential Habitat Present
	USFWS	NMDGF	TWPD			
BIRDS						
southwestern willow flycatcher <i>Empidonax traillii extimus</i>	E	E	E	Brushy fields, thickets along streams, and open woodland edges.	Yes	Yes ^c
northern aplomado falcon <i>Falco femoralis septentrionalis</i>	E	E		Brushy prairie and yucca flats.	Yes ^b	No
American peregrine falcon <i>Falco peregrinus anatum</i>		T	T	Canyons with steep, rocky cliffs, close to water.	Yes	Yes ^a
arctic peregrine falcon <i>Falco peregrinus tundrius</i>		T		Canyons with steep, rocky cliffs, close to water.	Yes	Yes ^c
bald eagle <i>Haliaeetus leucocephalus</i>		T		Riparian; timbered areas along coasts, large lakes, and rivers.	Yes	Yes ^d
common black hawk <i>Buteogallus anthracinus anthracinus</i>		T		Riparian areas.	Yes	Yes ^c
interior least tern <i>Sterna antillarum</i>	E	E	E	River sandbars and beaches.	Yes ^b	Yes ^e
broad-billed hummingbird <i>Cynanthus latirostris magicus</i>		T		Desert canyons, mesquite shrublands, mountain slopes, and succulent shrublands; known breeding location at Guadalupe Canyon in Hidalgo County.	Yes ^c	No
Costa's hummingbird <i>Calypte costae</i>		T		Deserts, washes, mesas, sage scrub, and arid hillsides.	Yes ^c	Yes
Bell's vireo <i>Vireo bellii</i>		T		Dense shrubby vegetation in riparian, second-growth forests and mesquite brushlands.	Yes	Yes
gray vireo <i>Vireo vicinior</i>		T		Riparian willows, thorn scrub, oak-juniper woodlands, pinon-juniper woodlands and mesquite shrublands; potential at Sunland Park.	Yes	Yes
Baird's sparrow <i>Ammodramus bairdii</i>		T		Desert grassland and mountain meadows.	Yes ^c	Yes ^c
common ground dove <i>Columbina passerina pallescens</i>		E		Farms, orchards, wood edges, and roadsides; xeric riparian areas.	Yes	Yes
yellow-billed cuckoo <i>Coccyzus americanus occidentalis</i>	C			Riverine woodlands, thickets, and farms.	Yes	No
Mexican spotted owl <i>Strix occidentalis lucida</i>	T		T	Dense coniferous forests.	Yes	No

TABLE D-3

Literature Review of Presence/Absence of Suitable Habitat for Potentially Occurring Listed Bird Species in the Study Area as Reported in Doña Ana County, New Mexico and El Paso County, Texas

Common Name <i>Scientific Name</i>	Designation or Status			Habitat Requirements	Within Known Distribution	Potential Habitat Present
	USFWS	NMDGF	TPWD			
whooping crane <i>Grus americana</i>	Experi- mental	E		Marshes, wetlands, and pastures.	Yes ^f	No ^f
brown pelican <i>Pelicanus occidentalis</i>		E		Occasionally inland in southwestern region.	Yes	No ^f
neotropic cormorant <i>Phalacrocorax brasilianus</i>		T		Generally on larger bodies of water; known to occur only in Sierra and Socorro Counties.	Yes ^a	No

^aBreeding & Migratory

^bHistoric

^cMigratory only

^dWinter

^eOnly in dry years

^fAccidental

Notes:

C = Candidate

E = Endangered

T = Threatened

T^{SA} = Threatened because of similarity of appearance

Sources: CH2M HILL and Geo-Marine, 2000; USIBWC, 2004; TPWD, 2012; NMDGF, 1999; USFWS, 2012b; USFWS, 2012c; USFWS, 2012d; NMACP, 2012.

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Rio Grande Site Photographs



PHOTO 1
Mowed vegetation along the bank of the Rio Grande River
(Location: near Interstate 10 and Amusement on November 7, 2012)

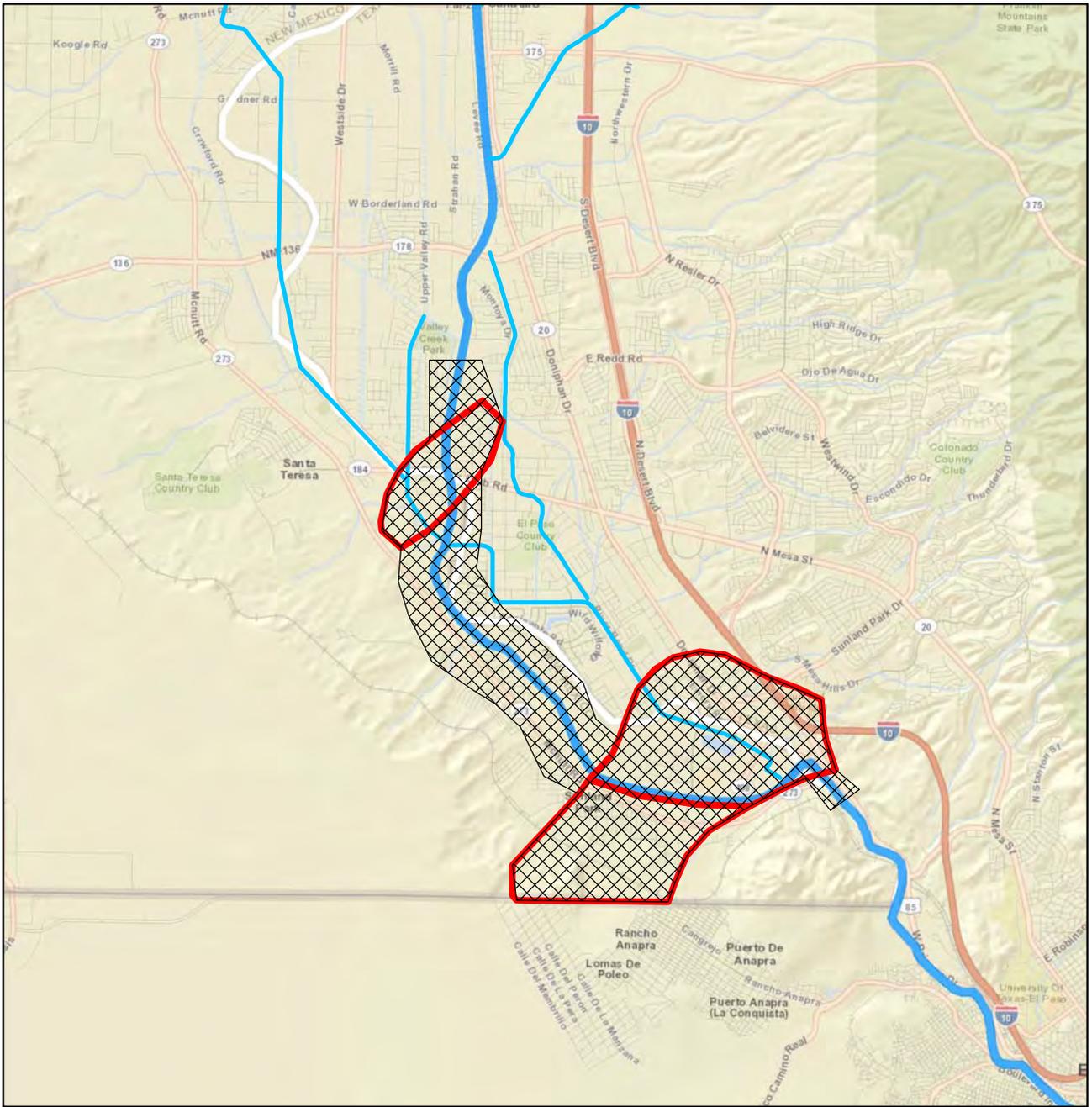


PHOTO 2
Russian thistle along the bank of the Rio Grande
(Location: near El Paso Country Club on November 7, 2012)

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Figures

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VICINITY MAP

LEGEND

-  Area for Ecosystem Framework Analysis
-  Potential Salinity Control Project Sites
-  Rio Grande
-  Ag Drains

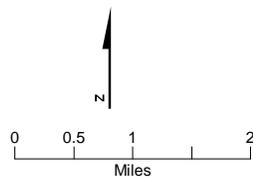
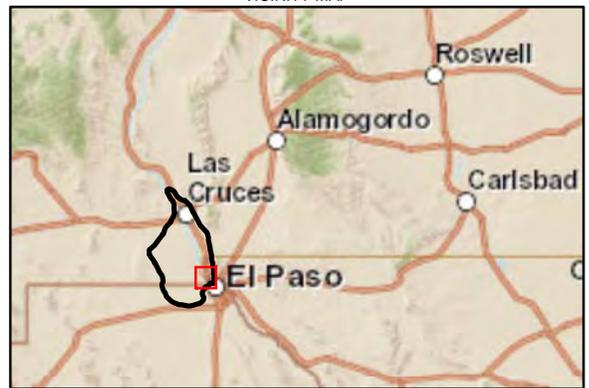
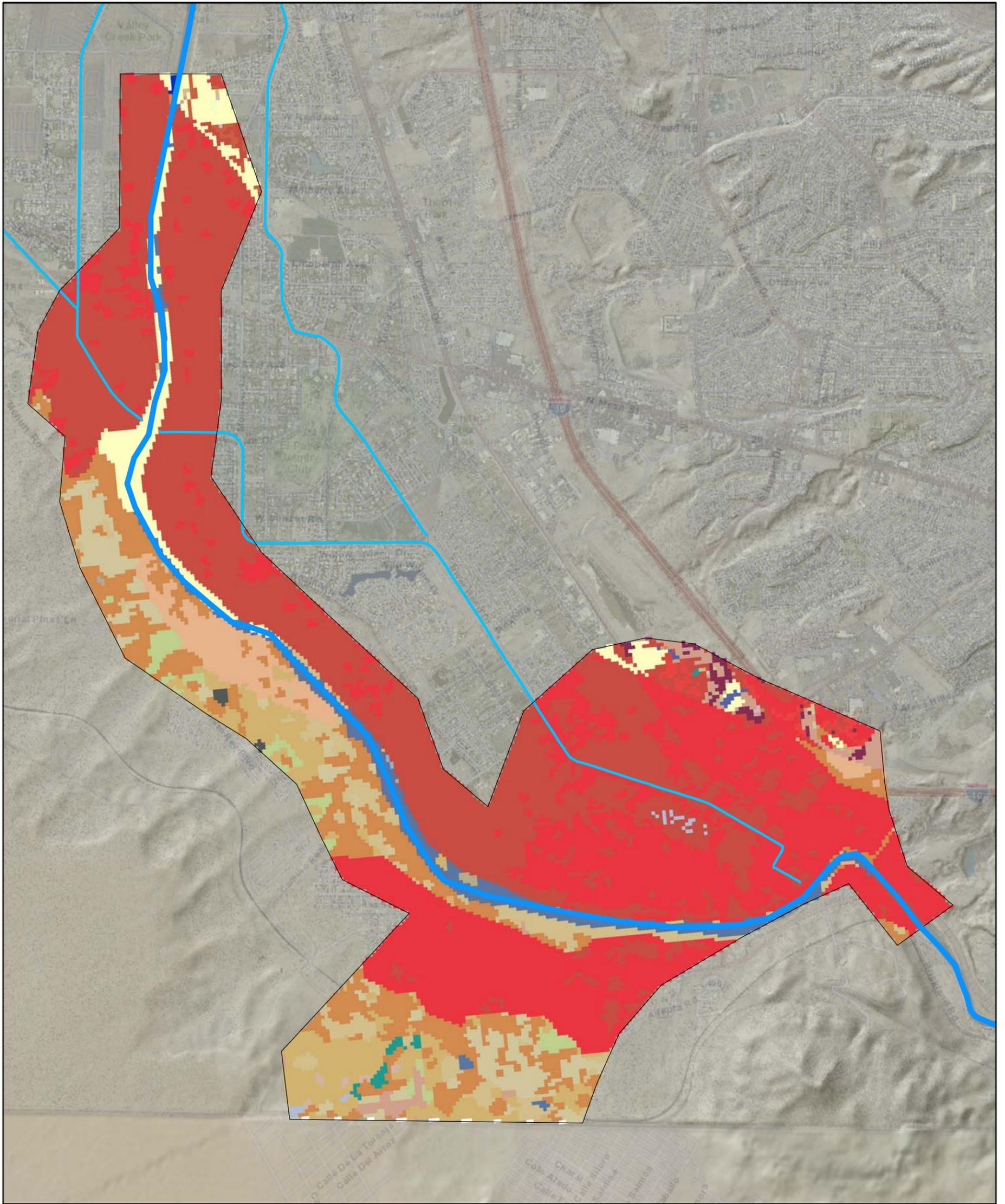


FIGURE D-1
Ecosystem Framework Study Area
 Distal Mesilla Conceptual Site Model
 Rio Grande Salinity Management Program

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- LEGEND**
- Study Area
 - River
 - Ag Drains
 - Developed, Open Space
 - Disturbed, Non-specific
 - Inter-Mountain Basins Semi-Desert Shrub Steppe
 - Introduced Riparian and Wetland Vegetation
 - Madrean Encinal
 - Madrean Juniper Savanna
 - Madrean Pinyon-Juniper Woodland
 - North American Arid West Emergent Marsh
 - North American Warm Desert Active and Stabilized Dune
 - North American Warm Desert Pavement
 - North American Warm Desert Playa
 - North American Warm Desert Riparian Systems
 - North American Warm Desert Riparian Woodland and Shrubland
 - North American Warm Desert Wash
 - Open Water (Fresh)
 - Pasture/Hay
 - Apacherian-Chihuahuan Mesquite Upland Scrub
 - Apacherian-Chihuahuan Semi-Desert Grassland and Steppe
 - Chihuahuan Creosotebush, Mixed Desert and Thorn Scrub
 - Chihuahuan Gypsophilous Grassland and Steppe
 - Chihuahuan Loamy Plains Desert Grassland
 - Chihuahuan Mixed Salt Desert Scrub
 - Chihuahuan Sandy Plains Semi-Desert Grassland
 - Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub
 - Chihuahuan Succulent Desert Scrub
 - Cultivated Cropland
 - Developed, High Intensity
 - Developed, Low Intensity
 - Developed, Medium Intensity

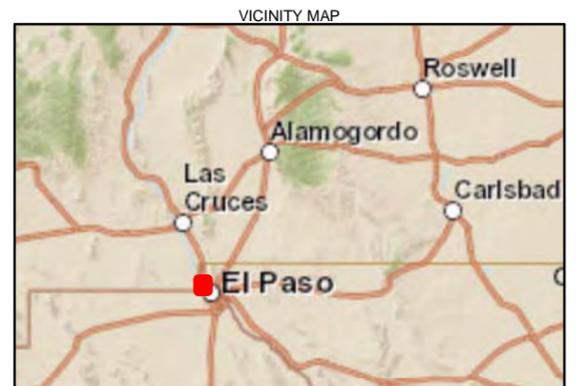
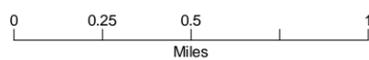
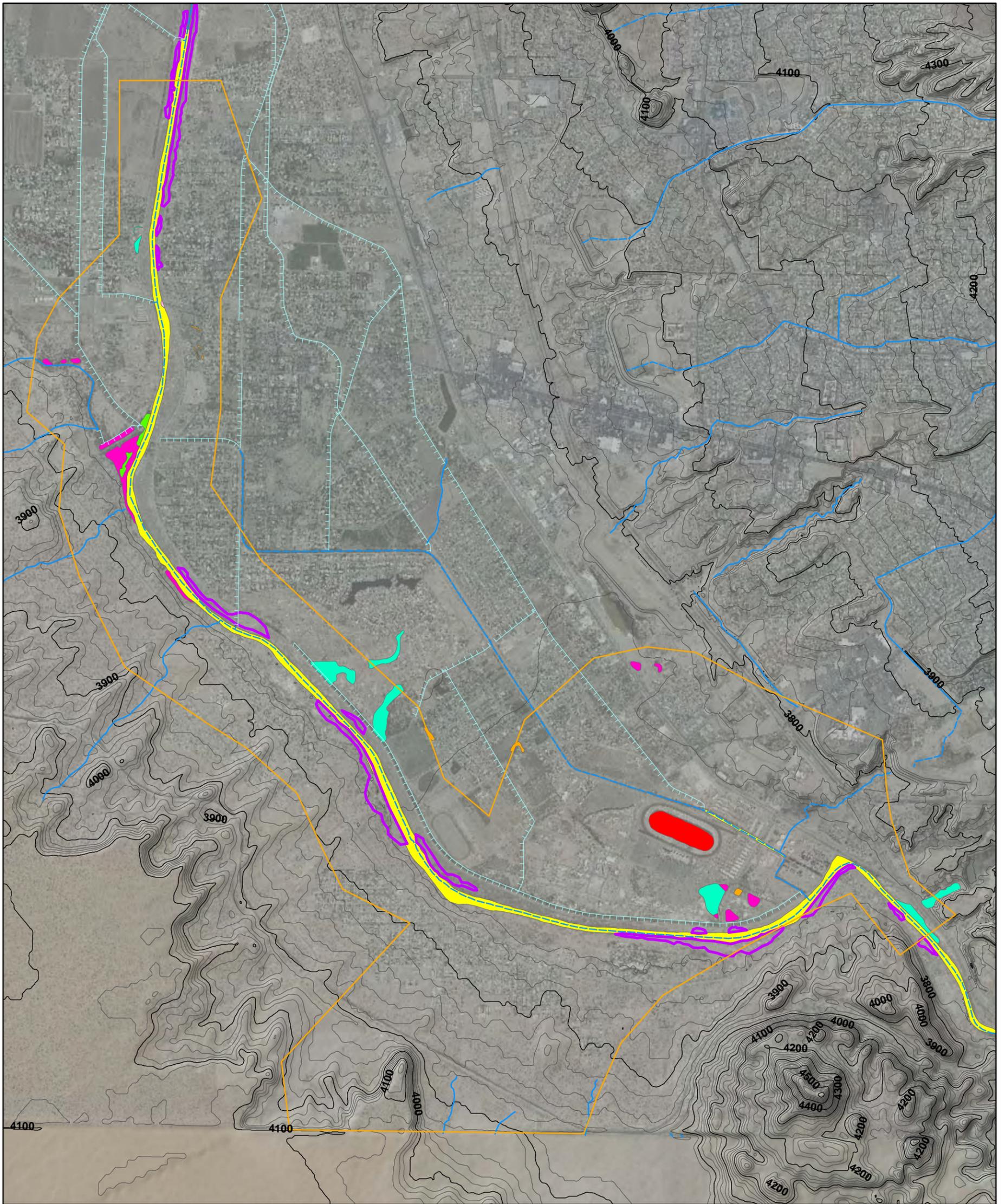


FIGURE D-2
Vegetation Types at Ecological System Level (USGS GAP)
 Distal Mesilla Conceptual Site Model
 Rio Grande Salinity Management Program

Source: USGS National Gap Analysis Program, 2011



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- LEGEND
- Study Area
 - 100-ft land surface contours
 - National Wetland Inventory Type**
 - Lacustrine Limnetic Unconsolidated Bottom, Permanently Flooded, Excavated (L1UBHx)
 - Palustrine Forested, Broad-leaved Deciduous, Temporarily Flooded (PFO1A)
 - Palustrine Scrub-Shrub, Needle-leaved Deciduous, Intermittently Flooded (PSS2J)
 - Palustrine Scrub-Shrub, Needle-leaved Deciduous, Temporarily Flooded (PSS2A)
 - Palustrine Unconsolidated Bottom, Permanently Flooded, Excavated (PUBHx)
 - Riverine Intermittent Streambed, Seasonally Flooded, Excavated (R4SBCx)
 - Riverine Intermittent Streambed, Temporarily Flooded (R4SBA)
 - Field checked wetlands, approximate location (from CH2M HILL and Geo-Marine, 2000)
 - NHD Flowline**
 - ArtificialPath
 - CanalDitch
 - StreamRiver

VICINITY MAP

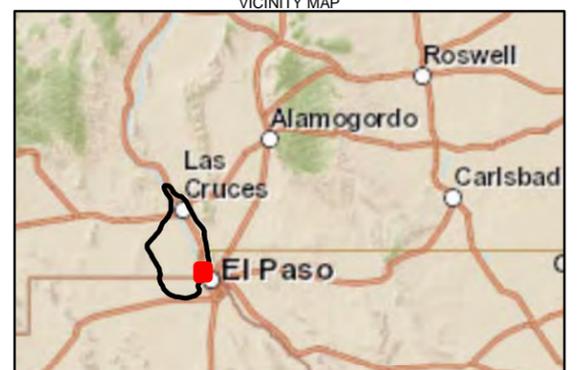


FIGURE D-3
Potential Jurisdictional Waters of the U.S. and/or in the State in Study Area
 Distal Mesilla Conceptual Site Model
 Rio Grande Salinity Management Program



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