Technical Report

Distal Mesilla Conceptual Site Model

Prepared for

United States Army Corps of Engineers

November 15, 2013

CH2MHILL®

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Acronyms and Abbreviations

^{10}B	Boron-10
^{11}B	Boron-11
$\delta^{11}B$	isotopic signature of boron
af	acre-foot (feet)
afy	acre-foot (feet) per year
cfs	cubic foot (feet) per second
Cl-Br	chloride-bromide
Coalition	Rio Grande Salinity Management Coalition
ft/d	foot (feet) per day
ft^2/d	square foot (feet) per day
HSU	hydrostratigraphic unit
ISC	New Mexico Interstate Stream Commission
mg/L	milligram(s) per liter
NM OSE	New Mexico Office of the State Engineer
NRCS	Natural Resources Conservation Service
Program	Rio Grande Salinity Management Program
TDS	total dissolved solids
tons/yr	tons per year
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WRDA	Water Resources Development Act of 2007

SECTION 1

Executive Summary

The U.S. Army Corps of Engineers (USACE), along with the New Mexico Interstate Stream Commission (ISC) and the state of Texas, have entered into an agreement to implement projects associated with the Rio Grande Salinity Management Program (Program). The purpose of the Program is to study, account for, and ultimately intercept sources of salinity in the Rio Grande Basin—focusing from San Acacia, New Mexico, to Fort Quitman, Texas—that adversely affect water quality and limit full utilization of the water resources in the basin. CH2M HILL previously conducted an Alternatives Analysis for the Program. The Alternatives Analysis yielded Distal Mesilla Basin, Truth or Consequences, and Fabens as the preferred sites for additional investigations (CH2M HILL, 2011).

This report summarizes a conceptual model that was developed to gain a better understanding of the salinity source in the Distal Mesilla Basin, and to identify data gaps that need to be filled to support selection and location of a potential salinity control project. The significant amount of work that has been completed in the area was relied upon, including numerous hydrogeologic reports and data compiled in the ISC data compendium (Burley, 2010).

Results of this analysis suggest that two sites associated with the Distal Mesilla source may be targeted for a potential salinity capture project (Figure 1-1). Each site is discussed below, followed by a summary of other considerations.

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). Site 1 was selected based on an observed increase in total dissolved solids (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 (Figure 1-1). Based on a 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, but decreased to between 50 and 2,500 tons/yr in February 2013. 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.

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 milligrams per liter [mg/L] TDS), or (2) a localized low-flow, high-salinity source—perhaps deep saline brines brought to the surface relatively quickly by faults or hydrothermal systems—that is not represented by the model and is not observed in existing groundwater wells.

Available data suggest that a potential salinity control project at Site 1 could reduce average non-irrigation season chloride loads in the Rio Grande at El Paso by approximately 8 percent (Table 1-1). If such a project is considered, it is recommended that a detailed, localized, hydrogeologic and geochemical evaluation be performed near Site 1 to evaluate flow rates and salinity of groundwater that discharges to the Montoya Drain, how flow rates may change seasonally and in response to drought and wet periods, and the location of the salinity source.

1.2 Southern Site (Site 2)

The southern site, Site 2, has high TDS concentrations observed in groundwater, typically greater than 30,000 mg/L at ISC-4B (Figure 1-1). 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 acre-feet per year (afy). Mass balance mixing models done as part of this work suggest 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. 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. A potential salinity control project at Site 2 could reduce average non-irrigation season chloride loads in the Rio Grande at El Paso by approximately 9 percent (Table 1-1).

The source of salinity at Site 2, however, is not well understood. It is recommended that additional detailed flow and water quality measurements be performed to estimate groundwater discharge rates and saline mass flux to Rio Grande, and how they may change through time. It is also recommended that additional detailed, localized hydrogeologic and geochemical investigations be performed to help evaluate the source of water to wells in the area.

1.3 Other Considerations

Municipal pumping from the Conejos-Medanos wellfield in northern Chihuahua, Mexico, began in 2010, with current pumping of approximately 25,000 afy. The source of water to these wells in the short term is dominantly extraction of water from storage; however, the water source will likely shift toward interception of water that otherwise would have discharged to the Rio Grande and drains, as well as additional induced inflow from the Rio Grande. It is likely that pumping from the Conejos-Medanos wellfield would reduce or even eliminate groundwater discharge to the Rio Grande at Site 2. These impacts could occur decades from now, although possibly sooner.

Similarly, the source of water for municipal and industrial wells in the Santa Teresa and Sunland Park areas is effectively the same as that of the Conejos-Medanos wellfield. Municipal pumping near Santa Teresa is currently approximately 6,000 afy, less than half of permitted pumping. If pumping near Santa Teresa and/or Sunland Park increases in the future, it would likely result in increased drawdown in the area, as well as reduced groundwater discharge to the Rio Grande and possibly to the Montoya Drain (water to the wells is intercepting water that otherwise would have discharged to the Rio Grande or the Montoya Drain).

Evaluation of a potential salinity control project should consider potential future groundwater pumping from near Santa Teresa, Sunland Park, and the Conejos-Medanos wellfield. The concept of the salinity control project evaluated herein is that saline groundwater that otherwise would have discharged to the Rio Grande or Montoya Drain is intercepted and treated. This concept fundamentally assumes that the saline groundwater would otherwise be discharging to the Rio Grande or Montoya Drain.

If pumping from Conejos-Medanos and/or the Santa Teresa or Sunland Park areas causes reduction or cessation of saline groundwater discharge to the Rio Grande or the Montoya Drain, short-term benefits of reduced salinity loads in the Rio Grande may occur. However, the saline mass would remain in the groundwater system, slowly moving toward the pumping wells. This differs from a salinity control project, where salinity would be removed from the system.

TABLE 1-1
Summary of Potential Salinity Control Sites

	Site 1 (Montoya)	Site 2 (ISC-4 area)
Cl Load (tons/yr)	As high as 7,500 (in 2000) 50 to 2,500 (in 2013, drought)	7500 (change during drought unknown)
TDS concentration of groundwater (mg/L)	4,000 to >20,000	15,000 to 30,000
Groundwater flow rate (afy)	100 to 1,500	500 to 1,000
Groundwater flow rate (cfs)	0.1 to 2	0.7 to 1.5
Localization (cross-sectional width)	< 0.5 mile to 2 miles	2 miles
Additional information/analysis needed to quantify flux	Relatively complicated; may require long-term monitoring and installation of new well(s)	complicated
Effect of other pumping; potential influence and timing	Potential; later than Site 2	Very likely; sooner than Site 1
Average percent reduction of Cl load at El Paso, non-irrigation season[1]	8%	9%
Average percent reduction of Cl load at El Paso, irrigation season[1]	1%	3%

[1] Assumes 30 percent of source is captured.
Site 1 non-irrigation season based on two points in time (2000 and 2013), using actual Cl load in the Rio Grande at El Paso.
Site 2 non-irrigation season based on source of 7,500 tons/yr and average non-irrigation season load at El Paso from Hogan (2010) (2,000 tons/mo).
Site 1&2 irrigation season estimates assume source is constant throughout the year (Site 1 assumed to be long-term average of 2,000 tons/yr) and long-term average irrigation season load at El Paso from Hogan (2010) (7,000 tons/mo)

SECTION 2

Introduction and Purpose

USACE, ISC, and the state of Texas, under Section 729 of the Water Resources Development Act (WRDA) of 2007, have entered into an agreement to implement projects associated with the Program. The purpose of the Program is to study, account for, and ultimately intercept sources of salinity in the Upper Rio Grande Basin—focusing from San Acacia, New Mexico, to Fort Quitman, Texas—that adversely affect water quality and limit full utilization of the water resources in the basin.

In June 2010, USACE contracted with CH2M HILL to conduct an Alternatives Analysis for the Program. This project developed and screened salinity management alternatives to refine six elevated salinity areas plus one river site and associated treatment options (previously identified by the Rio Grande Salinity Management Coalition [Coalition]) to three prioritized areas. A formal decision support process was used to evaluate alternatives. The final ranking of sites, based on the attribute-to-cost ratios and further screened according to anticipated non-monetary attributes, yielded Distal Mesilla Basin, Truth or Consequences, and Fabens as the preferred sites for additional investigations (CH2M HILL, 2011).

In May 2012, USACE contracted with CH2M HILL to prepare a conceptual model of one of the preferred sites, the Distal Mesilla Basin (Figure 2-1). As part of the contract, CH2M HILL has consulted with Dr. Fred Phillips, New Mexico Institute of Mining and Technology, and Dr. John Hawley, Hawley Geomatters. Jim Witcher of Witcher Associates provided information during an initial site visit, and Dr. James Hogan, New Mexico Environment Department, provided additional input. All are widely recognized as subject matter experts on the geology and hydrogeology of the Rio Grande, and all have reviewed and contributed to this report, either directly or through their published research.

The purpose of the conceptual model is to gain a better understanding of the salinity source in the Distal Mesilla Basin, and to identify data gaps that need to be filled to support selection and location of a potential salinity control project. The significant amount of work that has been completed in the area was relied upon, including numerous hydrogeologic reports and data compiled in the ISC data compendium (Burley, 2010).

This report first discusses previous work (Section 3) and the hydrologic setting (Section 4) and then summarizes available groundwater (Section 5) and surface water (Section 6) data. This information is synthesized in analysis of the potential salinity source (Section 7). Ecosystem (Section 8) and anthropogenic (Section 9) frameworks are then presented to provide a basis for future evaluation of potential impacts and effectiveness of a salinity control project. Finally, a summary and recommendations are presented (Section 10).

SECTION 3

Previous Work and Background

The hydrogeology of the Mesilla Basin has been extensively characterized. Among the most notable references are the historic work by Slichter (1905) and Leggat, Lowry, and Hood (1962). Hawley and Kennedy (2004) present a more recent hydrogeologic framework as well as a comprehensive list of references for other hydrogeologic work in the basin.

Groundwater flow in the Mesilla Basin has been extensively modeled. The most prominent numerical models of the Mesilla Basin include Frenzel and Kaehler (1992), Hamilton and Maddock (1993), Weeden and Maddock (1999), and most recently the New Mexico Office of the State Engineer (NM OSE) Administrative Model (SSPA, 2007).

It has long been recognized that salinity in the Rio Grande increases with distance downstream. Moyer, et al. (2009) summarized the current understanding of sources of salinization. One source of salinity identified is saline groundwater discharge to the Rio Grande in the Distal Mesilla Basin. Observed TDS concentration in groundwater is as high as 30,000 mg/L just northwest of the El Paso Narrows (Figure 3-1).

Geochemical analyses and mass balance approaches (Mills, 2003; Hogan et al., 2007; Moore et al., 2008; Moyer et al., 2009) suggested that the high salinity observed at the most saline wells (e.g., ISC-4A and ISC-4B, with TDS concentrations greater than 30,000 mg/L) is likely from upwelling groundwater brines and that this flow discharges to both the Rio Grande and the Montoya Drain (Lacey, 2006). Based on local geology and groundwater flow directions, it was inferred for this Study that high-salinity groundwater flows from the northwest toward the southeast. However, these are indirect conclusions based on geochemistry and mass balance approaches, and there are no wells in the deep portion of the basin northwest of ISC-4A and ISC-4B to confirm the existence of deep groundwater brines in that area.

In addition, there is known geothermal activity in the vicinity of the study area. Geochemical and isotopic investigations have suggested that water in the Montoya Drain is a mix of geothermal groundwater, groundwater brines, and Rio Grande water (Moore et al., 2008; Bastien 2009).

Mass balance modeling has been performed to estimate the saline mass flux of groundwater discharging to the Rio Grande. Based on the mass balance modeling of Mills (2003) and an isotopic mixing model (Hogan et al., 2007), the Distal Mesilla site appears to contribute approximately 6,500 to 9,750 tons of chloride per year to the Rio Grande, or 10 to 15 percent of the annual chloride load in the Rio Grande at El Paso. Mills (2003) estimated a brine input of 540 to 900 tons of chloride per month (6,480 to 10,800 tons of chloride per year), whereas Lacey (2006) estimated 163 to 819 tons of chloride per month (1,956 to 8,828 tons of chloride per year).

SECTION 4

Catchment Framework (Hydrologic Setting)

The surface water drainage system that contributes to the Rio Grande above the Distal Mesilla site is approximately 30,500 square miles and is outlined on Figure 4-1. The Distal Mesilla site is located along the Rio Grande just north of El Paso. The site is at the distal end of the Mesilla Groundwater Basin, which encompasses approximately 1,100 square miles and stretches from Selden Canyon just north of Las Cruces, New Mexico, to approximately 20 miles south of the U.S.-Mexico border (Figure 4-1).

SECTION 5

Hydrogeologic Framework

The Distal Mesilla site is located in the southwestern portion of the Mesilla Groundwater Basin (Figure 2-1). The Mesilla Basin is bounded on the west by fault-block and volcanic uplands and on the east by the Organ-Franklin-Sierra Juarez mountain chain (Hawley and Kennedy, 2004). The discharge point for surface and groundwater under pre-development conditions was the Rio Grande upstream of the El Paso Narrows, which is a bedrock constriction just northwest of El Paso, Texas.

This conceptual model focuses on the distal Mesilla Basin, or the portion between the El Paso Narrows and Vinton, Texas (Figure 3-1). The study area was defined based on observed salinity in the area, which decreases north of Cañutillo (Figure 3-1) and the location of municipal pumping near Cañutillo (northern boundary), and on previous hydrogeologic work, suggesting that groundwater discharges to the Rio Grande immediately upstream of the El Paso Narrows (southern boundary). The study area is bound on the east by Franklin Mountains (the edge of the aquifer) and on the west by an area in which groundwater is minimally utilized. The hydrogeologic framework model developed by Hawley and Kennedy (2004) provides a more complete description of the hydrogeology of the entire Mesilla Basin.

5.1 Groundwater Use

Groundwater pumping influences the direction and quantity of groundwater flow. This section summarizes current and potential future groundwater pumping in the area, with the intent of understanding how current pumping affects groundwater flow, and how potential changes to pumping may affect a potential salinity control project in the area.

Land use in the study area ranges from predominantly agricultural in the northern part to residential, commercial, and industrial in the southern part of the river valley (Figure 5.1). The majority of the groundwater used in the study area is for agricultural irrigation and municipal and industrial purposes; Table 5-1 summarizes recent and projected future pumping by use category. Location and use of wells in the area is presented on Figure 5-2. Figures 5-3 and 5-4 show recent pumping rates and permitted pumping rates.

TABLE 5-1
Recent and Potential Future Groundwater Use in the Study Area

	Type	State	Description	Recent Pumping (afy)	Potential Future Pumping (afy)
Study Area	Municipal and Industrial[a]	NM[b]	Primarily Santa Teresa	7,400	33,100
		TX	Primarily Cañutillo[c]	20,000	20,000
		Total M&I		**27,400**	**53,100**
	Agricultural	NM[b]		8,000	18,500
		TX	estimate[d]	10,000	20,000
		Total Agricultural		**18,000**	**38,500**
	Domestic	NM[b]		*Not quantified*	
		TX			
		Total Domestic			

[a] Excludes pumping outside study area; notably Conejos Medanos (25,000 afy). Includes commercial pumping.

[b] NM data from WATERS database (Recent = 2011, Potential Future = total water rights)

[c] Cañutillo wellfield is only partially within the study area. This estimate includes all Canutillo Pumping (EPWU, 2012)

[d] TX data estimated based on model (SSPA, 2007) pumping.

5.1.1 Municipal and Industrial Groundwater Use

The largest municipal users of groundwater in the Distal Mesilla area are the cities of El Paso and Santa Teresa. The Cañutillo wellfield, located along the Rio Grande in the northern part of the study area (Figure 5-3), supplies the city of El Paso and has been pumping since the early 1950s. Approximately 20,000 afy is pumped (EPWU, 2012) in the Cañutillo wellfield. Thirty municipal wells in the Santa Teresa area are located west of Santa Teresa (Figure 5-3) and have been active since 1973 (SSPA, 2007). More than 5,600 afy was pumped in 2003 (SSPA, 2007), and 2011 pumping totaled approximately 6,000 afy.

In general, municipal use has increased throughout time (SSPA, 2007). Municipal and industrial pumping in 2011 in the New Mexico portion of the study area totaled approximately 7,400 afy, compared with 33,100 afy of permitted pumping (Table 5-1), suggesting that future pumping in the study area is likely to exceed current pumping amounts. The Santa Teresa area is a likely location for increased pumping, because current pumping is less than half of permitted water rights.

Although it is outside the study area, the Conejos-Medanos wellfield in northern Chihuahua, Mexico (Figure 5-5), could be significant in the context of a potential salinity control project. The Conejos-Medanos wellfield began pumping 25,000 afy starting in 2010, and the wellfield provides water to Ciudad Juarez, Mexico (Transboundary Aquifer Assessment Program, 2010). Plans for future pumping are not known, so for the purpose of this evaluation, it is assumed that pumping will continue at 25,000 afy, although that rate may change.

5.1.2 Agricultural Groundwater Use

Irrigation wells throughout the study area provide supplemental water for agriculture, which is primarily supplied by surface water. Numerous irrigation wells are in the study area, nearly all of which are located in the river valley. Total agricultural groundwater use is estimated at 18,000 afy (Table 5-1), although that estimate is uncertain because pumping rates are not reported in Texas.

The amount of groundwater pumped varies seasonally, with the majority of pumping occurring in the irrigation season (March through September), and a lesser amount occurring during the non-irrigation season (October through February).

The amount of groundwater pumped varies considerably from year to year, based on the availability of surface water. Accurate records of historical and current agricultural pumping do not exist (SSPA, 2007). Future pumping will continue to be variable, and it could increase if surface water supply is limited because of potential changes in policy and/or climate.

5.2 Basin Geology

The conceptualization of the salinity source in this area is that the geologic structures force deep saline water to the surface, where the water discharges to the Rio Grande and/or agricultural drains. Understanding the basin geology is important for evaluating the physical controls on salinity and for assessing potential salinity control project locations. The geologic model for the Distal Mesilla area is based on maps from Hawley and Kennedy (2004). Since publication, these maps have been updated to include the Upper and Middle Santa Fe Groups.

Groundwater flow in the Mesilla Basin is primarily in an aquifer system consisting of poorly consolidated sediments that have accumulated within the basin over a long period of time (“basin fill”) (Hawley and Kennedy, 2004). The basin fill accumulated above deeper consolidated rock and bedrock material, which is relatively impermeable to groundwater flow. Basin-fill thickness ranges from less than 75 feet in the El Paso Narrows to a maximum thickness of nearly 3,000 feet northwest of the study area (Figure 5-6). Bedrock elevation contours are shown on Figure 5-7, illustrating the upward slope of the bedrock toward the southeast.

The Santa Fe Group exists throughout the study area and has been divided into upper, middle, and lower hydrostratigraphic units (HSUs) (Hawley and Kennedy, 2004). The upper Santa Fe HSU is characterized by high to moderate groundwater production potential; the middle Santa Fe HSU is characterized by moderate to low groundwater production potential; and the relatively impermeable lower Santa Fe HSU is characterized mostly by

low groundwater production potential (Hawley and Kennedy, 2004). The primary aquifers in the study area include the river alluvium and the upper and middle Santa Fe units. The upper Santa Fe is not present at all locations throughout the study area. The river alluvium is generally no more than 60 feet thick (Hawley and Kennedy, 2004). Elevations of the base of the Middle and Upper Santa Fe Groups are shown on Figures 5-8 and 5-9.

Extensive regional geological cross-sections were developed by Hawley and Kennedy (2004). As part of this project, additional local cross-sections were developed (Figures 5-10 through 5-18). The cross-sections show the revised HSU layers developed by Hawley (2012). In addition, 173 drillers' logs were compiled and digitized to supplement the more regional information compiled by Hawley. These logs are included in the attached CD and are described in Appendix A. It was assumed that the drillers' logs may provide additional information about more permeable zones within preferred locations for a potential salinity control project. The purpose of the local cross-sections and inclusion of local drillers' logs is to help evaluate sites for a potential salinity control project.

Well depth and well screen intervals are shown on Figures 5-19 and 5-20. Wells in the river alluvium are typically shallow (less than 100 to 200 feet deep); a group of domestic wells in the northwest is generally 200 to 300 feet deep. Additional wells in the study area, including municipal wells in the Santa Teresa area, are 300 to more than 500 feet deep and produce from the Middle Santa Fe (SSPA, 2007). Municipal wells in the Cañutillo wellfield range from 100 to more than 500 feet deep, and they produce from various depth intervals and aquifer zones within the Santa Fe Group (SSPA, 2007).

5.3 Aquifer Properties

Aquifer transmissivity is a measure of the ability of an aquifer to transmit water. Higher aquifer transmissivity allows water to flow more easily, and, therefore, higher well pumping rates can be expected. Transmissivity as measured from aquifer tests (compiled by SSPA, 2007) is presented on Figure 5-21. Transmissivity based on aquifer tests ranges from approximately 2,800 feet squared per day (ft^2/d) in the Santa Teresa area to greater than 20,000 ft^2/d in the Cañutillo area.

Transmissivity based on specific capacity (well pumping rate divided by drawdown in the pumping well) is also plotted on Figure 5-21. A conversion factor of 2,000 was used to convert specific capacity in units of gallons per minute per foot to transmissivity in units of gallons per day per foot. This factor is a standard conversion factor based on Driscoll (1986). When applied to wells in the study area with both specific capacity and aquifer test transmissivity data, this factor resulted in a very good match (r-squared equals 96 percent). Transmissivity estimates based on specific capacity are generally similar to estimates based on aquifer tests.

Transmissivity from the NM OSE administrative model is also presented on Figure 5-21. The model transmissivity was adjusted from observed values to calibrate to observed water level data and likely represents a reasonable regional distribution of transmissivity. Transmissivity is estimated to be between 10,000 and 15,000 ft^2/d in the river valley and less than 2,500 ft^2/d in areas outside the river valley.

Modeled hydraulic conductivity in the river alluvium is approximately 170 feet per day (ft/d), between approximately 10 to 50 ft/d in the Upper and Middle Santa Fe Groups, and approximately 5 ft/d in the Lower Santa Fe Group. These values are consistent with Hawley and Kennedy's 2004 general assessment of the relative permeability of the HSUs. Based on model properties and Hawley and Kennedy's 2004 assessment, a salinity control project should be sited in the Upper or Middle Santa Fe Groups. The Lower Santa Fe Group is likely not permeable enough to produce significant amounts of water from extraction wells. In addition, permeability is variable in the Middle Santa Fe Group (Hawley and Kennedy, 2004); therefore, it is recommended that existing local lithologic data, including the database compiled as part of this work, be used to help estimate local areas of higher permeability once a relative location for a potential salinity control project is delineated. It is likely that additional field testing will be required to find areas of reasonably high permeability for a potential salinity control project.

5.4 Groundwater Elevations and Flow

Groundwater levels are used to assess direction of groundwater flow. Changes in water levels are indicative of the aquifer's response to local and regional stresses, such as groundwater pumping.

Groundwater elevation maps for 2009 and 1974 are presented on Figures 5-22 and 5-23, respectively. These time periods were selected because they have the best spatial distribution of available data and allow for an assessment of relatively long-term changes in water levels. The groundwater elevation maps show that deep groundwater in the study area generally flows from the northwest toward the southeast. Shallow groundwater in the river valley generally flows parallel to the Rio Grande from north to south.

Comparing groundwater elevation maps from 1974 to 2009 (Figure 5-24) shows that water levels declined approximately 10 to 15 feet in the area west of Santa Teresa over 35 years. This drawdown is presumably in response to the municipal pumping in the area. Water levels in the river alluvium and in the northern part of the study area show little to no drawdown during this period. Changes in water levels can also be seen in hydrographs from select wells with the best periods of record (Figures 5-25 through 5-30).

Depth to groundwater is generally less than 20 feet in the river valley, and extends to approximately 300 feet in the west mesa area (Figure 5-31). The increase in depth to water is because of the topographic rise of the west mesa.

Vertical gradients, adjusted for density effects because of the highly saline water, are presented on Figures 5-32 and 5-33. Vertical gradients are consistently upward in the northern part of the study area (ISC-6 and ISC-7), representing a tendency for deep groundwater to flow upwards. Vertical gradients in the southern part of the study area (ISC-4 and ISC-5) are also generally upward, although not as strongly as in the northern part of the study area; this spatial trend may be driven by shallow agricultural groundwater pumping, which is predominantly north of ISC-6, as well as local geology. ISC-6 and ISC-7 are located where the aquifer is thinning rapidly toward the southwest, forcing water upward, whereas ISC-4 and ISC-5 are located in a relatively uniform, thinner part of the aquifer.

5.5 Groundwater Quality

This section summarizes observed groundwater quality in the study area. Spatial distribution of high-salinity groundwater and seasonal trends in groundwater quality are discussed.

Water quality data are available for a number of wells throughout the study area from the 1950s through the present (Figures 5-34 and 5-35). To represent salinity of groundwater, TDS concentration data from the ISC Compendium (Burley, 2010) was used.

Time-series plots of water quality ("chemographs") were developed for wells within the study area with the best periods of record of data (Figures 5-36 through 5-42). As these chemographs show, there is minimal seasonal variability, and any long-term trends that exist are minimal relative to the overall range of TDS (less than 500 mg/L to greater than 30,000 mg/L). The spatial variability between locations is significantly greater than temporal variability at a particular location; therefore, the median TDS value was used to assess spatial distribution of salinity.

Median TDS concentrations, along with depth (where available), are plotted on Figure 5-43. Observed TDS in the study area ranges from less than 500 mg/L to greater than 30,000 mg/L. TDS can also be seen at various depth intervals on Figure 5-44. These figures show a general trend of increased TDS at depth, and increasing TDS southward along the Rio Grande. The highest observed TDS concentrations are in the cluster of wells just northwest of the El Paso Narrows (i.e., ISC-4A, ISC-4B, and El Paso Electric monitoring wells EPE-X). Wells in this vicinity typically have TDS concentrations near or greater than 20,000 mg/L, with the deeper ISC well (ISC-4B) having TDS concentrations greater than 30,000 mg/L. Moyer et al. (2009) noted a similar trend of increasing TDS downstream along this reach of the Rio Grande.

A discussion of how observed water quality relates to a potential salinity control project is found in Section 7.

5.6 Water Budget

A water budget accounts for flows into and out of a system, with inflows balancing outflows. A water budget was developed for the study area for the purposes of better assessing the quantity and location of saline groundwater discharge and evaluating how changes in other components of the water budget, such as groundwater pumping, might affect the rate of saline groundwater discharge. This section discusses the groundwater budget only. The surface water and groundwater-surface water budgets are discussed in Section 6.

5.6.1 Study Area Groundwater Water Budget

The NM OSE administrative model (SSPA, 2007) was used as a basis for the water budget analysis. The time-series water budget for the entire transient simulation period (1940-2004) suggests that there are significant long-term and seasonal changes in the water budget (Figure 5-45). The primary long-term trends are because of the onset of Cañutillo pumping in the early 1950s and regional drought conditions (e.g., 1950s) causing an increase of groundwater pumping to meet irrigation demands.

Based on a detailed analysis of 10 water budget zones within the study area (Appendix B), the period 1980-1999 was selected for evaluation in this section because conditions were relatively stable during this period and most closely represent current conditions. However, this period does not include significant drought years, which may result in increased groundwater pumping. Water budget plots for 1980-1999 are presented on Figures 5-46 and 5-47.

Figures 5-46 and 5-47 suggest that the study area water budget is highly seasonal, resulting from the heavy influence of local irrigation. Processes driving the seasonal nature of the water budget include the following:

- Surface water and supplemental groundwater pumping provide irrigation water during the irrigation season.
- A portion of the applied irrigation water not used by crops recharges the groundwater system (deep percolation of applied irrigation water), also during the irrigation season.
- Much of the recharged water stays in the shallow groundwater system and eventually discharges to agricultural drains. This process is delayed, so the seasonal change in groundwater discharge to drains is less dramatic.

Because much of the irrigation-influenced processes are largely restricted to the shallow groundwater system (as represented by model layer 1), yet the saline groundwater source evaluated in this conceptual model is deep (as represented by model layers 2-5), it is useful to examine the water budget as broken out into both the shallow and the deep systems (Table 5-2).

TABLE 5-2
Study Area Water Budget Summary, 1980-1999 Average

	Shallow System (afy) Model Layer 1	**Deep System (afy) Model Layers 2-5**
Inflows:		
Groundwater inflow, from upgradient*	2,000	9,000
Deep percolation of applied irrigation water and precipitation	16,000	
Surface water: seepage from river and laterals	20,000	
Downward flow (shallow to deep)		7,000
Upward flow (deep to shallow)	2,000	
Storage (dewatering)	100	
Inflows Total	**40,100**	**16,000**

TABLE 5-2
Study Area Water Budget Summary, 1980-1999 Average

	Shallow System (afy) Model Layer 1	Deep System (afy) Model Layers 2-5
Outflows:		
Surface water: discharge to river and drains	27,000	
Riparian evapotranspiration	2,000	
Groundwater pumping, river valley	2,000	11,000
Groundwater pumping, elsewhere	2,000	3,000
Downward flow (shallow to deep)	7,000	
Upward flow (deep to shallow)		2,000
Outflows Total	**40,000**	**16,000**

*Model water budget likely under-represents inflow from the southwest (Mexico), because that is not explicitly modeled. Model shows approximately 77 afy; however, calculations based on observed transmissivity, gradient, and cross-sectional length suggest inflow from Mexico is approximately 2,000 afy.

A summary of individual components of the water budget is provided below. For each water budget component, summaries of the shallow and deep systems are presented, along with a summary of seasonal trends.

- **Inflow: Groundwater.** Simulated inflow of groundwater to the study area is approximately 11,000 afy. The majority of this inflow, approximately 9,000 afy, is deep groundwater (Table 5-2). The ultimate sources of groundwater inflow are seepage from the Rio Grande in the upgradient portion of the basin, deep percolation of applied irrigation water, and mountain-front recharge (SSPA, 2007). Groundwater inflow to the study area is primarily from the northwest. However, based on assumed transmissivity and observed gradients in Mexico, inflow from the southwest (Mexico) is estimated to be approximately 2,000 afy (Table 5-2; see note). Because of the slow nature of groundwater flow on a basin-wide scale, groundwater inflow to the study area is relatively constant throughout time, both on long- and short-term scales (Figures 5-45 and 5-46).
- **Inflow: Deep Percolation of Applied Irrigation Water and Precipitation.** Simulated deep percolation of applied irrigation water and precipitation is on average approximately 16,000 afy. Nearly all annual recharge occurs during the irrigation season (greater than 95 percent; Figure 5-47), because the primary source of recharge is irrigation water. Significant long-term trends in deep percolation of applied water are not noticeable in the water budget plots.
- **Inflow: Surface Water.** Simulated annual surface water inflow averages approximately 20,000 afy, with the majority of surface water inflow occurring during the irrigation season (approximately 17,500 acre-feet [af]; Figure 5-47). This seasonal trend is because of (1) inflow from canals/laterals that have greater flows during the irrigation season, (2) greater flow rates and higher stage in the Rio Grande, and (3) lower groundwater levels resulting from groundwater pumping. These processes result in an increased gradient from the surface water to the groundwater, thereby increasing flows.
- **Outflow: Surface Water**. Simulated surface water outflow to drains and the Rio Grande is approximately 18,000 af during the irrigation season and approximately 9,000 af during the non-irrigation season (Figure 5-47). The rate of discharge to surface water does not change appreciably from the irrigation to non-irrigation seasons. However, because of the length of the seasons, a greater volume of water discharges to drains and the Rio Grande during the irrigation season. A long-term trend of decreased outflow to surface water follows the onset of simulated Cañutillo pumping in the early 1950s (Figure 5-45).
- **Outflow: Wells**. Well pumping is a significant component of the water budget and is of particular interest because of its considerable variability from year to year. Simulated well pumping is greater during the irrigation season, with an average of approximately 13,000 af of water extracted over the 245-day period (Figure 5-47). During the non-irrigation season, an additional 5,000 af of water is extracted over the 120-day

period. Pumping is dominantly within the river valley (approximately 13,000 afy) and occurs primarily from the deep groundwater system (Table 5-2). There is a significant increase in pumping in the early 1950s (Figure 5-45), which is when pumping began at the Cañutillo wellfield. Groundwater pumping also tends to increase during drought years, when surface water supplies are limited and crop requirements are met by supplemental groundwater pumping. Seasonally, agricultural pumping results in increased pumping during the irrigation season.

- **Outflow: Evapotranspiration**. Evapotranspiration (evaporation and plant transpiration of shallow groundwater) is a relatively minor component of the water budget, at approximately 2,000 afy (Figure 5-47; Table 5-2). More than 85 percent of the annual total evapotranspiration occurs during the irrigation season, primarily resulting from higher temperatures and potential evapotranspiration rates. There is no long-term trend in evapotranspiration.
- **Storage**. The above water budget components result in seasonal changes in groundwater storage, with an increase in storage during the irrigation season (increased recharge from applied irrigation water and surface water inflow, which outweigh increased agricultural groundwater pumping) and a decrease in storage during the non-irrigation season (primarily resulting from discharge to drains and municipal groundwater pumping). Net average annual change in storage during the period 1980-1999 is approximately 100 afy coming out of storage (Table 5-2).

5.6.2 Deep Saline Groundwater Flow Estimates

A detailed water budget was developed for 10 zones within the study area (Figure 5-48; Appendix B), based on the NM OSE administrative model (SSPA, 2007). Water that originated from the deep northwest zone (Zone 10, Model Layer 5) was tracked through the model domain to obtain estimates of deep saline water discharge to local surface water. Results are presented in Table 5-3. A total of approximately 3,400 afy of groundwater flows into Layer 5 of the northwest zone. Only a small portion of this water is likely saline, as the conceptual understanding is that the saline water flows along the bottom of the aquifer.

Results of the water budget suggest that of the 3,400 afy of deep groundwater that flows into the northwestern portion of the study area, approximately 430 afy discharges to drains or the Rio Grande. Although not all of the 3,400 afy of inflow is saline, based on flow patterns it is not unreasonable to assume that the deepest water, assumed to be most saline, is the most likely to flow toward the surface water discharge points (i.e., not get pulled upward to wells). Therefore, the model suggests that a reasonable upper bound on the rate of saline discharge to the surface water system for saline water originating in the northwest is approximately 430 afy.

TABLE 5-3
Summary of Discharge Locations and Rates for Deep Groundwater from the Northwest

	Total Flow from Northwest Layer 5	
Discharge Point	**afy**	**Percent**
Wells, Santa Teresa Area	1,250	37%
Wells, Cañutillo Area	1,100	33%
Other Wells, River Valley	577	17%
Surface Water	430	13%
Total	**3,358**	**100%**

5.6.3 Other Nearby Conditions: Conejos-Medanos Wellfield Water Budget

Municipal pumping from the Conejos-Medanos wellfield (Figure 5-5) began in 2010, with current pumping of approximately 25,000 afy (Transboundary Aquifer Assessment Program, 2010). Future pumping rates are

uncertain, but for the purpose of this evaluation it is assumed that the wellfield will continue to pump 25,000 afy. Currently, pumped water from the Conejos-Medanos wellfield (located south of the model domain) is presumably derived primarily from aquifer storage. However, as the wellfield continues to pump, water from storage will become a less dominant source of water to the wells, and drawdown from the wellfield will induce inflow from other areas. The water budget analysis is useful in estimating potential long-term sources of water to the wellfield.

Prior to pumping at the Conejos-Medanos wellfield, it is estimated that approximately 2,000 afy of water was flowing toward the northeast, from Mexico into the U.S. (based on a calculation using observed gradient [0.001 foot per feet], observed aquifer transmissivity near the wellfield [165,000 ft^2/d], and estimated cross-sectional distance [25 kilometers]). Because the Rio Grande in the study area is the primary discharge sink for flow originating from Mexico, 2,000 afy is a reasonable estimate of long-term average recharge to the Mexico portion of the Mesilla Basin. Recharge in Mexico is the most reasonable source of long-term water to the wells; however, it only accounts for approximately 10 percent of the total water being pumped. Other sources of water to the wells that could be long-term are shown on Figure 5-49 and include the following:

- Upgradient groundwater from the U.S.: There is currently approximately 11,000 afy of inflow from areas upgradient of the study area. However, as discussed in the preceding section, a significant amount of the upgradient inflow is currently being intercepted by wells in the U.S., so not all of this water is available to the Conejos-Medanos wellfield.
- Induced inflow from the Rio Grande and laterals: There is currently approximately 20,000 afy of inflow from surface water in the study area.
- Reduced outflow to the Rio Grande and drains: There is currently 27,000 afy of outflow to rivers and drains in the study area.
- Water from storage: Water from storage as a source of water to wells typically decreases through time. However, the southern Mesilla Basin boundary is a non-structural groundwater flow divide. It is expected that the divide will migrate south as groundwater levels decline, in effect providing a “reservoir” of storage available to the wells over a long-term period.

It is likely that each of these will be long-term sources of water to the Conejos-Medanos wellfield. The potential for the Conejos-Medanos wellfield to induce additional inflow from the Rio Grande and laterals, and/or to reduce outflow to the Rio Grande, is significant in the context of a potential salinity control project. As discussed in the following sections, only approximately 500 to 1,000 afy of groundwater is discharging to the Rio Grande in the southern portion of the study area. Because the groundwater recharge area is the closest reach of the Rio Grande to the wellfield, it is not unreasonable to assume that pumping from the Conejos-Medanos wellfield may result in reduced groundwater discharge to the Rio Grande, possibly eliminating that flow altogether. Reduced groundwater discharge could occur decades from now, or possibly sooner. The existing groundwater models do not include the portion of the aquifer where the Conejos-Medanos wellfield is located. A groundwater model calibrated to monitoring wells showing response of the aquifer to the Conejos-Medanos wellfield pumping would be the best tool for assessing magnitude and timing of potential impacts on the Rio Grande. Recommendations for modeling are discussed further in Section 10.

SECTION 6

Hydrological and Surface Water Framework

This section discusses local hydrology and surface water characteristics.

6.1 Hydrological Framework

This section summarizes meteorological conditions affecting the hydrologic cycle in the study area. Precipitation and evapotranspiration data within the study area are only available for 2002-2012 (Figure 6-1). Recent annual average precipitation in the study area is approximately 10 inches per year, and annual average potential evapotranspiration is approximately 62 inches per year (average at Santa Teresa, 2002-2012). Long-term average precipitation at Las Cruces, New Mexico, from 1851 to 1976 is 8.4 inches per year (Frenzel and Kaehler, 1992). Precipitation tends to be greatest during the summer monsoon months, typically July through September, when storms tend to be of high intensity and short duration.

Monthly data suggest that potential evapotranspiration exceeds precipitation (Figure 6-1) for all months. Because potential evapotranspiration exceeds precipitation, recharge to the groundwater resulting from deep percolation of precipitation in the study area is minimal (Section 5.6 for other sources of recharge to the groundwater basin). Precipitation in the study area is generally either evapotranspired or, during high-intensity storms in the summer monsoon months, a portion of precipitation may run off to local surface water systems. Based on precipitation rates, the rate of potential runoff is likely small relative to surface water flow rates in the Rio Grande. As discussed below, significant surface water flow occurs during these irrigation months. Accordingly, the effect of precipitation on groundwater and surface water systems in the study area is assumed minimal. Processes related to irrigation of agricultural land, including releases from Caballo Reservoir, diversions through laterals, and groundwater pumping, have a much greater effect on the local groundwater and surface water systems in the study area than does precipitation.

6.2 Surface Water Framework

This section summarizes the surface water system in the context of the Rio Grande Project, followed by specific discussion related to the study area.

6.2.1 Regional Water Supply Management

Rio Grande water supplies are managed by (1) the three-state 1938 Compact that sets forth the allocation of water among Colorado, New Mexico, and Texas; (2) the 1906 Treaty between U.S. and Mexico; and (3) the water allocation and operating rules under the Rio Grande Project contracts (Michelsen et al., 2009). According to the U.S. Bureau of Reclamation, the Rio Grande Project provides flood control, irrigation, and recreational benefits. Approximately 178,000 acres of land is irrigated, and electric power for communities and industries in the area is supplied through this project (Reclamation, 2012). Also according to the U.S. Bureau of Reclamation:

> *Project lands occupy the river bottom land of the Rio Grande Valley in south-central New Mexico and west Texas. About 60 percent of the lands receiving water are in New Mexico; 40 percent are in Texas. Water is also provided for diversion to Mexico by the International Boundary and Water Commission-United States Section to irrigate about 25,000 acres in the Juarez Valley.* (Reclamation, 2012)

Elephant Butte Reservoir and Caballo Reservoir, with a combined storage capacity of 2.2 million af, were constructed to capture and store spring snowmelt flows to be released during irrigation season for agricultural use. According to Michelsen, et al. (2009):

> *Releases are designed to conserve water supplies, resulting in reduced to little or no flow below the agricultural areas in El Paso in Texas, where there is no downstream obligation for water delivery.*

During the non-agricultural irrigation season, typically late October or November to February or early March, reservoir gates are closed and the flow of water in the river is from effluents of municipal treatment plants, groundwater inflows, agricultural return flows from drains, and runoffs from creeks.

The Distal Mesilla study area is in the Rio Grande Project area, toward the southeast of the Upper Rio Grande Basin, just north of El Paso, Texas. Because the study area is downstream of the project facilities, Rio Grande flow in the study area is greatly influenced by project operations, and the effect of seasonal reservoir releases is directly observed in flow and water quality data.

6.2.2 Study Area Surface Water Characteristics

Figures 6-2 and 6-3 present gauge locations and data availability in the study area. Montoya Drain and Rio Grande at Courchesne Bridge are the two locations with extensive flow and water quality data. All other stations were generally monitored once per year, during the non-irrigation season, as part of the USGS seepage studies (USGS, 2012).

6.2.2.1 Surface Water Flow and Water Quality Long-term Trends

The data for Montoya Drain and Rio Grande at Courchesne Bridge flow and water quality (TDS) are evaluated for any possible long-term trend. Data were collected at Rio Grande from 1905 to 1907 (Figures 6-4 and 6-5). Flow records (Figure 6-4) for this period demonstrate a natural snowmelt-driven hydrograph because the flow was recorded before construction of Elephant Butte and Caballo Dams. TDS records (Figure 6-5) show peaks following the months of high-peak flows. These peaks are probably a result of increased groundwater levels and gain from groundwater following the two high-flow events.

Because of the gap in data records, the data starting from October 1973 is plotted separately (Figure 6-6); data from 1971—2011 is shown on Figure 6-7. Records in later years were taken at low-flow conditions. Although there is a decreasing trend over time, because of the seasonal irregularity in flow sampling it is not possible to draw conclusions on the long-term trend. However, the Rio Grande shows a decrease in low flows (non-irrigation season), which is possibly a result of increased demand on surface water and possible increased losses to groundwater from the Rio Grande (Figure 6-6). No-flow conditions are observed consistently after 2003. With similar caveats, the TDS plot shows a decreasing trend over time with a sharp increase after 2004. Note that the records after 2004 were recorded in the non-irrigation season.

Flow and TDS data at Montoya Drain are available starting from February 1938. A slight increase is observed in the Montoya Drain flows over time, where TDS shows no significant trend (Figures 6-8 and 6-9).

6.2.2.2 Surface Water Flow and Water Quality Seasonal Trends

Monthly average flow and TDS at Montoya Drain and Rio Grande at Courchesne Bridge show the effect of reservoir releases during irrigation season. Figure 6-10 shows that flow in the Rio Grande (averaged from 1973 to 2011) is significantly greater during the irrigation season (average 861 cubic feet per second [cfs], April through September) than during the non-irrigation season (average 209 cfs, November through February).

Similarly, drain flows (averaged from 1938 to 2012) tend to be greater during the irrigation season (average 73 cfs, April through September) than during the non-irrigation season (average 33 cfs, November through February) because of greater applied irrigation water.

Conversely, as observed on Figure 6-11, water quality is better (TDS is low) during the irrigation season (Rio Grande = 683 mg/L; Montoya Drain = 1,322 mg/L) and worse in the non-irrigation season (Rio Grande = 1,451 mg/L; Montoya Drain = 1,621 mg/L). As expected, the drain water contains a higher TDS concentration in both irrigation and non-irrigation season than the Rio Grande, although the saline mass flux of the Rio Grande in the irrigation season is greater than that of the Montoya Drain.

6.2.2.3 Surface Water Flow and Water Quality Spatial Variability: Rio Grande

Because the USGS seepage studies have the best spatial resolution of data along the Rio Grande, they were relied upon for a local water budget and water quality analysis within the study area. Locations of measurements are

found on Figure 6-2. Key measurement points include six locations along the Rio Grande from "Rio Grande at TX-259 Bridge" (USGS Site ID: 314813106322810) at the upstream end to "Rio Grande at El Paso" (USGS Site ID: 314713106313610) at the downstream end. Additional measuring points of key inflow to the Rio Grande include the Montoya Drain, which collects effluent water from agricultural use, Sunland Wastewater Treatment Plant outfall, El Paso Electric river outfall, and Keystone Reservoir inlet and side channel inlet.

Flow and water quality data are available for only two dates for all stations: February 11, 2009, and February 23, 2010. Based on the available data, spatial distribution of flow and water quality plots were developed for these two dates (Figures 6-12 through 6-15).

Specific conductance and TDS were commonly measured in the study area. If the TDS data were not available for the two dates selected, then TDS is calculated from specific conductance (based on a relationship obtained from other time periods where both specific conductance and TDS were recorded at the same location) to present a spatial distribution on water quality.

Flow data was available for four other dates: March 4, 2005; February 15, 2006; February 14, 2007; February 13, 2008; and February 15, 2011. Spatial distribution of flow on these dates is presented on Figures 6-12 through 6-20.

All of these dates are in the non-irrigation season. Although it was not possible to capture spatial distribution of flow and water quality during irrigation season, these dates provide information about where gain from groundwater could occur. As observed from these figures, the river reach between river mile 1250 and 1252 gains groundwater in certain conditions. It can be concluded from these figures that the Montoya Drain is the main contributor in terms of TDS mass in the Rio Grande during the non-irrigation season.

The seepage studies are performed only during the non-irrigation season. A conceptual evaluation of how each of these flows may differ during the irrigation season is as follows:

- Rio Grande flow is significantly greater during the irrigation season, as discussed above (Figure 6-6).
- Montoya Drain flow has historically been significantly greater during the irrigation season. However, in recent years, even irrigation season flows are relatively low (Figure 6-8).
- Wastewater is presumably relatively steady in both flow and water quality, based on typical patterns of wastewater flow.
- River loss is generally greater during the irrigation season, because of greater flow in the river and lower groundwater levels resulting from agricultural pumping. Groundwater-surface water interaction is discussed further in the following section. Groundwater discharge to the lower reach of the Rio Grande (between Sunland Park Bridge and Courchesne Bridge) is likely reduced during the irrigation season.

6.2.2.4 Surface Water Flow and Water Quality Spatial Variability: Montoya Drain

The Montoya Drain was sampled for TDS, chloride, bromide, and temperature in February 2000 (Bakker et al., 2000). Flow was only measured at one location (EPCWID gage), downstream of the Nemexas Drain inlet (Figure 6-21). Water quality results show a notable increase in TDS, Cl-Br ratio, and temperature near Country Club Road (Figures 6-21 through 6-23). Because there are no nearby surface water inflows to the Montoya Drain, and tailwater is unlikely in February, these results suggest an influx of saline groundwater to the drain in the area near Country Club Road.

The Montoya Drain and tributaries were sampled again for water quality in February 2013, this time with flow also measured. Results are presented in Figures 6-24 through 6-26. During this sampling event, a less obvious increase in TDS was observed in the vicinity of Country Club Road. Conclusions based on these sampling results, in conjunction with groundwater results, are discussed in Section 7.

6.2.3 Groundwater and Surface Water Interaction

While the preceding section summarizes the best available observed data on groundwater-river interaction along the Rio Grande, the conclusions are limited in scope because (1) analysis is restricted to the non-irrigation season,

and (2) analysis is restricted to the Rio Grande, excluding laterals and drains, which are a significant part of the surface water system. This section discusses groundwater-surface water interaction from the NM OSE model to assess seasonal changes in flows, as well as losses to groundwater from laterals and gains from groundwater in drains.

6.2.3.1 Groundwater and the Rio Grande

Cumulative gain and loss to or from the Rio Grande in the study area, as simulated by the NM OSE administrative model, is presented on Figures 6-27 and 6-28, along with observed cumulative gain and loss based on the USGS seepage studies (USGS, 2012). The model matches the observed data reasonably well, although there is no overlap in time between the model (1940-2004) and the USGS seepage studies (2004-2011). Qualitatively, however, this reasonable match suggests that the model is a good tool for a qualitative assessment of groundwater-surface water interaction. However, model results should be used with caution; the cell size of the model is large relative to the dimensions of local rivers and drains, and it may not be adequate to delineate detailed locations of recharge and discharge to surface water bodies.

Figures 6-27 and 6-28 show that river losses are greater during the irrigation season than during the non-irrigation season. Increased river losses are presumably because of higher flows (and higher stage) in the Rio Grande (Figure 6-10), and more groundwater pumping (lower groundwater levels) during the irrigation season.

Long-term trends in river gain and loss can be seen by plotting annual cumulative gain/loss along the entire study area (Figure 6-29); cumulative river loss increased significantly following the onset of pumping from the Cañutillo wellfield in the 1950s. There is some correlation between the river and annual pumping amounts, which appears to follow a multi-year time scale. There is also some correlation between the river and releases from Caballo Reservoir (Figure 6-30), particularly in years of notably low (1964) or high (1986) releases.

Spatially, Rio Grande gains and losses are presented on Figures 6-31 and 6-32. Figure 6-31 suggests that the Rio Grande is primarily gaining between local river miles 12 and 14, or roughly between Sunland Bridge and Courchesne Bridge. This is consistent with seepage study results, which typically show the Rio Grande gaining in this reach.

Simulated gain between Sunland Park and Courchesne Bridge is generally between 0 cfs and approximately 2 cfs, compared with observed gain ranging from approximately -4 cfs (river is losing to groundwater) to approximately 5 cfs (Figure 6-33). The USGS seepage studies use a flow balance approach, calculating gain as the difference between downstream flow and upstream flow plus all inflows. Accordingly, a high degree of uncertainty exists in the observed data. Seasonally, the model suggests that groundwater flows to the Rio Grande at a greater rate in the non-irrigation season than in the irrigation season, with limited inflow from groundwater during the irrigation season.

6.2.3.2 Groundwater and Laterals and Drains

Along the Rio Grande in the study area, six laterals are included in the model (Figure 6-34). Model results indicate that seepage rates from these laterals to the shallow groundwater are typically in the range of 1,000 (Montoya Main Lateral) to 10,000 afy (La Union East Lateral) when the laterals are active.

Four drains are also included in the model (Figure 6-35). Simulated inflow rates of groundwater to these drains is significant and in the range of 5,000 (Montoya and Central Drains) to 20,000 afy (Nemexas Drain). Of particular significance is the Montoya Drain, which is located east of the Rio Grande in the southern portion of the study area where deep groundwater is suspected to discharge to surface water.

6.2.3.3 Summary: Groundwater-Surface Water Interaction

In summary, model results combined with USGS seepage study results suggest that the primary location of groundwater discharge to the Rio Grande is between Sunland Park (local river mile 12) and just upstream of Courchesne Bridge (local river mile 14) (Figure 6-32). It is likely that groundwater discharge to the Rio Grande is greater during the non-irrigation season than during the irrigation season, and average groundwater discharge rates are approximately 500 to 1,000 afy.

In addition, discharge from groundwater to the Montoya Drain is significant, with historical flow rates in the Montoya Drain typically around 80 cfs during the irrigation season and 30 cfs during the non-irrigation season. Since 2004, however, Montoya Drain flow rates have rarely exceeded 20 cfs, even during the irrigation season.

SECTION 7

Analysis of Salinity Source and Potential Salinity Control Project

Geochemical analyses and mass balance approaches (Mills, 2003; Hogan et al., 2007; Moore et al., 2008; Moyer et al., 2009) have suggested that the high-salinity groundwater observed in the Distal Mesilla area is from deep, old groundwater brines. However, these interpretations do not clearly indicate the location of the source water, which is important in siting a potential salinity control project. Based on local hydrogeology and groundwater flow patterns, it has been assumed that the source of the water to these wells is from the northwest.

This section is divided into two subsections. The first subsection discusses the potential for the high-salinity groundwater to be "originating" in the deep portion of the aquifer in the northwestern part of the study area, as well as the potential to capture and treat that water. The second subsection examines the local flow conditions around ISC-4, with the intent of assessing whether the high-salinity groundwater at ISC-4 contributes a significant amount of saline mass to the Rio Grande.

7.1 Potential Saline Flow from the Northwest (Site 1)

7.1.1 Montoya Drain Water Quality Data

Two water quality sampling events were performed along the Montoya Drain, one in 2000 and one in 2013. Detailed analysis of these data, using a mass balance mixing model, is presented in Appendix C.

During February 2000, the annualized chloride-loading rate from groundwater to the Montoya Drain between Country Club Road and approximately 1 mile downstream of the Nemexas Drain inlet may have been as much as 5,000 to 7,500 tons/yr, based on the mass balance mixing model. Of this amount, it is estimated that as much as 4,000 tons/yr could be localized flow of higher concentration, near Country Club Road (Figure 7-1). However, as noted in Appendix C, a high degree of uncertainty is associated with these estimates, and actual chloride flux may be less than the calculated values.

During February 2013, estimated saline flux to the Montoya Drain in this area was significantly less than in 2000. The mass balance model suggests an annualized chloride-loading rate of 50 to 2,500 tons/yr, with a best estimate of approximately 1,400 tons/yr. Of this amount, it is estimated that less than 500 tons/yr of chloride was discharging from groundwater to the Montoya Drain in the area near Country Club Road (Figure 7-1).

In 2000, groundwater inflow near Country Club Road appears to have had a high Cl-Br ratio of approximately 1,200, compared with observed Cl-Br ratio upstream in the Montoya Drain of approximately 400 (Appendix C). In 2013, there is also an observed increase in Cl-Br ratio in the Montoya Drain; however, it is not as pronounced. Cl-Br increased from approximately 800 above Country Club Road to above 900 below Country Club Road (Figure 6-26), suggesting a Cl-Br ratio in groundwater of approximately 1,000 (based on the best estimate of flow in Appendix C). The relatively high Cl-Br ratio of groundwater may be representative of groundwater brines.

While data from 2000 show a sharp increase in TDS and Cl near Country Club Road, data from 2013 do not show the same sharp increases. Data from the two Montoya Drain sampling events suggest that the saline flux from groundwater to the Montoya Drain may have decreased between 2000 (as much as 5,000 to 7,500 tons/yr) and 2013 (50 to 2,500 tons/yr). This change could be attributed to one or both of the following:

1. Uncertainty associated with the mass balance approach. Both flow measurements and attempts to measure flow-weighted average concentration have uncertainty associated with them. In addition, both flow and concentration may change through time, even over the course of hours, and it is often difficult to time the sample collection according to velocity of water in the drain, such that the same water is being sampled. As discussed in Appendix C, results from the 2000 sampling event have a greater degree of uncertainty than those from the 2013 event and may be overestimating the saline flux from groundwater.

2. Long-term trends and influence of drought. 2013 represents drought conditions, with lower drain flow rates and lower groundwater levels. The measured flow rate in the drain in 2013 of approximately 5.6 cfs is notably less than historical non-irrigation season flow rates, whereas the flow rate in 2000 of approximately 24 cfs is somewhat typical (see Figure 6-8). Paired groundwater level data near the drain are not available for February 2000 and February 2013. However, from available data, it can be inferred that groundwater levels may have been approximately 0.8 foot lower in 2013 than in 2000 (see Figure 7-2; see also Figure 5-27, well 49-12-502). Estimated groundwater levels along the Montoya Drain were inferred based on observed levels at nearby wells (for water level magnitude) and the 2009 groundwater level map (for spatial distribution) and are presented in Figure 7-2. Figure 7-2 suggests that the gradient of groundwater levels may be slightly flatter than the gradient of the Montoya Drain. The result is that a uniform decline in groundwater levels, as may be associated with drought, could result in a greater decrease in groundwater flow to the Montoya Drain near Country Club Road than farther downstream, below the Nemexas Drain inlet. Accordingly, it is possible that the drought conditions have caused a temporary reduction or even elimination of the saline flux to the drain near Country Club Road that was observed in 2000. Under this hypothesis, the source of salinity is still present and would either resume discharging to the drain when groundwater levels rise or migrate southward.

7.1.2 Groundwater Model Particle Tracking

The NM OSE administrative model was used to help assess flow directions of deep groundwater from the northwest. The USGS particle tracking software MODPATH (Pollock, 1994) was used to estimate potential flow patterns. Particles were started near the bottom of the Santa Fe Group, where it is assumed that the deep saline water exists, in a southwest-northeast line roughly perpendicular to the direction of flow (from northwest to southeast). To assess flow conditions over a range of hydraulic conditions (pumping, recharge from surface water and applied irrigation), particles were run on a “snapshot” of water level conditions for six time periods. Three years were selected based on high, low, and average conditions; for each of the three years, particles were run during both non-irrigation and irrigation season water level conditions.

Results of particle tracking suggest that the deep saline water flows southeast and converges laterally in an area near well ISC-5, as it is forced upward toward the surface by the local geology (Figures 7-2 and 7-3). This is consistent with observed vertical gradients, which are upward near ISC-6 and ISC-7, suggesting upward flow.

The simulated particles generally discharge to the Montoya Drain; some particles discharge to the Rio Grande, and others diverge toward agricultural wells in the river valley and municipal wells near Santa Teresa and Cañutillo. The simulated flow rate of deep saline water flowing up and discharging to surface water bodies, based on analysis of the model water budget, is approximately 400 afy (0.55 cfs, Section 5.6.2; Table 5-2). While these results are generally consistent with findings of Moore et al. (2008) and Bastien (2009), note that the resolution of the model is likely not sufficient to adequately assess the ultimate discharge location, Rio Grande versus Montoya Drain. However, the model provides a reasonable representation of regional flow and potential location where the deep saline water converges and flows upward toward the surface.

7.1.3 Soil Salinity

Prior to development of this area, a soil survey was performed that highlighted areas of alkali soils (Nelson and Holmes, 1912). Areas with highly alkaline soils may represent pre-development locations where groundwater brines discharged to the land surface. Figure 7-3 shows these locations. Two locations are worth noting: the area around well ISC-6, and the area where the sharp increase in TDS, Cl, and Cl-Br ratios were observed in the Montoya Drain in 2000. These findings are not definitive on their own, because of changing conditions since 1912. However, together with particle tracking and Montoya Drain water quality results discussed above, these findings do support the hypothesis of potential upwelling of groundwater brines in this area.

7.1.4 Summary

Based on observed water quality data, historical soil salinity, and groundwater model particle tracking results, “Site 1” was delineated on Figure 7-3 as a potential location for a salinity control project. Mass loading, flow rates, and concentration of the salinity source are not well constrained with available data. Available data suggest that

chloride load from groundwater could have been as high as 5,000 to 7,500 tons/yr in February 2000, but decreased to between 50 and 2,500 tons/yr in February 2013. However, as discussed in Appendix C, the estimate for chloride load in 2000 may be an overestimate and should be used with caution.

One hypothesis for the apparent reduction in saline discharge to the drain is that it results from declining water levels owing to drought conditions. In this case, saline discharge would likely resume when groundwater levels rise, or it could migrate southward if groundwater levels remain depressed. However, the salinity source is not well characterized, and a more detailed evaluation (including additional data) would need to be performed to better characterize the source and how it may change in response to drought.

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—perhaps deep saline brines brought to the surface relatively quickly by faults or hydrothermal systems—that is not represented by the model and is not observed in existing groundwater wells.

Key data gaps that would need to be filled to better characterize the salinity source near Site 1 are as follows:

1. Uncertainty associated with the mass flux estimates. Measured flow rates and flow-weighted average concentration both have uncertainty, and that uncertainty is compounded when evaluating the difference in mass flux because of groundwater between two locations. This could partially be addressed by additional sampling and perhaps improving timing of the sampling.
2. Understanding of the salinity source. The source of the salinity is not well understood. The chemistry, particularly the observed increasing Cl-Br ratio in the Montoya Drain, suggests groundwater brines, but the flow rate and location where those brines travel to the surface is not well constrained.
3. Understanding of how the salinity source changes through time, both seasonally and in long-term response to droughts and wet periods.
4. Potential long-term effect of increased local municipal groundwater pumping on the salinity source.

Recommendations for addressing the data gaps can be found in Section 10.

7.2 Evaluation of Inflow to the Rio Grande near ISC-4 (Site 2)

The highest salinity groundwater in the study area is located just northwest of the El Paso Narrows, near well ISC-4 (Figure 7-3), with TDS concentrations in water from some wells exceeding 30,000 mg/L. The purpose of this section is to attempt to quantify the mass flux of saline groundwater to the Rio Grande and to identify data gaps associated with the quantification. Quantifying the mass flux can help in assessing the potential for a salinity control project that intercepts and treats saline groundwater before discharge to the Rio Grande.

The groundwater-surface water budget analysis, based in large part on USGS seepage studies and groundwater model results, suggests that groundwater discharge to the Rio Grande between Sunland Park Bridge and Courchesne Bridge is approximately 500 to 1,000 afy. This section evaluates whether the groundwater that is discharging to the Rio Grande is of similar quality to that of the wells near ISC-4; or more specifically, whether water of that quality could be captured and treated before discharge to the Rio Grande.

During the Rio Grande Salinity Coalition meeting on August 28, 2012, it was noted that groundwater at ISC-4 has a unique boron isotope signature. Accordingly, boron isotopes were used for this analysis, in addition to total boron, chloride, and TDS. Boron isotope samples from both groundwater and the Rio Grande were taken during 2 months: February 2007 (non-irrigation season; flows in the Rio Grande approximately 16 cfs) (Figure 7-5), and August 2006 (irrigation season; observed flow in the Rio Grande approximately 460 cfs) (Figure 7-6). Boron-11 (^{11}B) is the most abundant of the two stable isotopes of boron, constituting approximately 80 percent of all boron in nature, with Boron-10 (^{10}B) making up the remainder. The isotopic signature of boron is determined by measuring the ratio of $^{11}B/^{10}B$ and comparing to the ratio in a fixed standard. The signature is reported as a part per thousand (‰) difference from the standard (i.e., a percentage difference multiplied by 10), and depicted as a

delta symbol, $\delta^{11}B$ (i.e., the isotopic signature of boron). Values of zero indicate no difference from the standard, and positive values indicate enrichment of ^{11}B relative to the standard. For reference, $\delta^{11}B$ of seawater is approximately 40‰, so it is reasonable to assume that the sedimentary brines would have high $\delta^{11}B$ values. Samples can be compared, and mixing proportions may be estimated by combining $\delta^{11}B$, B, and flow of each source.

The boron observed in the downstream Rio Grande sampling site ("RG-PASO"; $\delta^{11}B$ = 30.2‰) during the non-irrigation season is significantly higher than the boron observed in the upstream Rio Grande site ("RG-CLUB"; $\delta^{11}B$ = 12.4‰; Figure 7-5). Other primary inflows along between RG-CLUB and RG-PASO, including the Montoya Drain ("DR-MONT"), Sunland Park wastewater ("WW-SUNL"), and El Paso Electric wastewater ("WW-EPE1" and "WW-EPE2"), generally have $\delta^{11}B$ values less than approximately 20‰, which cannot explain observed downstream value of 30.2‰. Only groundwater, as represented by well ISC-4B (37‰ in February 2007), has values greater than the RG-PASO measurement. This suggests that groundwater may be a significant source of ^{11}B to the Rio Grande between RG-CLUB and RG-PASO. A similar trend was observed during the irrigation season (Figure 7-6), although the trend is not as strong because of dilution. Flows in the Rio Grande are about an order of magnitude greater than during the non-irrigation season, whereas groundwater inflow is similar or less than during the non-irrigation season (Section 6), thereby minimizing the relative effect of groundwater inflow.

A quantitative mixing model was used to assess potential groundwater inflow to the Rio Grande (Table 7-1; see also Appendix C). The mixing model considered ^{11}B isotopic signatures, but also was constrained by TDS, chloride, and total boron concentrations. The $\delta^{11}B$ values suggest significant groundwater inflow (as represented by water in ISC-4A and ISC-4B) to the Rio Grande; however, the TDS and chloride concentrations suggest minimal groundwater inflow (as represented by water in ISC-4A and ISC-4B) to the Rio Grande. Accordingly, observed concentrations and flows were adjusted within reasonable bounds, based on assumed uncertainties, until mass balance could be obtained for all constituents.

Results of the mixing model analysis suggest that between approximately 1 and 1.5 cfs (between approximately 700 and 1,100 afy) of groundwater discharged to the Rio Grande in February 2007. These results are consistent with other estimates of groundwater inflow between Sunland Park Bridge and Courchesne Bridge (500 to 1,000 afy), based on USGS seepage studies and the NM OSE administrative model.

Results of the mixing model suggest that the average water quality of groundwater flowing into the Rio Grande between Sunland Park Bridge and Courchesne Bridge is somewhat similar to that observed at well ISC-4, but that it might have even higher boron concentration and $\delta^{11}B$, and slightly lower chloride (approximately 7,000 mg/L) and TDS (approximately 20,000 mg/L) concentrations, as compared to ISC-4. These concentrations appear to be consistent with a sedimentary brine source, perhaps mixed with some younger, cleaner groundwater. Mass flux of chloride from groundwater to the Rio Grande was estimated to be approximately 7,500 tons/yr. This mass loading rate is consistent with mass balance modeling of Mills (2003) and an isotopic mixing model (Hogan et al., 2007), which suggested that this site appears to contribute approximately 6,500 to 9,750 tons of chloride per year to the Rio Grande.

However, as noted in Appendix C, there is significant uncertainty associated with the results of the mixing model. Observed data had to be adjusted to obtain mass balance; and because of variable sampling times in August 2006, only the February 2007 results are presented here. It is recommended that additional sampling be performed similar to these previous sampling events. Consideration should also be given to variability in flows and lag times in flow between sampling locations when developing the sampling plan.

TABLE 7-1
Results of Mixing Model (Feb-2007)

		Adjusted					Observed				
Description	**Map Label**	**Flow (cfs)**	**B (mg/L)**	**$\delta^{11}B$ (‰)**	**TDS (mg/L)**	**Cl (mg/L)**	**Flow (cfs)**	**B (mg/L)**	**$\delta^{11}B$ (‰)**	**TDS (mg/L)**	**Cl (mg/L)**
Rio Grande at TX-260 (Country Club Rd) **(upstream end-member)**	RG-CLUB	18.7	0.24	15.5	769	152	15.6	0.27	12.4	840	190
Seepage to groundwater, "at TX-260" to "Near Sunland Park"		-3.5	0.24	15.5	769	152	-3.6	0.27	12.4	840	190
Evaporation		-0.5	0.00	0.0	0	0	0.0	0.00	0.0	0	0
Sunland Park Wastewater Discharge	WW-SUNL	2.9	0.55	20.6	1,472	394	3.0	0.55	16.5	1,500	420
Seepage to groundwater, "Near Sunland Park" to "at Sunland Park Bridge"		-0.5	0.24	15.5	769	152	-0.5	0.27	12.4	840	190
Groundwater inflow, "at Sunland Park Bridge" to "at Courchesne Bridge"		1.2	3.10	40.8	20,738	7,000	1.9	2.40	37.0	31,000	14,000
Montoya Drain	DR-MONT	18.2	0.59	17.9	1,956	456	20.8	0.74	14.3	2,300	570
Keystone Reservoir Inlet[1]		0.6	1.14	34.2	2,197	439	0.6	1.10	30.0	2,200	440
El Paso Electric Discharge 1	EPE1	0.6	0.70	22.1	3,781	1,186	0.6	0.70	21.1	3,800	1,200
El Paso Electric Discharge 2	EPE2	0.6	1.31	21.5	5,448	1,075	0.6	1.30	19.3	5,500	1,100
Rio Grande at El Paso (Courchesne Bridge) **(downstream end member)**	RG-PASO	38.4	0.56	22.7	2,181	564	38.4	0.61	30.2	1,900	470
Calculated based on mixing		**38.4**	**0.56**	**22.5**	**2,181**	**572**	**39.0**	**0.69**	**18.7**	**3,322**	**1,132**
Difference from observed		0.00	0.00	-0.2	0	8	0.61	0.08	-11.5	1,422	662
Percent difference from observed		0%	0%	-1%	0%	1%	2%	13%	-38%	75%	141%

[1]Keystone Reservoir measurements from 2008, except $\delta^{11}B$, which was approximated. Results are insensitive to these values since it is low-flow.

The source of the high TDS and high $\delta^{11}B$ groundwater discharging to the Rio Grande, including water at wells near ISC-4, is assumed to be sedimentary brines; however, the flow path of these brines to the area around ISC-4 is not well characterized. Because the wells with observed high-salinity water are on the northern side of the Rio Grande and because groundwater flow in the area is from north to south, it is reasonable to assume that the source of water is to the north. It is possible that a portion of the brines near Site 1 do not discharge to the Montoya Drain; rather, they continue to flow south and discharge directly to the Rio Grande, or there may be another path south of Site 1 for deep sedimentary brines to flow toward the surface. One such pathway may be upward flow along the Mesilla Valley fault zone.

The following additional hypotheses of the source of salinity and high $\delta^{11}B$ values at ISC-4 were raised by the Rio Grande Salinity Coalition at the August 28, 2012, meeting:

1. Deep groundwater brines flowing northeast from Mexico
2. Influence of the nearby Cristo Rey volcanic rocks, located just south of Sunland Park and west of El Paso Narrows

Both hypotheses represent a salinity source from the south or southwest. The limited available data do not show high TDS water in that area (Figure 5-43); water from nearby wells to the southwest has TDS concentration ranging from 1,200 to 3,200 mg/L. However, the depth of those wells is unknown, and it is possible that deep groundwater brines may be flowing below the wells, and they are therefore not represented in these samples. Lack of groundwater quality data immediately south/southwest of the Rio Grande between Sunland Park Bridge and Courchesne Bridge is a significant data gap.

For the source to be from the south or southwest, groundwater historically would have had to have been pulled under the river, resulting in high salinity observed just north of the river at ISC-4 and nearby wells. This is conceivable, although available data are insufficient to draw historical water level maps and flowlines to confirm or deny the possibility of northward flow under the Rio Grande.

Based on this analysis, further evaluation of this area is recommended for a potential salinity control project. The site is labeled “Site 2” on Figure 7-1 and has been split into two subsites: “Site 2S” assumes that the saline source flows from the south or southwest toward the Rio Grande, and “Site 2N” assumes that the saline water flows from the north toward the Rio Grande.

While additional sampling and analysis is recommended to confirm that the saline flux from groundwater to the Rio Grande is significant, it is also recommended that additional hydrogeologic and geochemical investigations be performed to help evaluate the source of water to these wells. Understanding the source of water is important to design a salinity control project. It is assumed that the uniquely high $\delta^{11}B$ observed in groundwater may be a valuable tracer in assessing the source of water discharging to the Rio Grande.

SECTION 8

Ecosystem Framework

This section summarizes biological resources that may be dependent on Rio Grande water or shallow groundwater. The purpose of this section is to provide a framework within which potential environmental impacts of a salinity control project could be measured in a subsequent work effort. A more complete assessment of the ecosystem framework is found in Appendix D.

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 (USGS, 2011). Each of these macro-level land covers contains several subclasses, classified at the ecosystem level within the study area as shown on Figure 8-1. The dominant soil types within the study area include Agua variant and Belen variant, Bluepoint loamy sand, and Harkey loam sand, according to the Natural Resources Conservation Service (NRCS) Web Soil Survey (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; USIBWC, 2004), the study area supports potential jurisdictional waters of the United States and potential waters in the states of New Mexico and Texas, including wetlands, as shown on Figure 8-2. A wetland delineation of the potential jurisdictional wetland features is recommended to establish a baseline before 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 8-1); Texas horned lizard and spotted bat (Table 8-2); 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 (Table 8-3). 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.

TABLE 8-1
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 *Scientific Name*	**USFWS**	**NMRPTC**	**TPWD**	**Habitat Requirements**	**Within Known Distribution**	**Potential Habitat Present**
mescalero milkwort *Polygala rimulicol mescalerorum*		E		Crevices in sandy limestone cliffs in montane scrub at 5,700-6,300 feet	No	No
desert night-blooming cereus *Cereus greggii var. greggii*		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 *Coryphantha sneedii sneedii*	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 *Opuntia arenaria*		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, 2012a; USFWS, 2012b

TABLE 8-2

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 *Scientific Name*	**USFWS**	**NMDGF**	**TPWD**	**Habitat Requirements**	**Within Known Distribution**	**Potential Habitat Present**
MOLLUSC						
Doña Ana talus snail *Sonorella todseni*	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 *Notropis simus*			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 *Hybognathus amarus*	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 *Trimorphodon vilkinsonii*			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 *Phyrnosoma hernandesi*			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 *Phyrnosoma cornutum*			T	Open, arid, and semi-arid regions with sparse vegetation, including grass, cactus, scattered brush or scrubby trees; widespread, particularly in lower elevations and open country	Yes	Yes
BATS						
spotted bat *Euderma maculatum*		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
Sources: CH2M HILL and Geo-Marine, 2000; USIBWC, 2004; TPWD 2012; NMDGF, 2012; USFWS 2012a; USFWS, 2012b

TABLE 8-3
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

	Designation or Status					
Common Name *Scientific Name*	**USFWS**	**NMDGF**	**TWPD**	**Habitat Requirements**	**Within Known Distribution**	**Potential Habitat Present**
southwestern willow flycatcher *Empidonax traillii extimus*	E	E	E	Brushy fields, thickets along streams, and open woodland edges	Yes	Yes[c]
northern aplomado falcon *Falco femoralis septentrionalis*	E	E		Brushy prairie and yucca flats	Yes[b]	No
American peregrine falcon *Falco peregrinus anatum*		T	T	Canyons with steep, rocky cliffs, close to water	Yes	Yes[a]
arctic peregrine falcon *Falco peregrinus tundrius*		T		Canyons with steep, rocky cliffs, close to water	Yes	Yes[c]
bald eagle *Haliaeetus leucocepalus*		T		Riparian; timbered areas along coasts, large lakes, and rivers	Yes	Yes[d]
common black hawk *Buteogallus anthracinus anthacinus*		T		Riparian areas	Yes	Yes[c]
interior least tern *Sterna antillarum*	E	E	E	River sandbars and beaches	Yes[b]	Yes[e]
broad-billed hummingbird *Cynanthus latirostris magicus*		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 *Calypte costae*		T		Deserts, washes, mesas, sage scrub, and arid hillsides	Yes[c]	Yes
Bell's vireo *Vireo bellii*		T		Dense shrubby vegetation in riparian, second-growth forests and mesquite brushlands	Yes	Yes
gray vireo *Vireo vicinior*		T		Riparian willows, thorn scrub, oak-juniper woodlands, pinon-juniper woodlands and mesquite shrublands; potential at Sunland Park	Yes	Yes
Baird's sparrow *Ammodramus bairdii*		T		Desert grassland and mountain meadows	Yes[c]	Yes[c]

TABLE 8-3
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

	Designation or Status					
Common Name *Scientific Name*	**USFWS**	**NMDGF**	**TWPD**	**Habitat Requirements**	**Within Known Distribution**	**Potential Habitat Present**
common ground dove *Columbina passerina pallescens*		E		Farms, orchards, wood edges, and roadsides; xeric riparian areas	Yes	Yes
yellow-billed cuckoo *Coccyzus americanus occidentalis*	C			Riverine woodlands, thickets, and farms	Yes	No
Mexican spotted owl *Strix occidentalis lucida*	T		T	Dense coniferous forests	Yes	No
whooping crane *Grus americana*	Experi-mental	E		Marshes, wetlands, and pastures	Yes[f]	No[f]
brown pelican *Pelicanus occidentalis*		E		Occasionally inland in southwestern region	Yes	No[f]
neotropic cormorant *Phalacrocorax brasilianus*		T		Generally on larger bodies of water; known to occur only in Sierra and Socorro Counties	Yes[a]	No

[a]Breeding & Migratory
[b]Historical
[c]Migratory only
[d]Winter
[e]Only in dry years
[f]Accidental

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, 2012a; USFWS, 2012b; USFWS 2012c; NMACP, 2012

SECTION 9

Anthropogenic Framework

The surface and groundwater systems in the Distal Mesilla Basin are currently strongly driven by human factors. Because these factors may change, it is important to consider what the potential effects may be on the surface and groundwater systems, particularly in the context of how a potential salinity control project might be affected. Following is a summary of how human factors affect the current system, how changes to those factors may affect the natural system in the future, and how those changes may affect a potential salinity control project.

9.1 Surface Water

Land use in the Distal Mesilla area has historically been primarily agricultural, with increasing municipal and industrial land uses. Agriculture is the primary driver of the surface water flow regime in the Distal Mesilla area, resulting in a complex network of laterals and drains to deliver water to farms and to collect runoff and shallow return flows for return to the Rio Grande.

Timing and magnitude of Rio Grande flow is controlled by releases from Caballo Reservoir. These releases are timed to coincide with the irrigation season, typically March through September. Similarly, flows in the laterals and drains are related to the agricultural practices and are typically significantly greater during the irrigation season. Flow rates in the Rio Grande are based on agreements between Texas, New Mexico, and Mexico governing the allocation of Rio Grande water (Section 6.2.1), which take into account hydrologic conditions (i.e., natural flows in the Rio Grande and quantity of water in storage in the reservoirs). Therefore, potential changes to policy, hydrology, and land use may affect the surface water flow system. Potential changes may include the following:

- **Policy changes**. Because Rio Grande flows are determined by agreements between New Mexico and Texas, potential policy changes have the potential to change flows in the Rio Grande. Potential policy changes could either increase or decrease flows in the Rio Grande in the study area.
- **Decreasing agricultural land use**. The historical trend in the area has been a shift in land use from agricultural to municipal and industrial. Typically, for the same land area, municipal and industrial water use is less than agricultural water use. In addition, current agricultural water use is primarily from surface water, whereas current local municipal water use is primarily from groundwater.

  It follows that, if the historical trend of shifting land use from agricultural to urban continues, it is likely that water flow in the agricultural laterals and drains may decrease. Flows in the Rio Grande, however, may or may not change in response to decreasing agricultural water use, because it is likely that any decrease in usage in the Rio Grande would be offset by a potential increase in water usage elsewhere. Any potential change in Rio Grande flows in response to land use changes would depend on the location of potential “offset water use,” and potential policy and hydrological changes would likely outweigh any effect of local water use changes.
- **Increasing municipal and industrial land use**. If municipal land use continues to increase, it is likely that an increase would occur in municipal, and potentially industrial, wastewater inflow to the Rio Grande. Typically, wastewater flows are relatively constant throughout the year, and may be more saline than natural flows, particularly if the water source is relatively saline groundwater.
- **Hydrological changes**. The surface water system is defined by a complex system of laterals and drains. It is possible that these laterals and drains may be operated differently, existing laterals or drains may be rerouted or retired, and/or new laterals and drains may be constructed. Any of these could result in significant changes to the local surface water system. In addition, future natural hydrological changes, such as a potential decrease in water availability resulting from climate change, may have the potential to change the surface water regime.

9.2 Groundwater

The groundwater system is also heavily influenced by human activity. As discussed in the hydrogeology section, the primary sources of recharge to the groundwater in the study area are seepage from the surface water system and deep percolation of applied irrigation water. Also, a significant amount of groundwater is used for municipal and industrial water supply, as well as for supplemental irrigation for agricultural lands.

It follows that potential changes to policy and land and water use may affect the groundwater flow system. These changes may include the following:

- **Municipal and industrial water use**. Current municipal and industrial water use includes groundwater pumping for El Paso, Santa Teresa area, Sunland Park area, and Ciudad Juarez:
  - **El Paso.** El Paso Water Utilities currently pumps approximately 20,000 afy from the Cañutillo wellfield. Cañutillo pumping has a significant effect on local groundwater levels, as well as on rates of infiltration from the Rio Grande.
  - **Santa Teresa area.** Municipal pumping in the Santa Teresa area has recently been approximately 6,000 afy. The source of water to these wells is partially extraction of water from storage, but also includes intercepting water that otherwise would have discharged to the Rio Grande. Historical pumping has resulted in drawdown of approximately 10 to 15 feet (Section 5.0). Groundwater rights in the Santa Teresa area are more than double what is currently being used, and it is likely that pumping from the Santa Teresa area will increase. If so, the increased pumping would result in increased drawdown in the area (water to the wells is withdrawn from aquifer storage), as well as a reduction of groundwater discharge to the Rio Grande (water to the wells is intercepting water that otherwise would have discharged to the Rio Grande).
  - **Ciudad Juarez.** Municipal pumping from the Conejos-Medanos wellfield (Figure 5-5) began in 2010; current pumping is approximately 25,000 afy (Transboundary Aquifer Assessment Program, 2010). As discussed in Section 5.0, it is likely that continued pumping from the Conejos-Medanos wellfield would decrease or even eliminate groundwater discharge to the Rio Grande in the Sunland Park area. These effects may not occur for decades, although they may occur sooner. Additional evaluation is necessary to help assess timing and magnitude of potential effects.
  - **Sunland Park area**. The Sunland Park area also uses water for municipal and industrial purposes. Two notable industrial groundwater rights are held by El Paso Electric (2,825 afy) and Sunland Park Development Company (1,630 afy), both with points of diversion near the Rio Grande. Recent El Paso Electric pumping has been close to 100 afy, and there has been no reported pumping from Sunland Park Development Company. In addition, there is a municipal groundwater right for Camino Real Regional Utility Authority, with one point of diversion near the Rio Grande. Recent pumping from Camino Real has not been near the Rio Grande, although it has occurred near Santa Teresa and has been accounted for there. Similar to pumping from Ciudad Juarez and Santa Teresa, potential additional future pumping in the Sunland Park area could reduce or even eliminate groundwater discharge to the Rio Grande in the Sunland Park area.
  - ***The potential for nearby pumping to reduce or eliminate discharge of saline groundwater to the Rio Grande is a critical finding***. It is strongly recommended that the effect of these wellfields be considered when evaluating the long-term effectiveness of a potential salinity control measure in the Distal Mesilla area. If pumping from Conejos-Medanos and/or the Santa Teresa and Sunland Park areas causes reduction or cessation of saline groundwater discharge to the Rio Grande or the Montoya Drain, short-term benefits of reduced salinity loads in the Rio Grande may occur. However, the saline mass would remain in the groundwater system, slowly moving toward the pumping wells. This differs from a salinity control project, where salinity would be removed from the system.

- **Agricultural water use**. Agricultural water use is currently close to 18,000 afy in the study area, primarily in the northern part. This makes up a significant portion of the water budget and has the potential to affect flows in both the Rio Grande and local drains.
- **Policy**. As discussed above, surface water availability in the study area is heavily influenced by agreements between New Mexico and Texas. Any policy changes that result in changes in Rio Grande flows and water availability may be offset by local groundwater pumping, particularly agricultural pumping. Depending on how policy may change, groundwater pumping could either increase or decrease, although an increase is more likely.
- **Agricultural land use**. Deep percolation of applied irrigation water is a significant source of recharge to the local groundwater system. If agricultural land use decreases, then local recharge to the groundwater from agricultural areas would be expected to decrease. However, this decreased recharge may be partially or entirely offset by increased infiltration from the Rio Grande, if Rio Grande flows are greater because of decreased agricultural use.
- **Surface water flows**. Infiltration from the Rio Grande and laterals is also a significant source of recharge to the local groundwater system. Infiltration from the Rio Grande and laterals is dependent on the stage of the rivers/laterals, the conductance of those laterals, and groundwater elevations. A decrease in surface water flows because of changes outlined in the surface water section (policy changes, climate change, etc.) would likely decrease the amount of recharge to the groundwater that is occurring from surface flows.
- **Hydrologic**. Most of the laterals in the area are currently unlined, and they serve as a source of recharge to the groundwater system. If these laterals were lined, a decrease in recharge would be expected, which may result in a decline in local groundwater levels.

9.3 Anthropogenic Framework Summary

The surface water and groundwater systems in the area are strongly interconnected, and they are heavily influenced by human factors. Potential anthropogenic changes outlined above generally cannot be considered alone, because a change to one part of the system will likely affect other parts. For example, policy changes resulting in less surface water availability for agriculture would likely result in an increase in groundwater usage for agriculture, which could affect the amount of seepage from the river to the groundwater. Accordingly, it is recommended that a detailed groundwater model be used to assess the effect of anthropogenic changes on a potential salinity control project.

Although changes in land/water use and changes in policy may have a significant effect on the local surface and groundwater systems, it is likely that the municipal pumping will be the most relevant anthropogenic factor to be considered when planning for a potential salinity control project. Groundwater pumping from the Santa Teresa and Sunland Park areas, as well as the Conejos-Medanos wellfield, may result in a decrease or even elimination of saline groundwater discharge to the Rio Grande.

SECTION 10

Summary and Recommendations

Results of this analysis suggest that two areas may be targeted for a potential salinity capture project (Figure 7-3). Each site is summarized below and in Table 10-1, followed by sections summarizing other considerations and recommendations for next steps.

TABLE 10-1
Summary of Potential Salinity Control Sites

	Site 1 (Montoya)	Site 2 (ISC-4 area)
Cl Load (tons/yr)	As high as 7,500 (in 2000) 50 to 2,500 (in 2013, drought)	7500 (change during drought unknown)
TDS concentration of groundwater (mg/L)	4,000 to >20,000	15,000 to 30,000
Groundwater flow rate (afy)	100 to 1,500	500 to 1,000
Groundwater flow rate (cfs)	0.1 to 2	0.7 to 1.5
Localization (cross-sectional width)	< 0.5 mile to 2 miles	2 miles
Additional information/analysis needed to quantify flux	Relatively complicated; may require long-term monitoring and installation of new well(s)	complicated
Effect of other pumping; potential influence and timing	Potential; later than Site 2	Very likely; sooner than Site 1
Average percent reduction of Cl load at El Paso, non-irrigation season[1]	8%	9%
Average percent reduction of Cl load at El Paso, irrigation season[1]	1%	3%

[1] Assumes 30 percent of source is captured.
Site 1 non-irrigation season based on two points in time (2000 and 2013), using actual Cl load in the Rio Grande at El Paso.
Site 2 non-irrigation season based on source of 7,500 tons/yr and average non-irrigation season load at El Paso from Hogan (2010) (2,000 tons/mo).
Site 1&2 irrigation season estimates assume source is constant throughout the year (Site 1 assumed to be long-term average of 2,000 tons/yr) and long-term average irrigation season load at El Paso from Hogan (2010) (7,000 tons/mo)

10.1 Summary of 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). Site 1 was selected based on observed increase in TDS and Cl-Br ratios in the Montoya Drain near Country Club Road, as well as simulated flow paths of deep groundwater that converge in this same area (Figure 7-3). Model results suggest a flux of approximately 400 afy. Nearby deep groundwater wells ISC-5B and ISC-6B have TDS concentrations between 4,000 and 5,000 mg/L. Based on a mixing model, the chloride load contributed to the drain near Site 1 could have been as high as 5,000 to 7,500 tons/yr in February 2000, but decreased to between 50 and 2,500 tons/yr in February 2013. While both results are uncertain, the estimate for chloride load in 2000 is highly uncertain and should be used with caution.

One hypothesis for the apparent reduction in saline discharge to the drain is that it results from declining water levels because of drought conditions. In this case, saline discharge would likely resume when groundwater levels rise, or it could migrate southward if groundwater levels remain depressed. However, the salinity source is not well characterized, and a more detailed evaluation (including additional data) would need to be performed to better characterize the source and how it may change in response to drought.

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—perhaps deep saline brines brought to the surface relatively quickly by faults or hydrothermal systems—that is not represented by the model and is not observed in existing groundwater wells.

To evaluate the potential for a salinity control project at Site 1 to reduce salinity loads in the Rio Grande at El Paso, an understanding is needed of how both the groundwater source and the load in the river change through time. While the chloride load of groundwater discharging to the drain apparently decreased between 2000 and 2013, so too did the chloride load in the Rio Grande. In both cases, the groundwater source represented approximately 25 percent of the total load in the Rio Grande at El Paso. Accordingly, if a potential salinity control project were able to capture and treat 30 percent of that load, the load at El Paso could be expected to decrease by approximately 8 percent (Table 10-1) during the non-irrigation season. It is important to note that these are two points in time, and there is uncertainty associated with estimates of groundwater load to the Montoya Drain at both times. Additional characterization of the salinity source is required to better assess expected potential reduction of load at El Paso under varying future conditions. Key data gaps that would need to be filled to better characterize the salinity source near Site 1 are as follows:

1. Uncertainty associated with the mass flux estimates. Measured flow rates and flow-weighted average concentration both have uncertainty, and that uncertainty is compounded when evaluating the difference in mass flux because of groundwater between two locations. This uncertainty could partially be addressed by additional sampling and perhaps improving timing of the sampling.
2. Understanding of the salinity source. The source of the salinity is not well understood. The chemistry, particularly the increase in Cl-Br ratios observed in the Montoya Drain, suggests groundwater brines, but the flow rate and location where those brines travel to the surface is not well constrained.
3. Understanding of how the salinity source changes through time, both seasonally and in long-term response to drought and wet periods.
4. Potential long-term effect of increased local municipal and industrial groundwater pumping on the salinity source.

10.2 Summary of Southern Site (Site 2)

The southern site, Site 2, has high TDS concentrations observed in groundwater (typically greater than 30,000 mg/L at ISC-4). Observed surface water flow data (USGS, 2012) and groundwater modeling suggest that groundwater discharges to the Rio Grande near Site 2 at a rate of approximately 500 to 1,000 afy. Mass balance mixing models done as part of this work suggest that the average TDS concentration of the groundwater discharging to the river is approximately 20,000 mg/L, with chloride concentrations of approximately 7,000 mg/L, although there is significant uncertainty associated with these estimates. These estimates result in mass flux of chloride from groundwater to the Rio Grande of approximately 7,500 tons/yr, which is consistent with mass balance modeling of Mills (2003) and an isotopic mixing model (Hogan et al., 2007), suggesting that this site appears to contribute approximately 6,500 to 9,750 tons of chloride per year to the Rio Grande. A potential salinity control project at Site 2 could reduce average non-irrigation season chloride loads in the Rio Grande at El Paso by approximately 9 percent (Table 1-1).

Key data gaps for Site 2 include the following:

1. The source of saline groundwater is not well characterized, including the direction of flow. A better understanding of the source of saline water is important for designing a potential salinity control project.
2. There is significant uncertainty regarding the rate of groundwater discharge to the Rio Grande near Site 2, the amount of saline mass flux discharging to the groundwater, and how that discharge changes seasonally and in response to drought and wet conditions.

3. Potential magnitude and timing of effects of municipal and industrial pumping from wells near Santa Teresa and Sunland Park, as well as the Conejos-Medanos wellfield, are unknown. It is likely that in the future, pumping from these wells will cause any discharge of saline groundwater to the Rio Grande to cease. However, timing of these effects is uncertain.

10.3 Summary of Other Considerations

Municipal pumping from the Conejos-Medanos wellfield (Figure 5-5) began in 2010, with current pumping of approximately 25,000 afy (Transboundary Aquifer Assessment Program, 2010). The source of water to these wells in the short term is dominantly extraction of water from storage; however, the source of water will likely shift toward interception of water that otherwise would have discharged to the Rio Grande and drains, as well as additional induced inflow from the Rio Grande. It is likely that pumping from the Conejos-Medanos wellfield would decrease or even eliminate groundwater discharge to the Rio Grande at Site 2. These impacts may not occur for decades, although they may occur sooner.

Similarly, the source of water for municipal and industrial wells in the Santa Teresa and Sunland Park areas is effectively the same as that of the Conejos-Medanos wellfield. Municipal pumping near Santa Teresa is currently approximately 6,000 afy, which is less than half of permitted pumping. If pumping near Santa Teresa and/or Sunland Park increases, it would likely result in increased drawdown in the area, as well as a reduction of groundwater discharge to the Rio Grande and possibly to the Montoya Drain (water to the wells is intercepting water that otherwise would have discharged to the Rio Grande or the Montoya Drain).

Evaluation of a potential salinity control project should take into consideration potential groundwater pumping from near Santa Teresa, Sunland Park, and the Conejos-Medanos wellfield. The concept of the salinity control project evaluated here is that saline groundwater that otherwise would have discharged to the Rio Grande or Montoya Drain is intercepted and treated. This concept fundamentally assumes that the saline groundwater would otherwise be discharging to the Rio Grande or Montoya Drain.

If pumping from Conejos-Medanos and/or the Santa Teresa or Sunland Park areas causes reduction or cessation of saline groundwater discharge to the Rio Grande or the Montoya Drain, short-term benefits of reduced salinity loads in the Rio Grande may occur. However, the saline mass would remain in the groundwater system, slowly moving toward the pumping wells. This differs from a salinity control project, where salinity would actually be removed from the system.

It is recommended that a groundwater model be developed that extends to the true southern boundary of the Mesilla Basin in Mexico. It is also recommended that simulations be run using a range of projected pumping to evaluate how groundwater discharge to the Rio Grande may decrease or even stop, and what the timing of those effects may be. The USGS is currently working on such a model that could be used for these evaluations.

10.4 Recommendations

The following subsections summarize recommendations for next steps. Sections 10.4.1 and 10.4.2 discuss the individual sites, Section 10.4.3 discusses both sites, and Section 10.4.4 provides general recommendations.

10.4.1 Northern Site

Available data suggest that a potential salinity control project at Site 1 could reduce average non-irrigation season chloride loads in the Rio Grande at El Paso by approximately 8 percent. If such a project is considered, it is recommended that a detailed hydrogeologic and geochemical evaluation be performed near Site 1 to evaluate the location of the salinity source, the flow rates and salinity of groundwater that discharges to the Montoya Drain, and the way in which flow rates may change seasonally and in response to drought and wet periods. Specific recommendations include the following:

1. Perform additional detailed localized flow and water quality sampling along the Montoya Drain. Evaluation of these samples would help in assessing the rate and water quality of localized groundwater inflow to the drain. Sampling should be done during the irrigation season as well as during the non-irrigation season to help

evaluate seasonal changes. It may be useful to have multiple sampling events within each season to help reduce uncertainty associated with individual sampling events. Sampling should also be performed over the course of several years to evaluate how saline discharge to the drain changes in response to drought and wet conditions. Due to changing flow conditions, an attempt should be made to time sampling according to the velocity of water in the drain, such that the same water is being sampled in the different locations.

2. Perform detailed, localized groundwater sampling in conjunction with surface water sampling above. Groundwater elevation and water quality should be measured at all wells near the Montoya Drain, and some additional wells more distal to the drain should also be sampled. Detailed, localized groundwater level maps should be developed for the area for each sampling event, and compared with the elevation of the water in the drain. The purpose of the groundwater evaluation is to help identify the location of the salinity source, as well as to constrain estimates of groundwater flux to the drain. Additional work that could support the groundwater analysis includes:
    a. Installing one or more new groundwater monitoring wells adjacent to the Montoya Drain, near Country Club Road, and collection both groundwater level data and depth-specific groundwater quality data at the new well(s).
    b. Updating the survey of Montoya Drain elevations, if the elevation is suspected to change through time. The last known survey was performed in 2004.
3. If the above suggests a high-temperature source, thermal sensors could be used to help identify the location of the potential salinity source.
4. Perform an assessment of how potential increases in nearby municipal groundwater pumping may affect future flows of the salinity source near Site 1.

10.4.2 Southern Site

The southern site (Site 2) has high salinity observed in groundwater. Multiple analyses suggest that the Rio Grande is gaining near Site 2 and that there is significant saline mass flux discharging to the river. However, the source of this salinity is not well constrained.

Key data gaps discussed above should be filled before designing a potential salinity control project at Site 2. Recommendations for filling these data gaps include the following:

1. Develop a groundwater model that extends to the true southern boundary of the Mesilla Basin, and run simulations using a range of projected pumping to evaluate how groundwater discharge to the Rio Grande may decrease or even stop and what the timing of those effects may be. The USGS is currently working on such a model (Crilley, 2012), and that model could be used for these evaluations.
2. Collect additional detailed flow and water quality measurements to estimate groundwater discharge rates and saline mass flux to river. These sampling events should be similar to those performed in February 2007 and evaluated here, including flow measurements and a full suite of water quality parameters with boron isotopes. Consideration should also be given to variability in flows and lag times in flow between sampling locations when developing the sampling plan. Mixing models, similar to the one performed in this work, should be used to quantify the groundwater contribution to the Rio Grande.
3. Perform additional hydrogeologic and geochemical investigations to help evaluate the source of water to these wells. Emphasis should be placed on understanding the direction of groundwater flow that is discharging to the Rio Grande, the longevity of the source of the flow, and the potential connection between the source at Site 2 and the source at Site 1. In addition, if the source is upgradient of Site 2, it is possible that saline water of even higher concentration could be intercepted in that area. It is likely that recent geochemical sampling performed by the USGS (John Bumgarner), and the evaluation of those samples (which is in progress), could be used as a basis for this evaluation. Specific investigations may include the following:
    a. Perform a detailed local groundwater level evaluation, including hydrographs and water level maps for different seasons, combined with a detailed survey of water surface elevation (stage) of the Rio Grande.

The purpose is to refine spatial location of groundwater discharge to the Rio Grande and to evaluate seasonal and long-term changes in that discharge.

b. Gather additional geochemical samples from local wells, including $\delta^{11}B$. It is recommended that a sampling plan be developed to include key wells that were not previously sampled, such as wells south and southwest of Sunland Park, and wells north, northeast, and northwest of ISC-4.

c. Perform additional geochemical evaluations along the Montoya Drain. The purpose is to help assess the location of groundwater brine discharge to the drain, which may help assess the location of the groundwater brine source. These evaluations should include mixing models with at least two groundwater sources: old groundwater brines, and younger, cleaner groundwater. The mixing models could be performed in conjunction with the Rio Grande mixing models to help evaluate potential connectivity between Site 1 and Site 2.

d. Identify and fill data gaps based on the above. Filling data gaps may include drilling additional test wells in key locations, particularly to the south and southwest of Sunland Park, if the groundwater brine source is potentially in that direction.

10.4.3 Northern Versus Southern Site

Both sites currently appear to have a similar magnitude of saline flux to surface water, and one site is not currently favored over the other for additional investigations. Based on the additional evaluations made above, specifically the saline mass flux and the ability to capture that mass flux, recommendations could be made for a preferred site. If the evaluation of the southern site suggests that there is no connection to the source at the northern site (i.e., two distinct and separate salinity sources), it is possible that both sites could be recommended for potential salinity control projects.

10.4.4 General Recommendations for Design of Potential Salinity Control Project

Once a general location for a potential salinity control project is selected, it is recommended that the following general tasks be performed to design it. This general work plan would need to be refined to conform to the more detailed analyses recommended above. It also assumes that (1) an analysis has been performed on potential magnitude and timing of effects of municipal pumping from the Santa Teresa area and the Conejos-Medanos wellfield and (2) that results of the analysis suggest that saline groundwater will continue to discharge to the Rio Grande for the foreseeable future. The design tasks are as follows:

1. Develop a detailed local groundwater model that is based on results of the additional local hydrogeologic and geochemical investigations recommended above.
2. Use the groundwater model to simulate preliminary potential configurations of capture wells. Evaluate the wells' ability to capture the source, and evaluate the effect they may have on local surface water bodies. It is recommended that capture scenarios consider a range of future land use and water use regimes.
3. Refine potential locations of capture wells, using field data:
   a. Use a lithologic database developed as part of this project to help assess potential areas of higher permeability for siting capture wells.
   b. Perform field testing to find local areas of higher permeability. This may include aquifer tests performed at existing wells or potential new test drilling of wells.
   c. Update the groundwater model based on additional field data, and reassess capture scenarios.

SECTION 11

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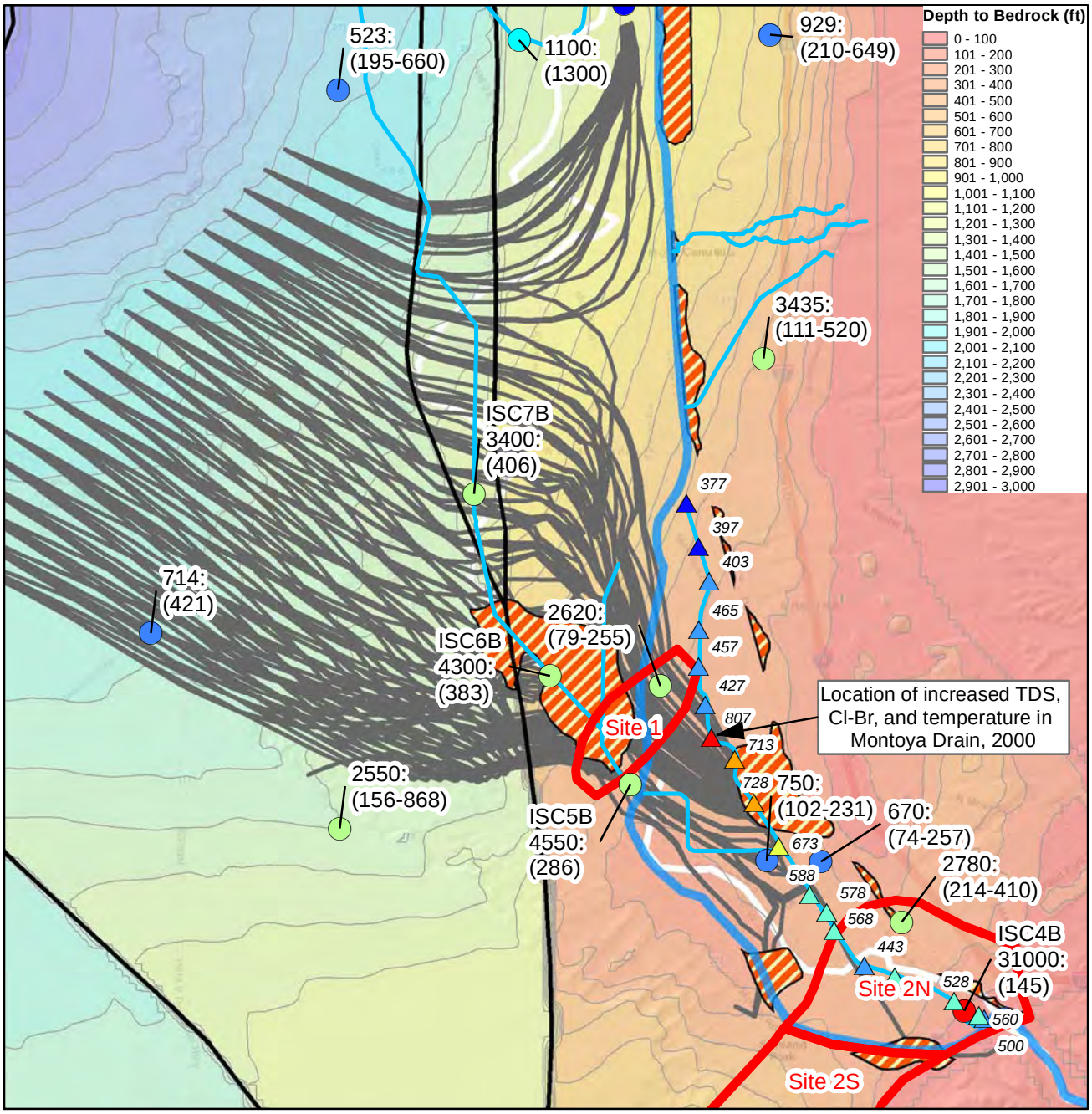
Figures



LEGEND

- Sites for Potential Salinity Control Project
- Rio Grande
- Faults
- Particle Traces
- Alkali Soils, 1912 (Nelsom and Holmes, 1912)

Median TDS in deep groundwater mg/L (label = value: depth)

- <= 500
- 501 - 1,000
- 1,001 - 2,000
- 2,001 - 5,000
- 5,001 - 10,000
- 10,001 - 20,000
- > 20,000

Cl-Br Ratio Montoya Drain

- < 400
- 401 - 500
- 501 - 600
- 601 - 700
- 701 - 800
- > 800

Data Sources:
--Particles: SSPA 2007 model
--TDS: NM ISC compendium Layer: Hawley, pers. comm.
--Cl-Br ratios: Bakker, et al., 2000

0 0.5 1
Miles

N

VICINITY MAP

FIGURE 1-1
Particle Traces
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

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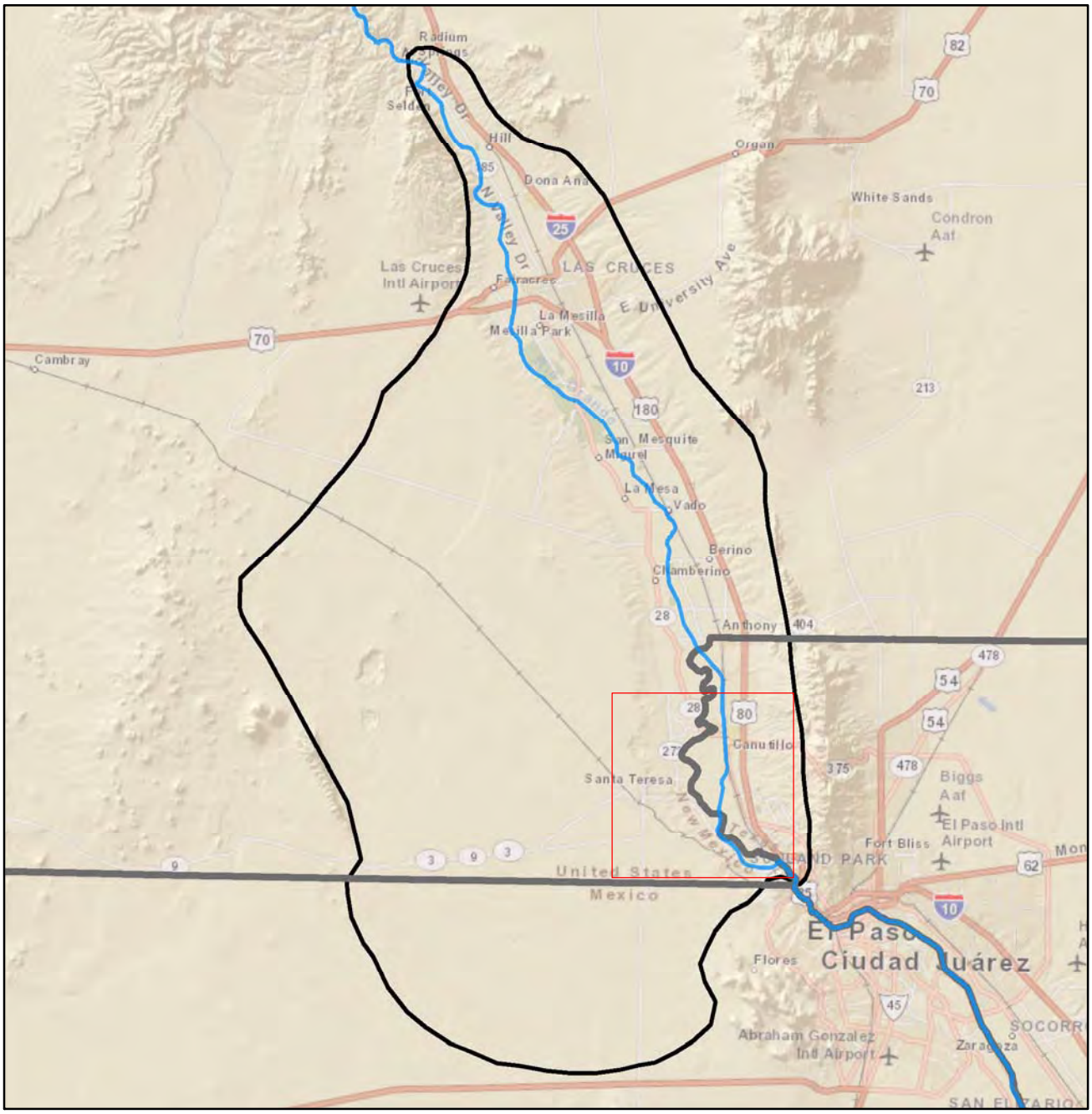


VICINITY MAP

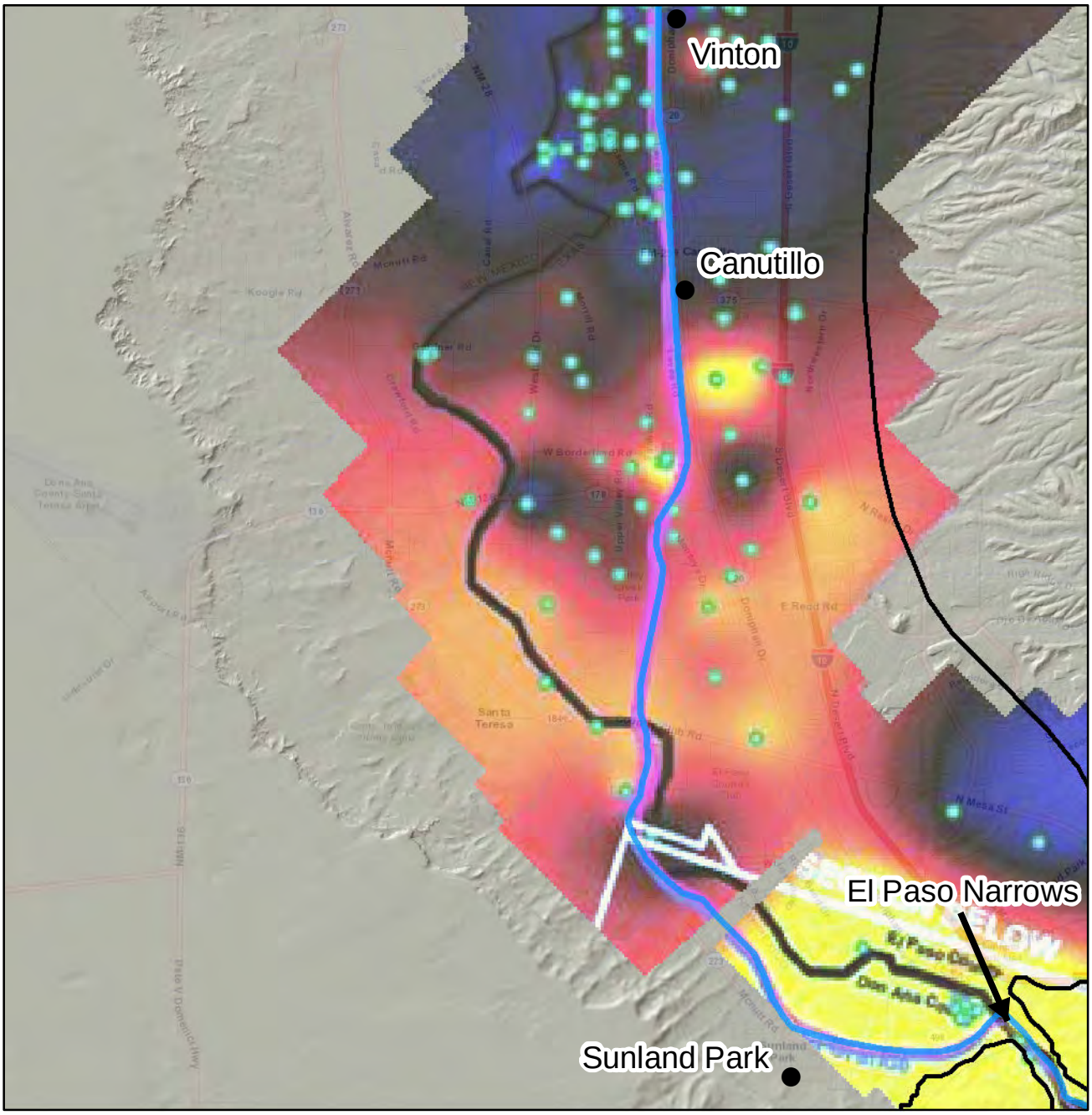
LEGEND

- Rio Grande
- Appoximate Boundary, Mesilla Groundwater Basin
- Study Area (and Extent of Subsequent Figures)

N

0 2.5 5 10 15
Miles

FIGURE 2-1
Study Area
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

Rio Grande

Approximate Extent of Alluvium

Data Source:
Moyer, et al. (2009)

Total disolved solids, in milligrams per liter

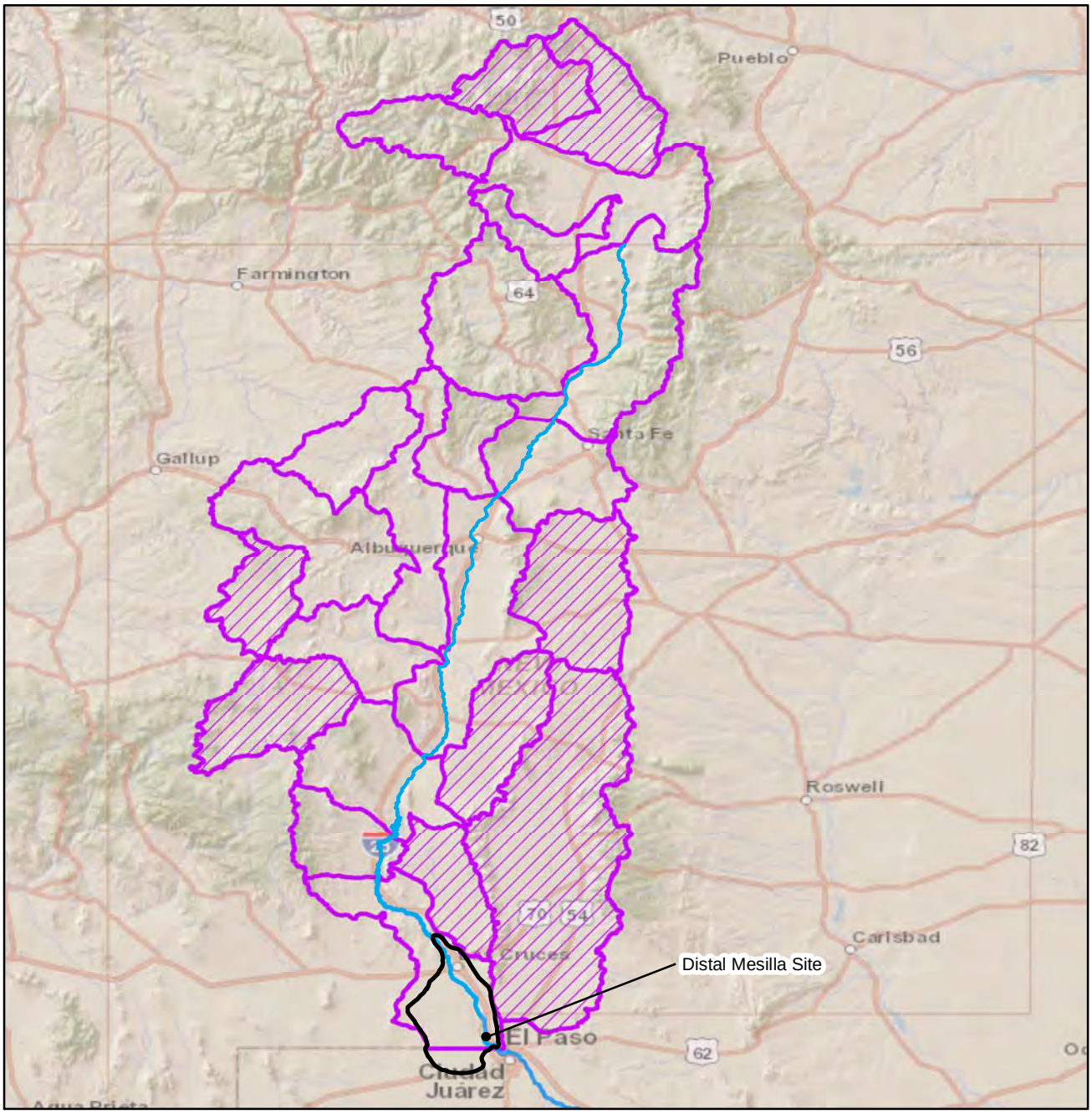
0 1,000 1,900 3,000 >5,400

VICINITY MAP

0 0.5 1
Miles

N

FIGURE 3-1
Spatial Distribution of TDS in Groundwater
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

LEGEND

- Rio Grande
- Mesilla Groundwater Basin
- Drainages to Rio Grande, Upstream of Study Area
- Adjacent Topographically Closed Basins, May Contribute Groundwater

N

0 25 50 100
Miles

FIGURE 4-1
Catchment Framework
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

LEGEND

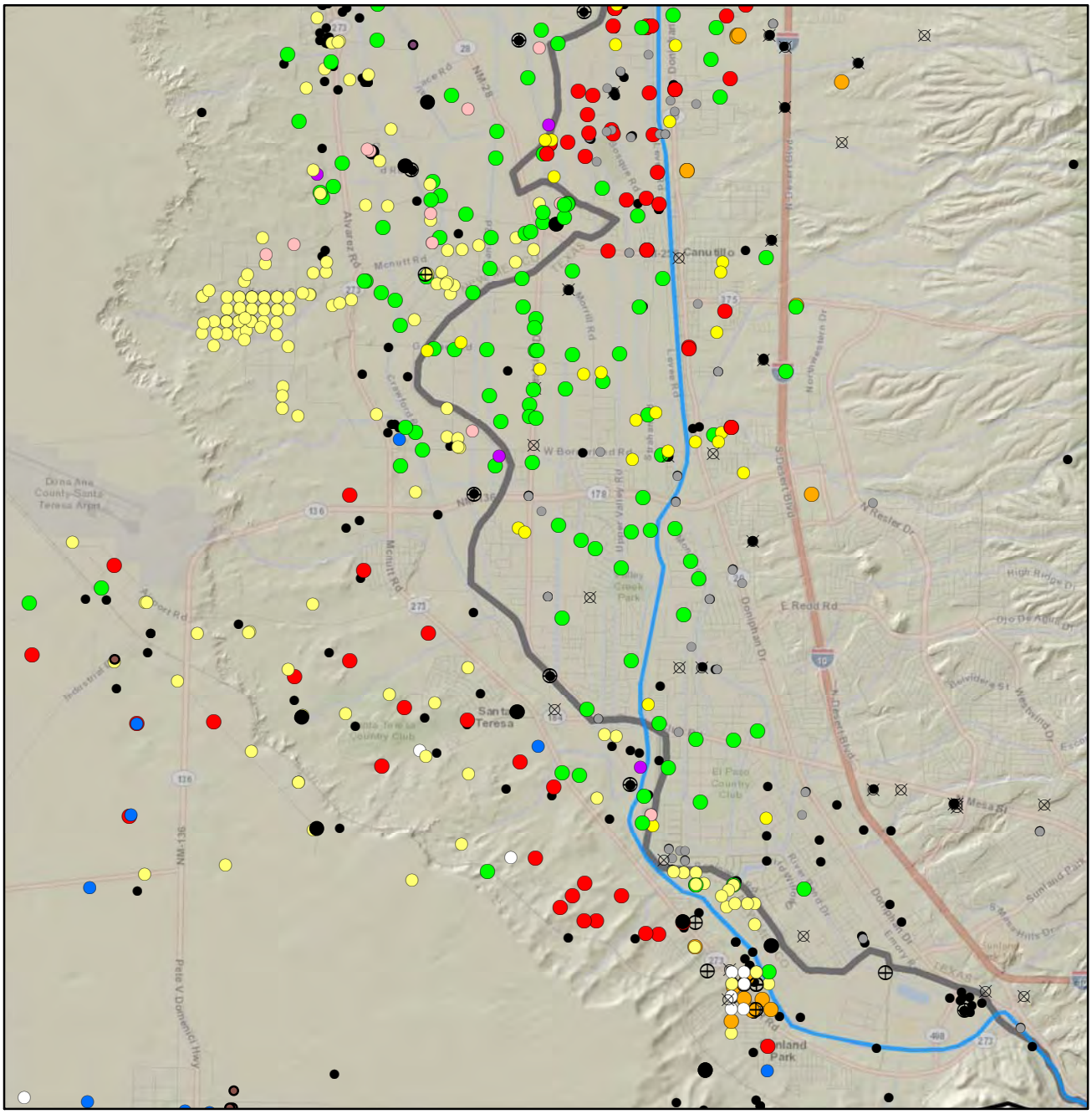
- Rio Grande
- State Boundary

VICINITY MAP

N

0 0.5 1 2
Miles

FIGURE 5-1
Aerial Photo
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

Well Use

- Commercial
- Domestic and Livestock
- Destroyed
- Domestic
- Exploration/Test Well
- Industrial
- Irrigation
- Livestock
- Municipal
- Observation
- Unknown
- Unused
- Rio Grande
- Mesilla Basin Boundary
- State Boundary

Data Sources:
NM: NM Office of the State Engineer "WATERS" database
TX: TX Water Development Board's groundwater database
Additional Wells: USGS-NMISC geodatabase compendium

N

0 0.5 1
Miles

VICINITY MAP

FIGURE 5-2
Well Locations and Use
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

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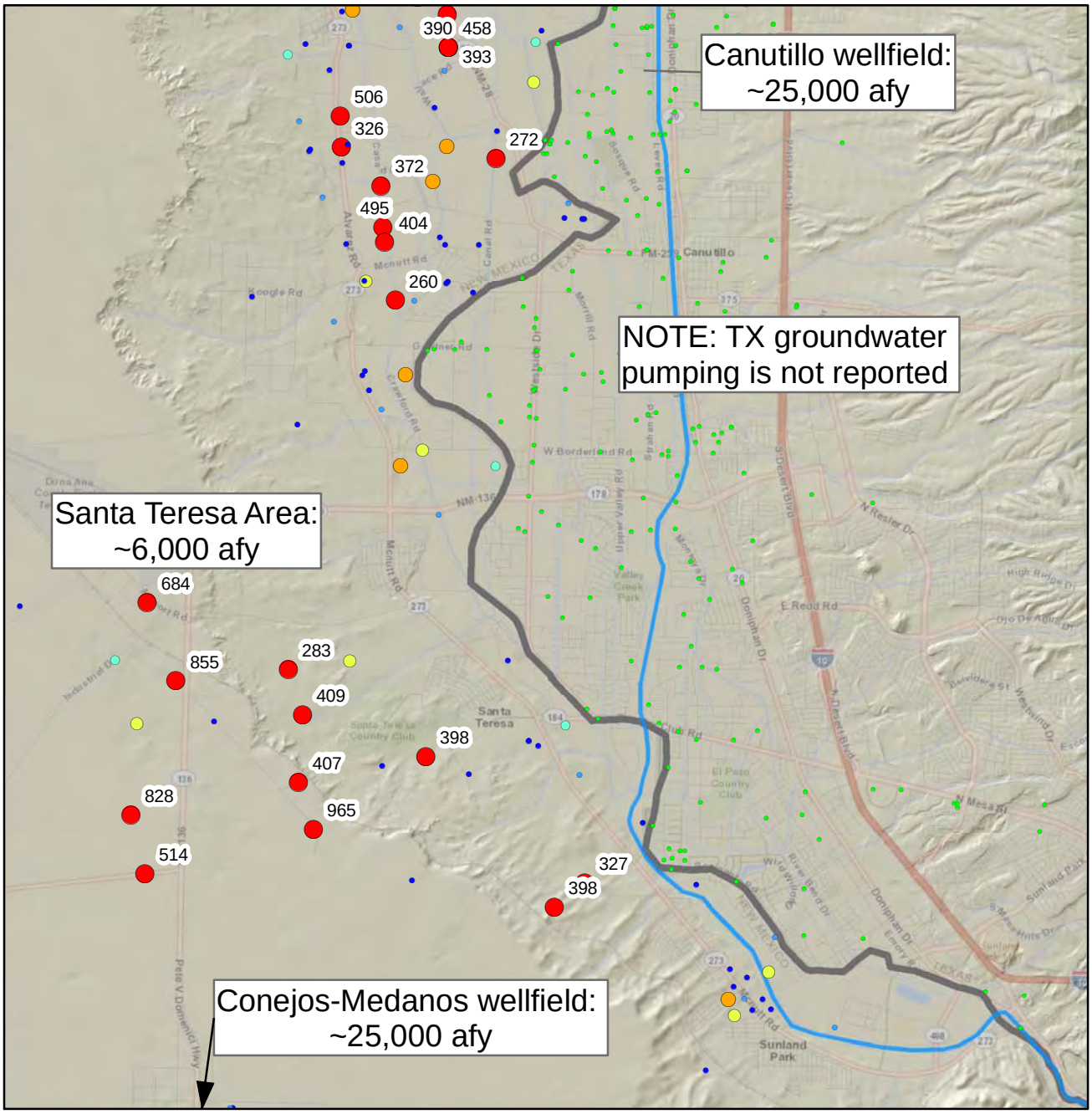


LEGEND

2011 Annual Pumpage (af)

- < 50
- 50.1 - 100.0
- 100.1 - 150.0
- 150.1 - 200.0
- 200.1 - 250.0
- > 250
- Rio Grande
- State Boundary

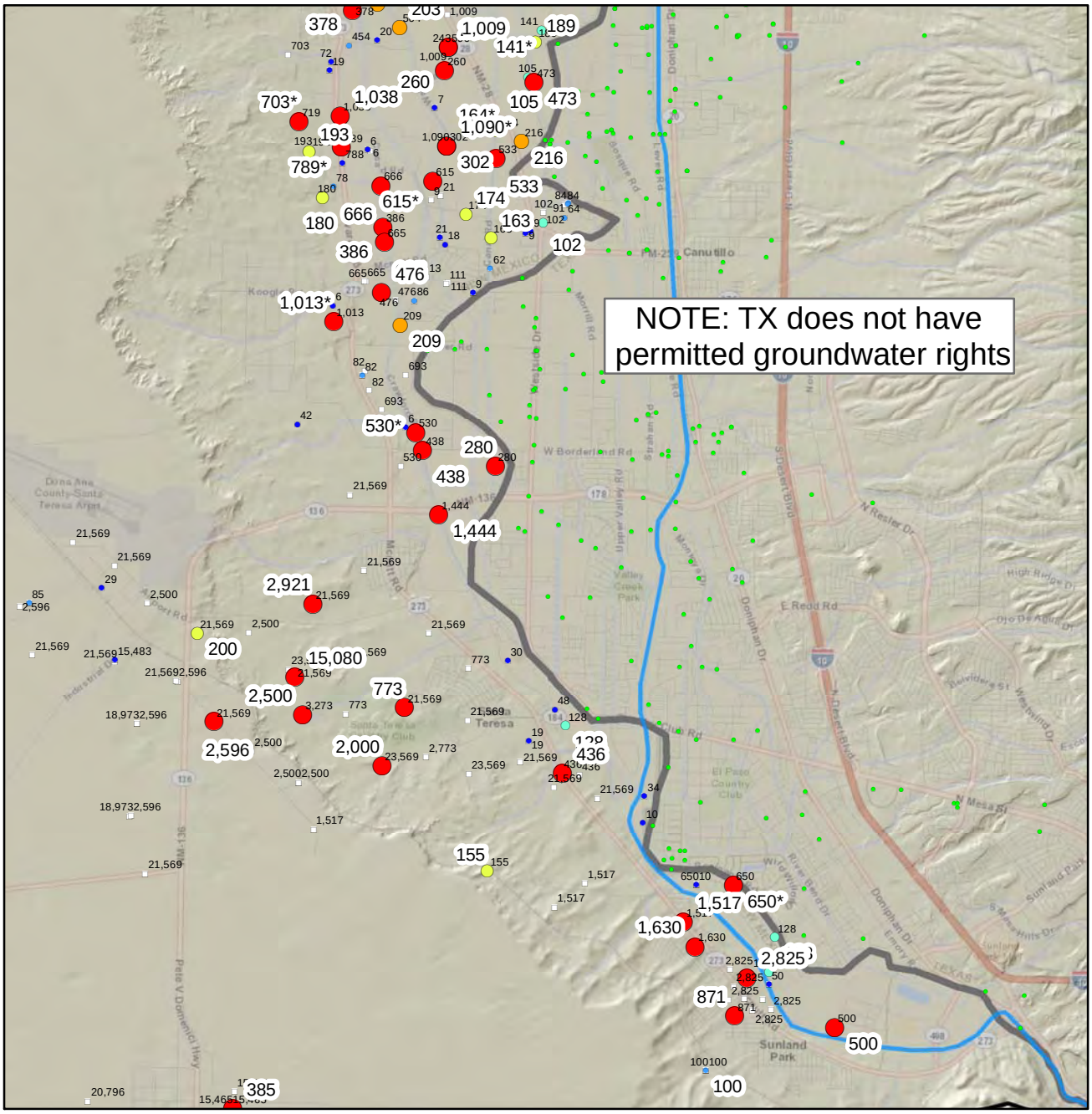
Data Sources:
NM: NM Office of the State Engineer "WATERS" database
TX: TX Water Development Board's groundwater database
Additional Wells: USGS-NMISC geodatabase compendium

VICINITY MAP

N

0 0.5 1
Miles

FIGURE 5-3
Well Pumping, 2011
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

Permitted Diversion (afy)

- 5.0 - 50.0
- 50.1 - 100.0
- 100.1 - 150.0
- 150.1 - 200.0
- 200.1 - 250.0
- > 250
- Potential Pumping From Individual Well (afy)
- Rio Grande
- State Boundary
- Mesilla Basin Boundary

Description:
Water rights may be shared amongst multiple wells.
Permitted Diversion layer displays each water right one time, so represents total potential pumping in the area. Labels only plotted if > 100 afy. *multiple rights combined

Potential Pumping layer represents the sum of all water rights associated with a well. Accordingly, not all wells can pump the amount shown in this layer in a given year.

Wells with rights < 5 afy excluded

Data Sources:
NM: NM Office of the State Engineer "WATERS" database
TX: TX Water Development Board's groundwater database
Additional Wells: USGS-NMISC geodatabase compendium

0 0.5 1
Miles

N

VICINITY MAP

FIGURE 5-4
Permitted Well Pumping (Diversion Limit)
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

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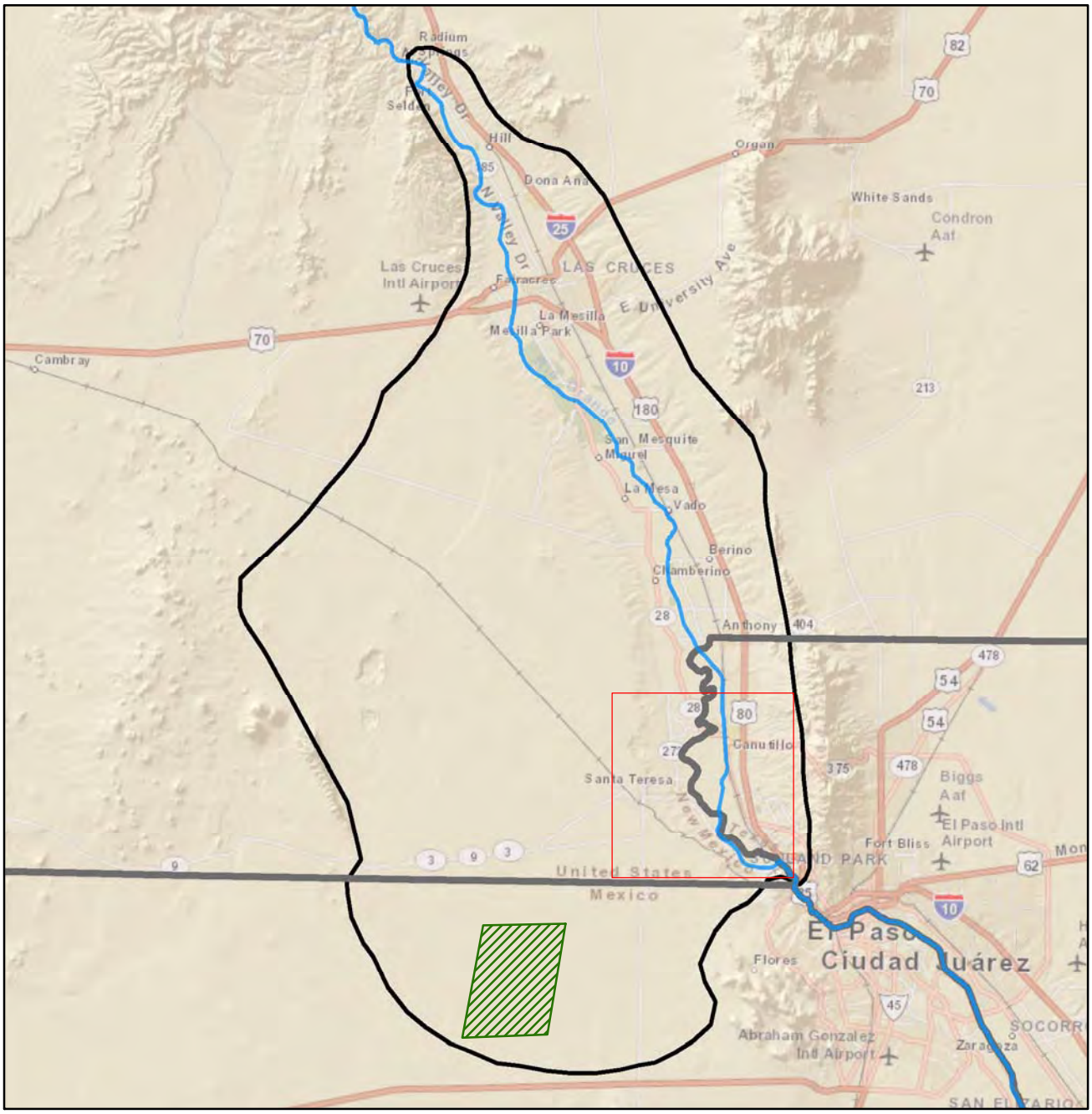


VICINITY MAP

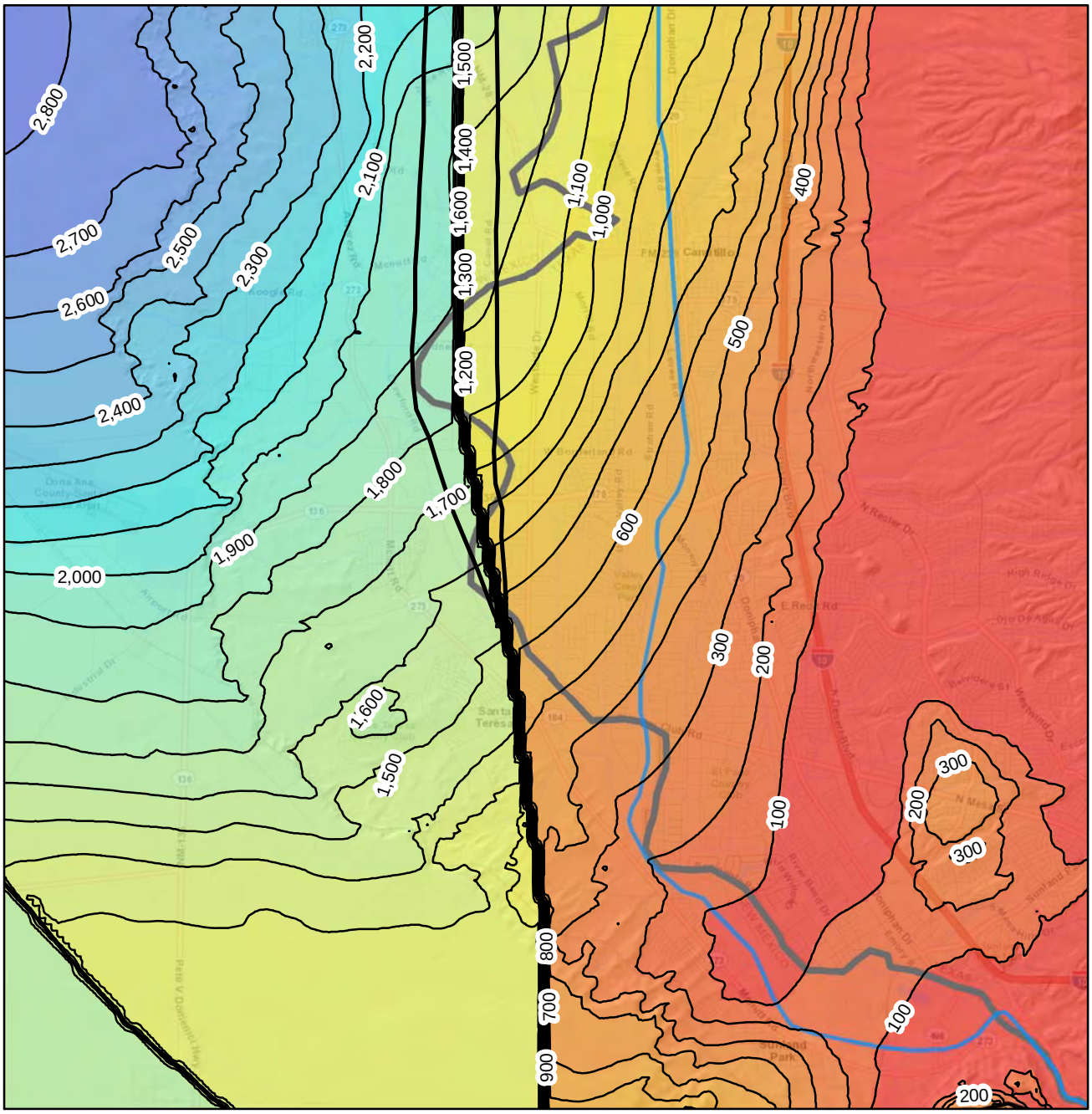
LEGEND

- Rio Grande
- Appoximate Boundary, Mesilla Groundwater Basin
- Study Area (and Extent of Subsequent Figures)
- Approximate Location of Conejos-Medanos Wellfield

N

0 2.5 5 10 15 20
Miles

FIGURE 5-5
Location of Conejos-Medanos Wellfield
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

- Depth (ft) to Base of Santa Fe Group
- Fault
- Rio Grande
- State Boundary
- Mesilla Basin Boundary

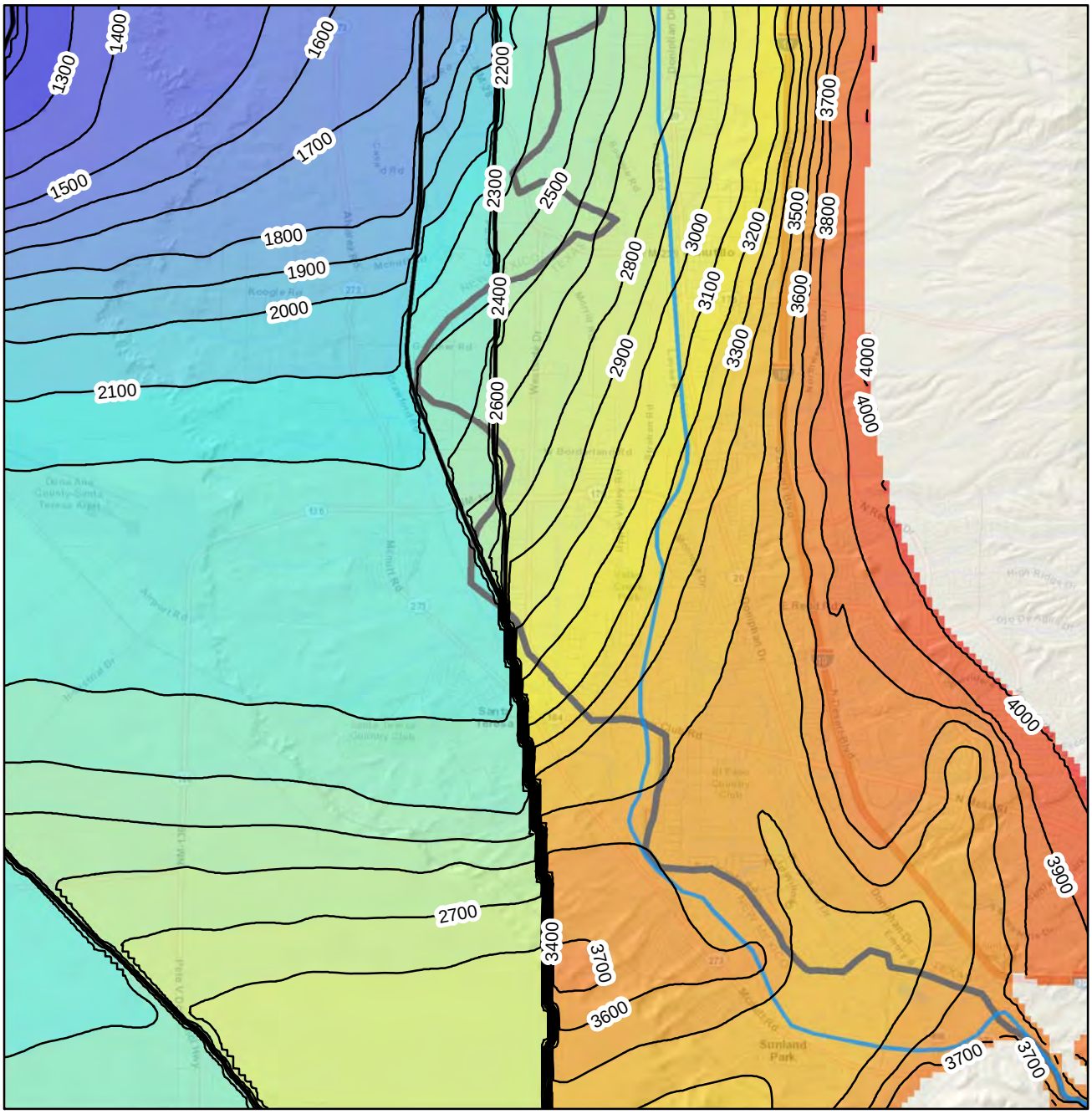
Data Sources:
Faults: Hawley and Kennedy (2004)
Depth: Based on DEM (land surface) and base of Santa Fe Group Elevation from Hawley and Kennedy (2004)

VICINITY MAP

N

0 0.5 1
Miles

FIGURE 5-6
Depth, Base of Santa Fe Group
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

- Rio Grande
- State Boundary
- Fault
- Elevation (ft), Base of Aquifer

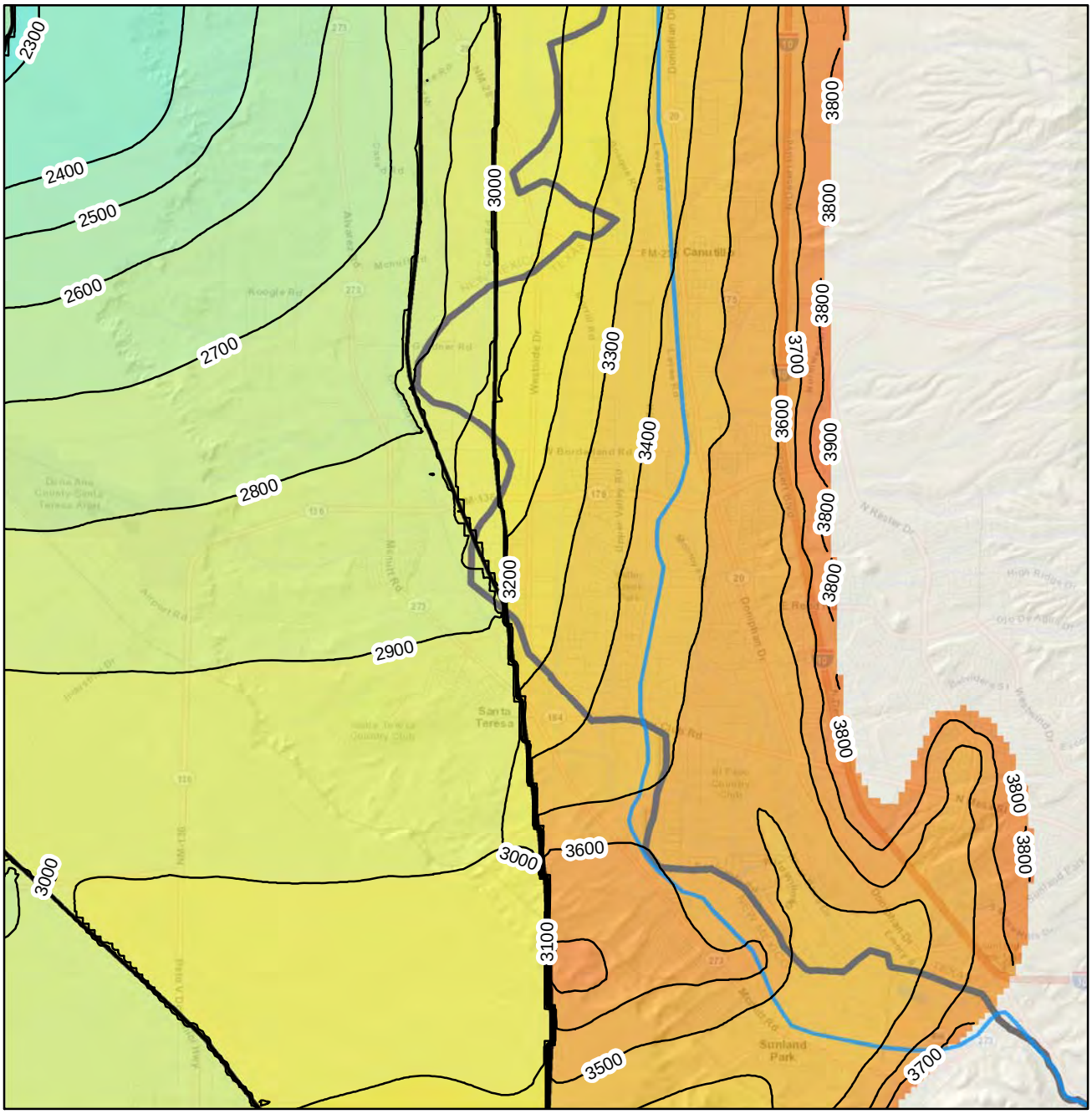
Data Source:
Hawley, pers. comm. (2012)

VICINITY MAP

N

0 0.5 1
Miles

FIGURE 5-7
Elevation, Base of Aquifer
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

- Rio Grande
- State Boundary
- Fault
- Elevation (ft), Base of Middle Santa Fe Group

Data Source:
Hawley, pers. comm. (2012)

VICINITY MAP

N

0 0.5 1
Miles

FIGURE 5-8
Elevation, Base of Middle Santa Fe Group
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

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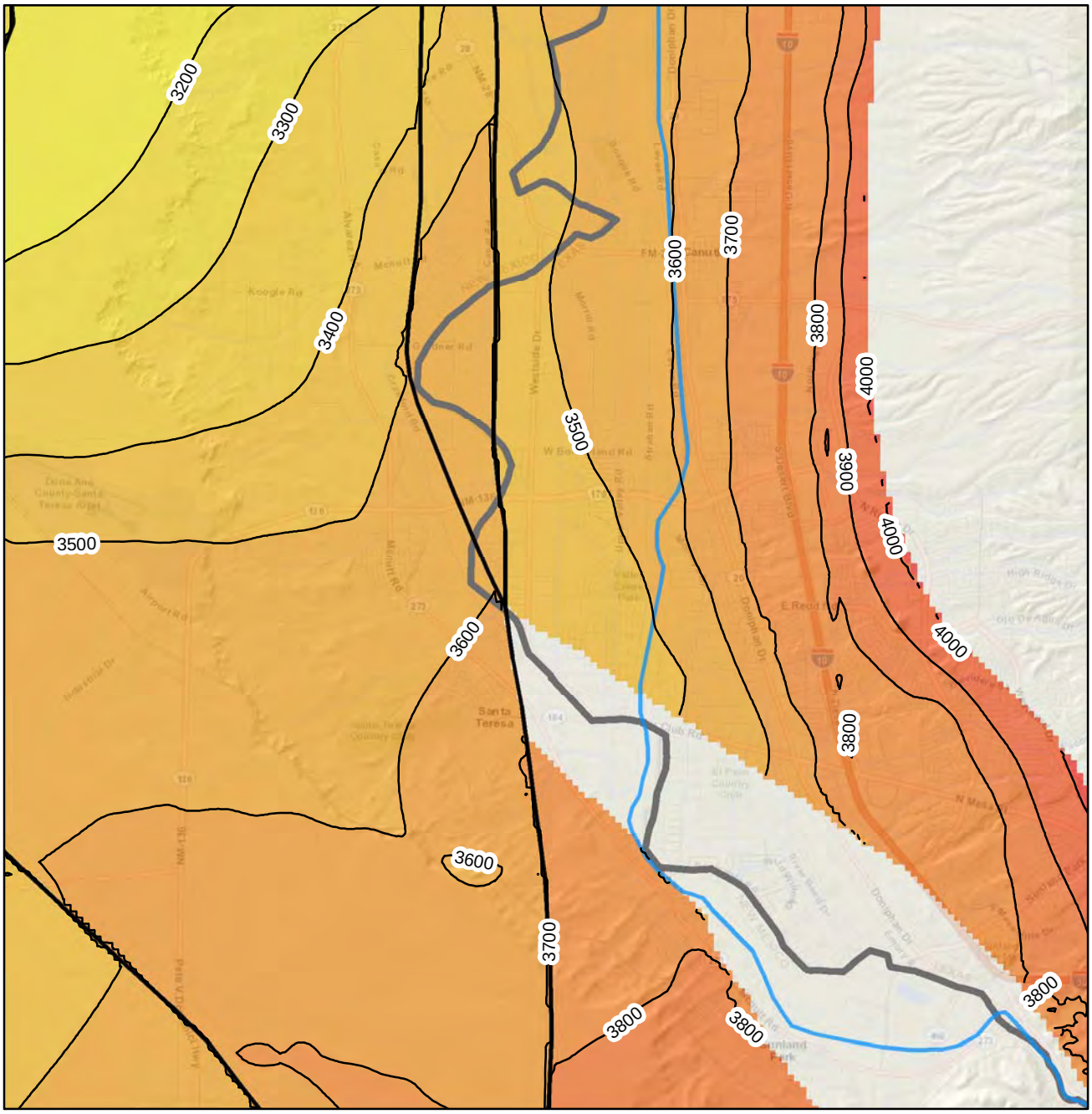


LEGEND

- Rio Grande
- State Boundary
- Fault
- Elevation (ft), Base of Upper Santa Fe Group

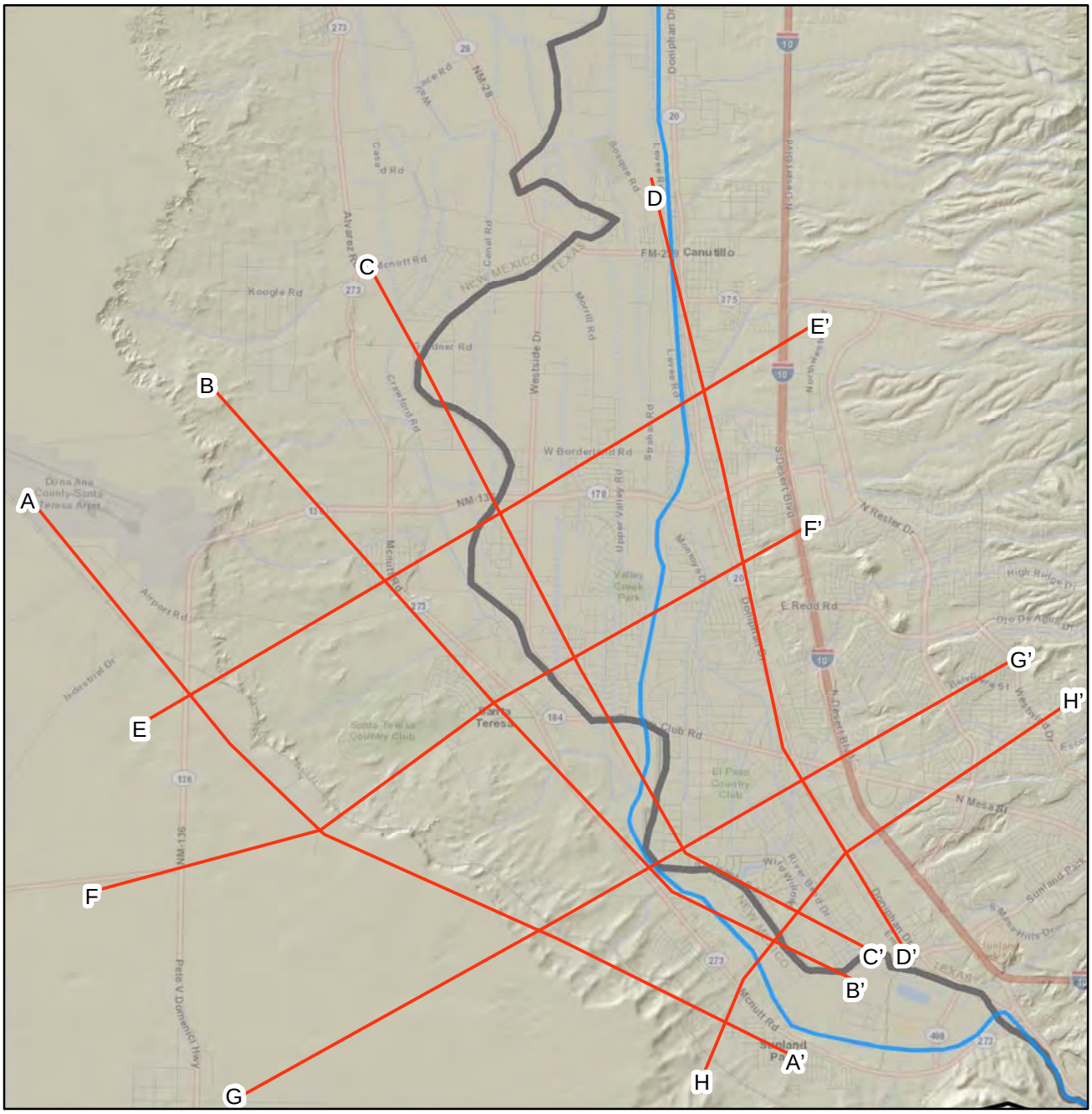
Data Source:
Hawley, pers. comm. (2012)

VICINITY MAP

N

0 0.5 1
Miles

FIGURE 5-9
Elevation, Base of Upper Santa Fe Group
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

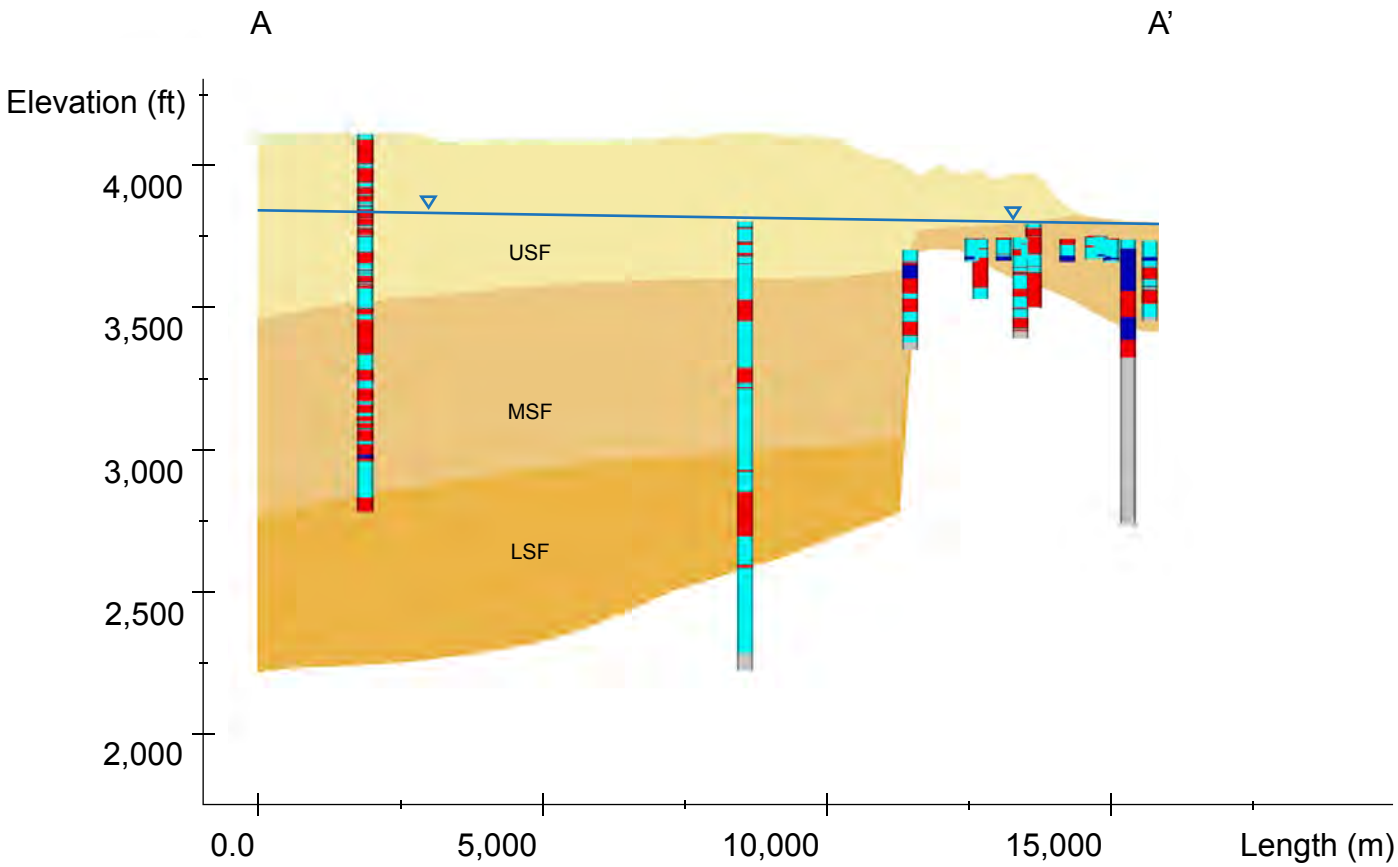
- Rio Grande
- Mesilla Basin Boundary
- State Boundary
- Cross-Section Location

VICINITY MAP

N

0 0.5 1 2
Miles

FIGURE 5-10
Cross-Section Locations
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

Hydrostratigraphic Unit

- River Alluvium (RA)
- Upper Santa Fe Group (USF)
- Middle Santa Fe Group (MSF)
- Lower Santa Fe Group (LSF)

Lithology from Drillers' Logs

- Clay
- Silt
- Sand
- Gravel
- BR

Approximate Water Table

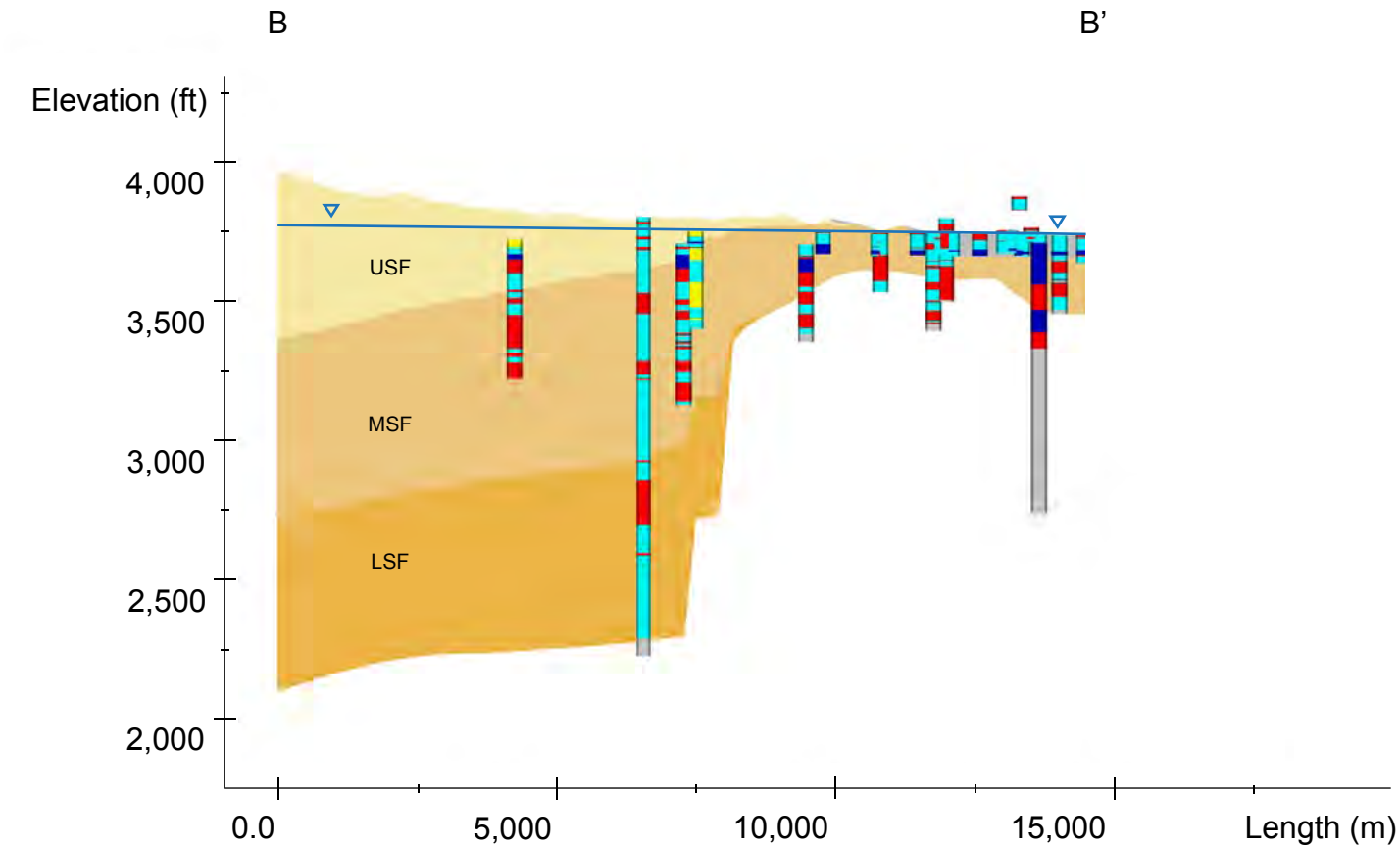
NOTES

Vertical Exaggeration = 16.5x

Wells within 3,000 feet of section line are plotted (many of the wells are in the river valley, and therefore appear to be below land surface)

FIGURE 5-11
Hydrogeologic Cross Section A-A'
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.



LEGEND

Hydrostratigraphic Unit

- River Alluvium (RA)
- Upper Santa Fe Group (USF)
- Middle Santa Fe Group (MSF)
- Lower Santa Fe Group (LSF)

Lithology from Drillers' Logs

- Clay
- Silt
- Sand
- Gravel
- BR

Approximate Water Table

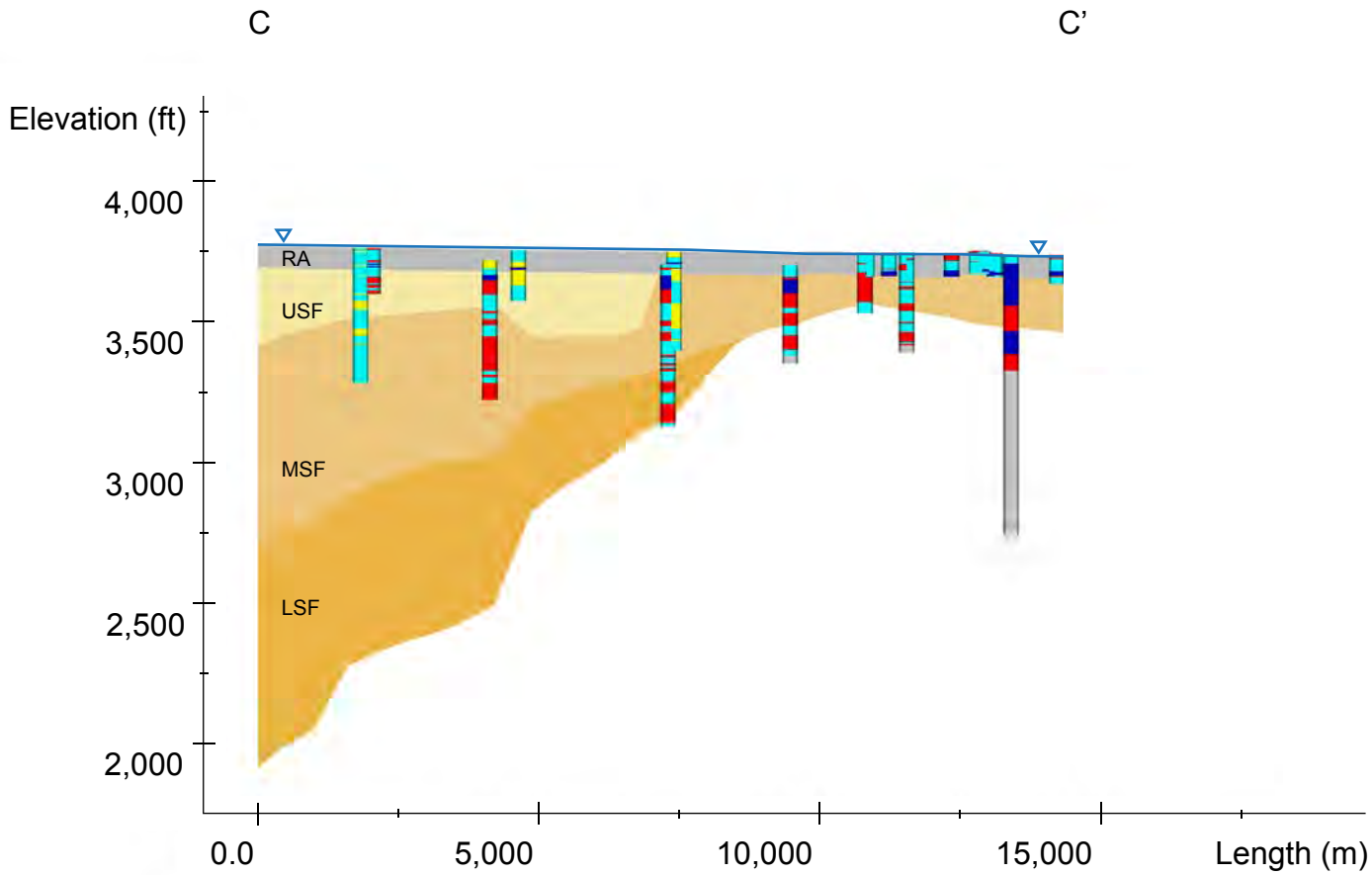
NOTES

Vertical Exaggeration = 16.5x

Wells within 3,000 feet of section line are plotted

FIGURE 5-12
Hydrogeologic Cross Section B-B'
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.



LEGEND

Hydrostratigraphic Unit

- River Alluvium (RA)
- Upper Santa Fe Group (USF)
- Middle Santa Fe Group (MSF)
- Lower Santa Fe Group (LSF)

Lithology from Drillers' Logs

- Clay
- Silt
- Sand
- Gravel
- BR

Approximate Water Table

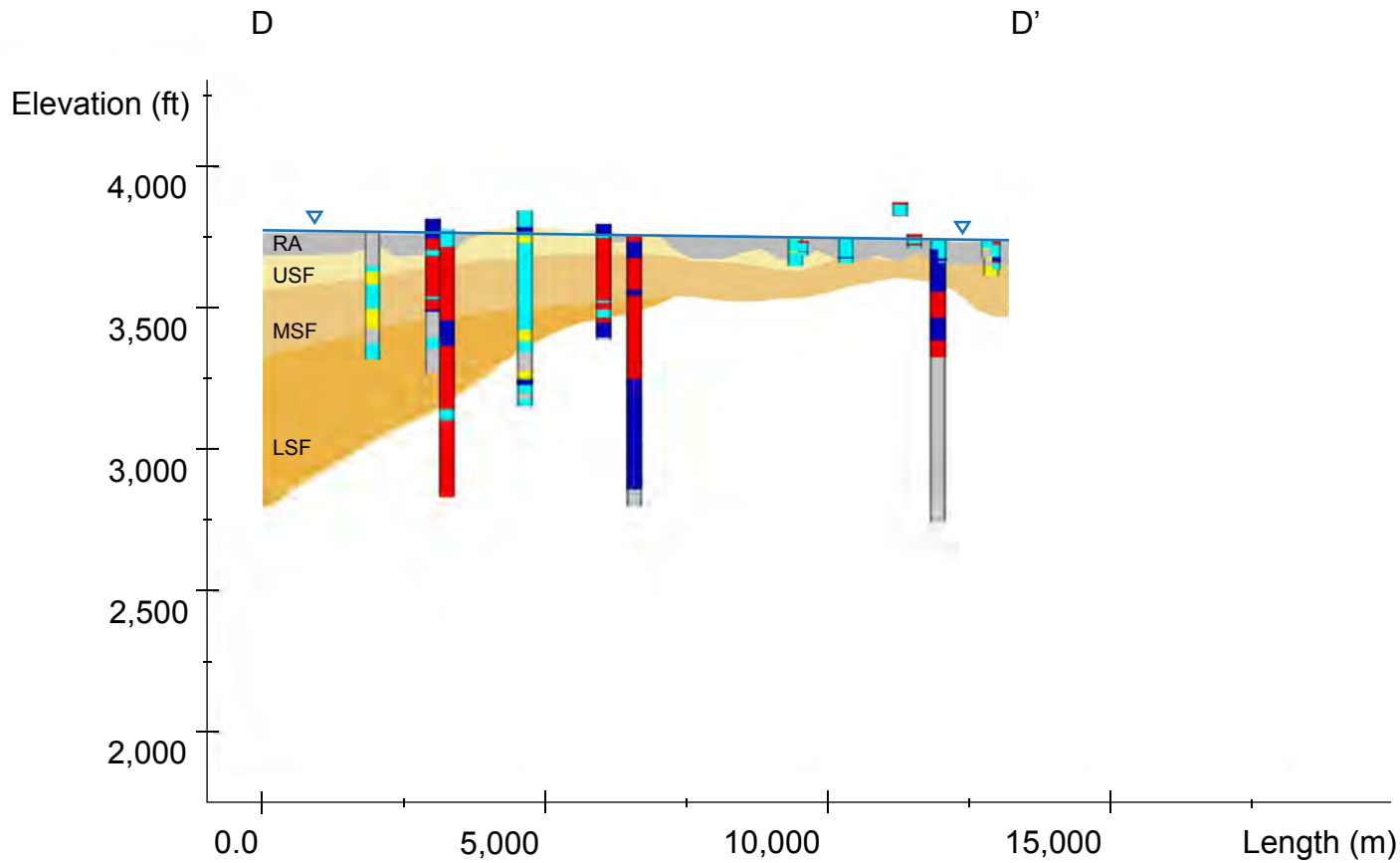
NOTE

Vertical Exaggeration = 16.5x

Wells within 3,000 feet of section line are plotted

FIGURE 5-13
Hydrogeologic Cross Section C-C'
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.



LEGEND

Hydrostratigraphic Unit

- River Alluvium (RA)
- Upper Santa Fe Group (USF)
- Middle Santa Fe Group (MSF)
- Lower Santa Fe Group (LSF)

Lithology from Drillers' Logs

- Clay
- Silt
- Sand
- Gravel
- BR

Approximate Water Table

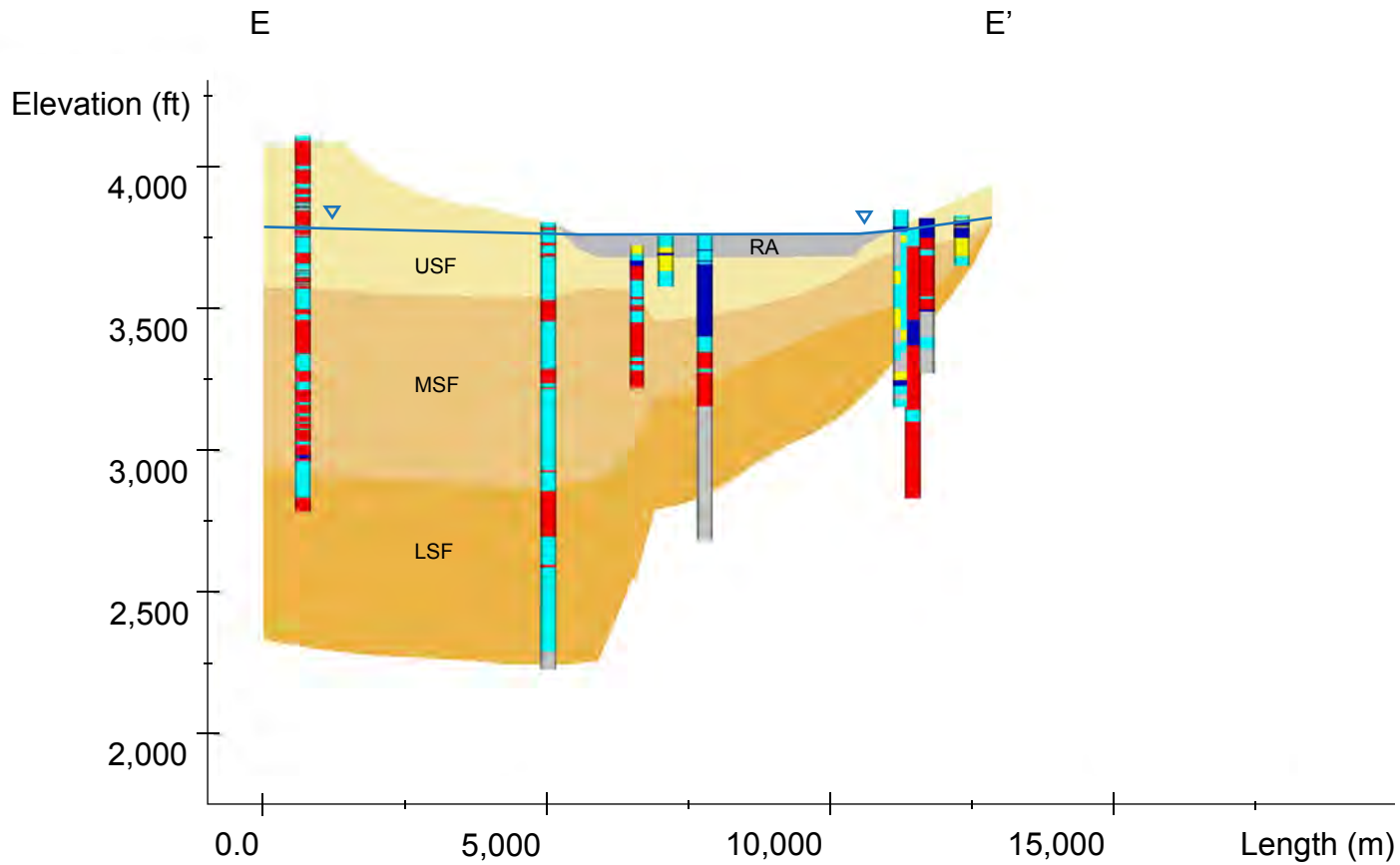
NOTES

Vertical Exaggeration = 16.5x

Wells within 3,000 feet of section line are plotted

FIGURE 5-14
Hydrogeologic Cross Section D-D'
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.



LEGEND

Hydrostratigraphic Unit

- River Alluvium (RA)
- Upper Santa Fe Group (USF)
- Middle Santa Fe Group (MSF)
- Lower Santa Fe Group (LSF)

Lithology from Drillers' Logs

- Clay
- Silt
- Sand
- Gravel
- BR

Approximate Water Table

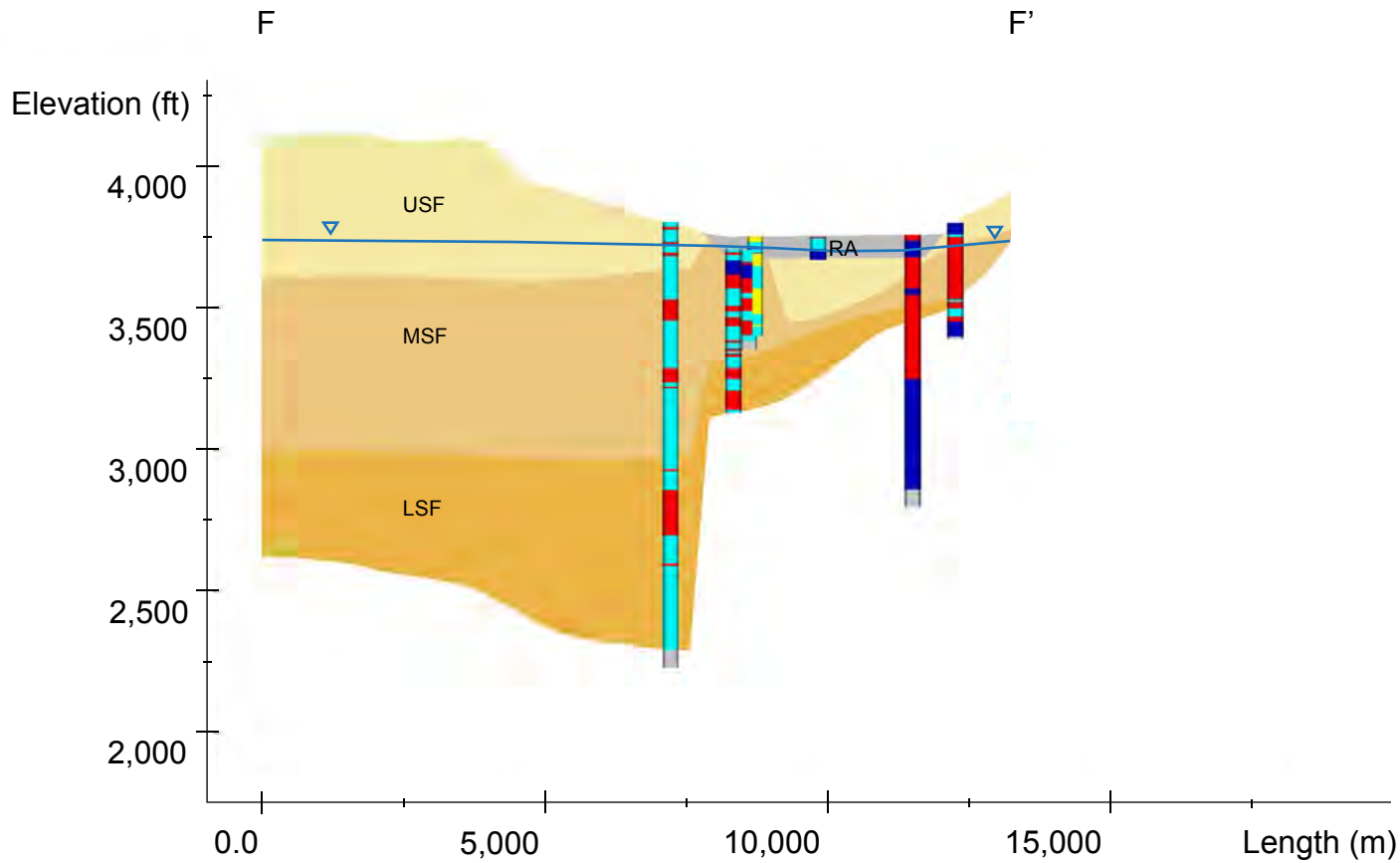
NOTE

Vertical Exaggeration = 16.5x

Wells within 3,000 feet of section line are plotted

FIGURE 5-15
Hydrogeologic Cross Section E-E'
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.



LEGEND

Hydrostratigraphic Unit

- River Alluvium (RA)
- Upper Santa Fe Group (USF)
- Middle Santa Fe Group (MSF)
- Lower Santa Fe Group (LSF)

Lithology from Drillers' Logs

- Clay
- Silt
- Sand
- Gravel
- BR

Approximate Water Table

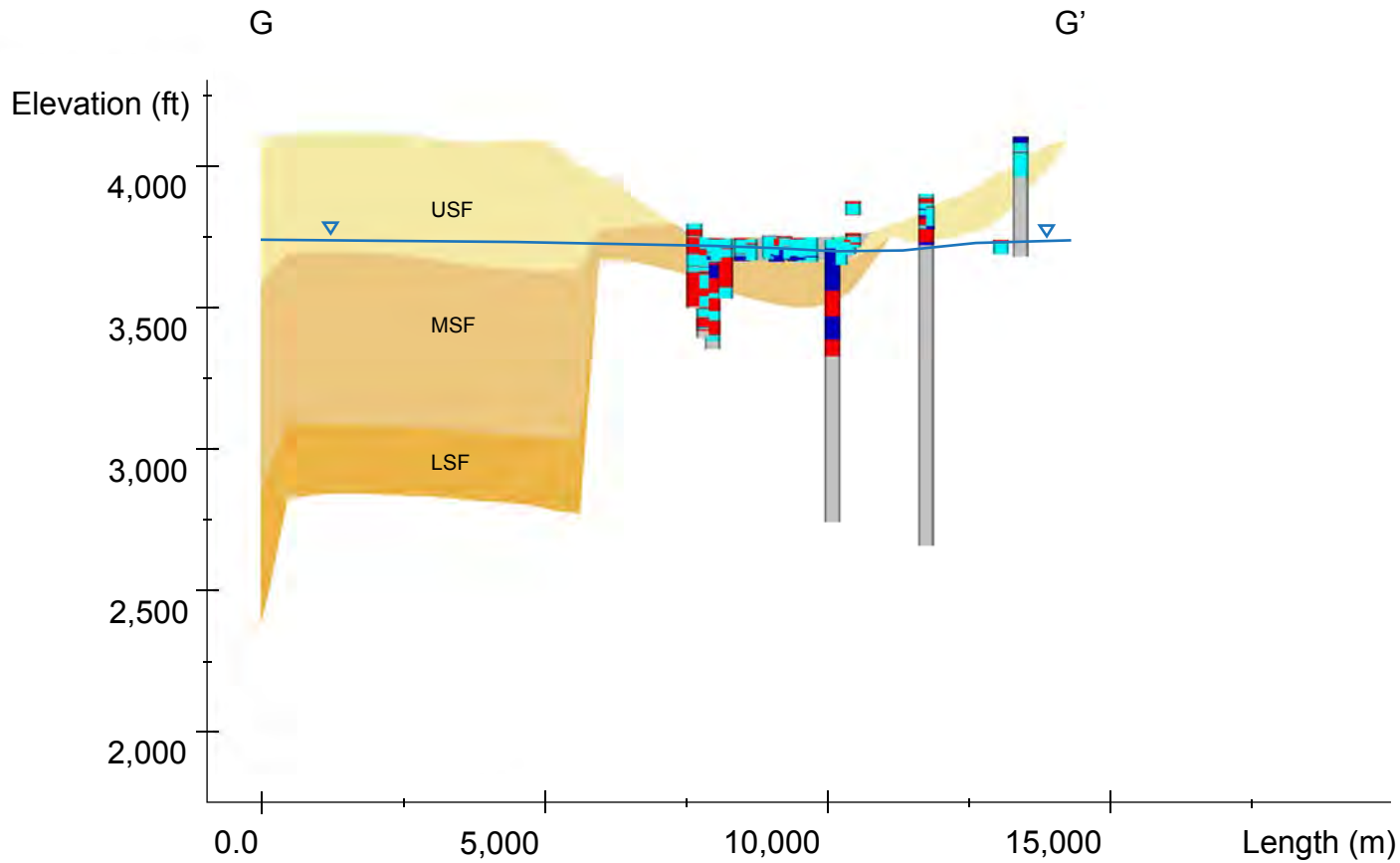
NOTES

Vertical Exaggeration = 16.5x

Wells within 3,000 feet of section line are plotted

FIGURE 5-16
Hydrogeologic Cross Section F-F'
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.



LEGEND

Hydrostratigraphic Unit

- River Alluvium (RA)
- Upper Santa Fe Group (USF)
- Middle Santa Fe Group (MSF)
- Lower Santa Fe Group (LSF)

Lithology from Drillers' Logs

- Clay
- Silt
- Sand
- Gravel
- BR

Approximate Water Table

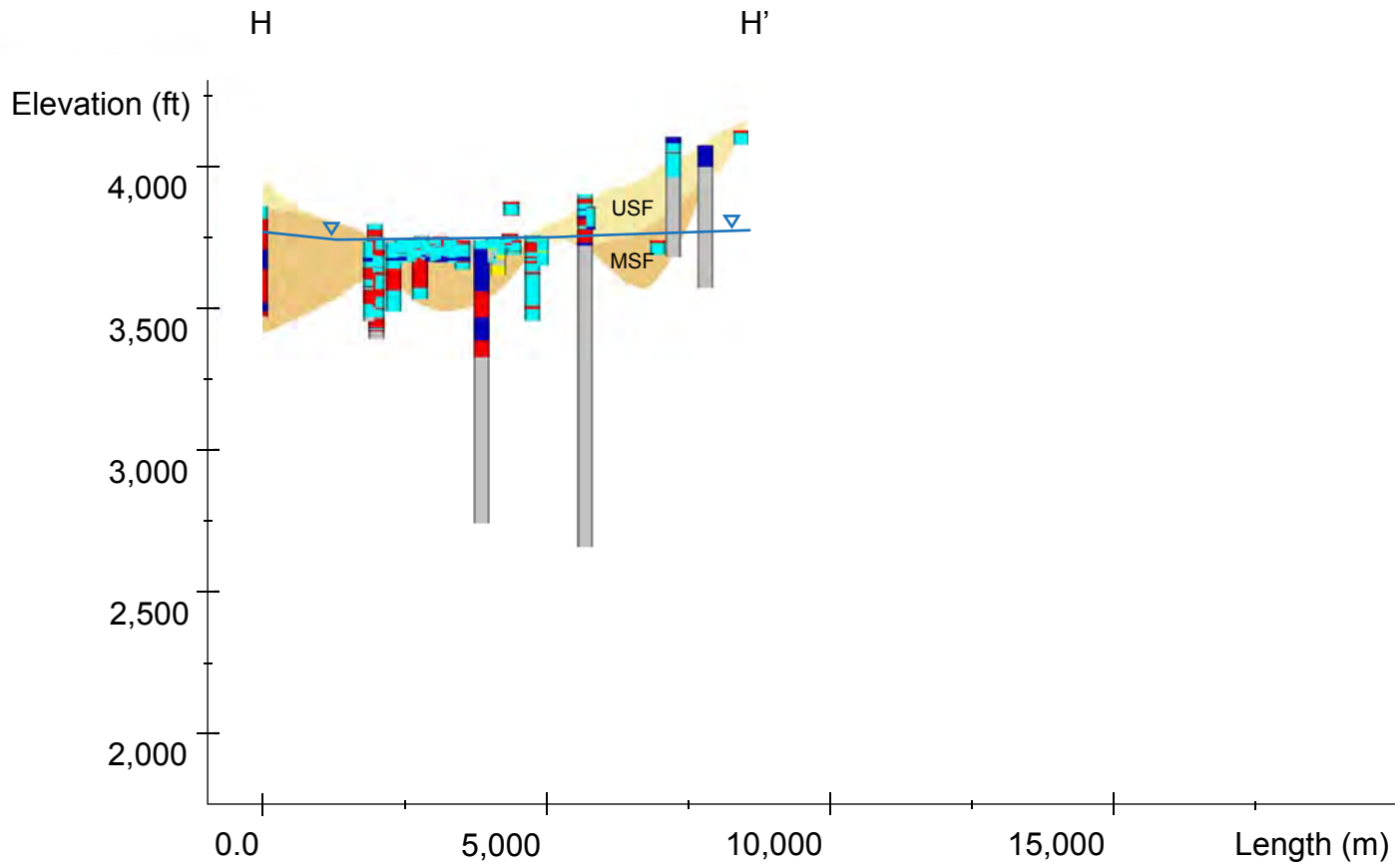
NOTES

Vertical Exaggeration = 16.5x

Wells within 3,000 feet of section line are plotted

FIGURE 5-17
Hydrogeologic Cross Section G-G'
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.



LEGEND

Hydrostratigraphic Unit

- River Alluvium (RA)
- Upper Santa Fe Group (USF)
- Middle Santa Fe Group (MSF)
- Lower Santa Fe Group (LSF)

Lithology from Drillers' Logs

- Clay
- Silt
- Sand
- Gravel
- BR

Approximate Water Table

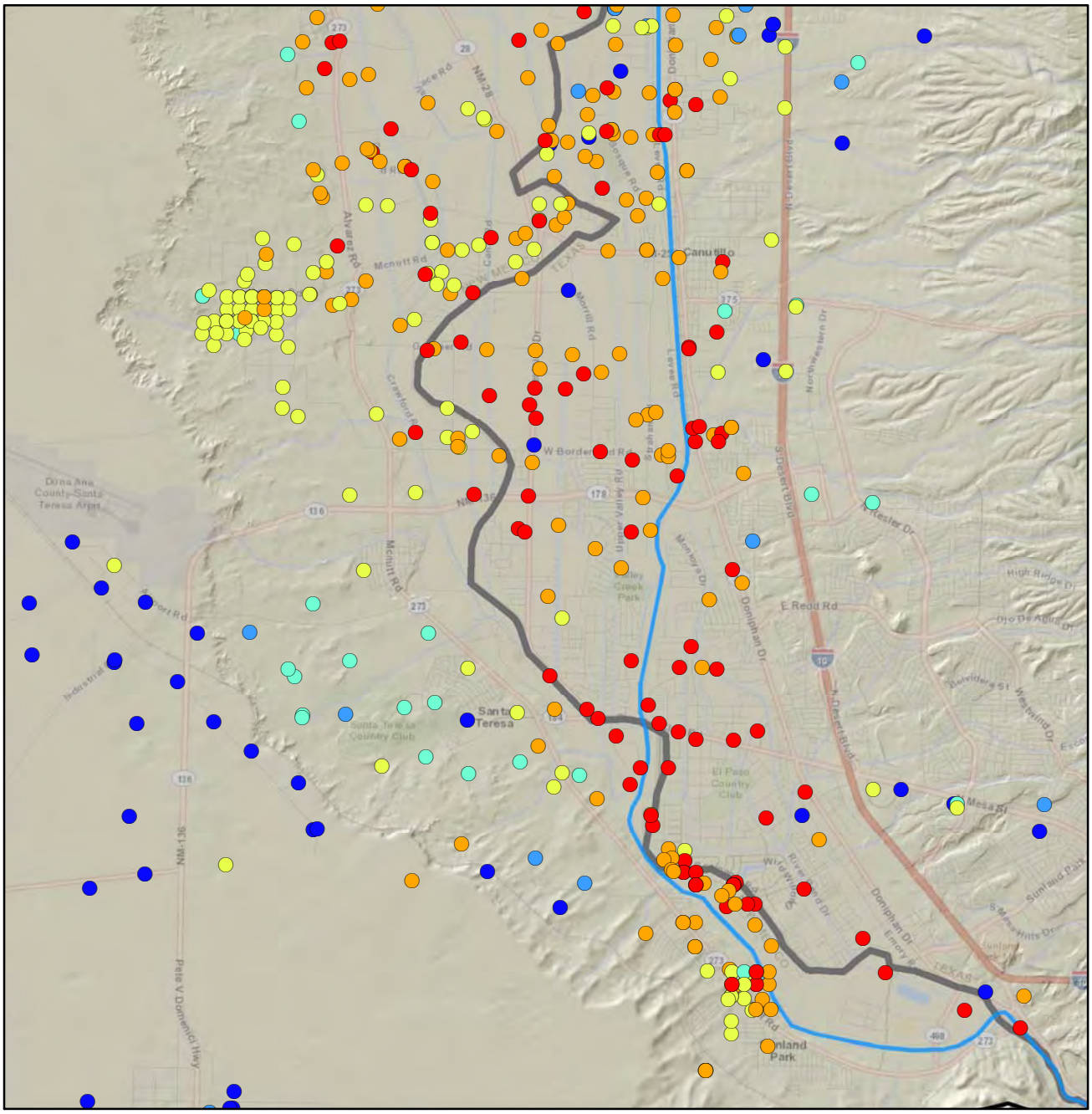
NOTES

Vertical Exaggeration = 16.5x

Wells within 3,000 feet of section line are plotted

FIGURE 5-18
Hydrogeologic Cross Section H-H'
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.



LEGEND

Depth (ft)

- < 100
- 100.1 - 200.0
- 200.1 - 300.0
- 300.1 - 400.0
- 400.1 - 500.0
- > 500
- Rio Grande
- Mesilla Basin Boundary
- State Boundary

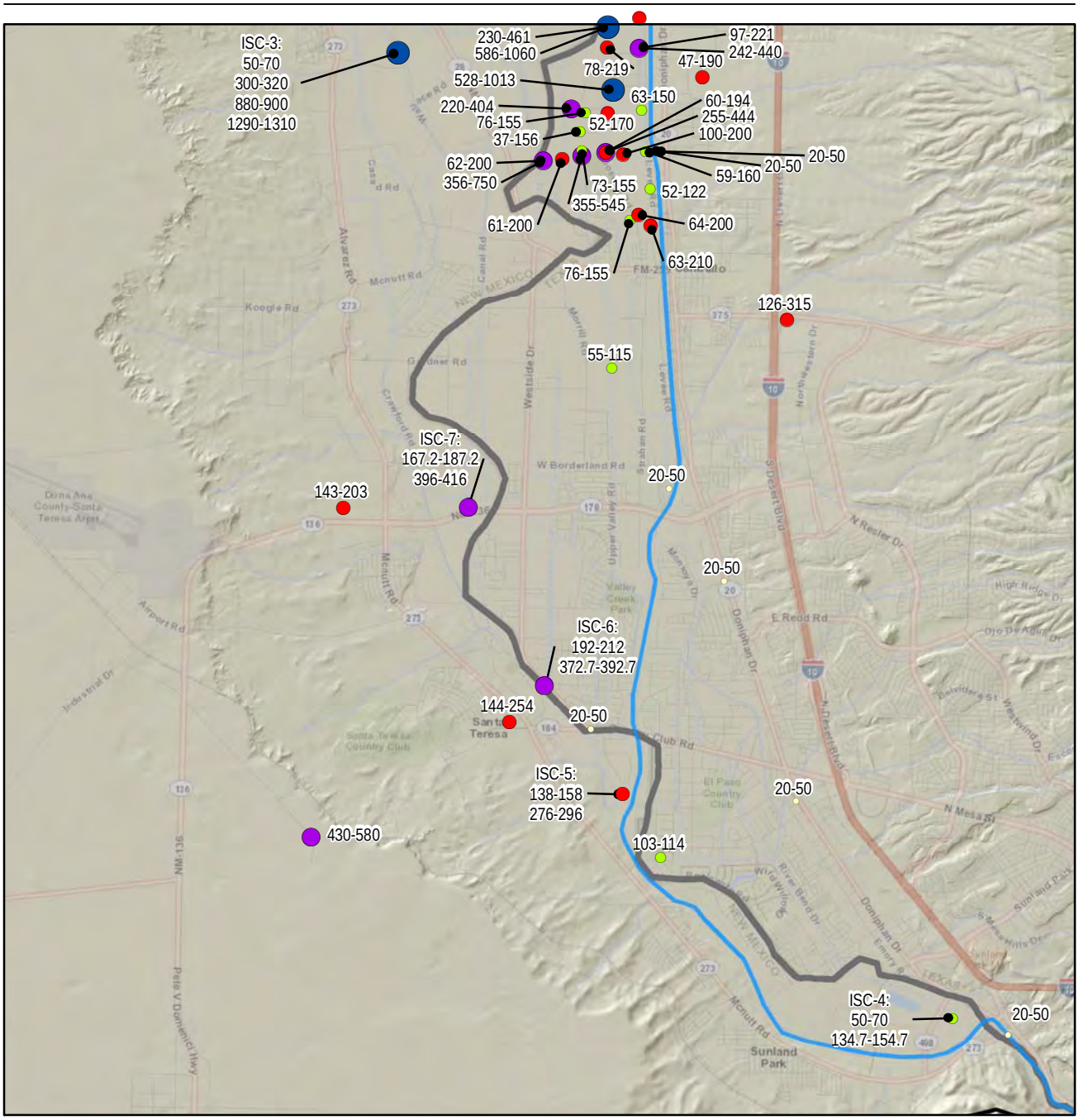
Data Sources:
NM: NM Office of the State Engineer "WATERS" database
TX: TX Water Development Board's groundwater database
Additional Wells: USGS-NMISC geodatabase compendium

N

0 0.5 1
Miles

VICINITY MAP

FIGURE 5-19
Well Depth
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

- Rio Grande
- State Boundary
- Mesilla Basin Boundary

Depth to Bottom of Well Screen (feet below ground surface)

- 18 - 80
- 81 - 160
- 161 - 350
- 351 - 800
- 801 - 1310

Labels:
Well Screen interval
(feet below ground surface)
ISC well nests/clusters are also identified by location ID

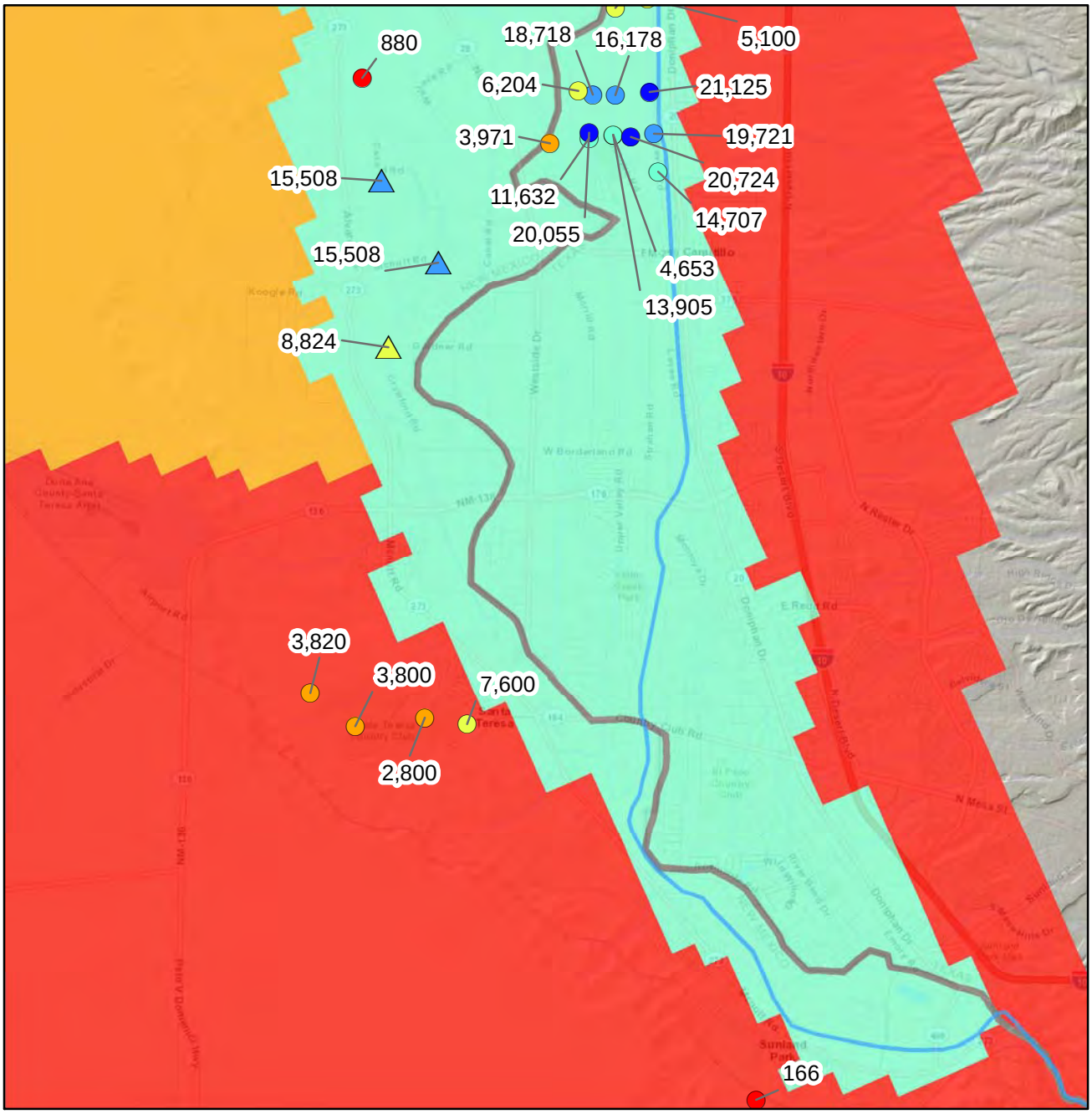
Data Sources:
SSPA, 2007,
Tetra Tech, 2003,
Leggat et al., 1962

VICINITY MAP

N

0 0.5 1 2
Miles

FIGURE 5-20
Well Screen Depths
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

LEGEND

River Rio Grande

State Boundary

Transmissivity (ft2/d)

- 0 - 2,500
- 2,501 - 5,000
- 5,001 - 10,000
- 10,001 - 15,000
- 15,001 - 20,000
- 20,001 - 30,000

Data Sources:
Model data from (SSPA, 2007)
Aquifer test data from various sources, compiled by (SSPA, 2007)

Background color-shade represents total model transmissivity (sum of all layers).

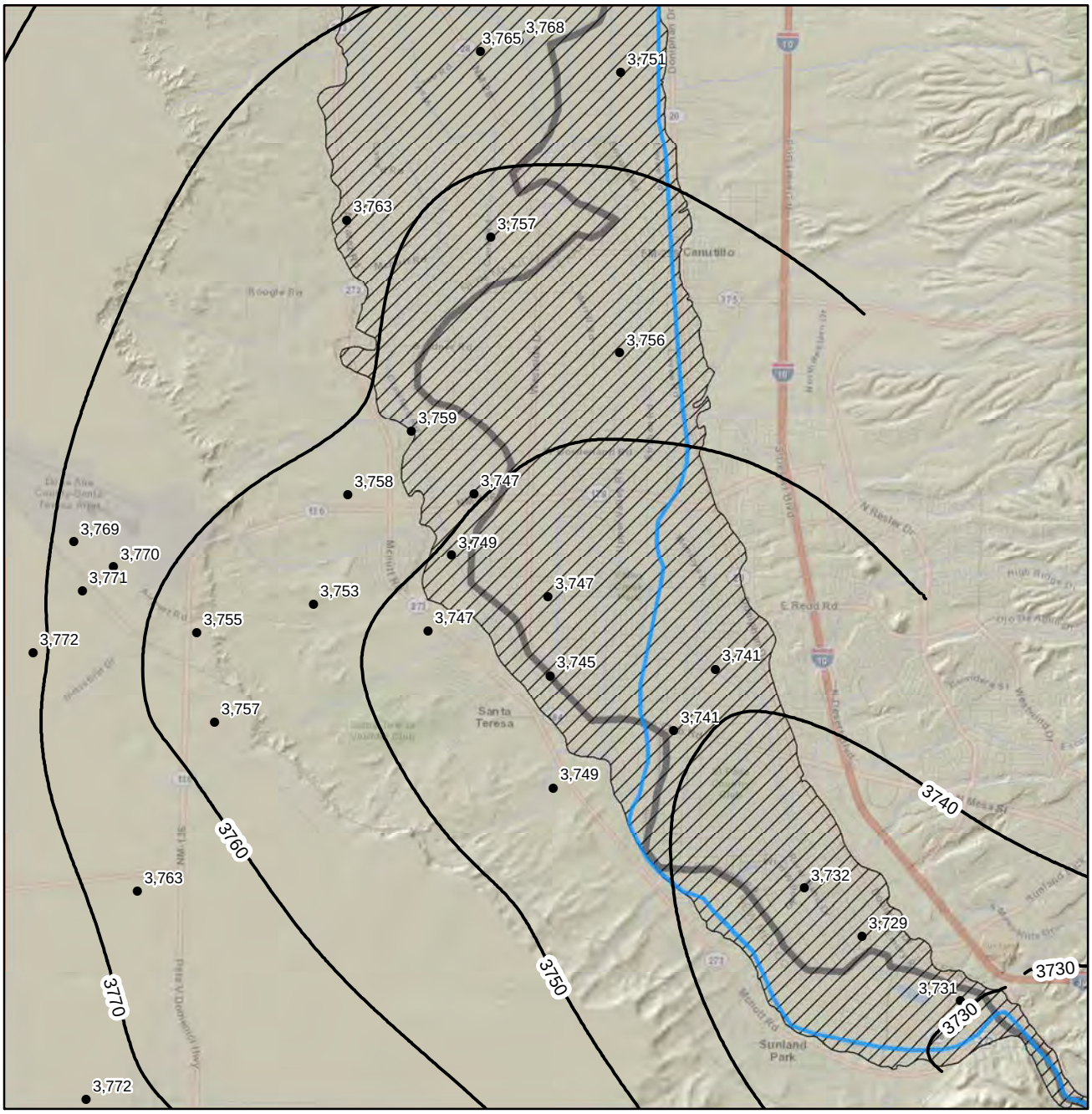
Circles represent transmissivity from aquifer tests.

Triangles represent transmissivity calculated from specific capacity.

N

0 0.5 1 2
Miles

FIGURE 5-21
Transmissivity (ft2/d)
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

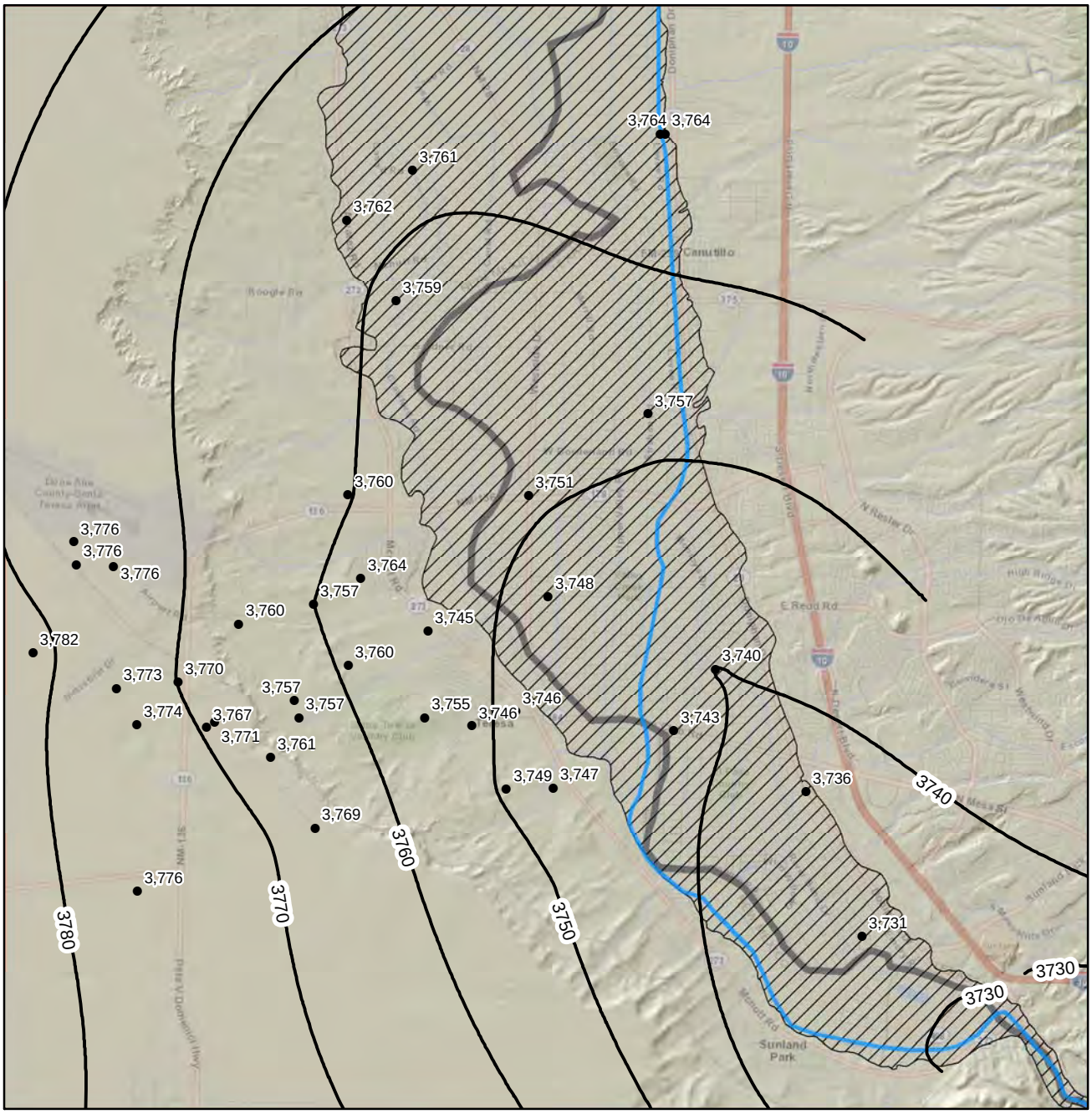
LEGEND

- Rio Grande
- River Alluvium (Hawley and Kennedy, 2004)
- State Boundary
- 10-ft Water Level Contour (water table)

N

0 0.5 1 2
Miles

FIGURE 5-22
Groundwater Elevation, Jan-09
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

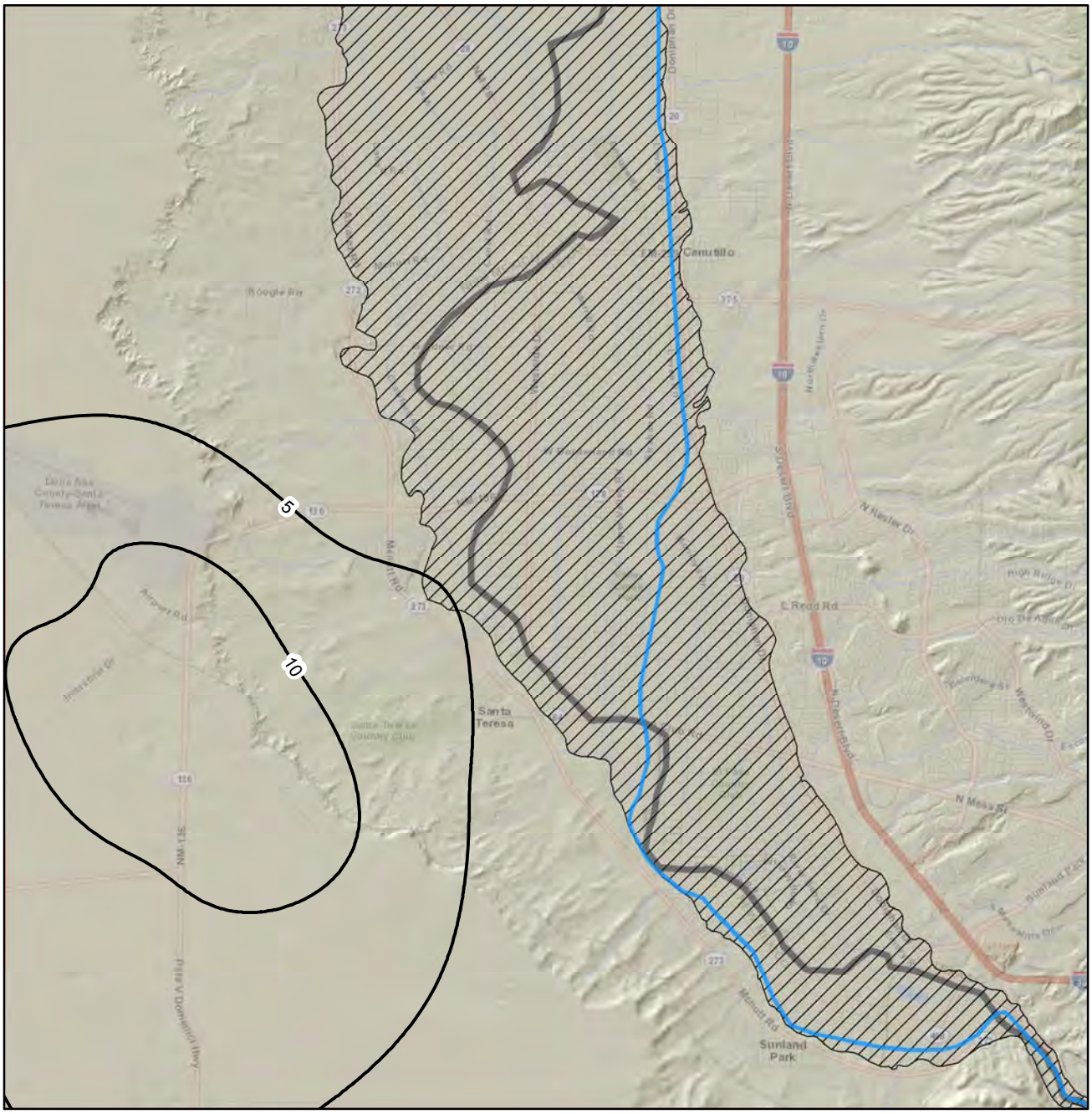
- Rio Grande
- River Alluvium (Hawley and Kennedy, 2004)
- State Boundary
- 10-ft Water Level Contour (water table)

VICINITY MAP

N

0 0.5 1
Miles

FIGURE 5-23
Groundwater Elevation, 1974
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

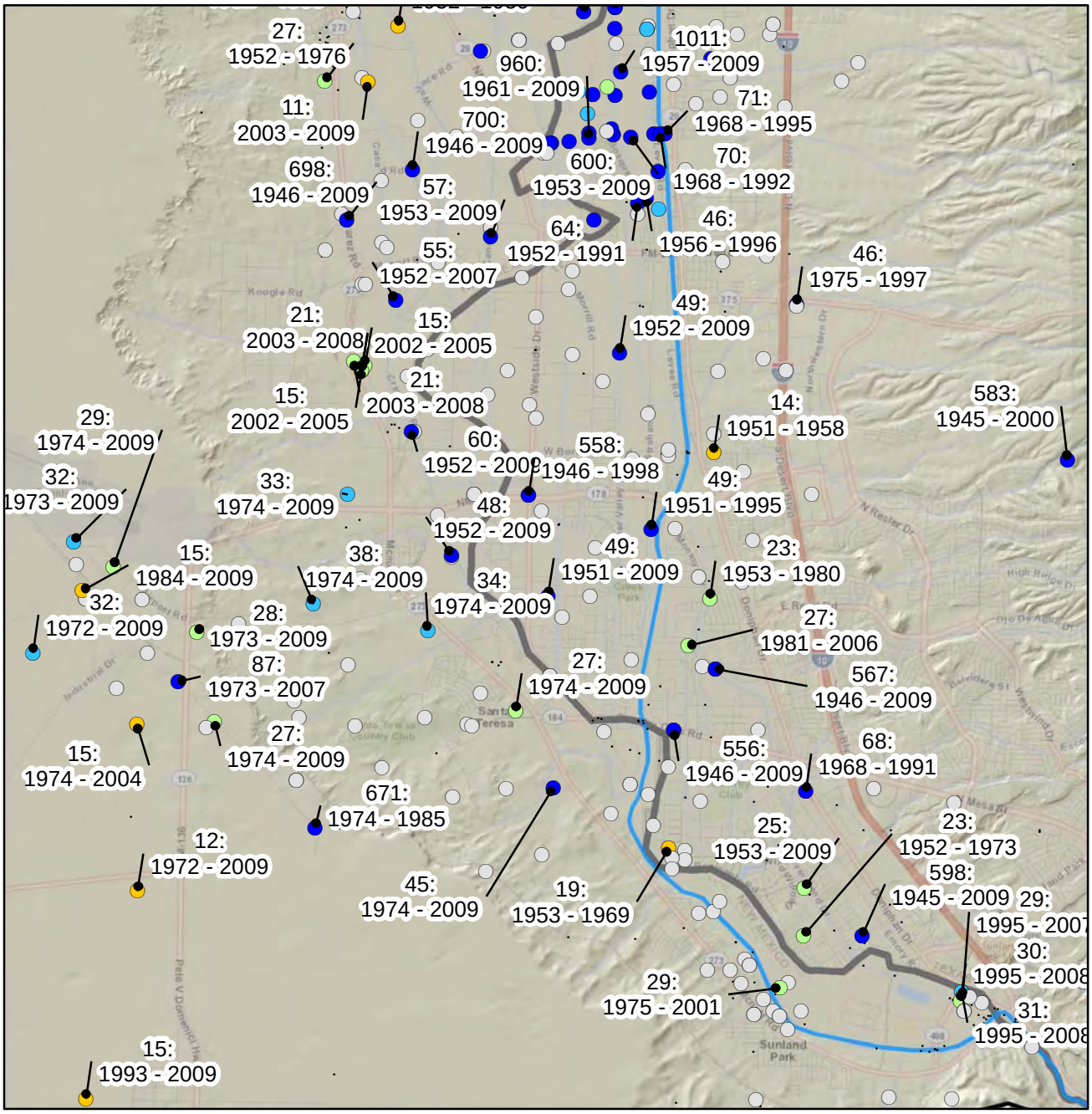
LEGEND

- Rio Grande
- River Alluvium (Hawley and Kennedy, 2004)
- State Boundary
- 5-ft Drawdown Contour (water table)

N

0 0.5 1 2
Miles

FIGURE 5-24
Drawdown, 1974 to 2009
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

- Rio Grande
- State Boundary
- Mesilla Basin Boundary

Number of Water Levels

- 1 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- > 40

Labels:
Count: First Year - Last Year
(only on wells with > 5
water level measurements)

Data Source:
USGS-NMISC
geodatabase compendium

VICINITY MAP

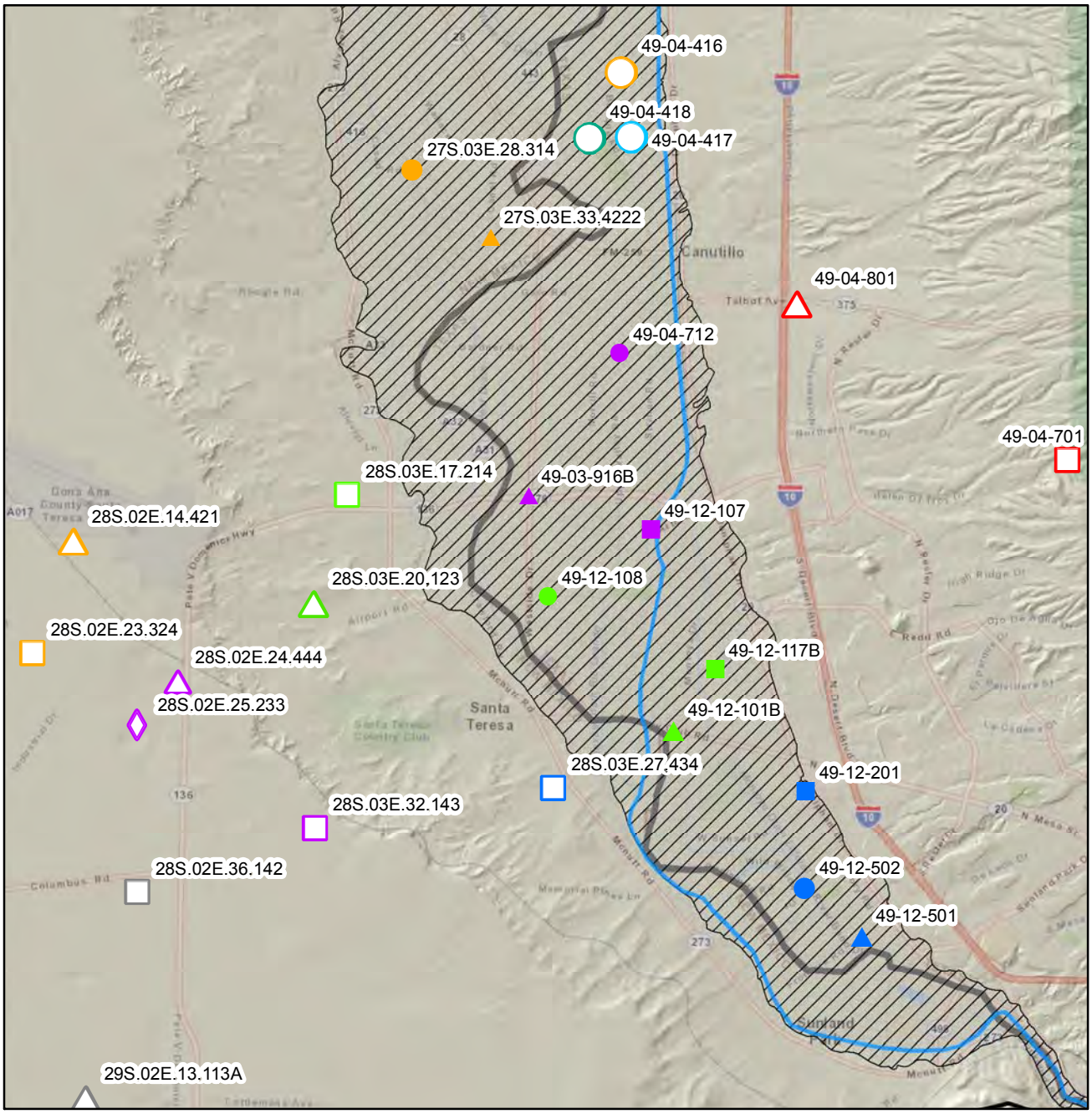
N

0 0.5 1
Miles

FIGURE 5-25
Groundwater Elevation Data Availability
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

\\ROSWELL\PROJ\USACE\408366MESILLA\GIS\MAPFILES\DISTALMESILLA\DistalMesilla_WL_Availability_v2.mxd



VICINITY MAP

LEGEND

- Rio Grande
- State Boundary
- Mesilla Basin Boundary
- River Alluvium (Hawley and Kennedy, 2004)

Labels:
(only on wells with > 5 water level measurements)
Count: First Year - Last Year

Data Source:
USGS-NMISC geodatabase compendium

N

0 0.5 1 2
Miles

FIGURE 5-26
Hydrograph Locations
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

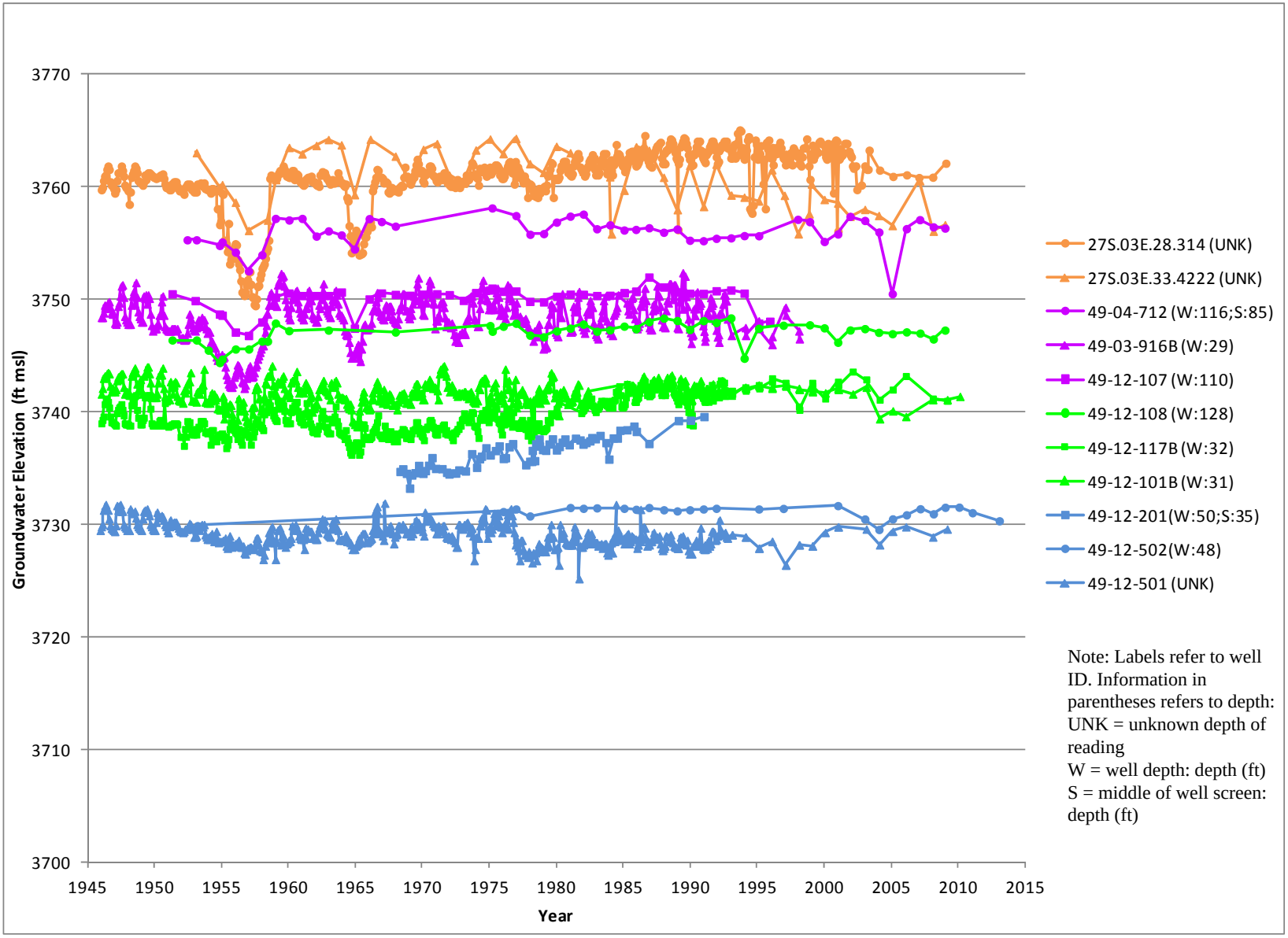


FIGURE 5-27
Groundwater Elevation, River Alluvium

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

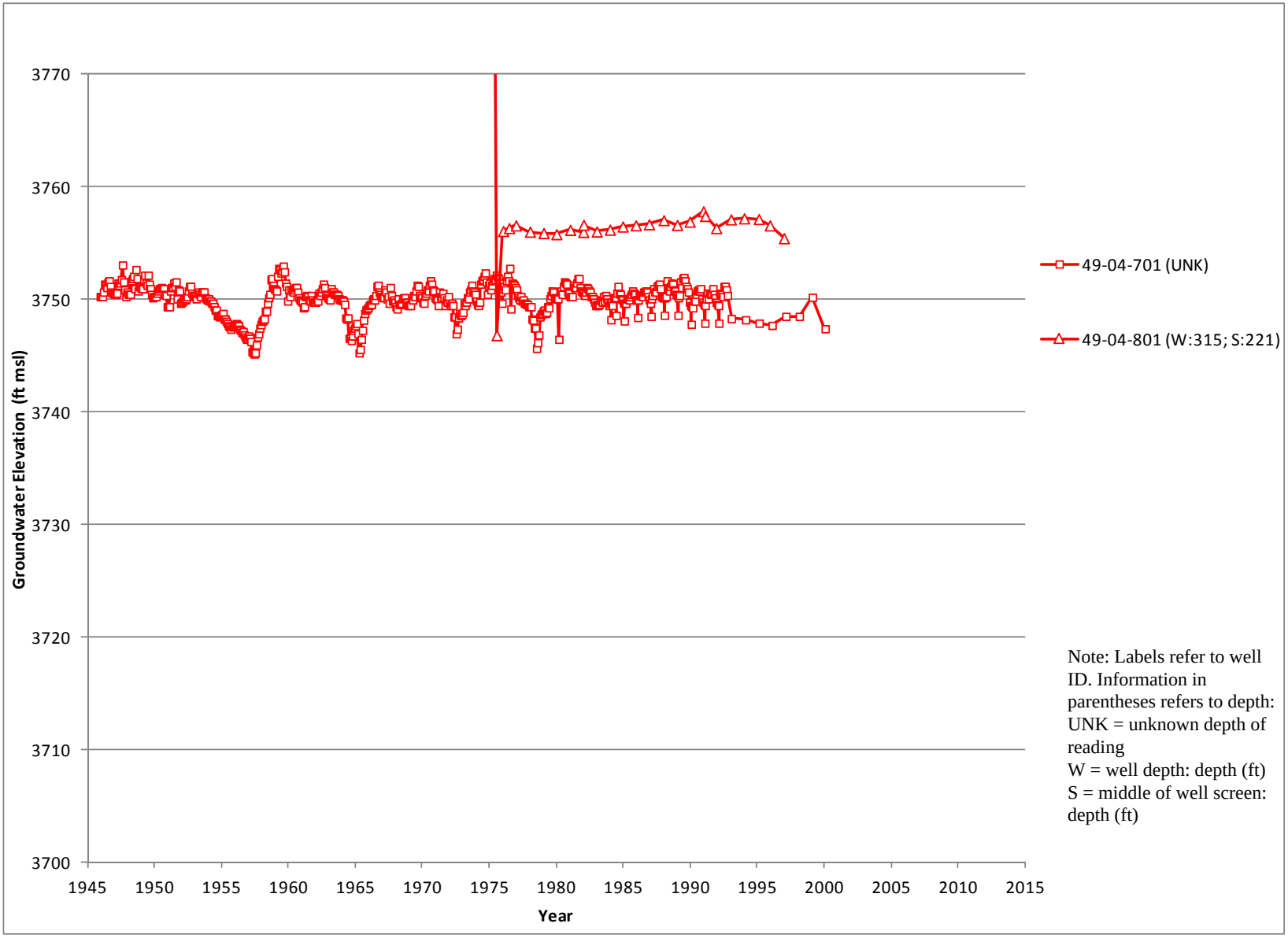


FIGURE 5-28
Groundwater Elevation, Santa Fe Group East of River

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

FIGURE 5-29
Groundwater Elevation, Santa Fe Group West of River

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

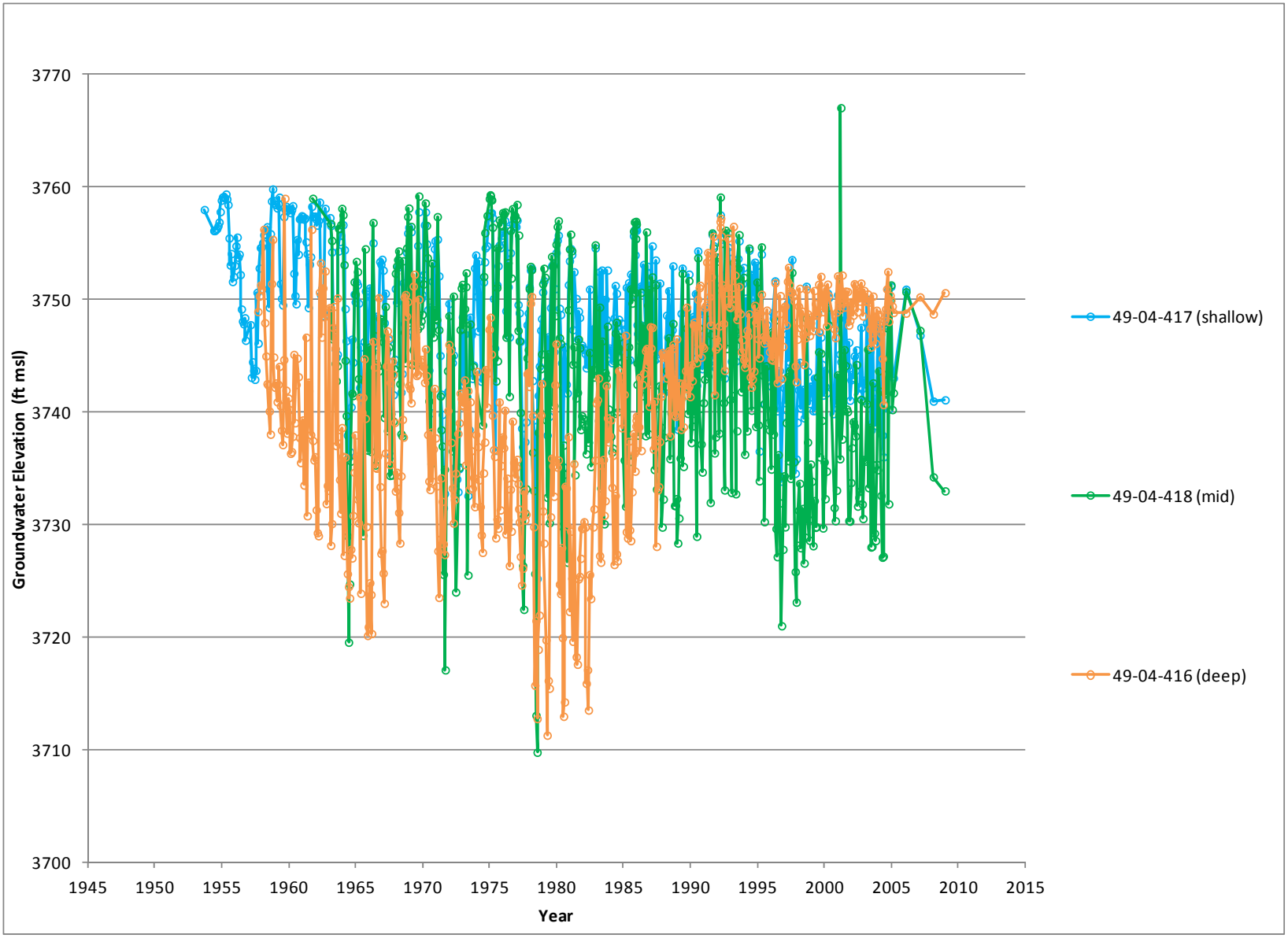
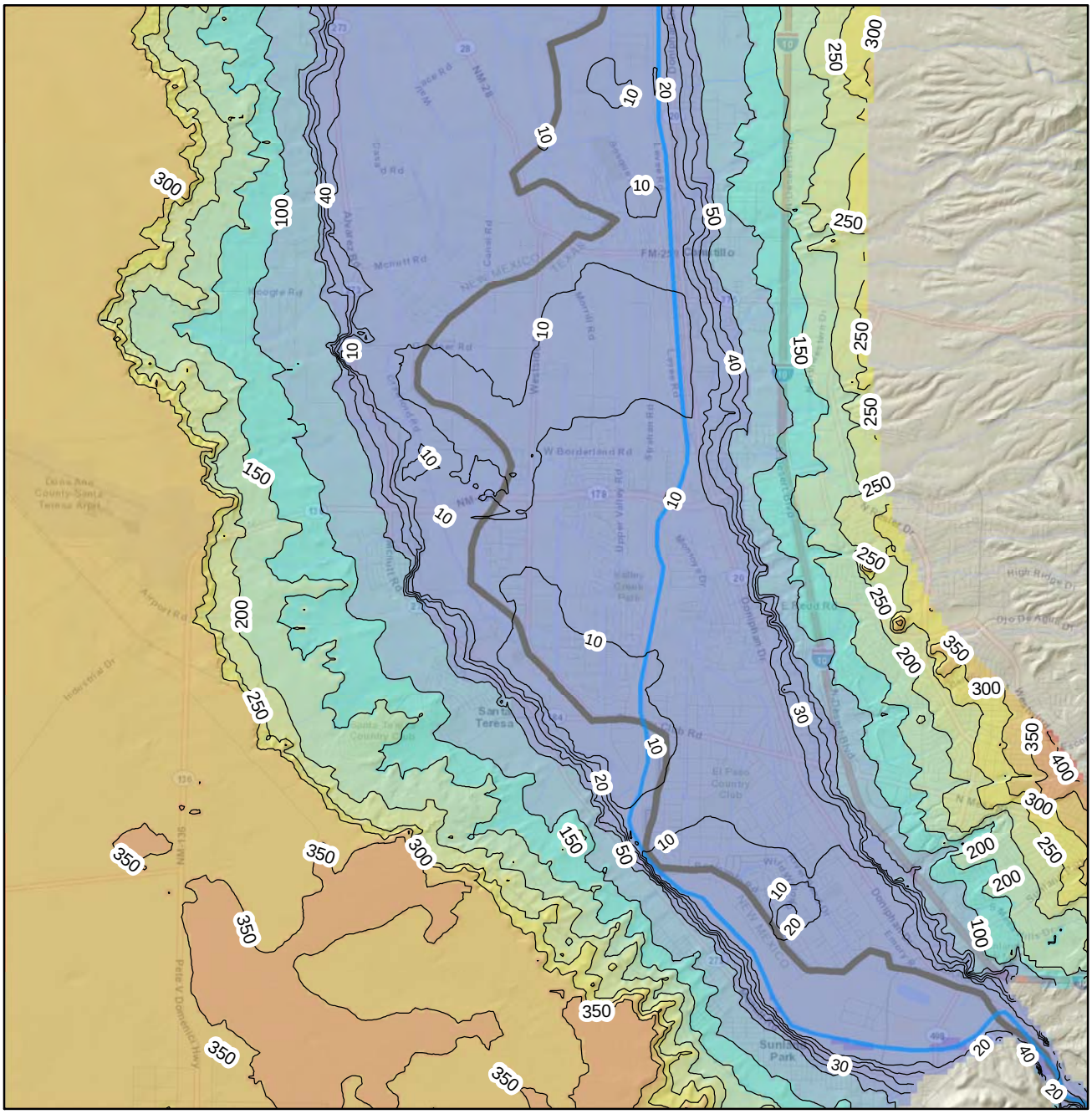


FIGURE 5-30
Groundwater Elevation, Canutillo Wellfield

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



VICINITY MAP

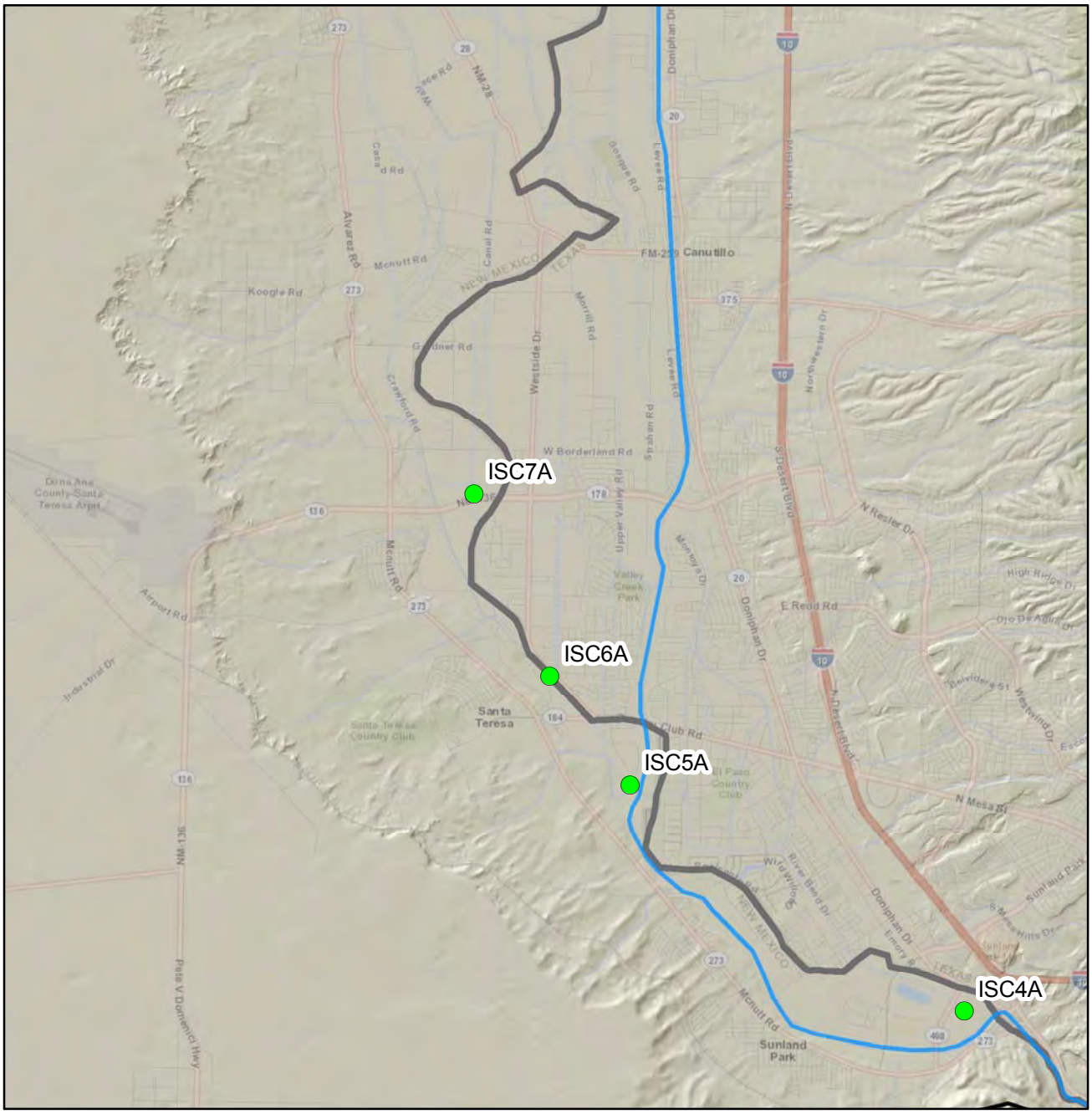
LEGEND

- Rio Grande
- State Boundary
- Contours of Depth to Water (ft) 10-ft intervals to 50 ft, then 50-ft intervals beyond 50 ft.

N

0 0.5 1
Miles

FIGURE 5-31
Depth to Groundwater 2009
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

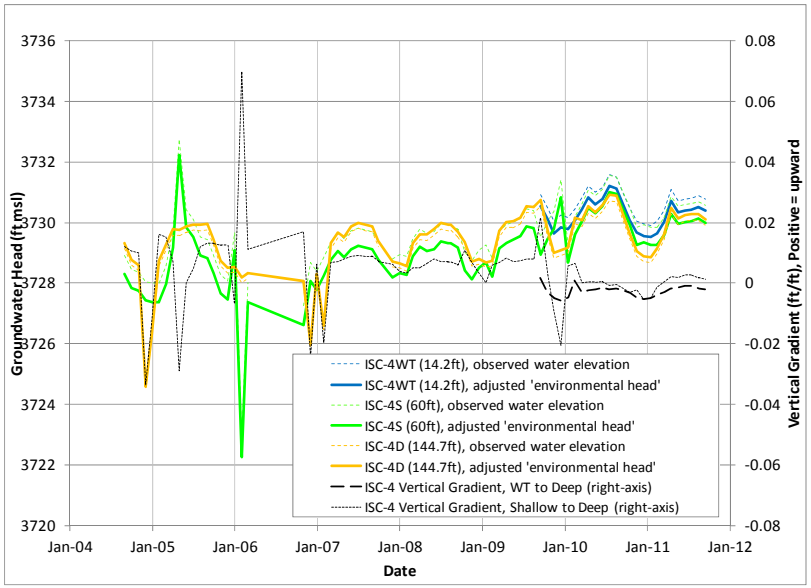
LEGEND

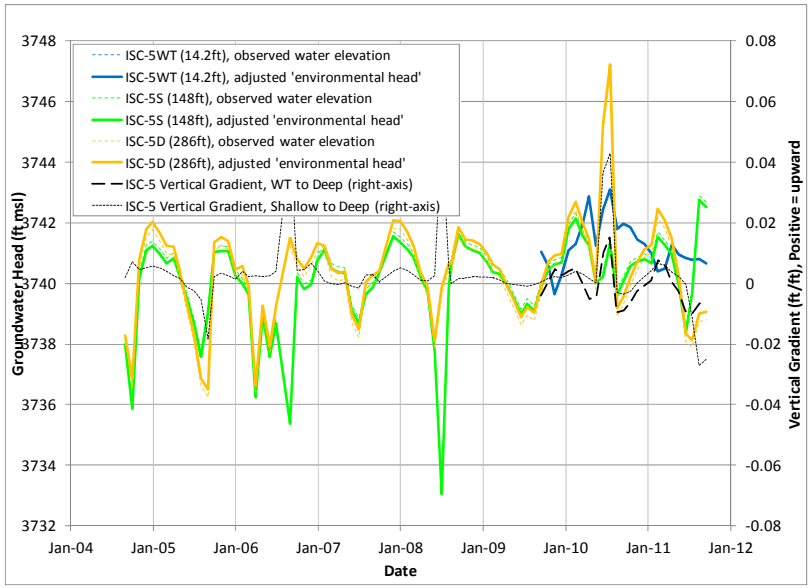
- Rio Grande
- Mesilla Basin Boundary
- State Boundary
- Vertical Gradient Locations

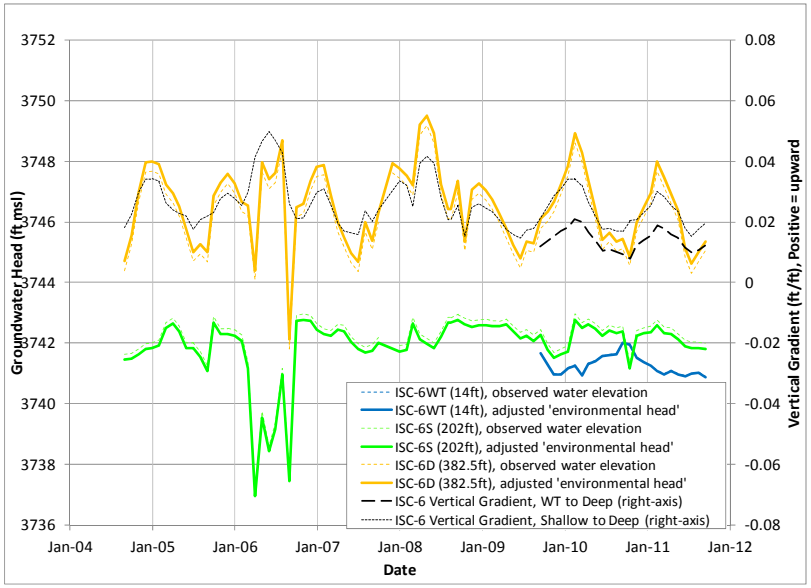
N

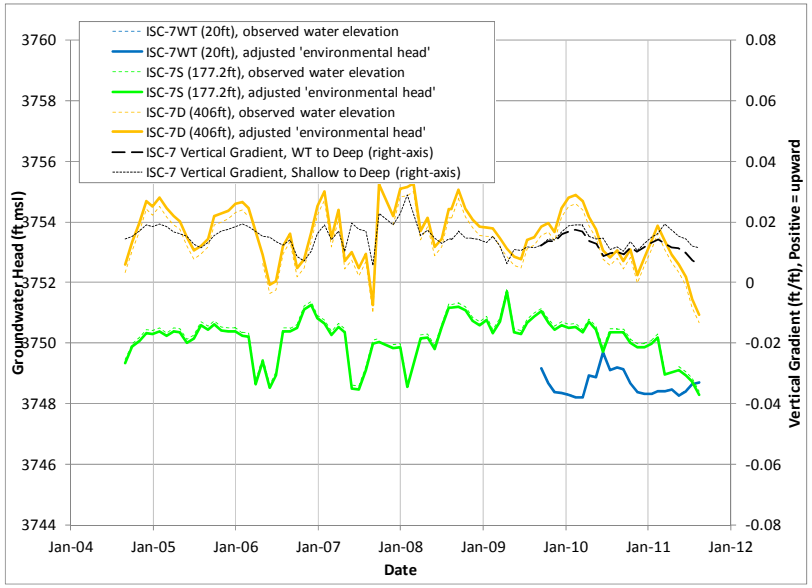
0 0.5 1 2
Miles

FIGURE 5-32
Vertical Gradient Locations
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program









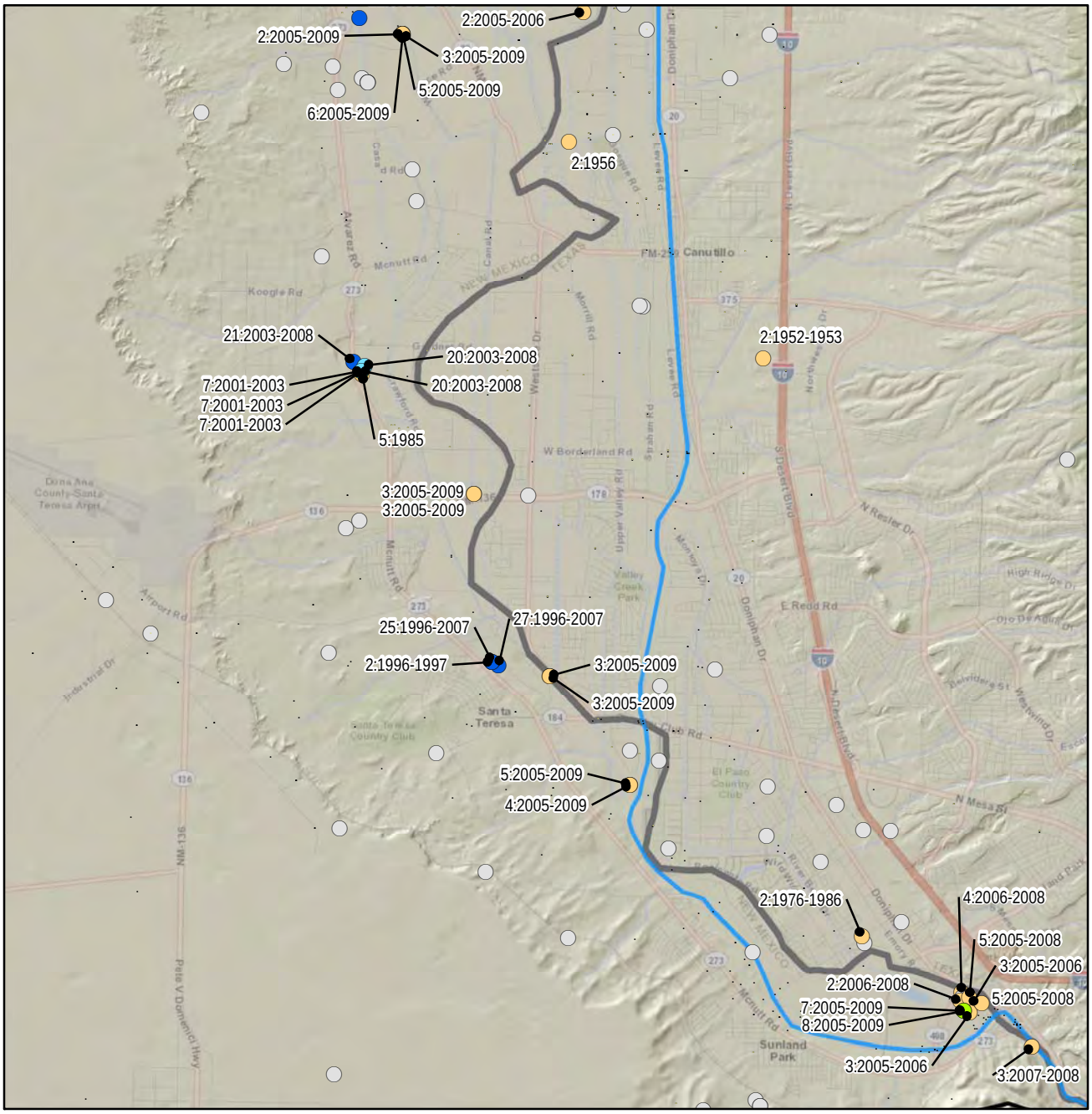
Notes

1. Vertical gradient based on "environmental water head," which takes into account salinity/density
2. Environmental water head calculated at reference elevation 3750. Calculated based on method in Luscynski (1961), as referenced by Post, et al. (2007)

FIGURE 5-33
Vertical Gradients

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



VICINITY MAP

LEGEND

- Rio Grande
- State Boundary
- Mesilla Basin Boundary

Number of Sample Events with Laboratory Analytical Data for Total Dissolved Solids

- 1
- 2 - 5
- 6 - 10
- 11- 20
- 21 - 56

Labels:
Count: First Year - Last Year
(only on wells with > 1 data point)

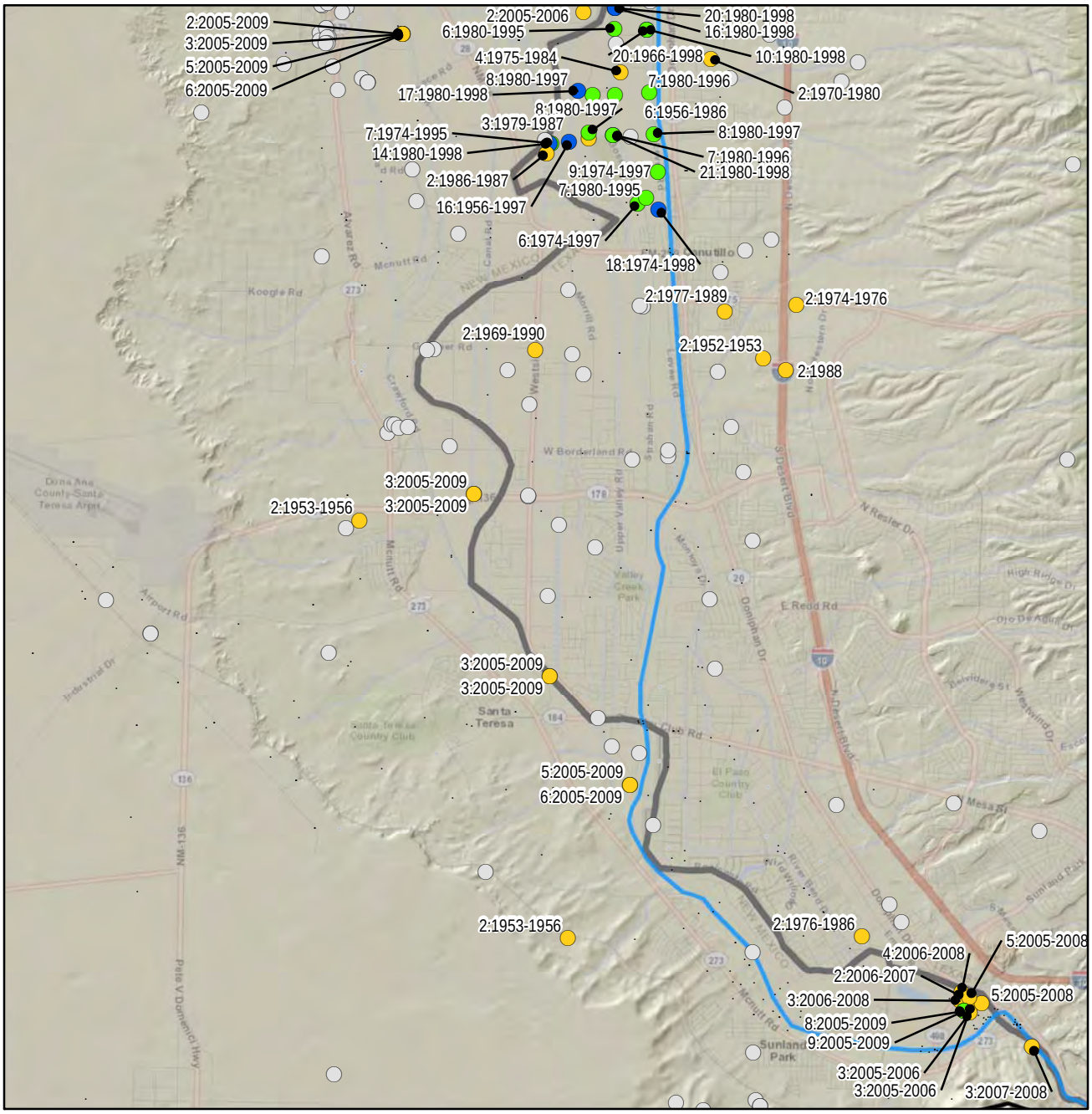
Data Source:
USGS-NMISC
geodatabase compendium

Note:
TDS Data are laboratory analytical results for total dissolved solids

N

0 0.5 1 2
Miles

FIGURE 5-34
TDS Data Availability
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

LEGEND

- Rio Grande
- State Boundary
- Mesilla Basin Boundary

Number of Sample Events with Specific Conductance Data

- 1
- 2 - 5
- 6 - 10
- 11 - 23

Labels:
Count: First Year - Last Year
(only on wells with > 1 data point)

Data Source:
USGS-NMISC
geodatabase compendium

Note:
Specific conductance data are field or laboratory results that estimate total dissolved solids

N

0 0.5 1 2
Miles

FIGURE 5-35
Conductance Data Availability

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

VICINITY MAP

LEGEND

- Rio Grande
- State Boundary
- Mesilla Basin Boundary

Well Symbols Corresponding to Symbols in Chemographs by Location

- Northern Study Area (Solid Squares in Texas)
- North Canutillo Area
- Central Study Area, South of Canutillo
- South-Central Study Area, Santa Teresa Valley
- Southeast Study Area

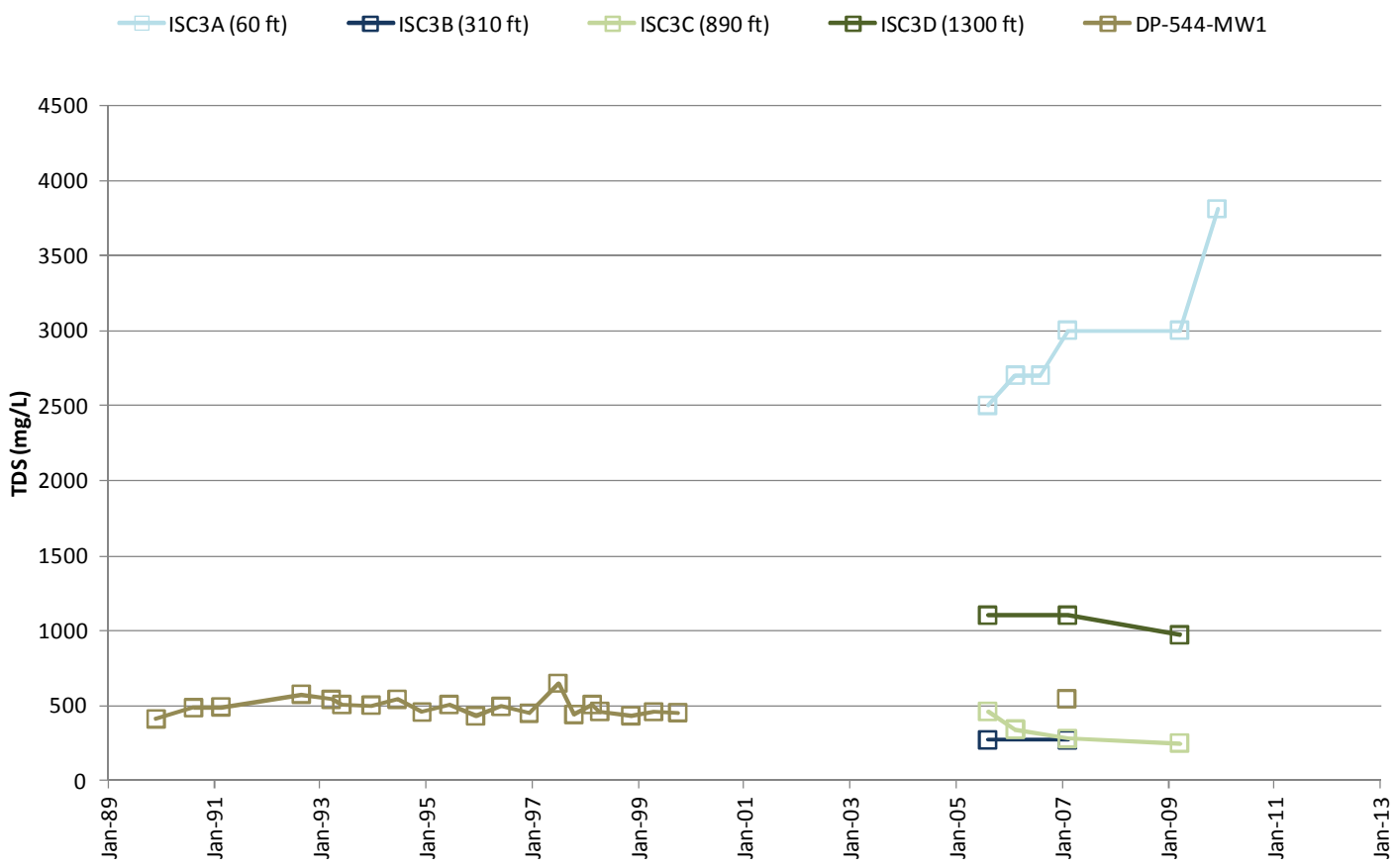
Labels: Well Identifier (Mid-Screen)
Mid-screen depth in feet below ground
Screen interval presented for large screens

Data Source:
USGS-NMISC
geodatabase compendium

N

0 0.5 1 2
Miles

FIGURE 5-36
Chemograph Locations
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

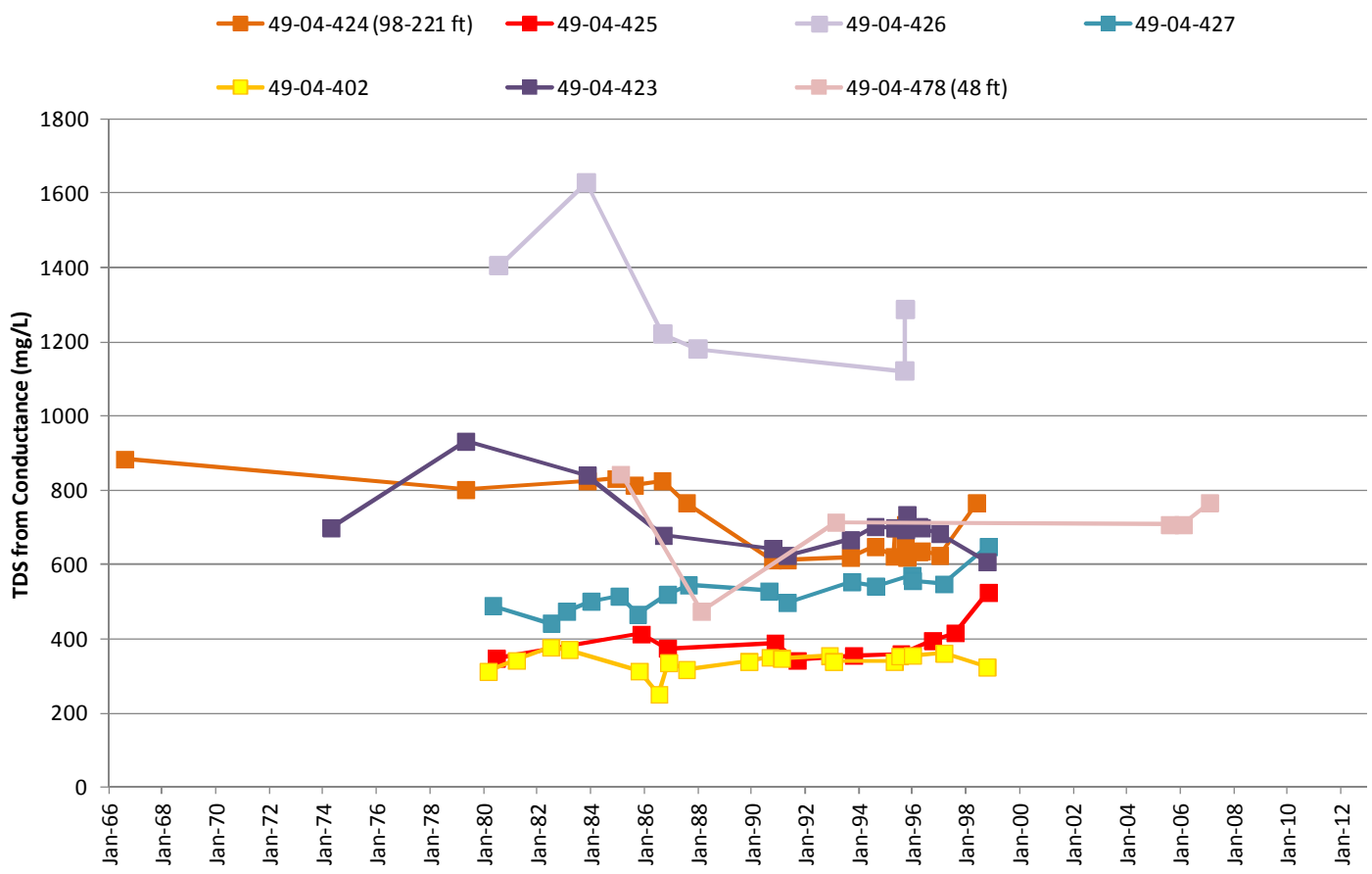


NOTE: Where screen interval is known, the mid-screen depth (in feet below ground surface) is presented next to the well identifier in parenteses.

FIGURE 5-37
Time-Series of TDS: North Study Area (NM)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

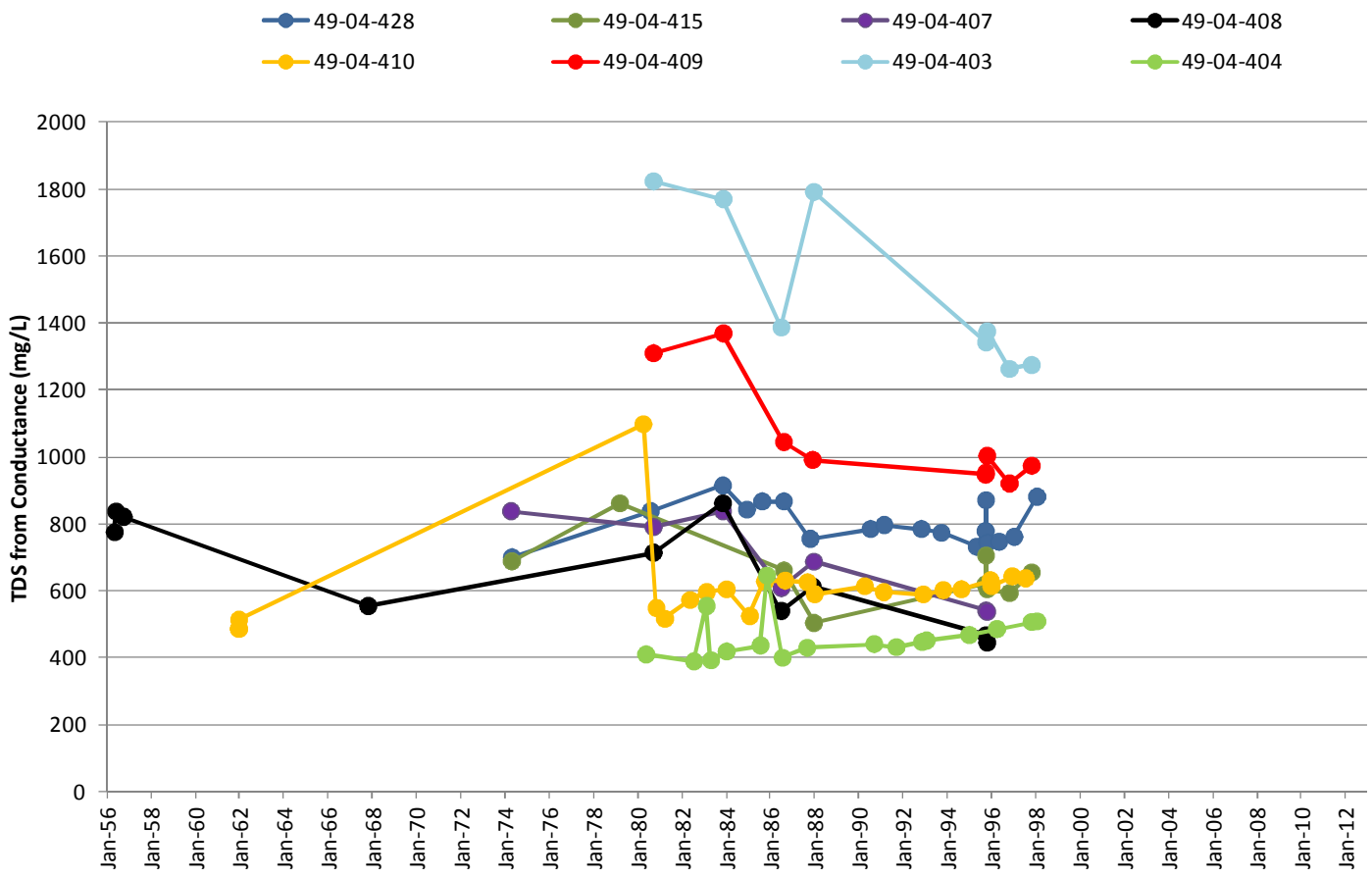


NOTES: 1) TDS data primarily computed from laboratory and field conductance methods by simple multiplication factor of 0.59
2) Where screen interval is known, the mid-screen depth (in feet below ground surface) is presented next to the well identifier in parenteses. A screen interval is presented for large well screens.

FIGURE 5-38
Time-Series of TDS: North Study Area (TX)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



NOTE: TDS data primarily computed from laboratory and field conductance methods by simple multiplication factor of 0.59

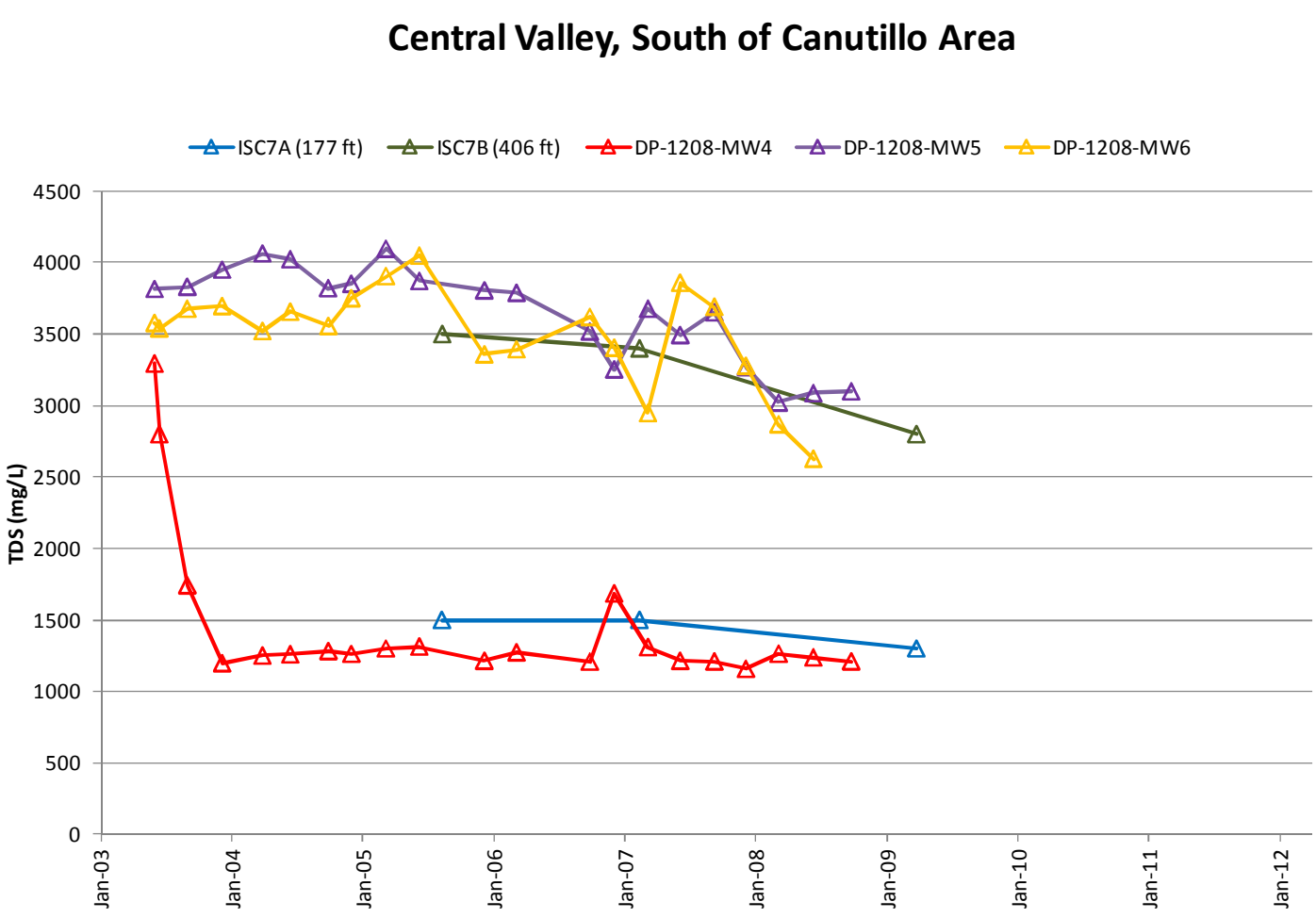
FIGURE 5-39

Time-Series of TDS: North Canutillo Area

Distal Mesilla Conceptual Site Model

Rio Grande Salinity Management Program

CH2MHILL

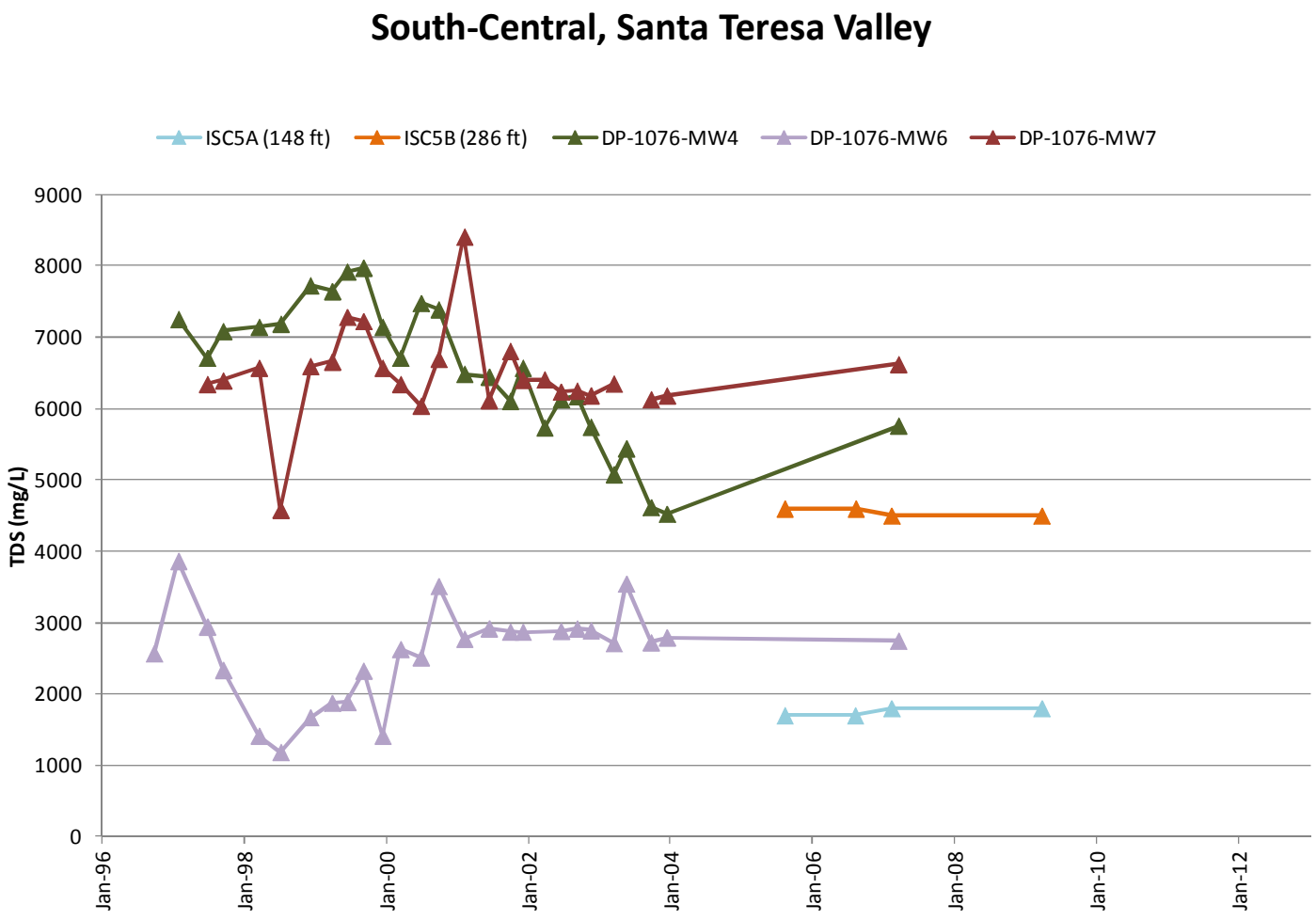


NOTE: Where screen interval is known, the mid-screen depth (in feet below ground surface) is presented next to the well identifier in parenteses.

FIGURE 5-40
Time-Series of TDS:
Central Valley, South of Canutillo Area

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



NOTE: Where screen interval is known, the mid-screen depth (in feet below ground surface) is presented next to the well identifier in parenteses.

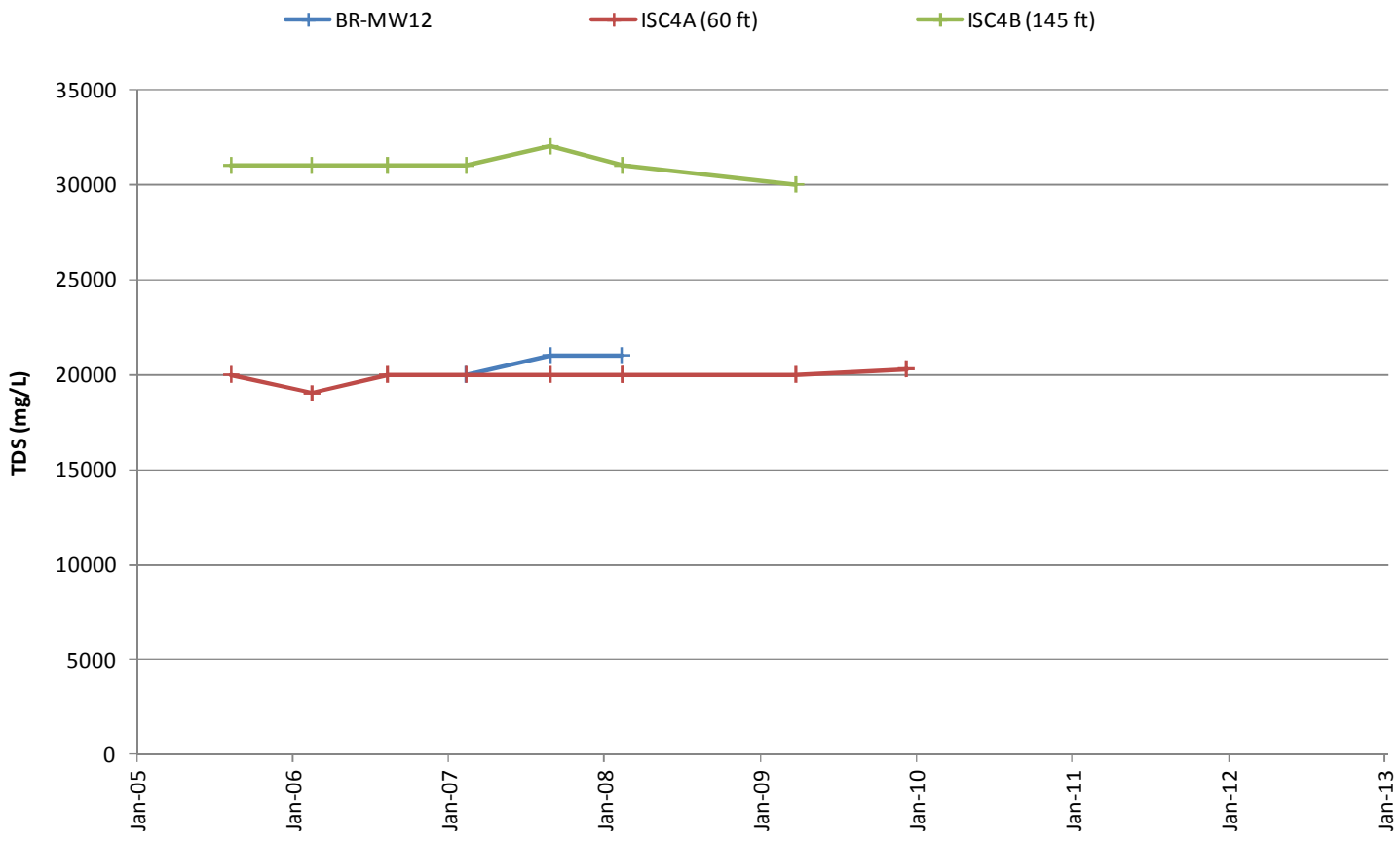
FIGURE 5-41

Time-Series of TDS: South-Central, Santa Teresa

Distal Mesilla Conceptual Site Model

Rio Grande Salinity Management Program

CH2MHILL



NOTE: Where screen interval is known, the mid-screen depth (in feet below ground surface) is presented next to the well identifier in parenteses.

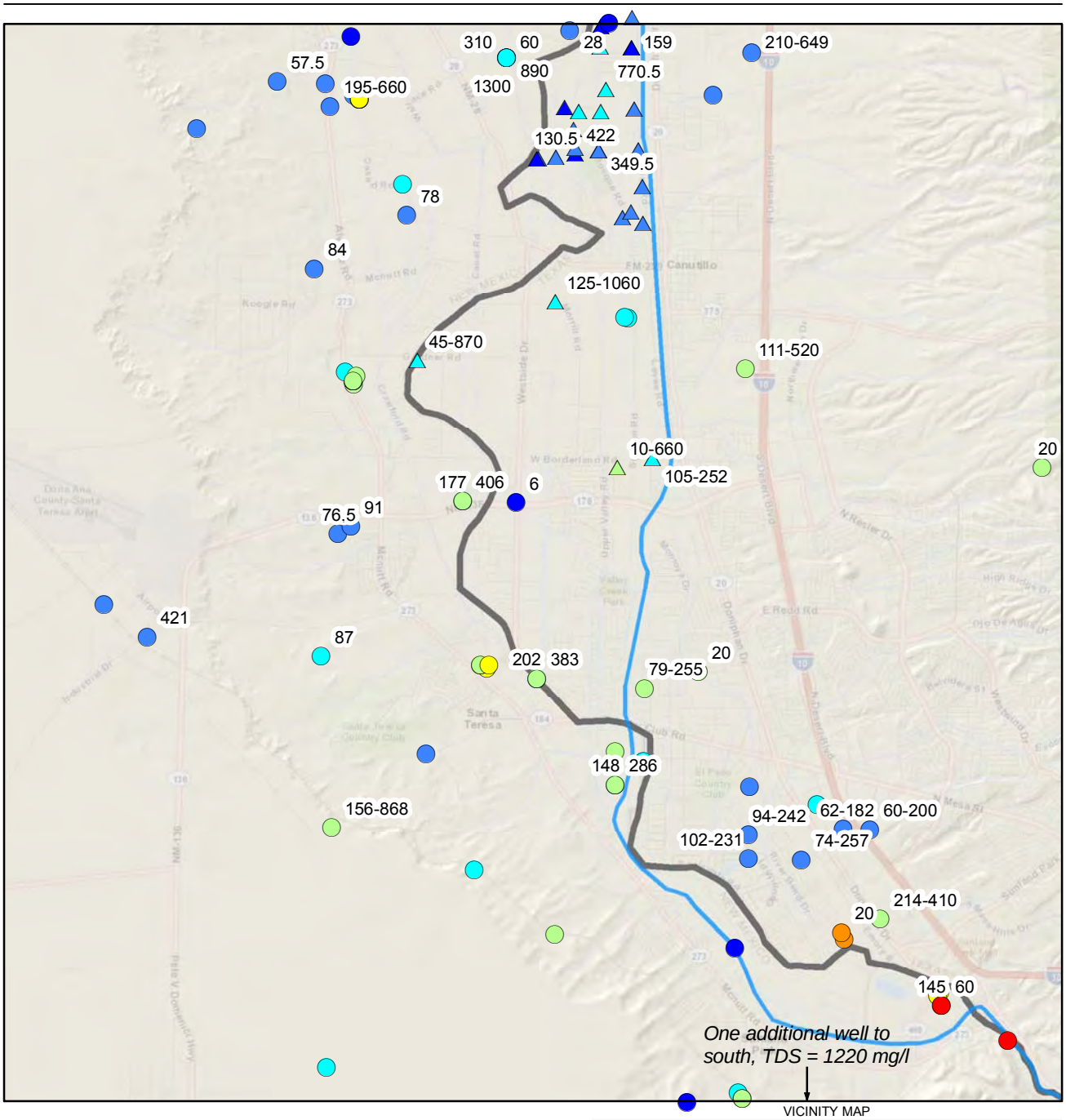
FIGURE 5-42

Time-Series of TDS: Near El Paso Narrows

Distal Mesilla Conceptual Site Model

Rio Grande Salinity Management Program

CH2MHILL



LEGEND

Rio Grande

State Boundary

MedianTDS (label = depth)

- 221 - 500
- 501 - 1,000
- 1,001 - 2,000
- 2,001 - 5,000
- 5,001 - 10,000
- 10,001 - 20,000
- 20,001 - 50,000

Triangles represent EC data converted to TDS

Data Source:
NM ISC Data Compendium

N

0 0.5 1 2
Miles

FIGURE 5-43
Median TDS
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

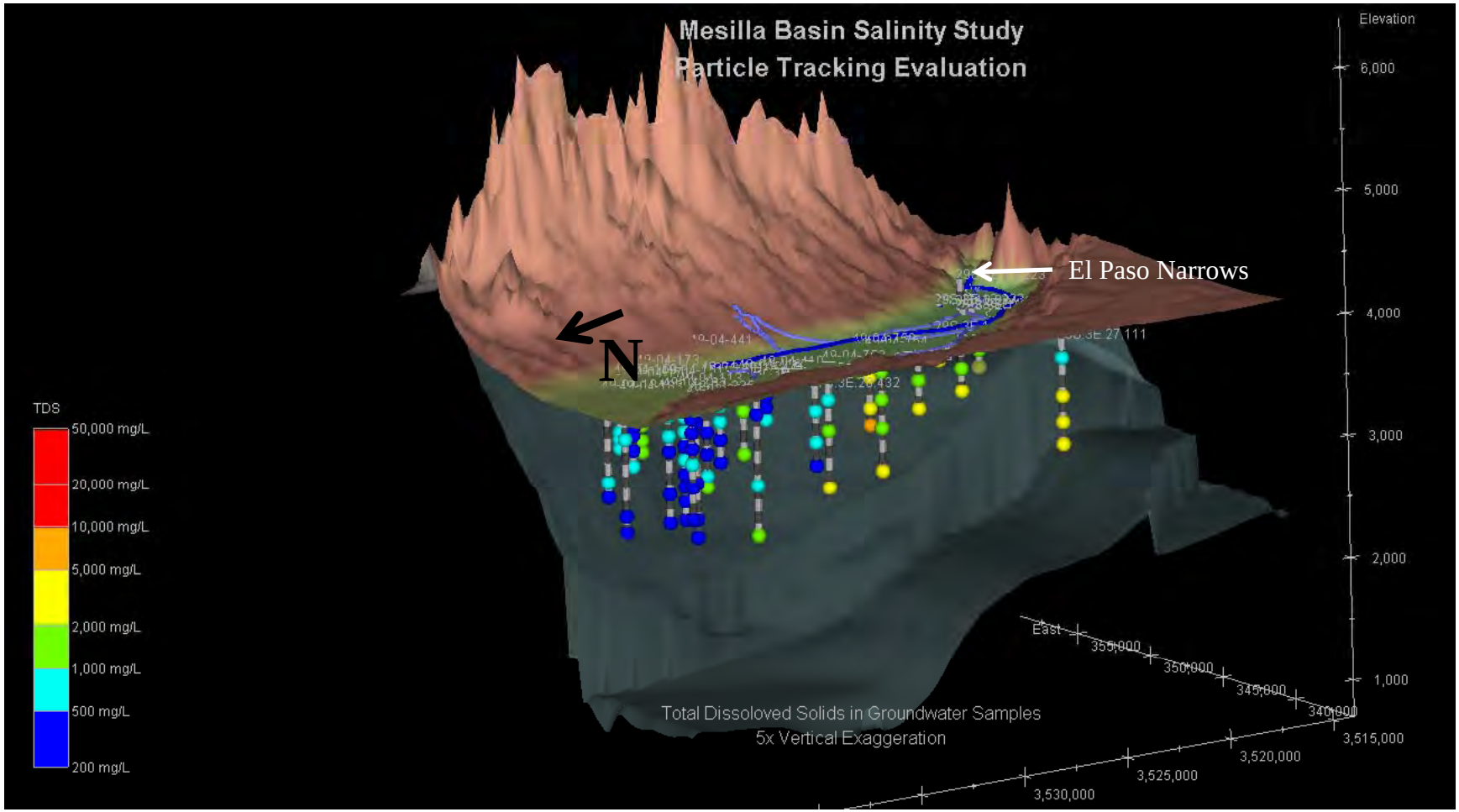


Image is a screen capture from a 3-D file that is available on the CD attachment to this report. The user can "spin," zoom in, etc.

FIGURE 5-44
TDS, 3-Dimensional View

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

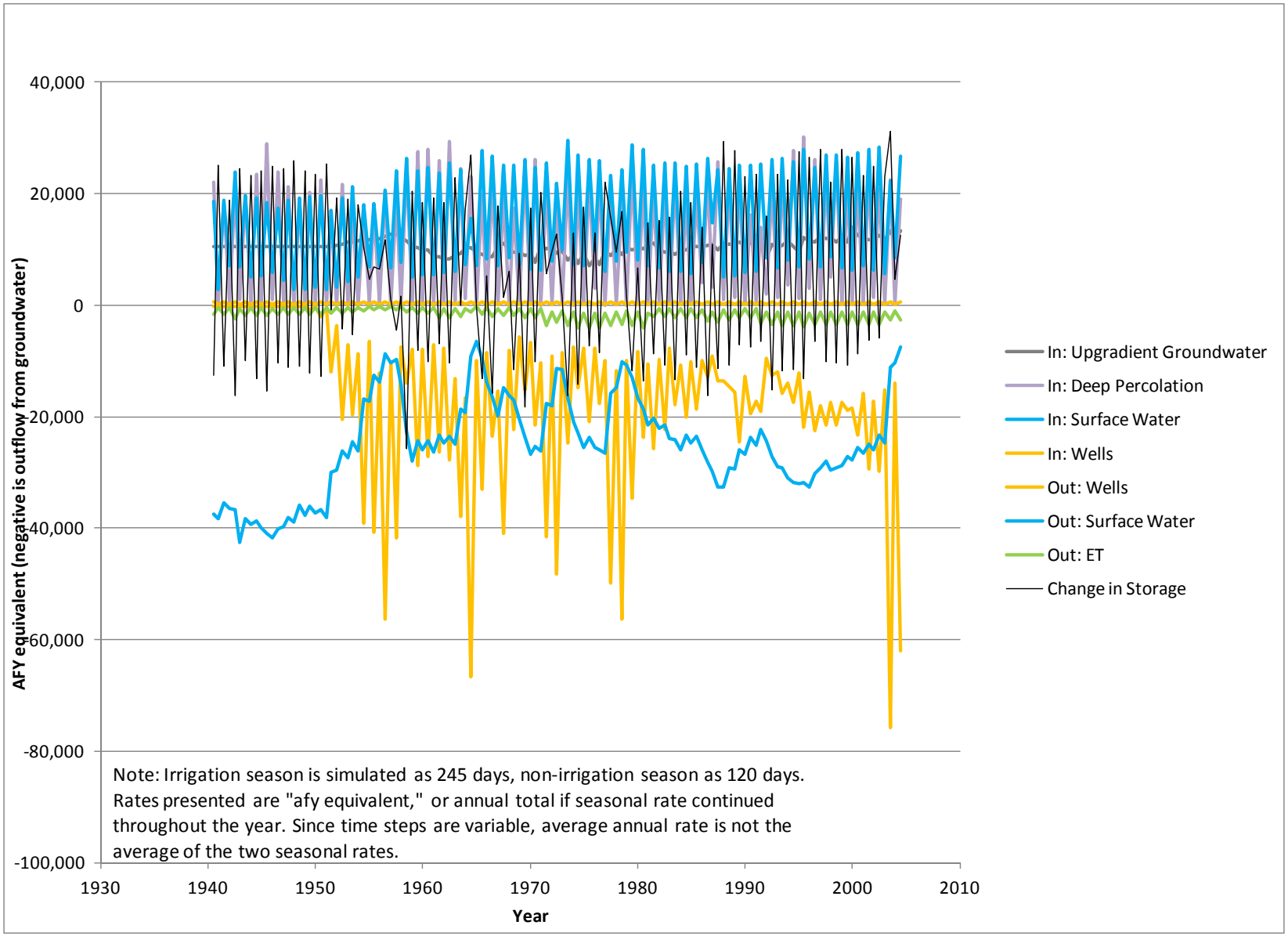


FIGURE 5-45
Transient Study Area
Water Budget, 1940-2004

Data source: NM OSE administrative model (SSPA, 2007)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

FIGURE 5-46
Transient Study Area
Water Budget, 1980-1999

Data source: NM OSE administrative model (SSPA, 2007)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

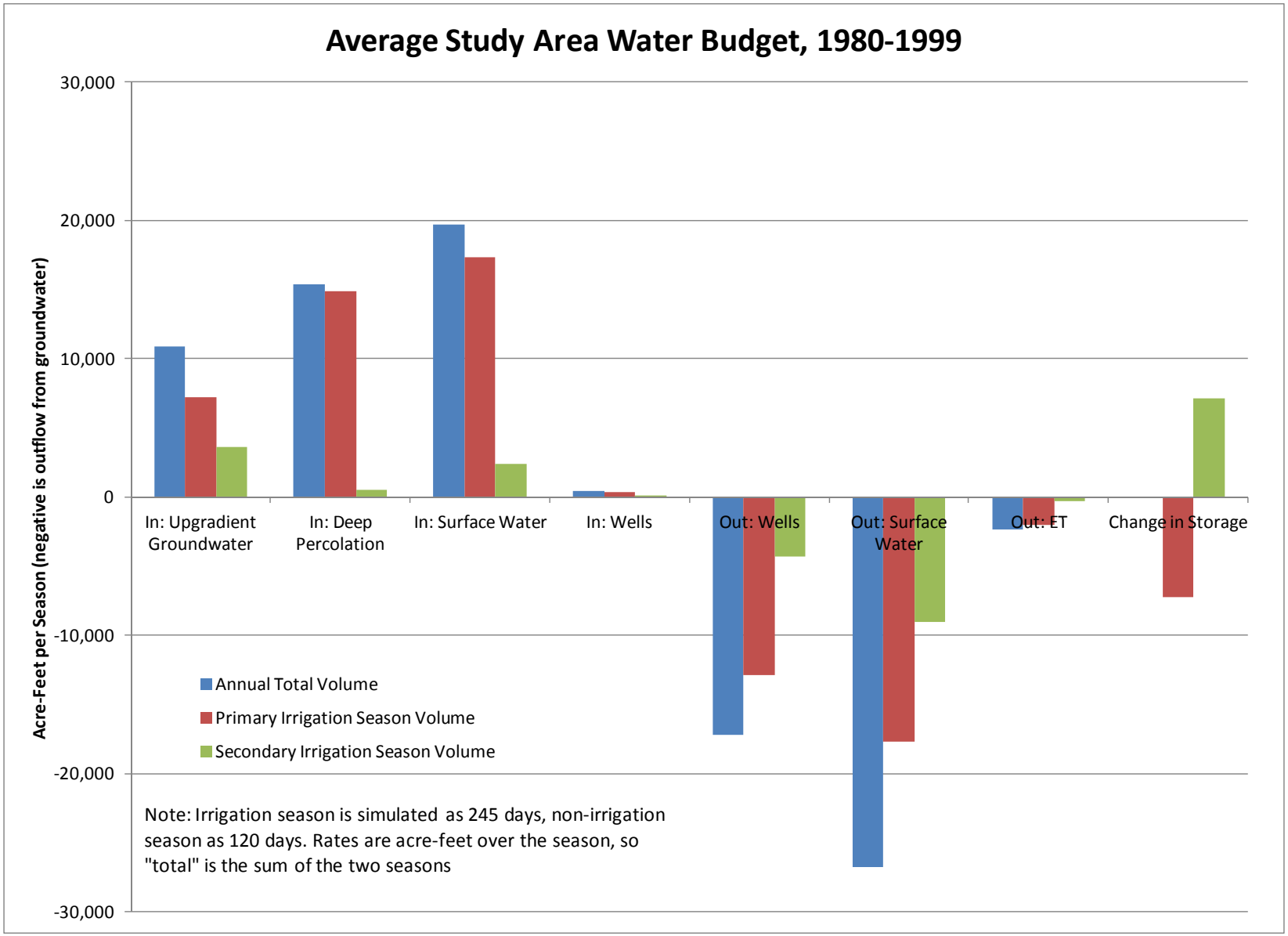
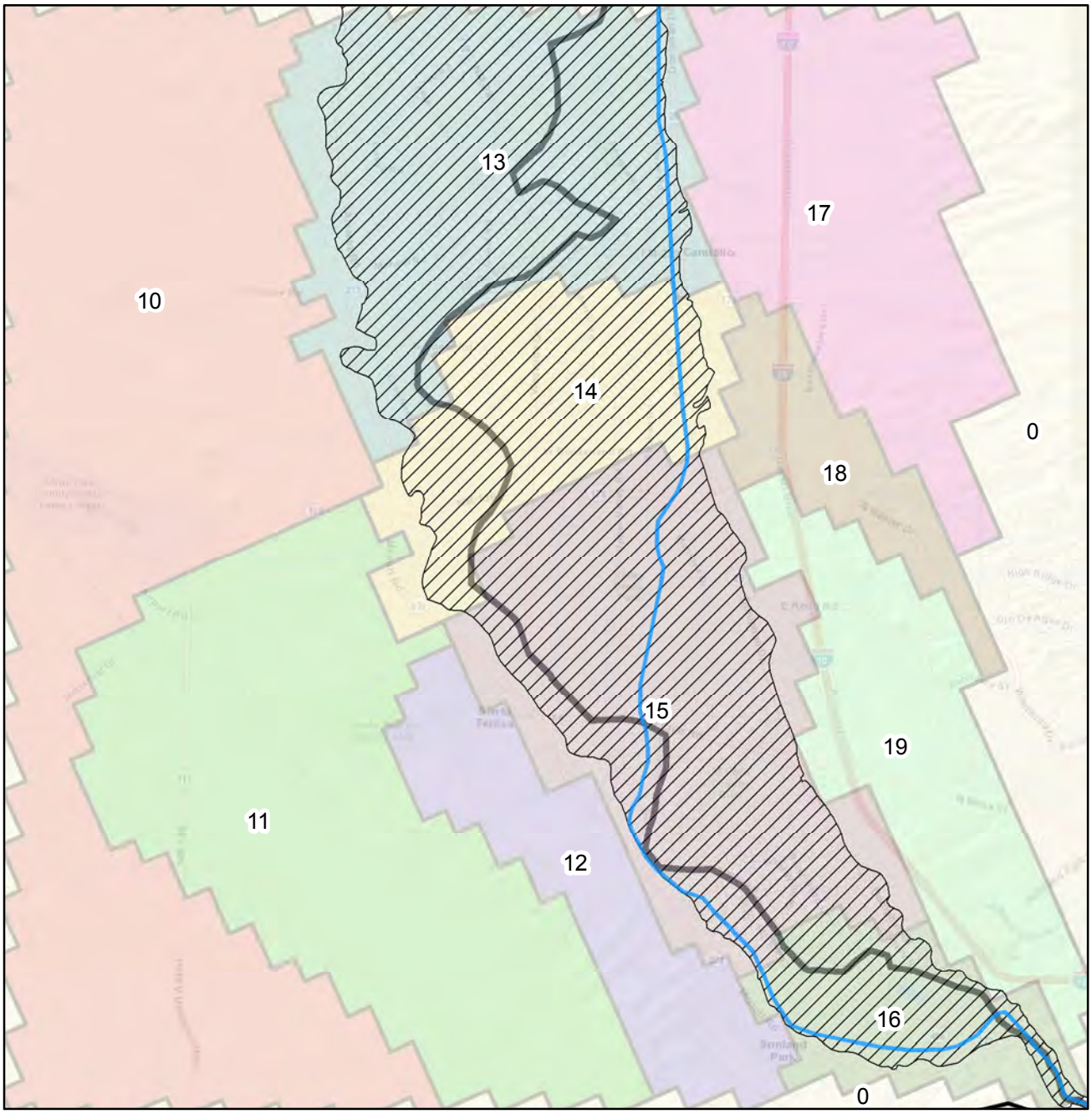


FIGURE 5-47
Average Study Area Water Budget, 1980-1999

Data source: NM OSE administrative model (SSPA, 2007)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



VICINITY MAP

LEGEND

- Rio Grande
- River Alluvium

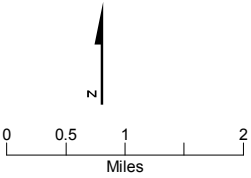
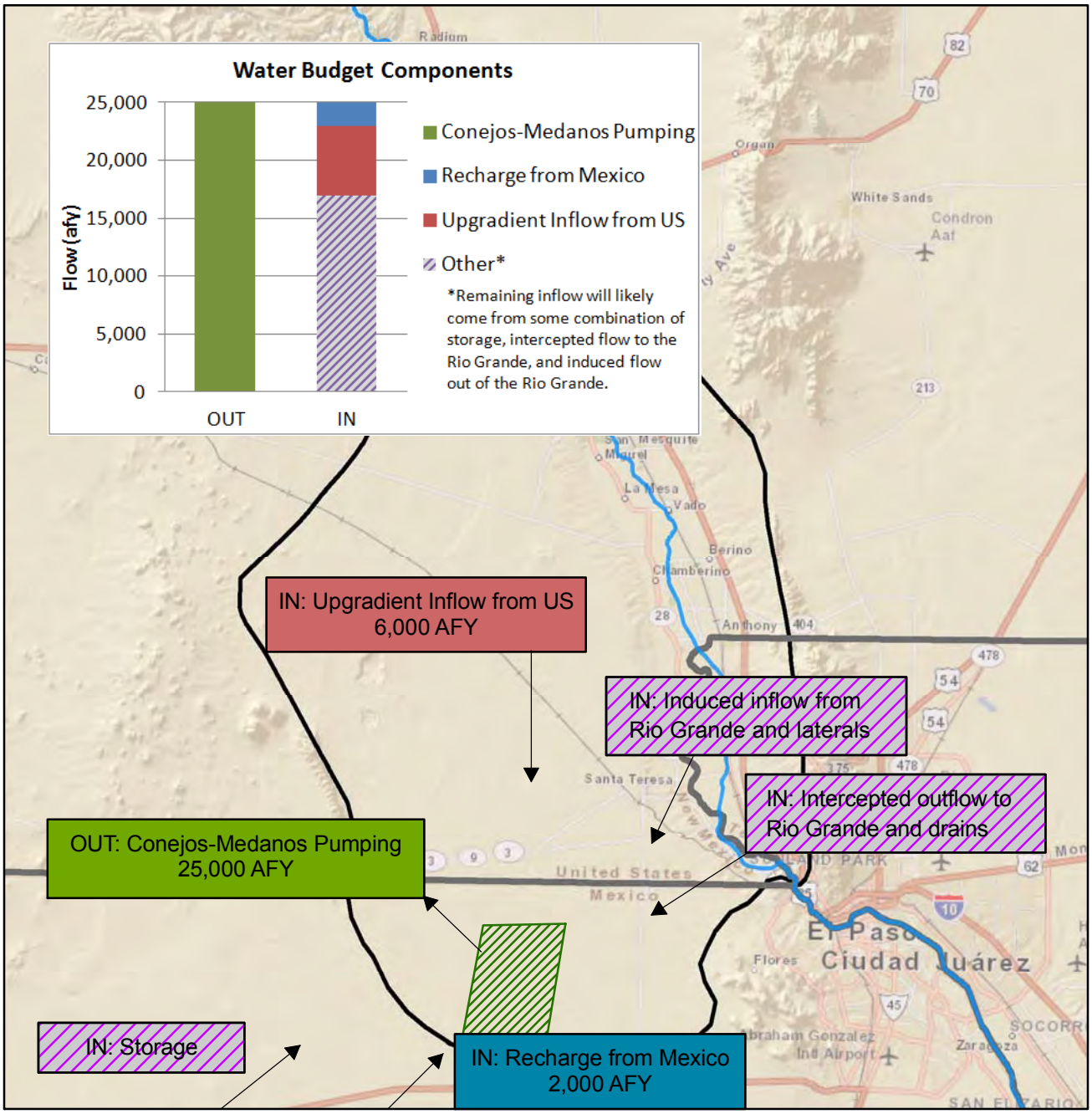


FIGURE 5-48
Model Water Budget Zones
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

LEGEND

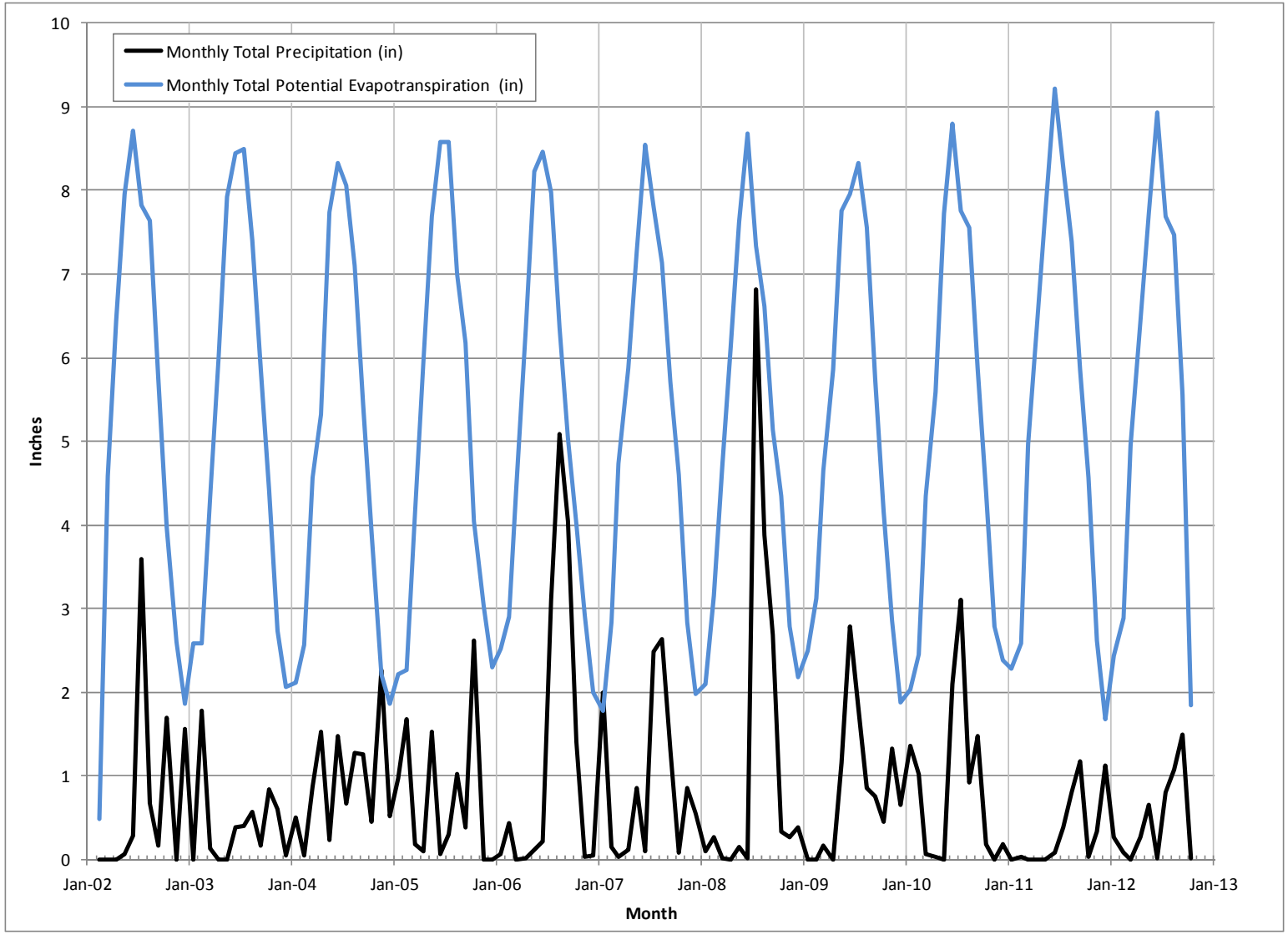
- Rio Grande
- Appoximate Boundary, Mesilla Groundwater Basin
- Approximate Location of Conejos-Medanos Wellfield

Notes:
Recharge from Mexico based on observed gradient and transmissivity.
Upgradient inflow from US based on assumption that Santa Teresa is pumping 5,000 afy.

N

0 2.5 5 10 15 20
Miles

FIGURE 5-49
Conejos-Medanos Water Budget
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

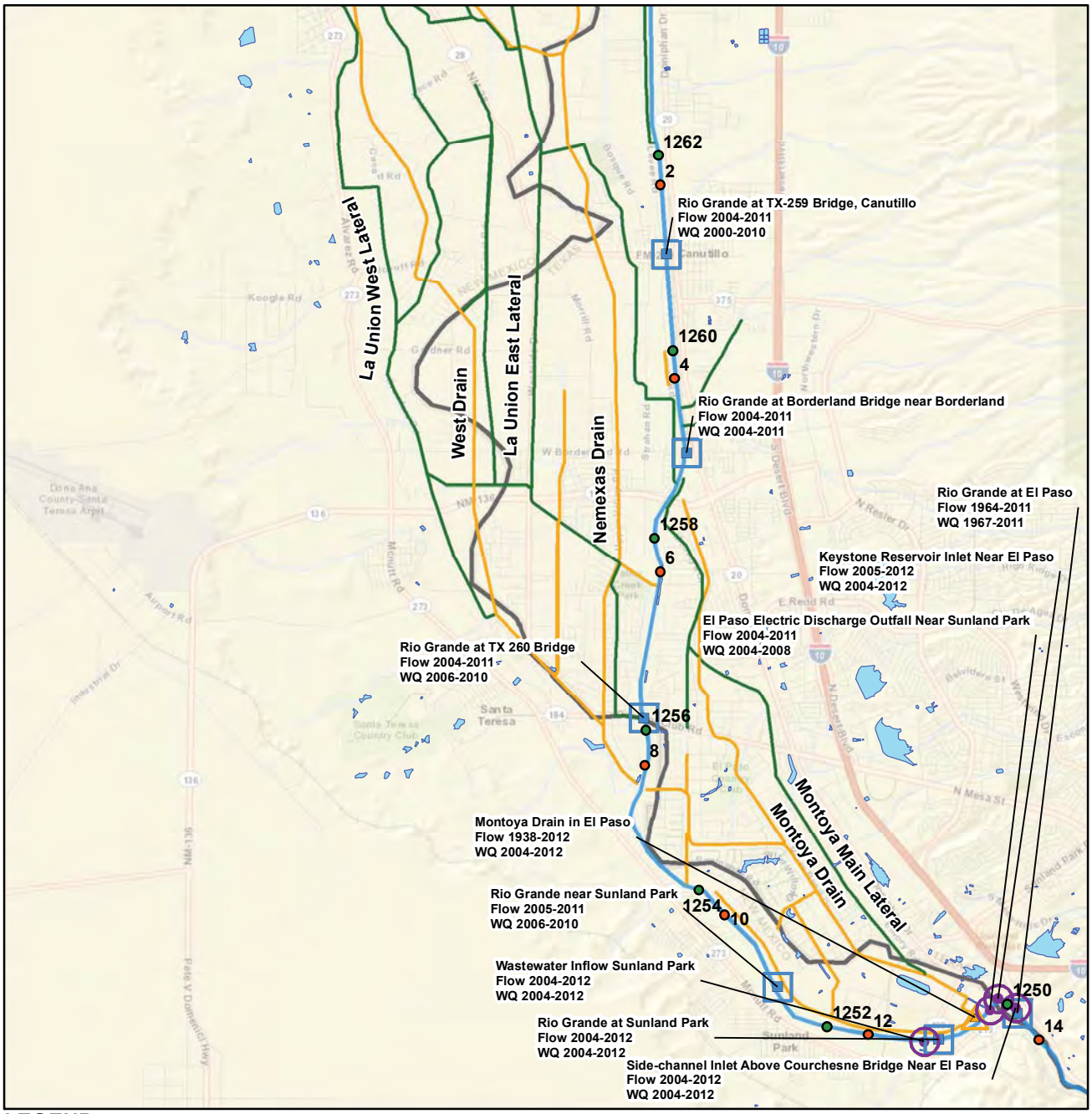


Data from New Mexico Climate Center, Santa Teresa site
Potential Evapotranspiration reported as "Hargreaves and Samani"

FIGURE 6-1
Precipitation and Evapotranspiration Data

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



LEGEND

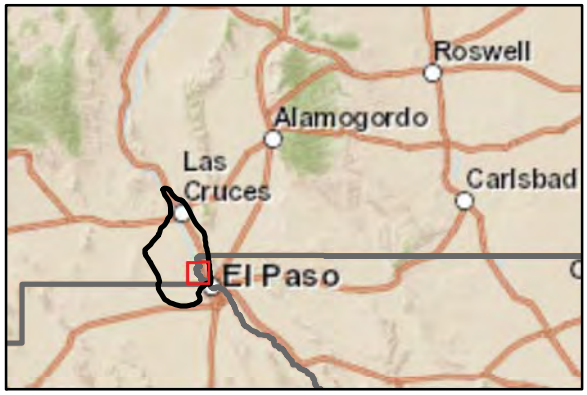
- Other Inflows Water Quality Data
- Other Inflows Flow Data
- Drain Water Quality Data
- River Water Quality Data
- Drain Flow Data
- River Flow Data
- USGS River Mile
- Local River Mile

HYDROLOGY

- Canal
- Drain
- Lateral
- State Boundary
- Rio Grande
- Mesilla Basin Boundary

Data Sources:
USGS-NMISC
geodatabase compendium
USGS-NWIS
EPA-STORET

VICINITY MAP



N

0 0.5 1 2
Miles

FIGURE 6-2
Water Quality and Flow Stations
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

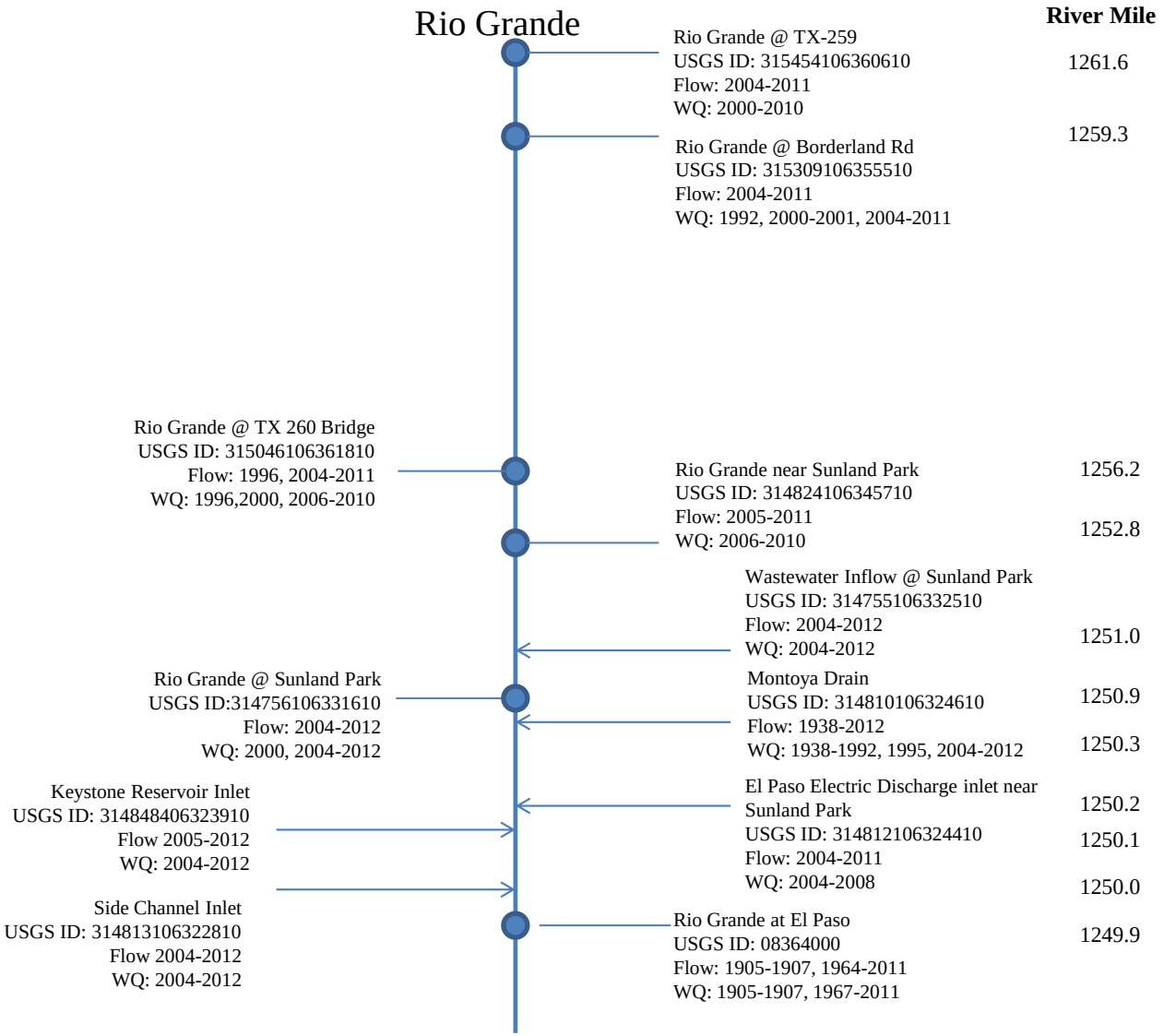


FIGURE 6-3
Data Availability Schematic
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.

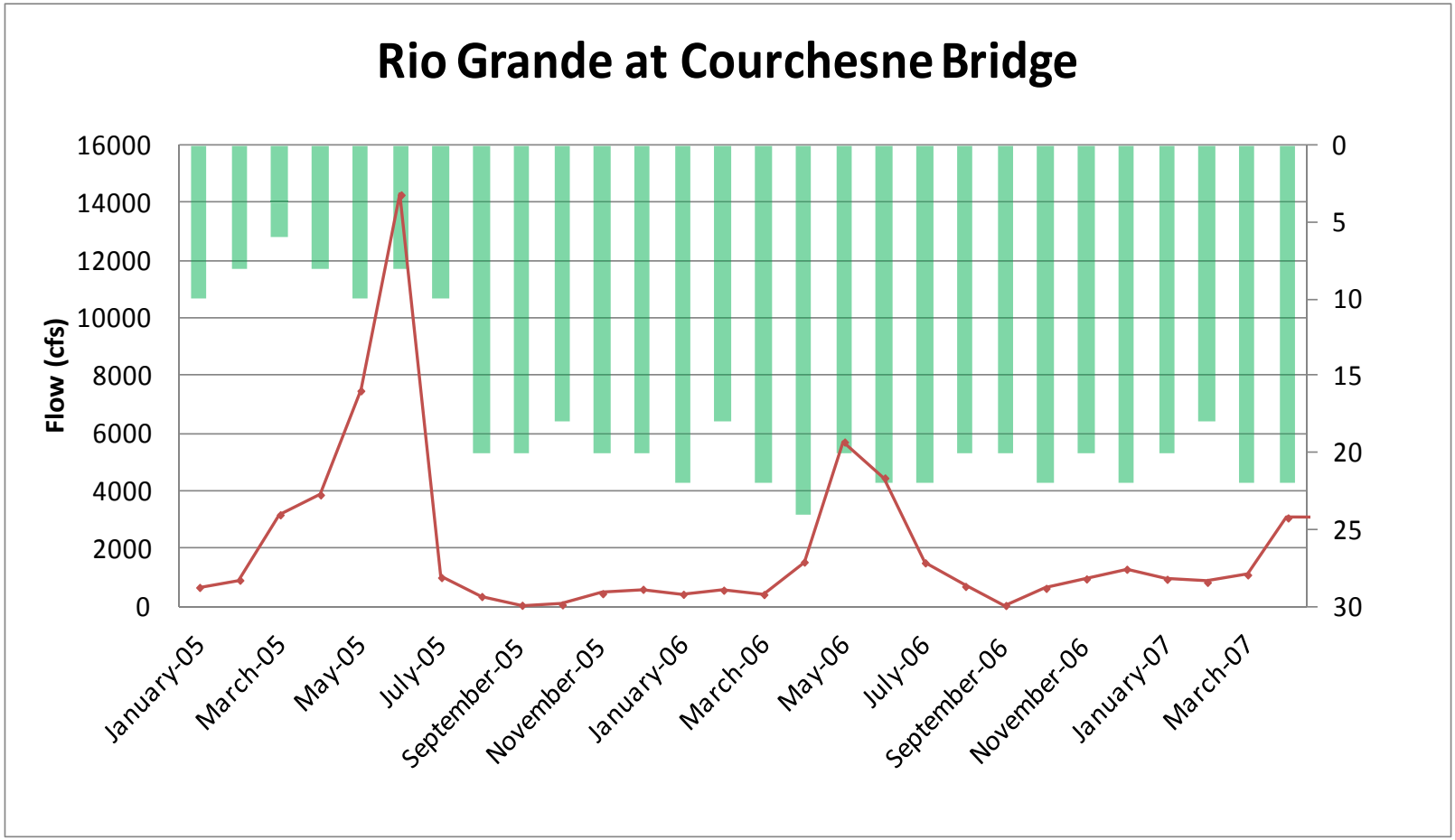


FIGURE 6-4
Rio Grande at Courchesne Bridge
Flow (cfs), 1905-1907
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.

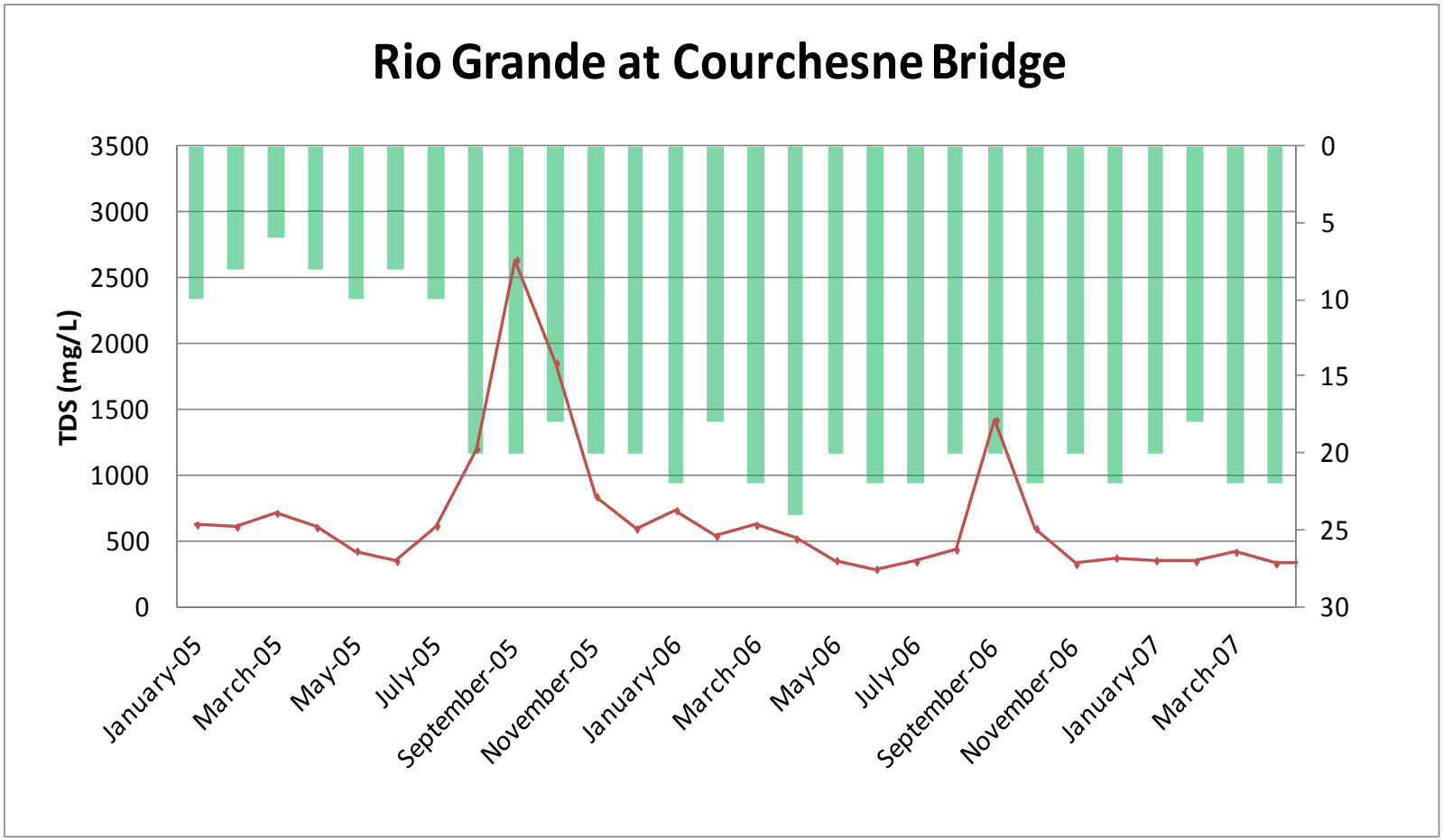


FIGURE 6-5
Rio Grande at Courchesne Bridge
Total Dissolved Solids (mg/L), 1905-1907
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.

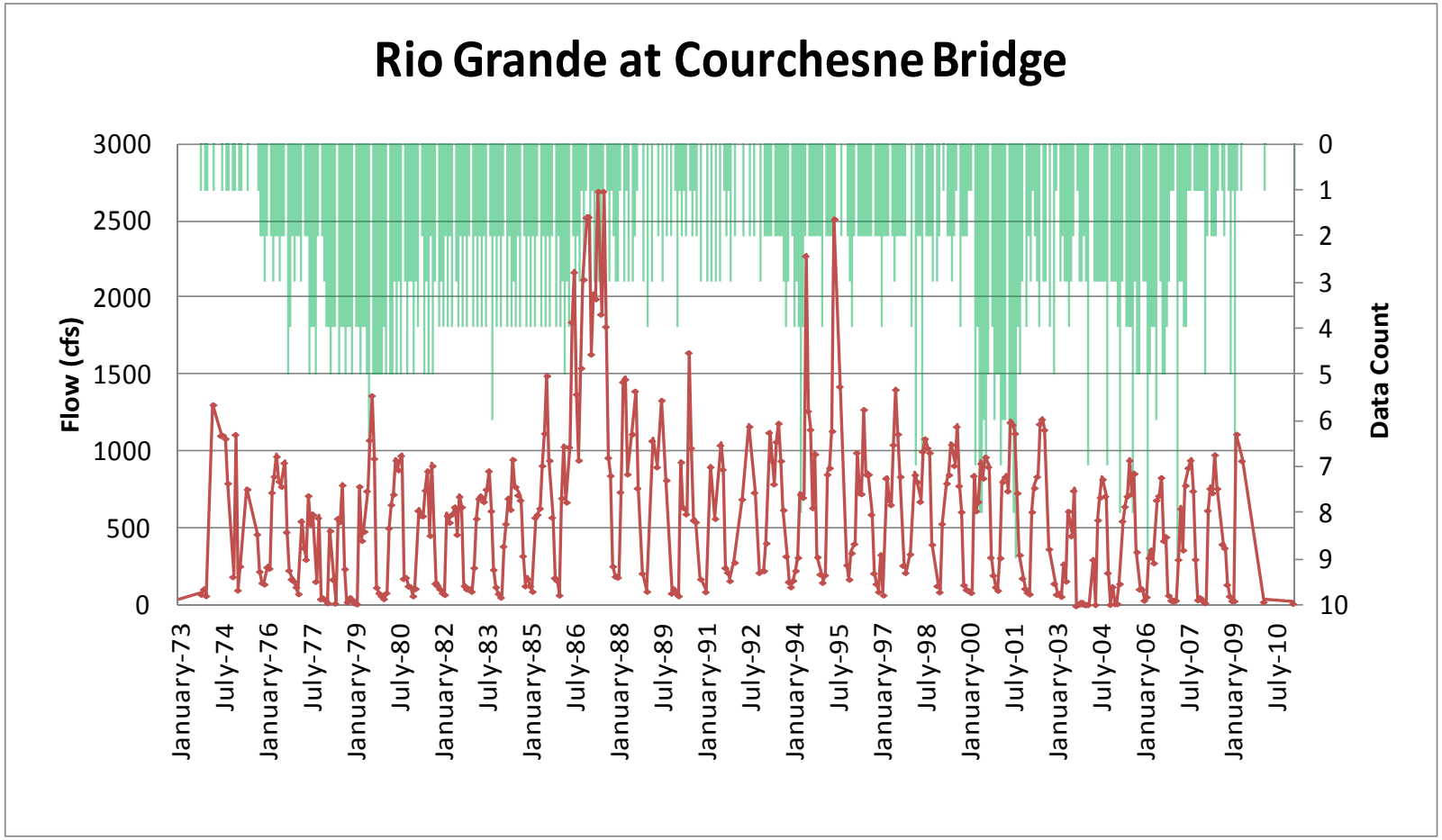


FIGURE 6-6
Rio Grande at Courchesne Bridge
Flow (cfs), 1973-2011
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.

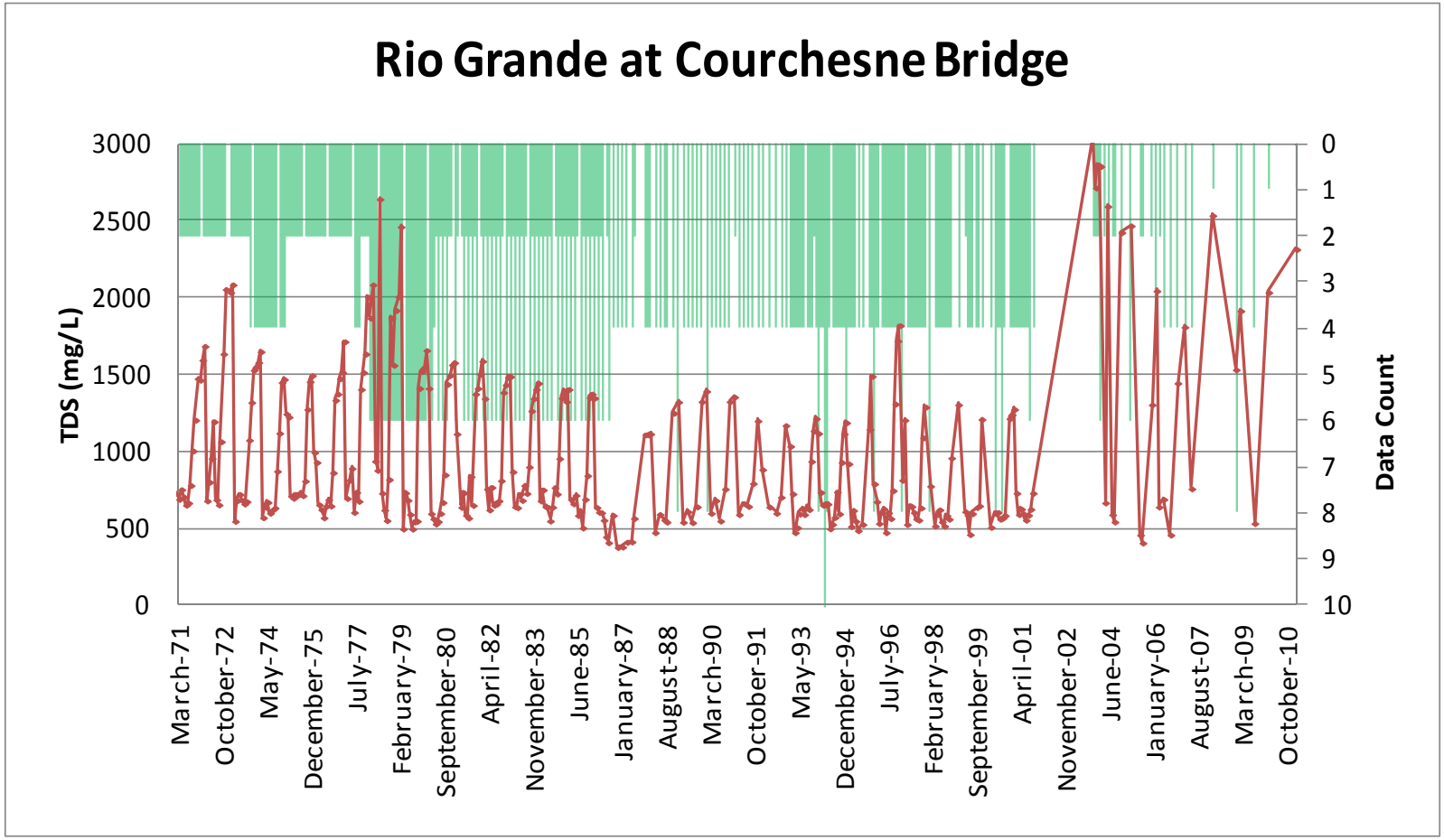


FIGURE 6-7
Rio Grande at Courchesne Bridge
Total Dissolved Solids (mg/L), 1971-2011
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.

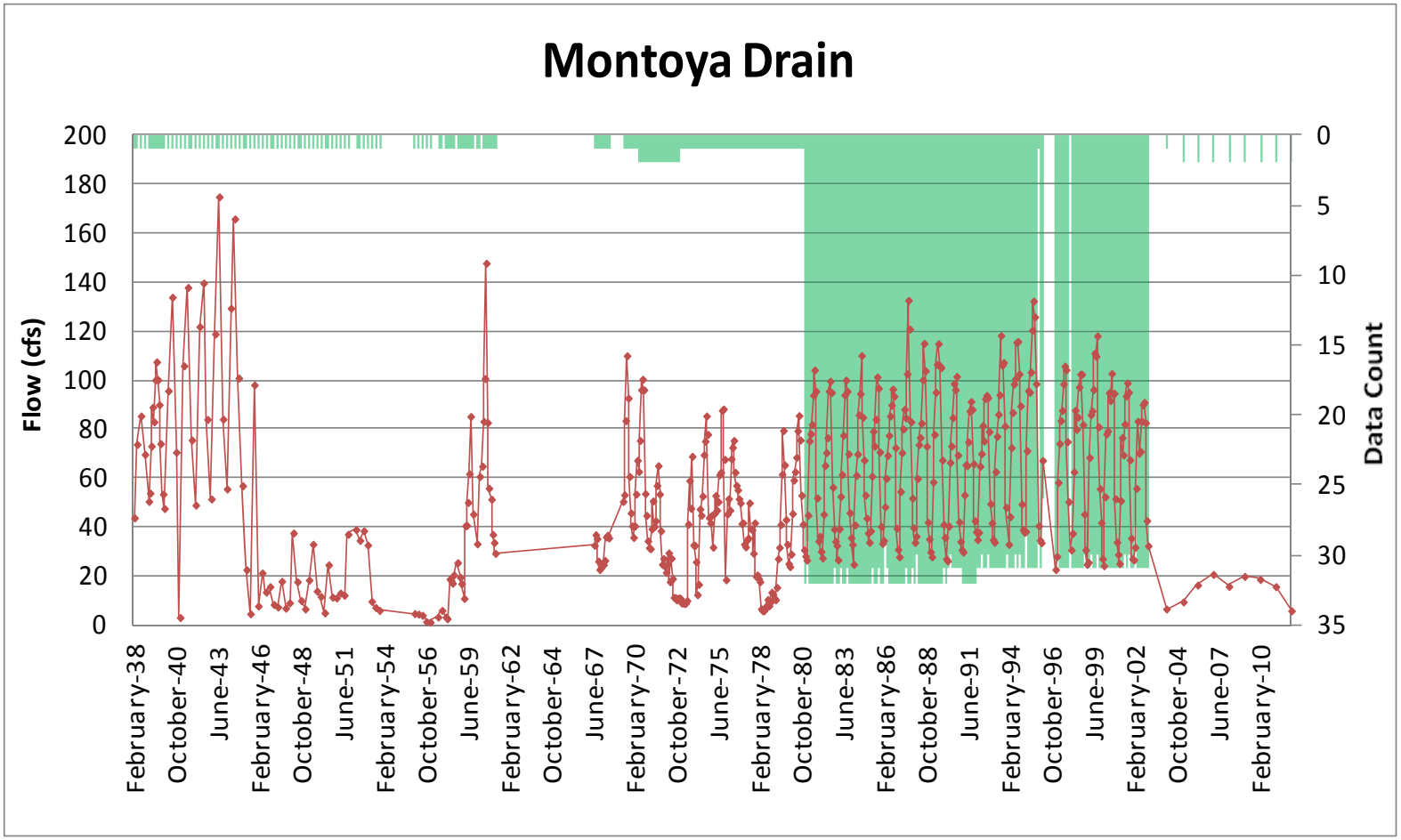


FIGURE 6-8
Montoya Drain
Flow (cfs), 1938-2012
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.

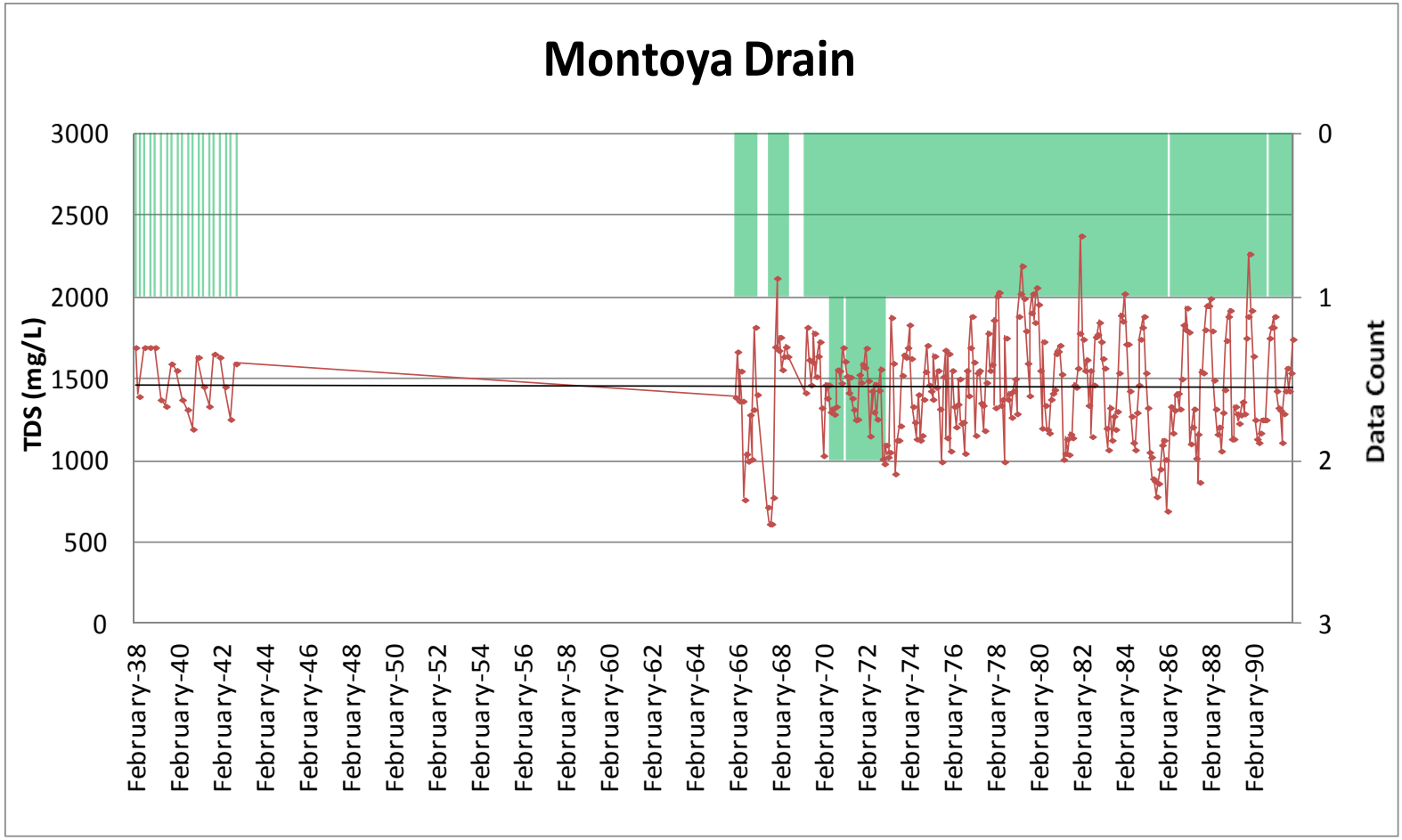
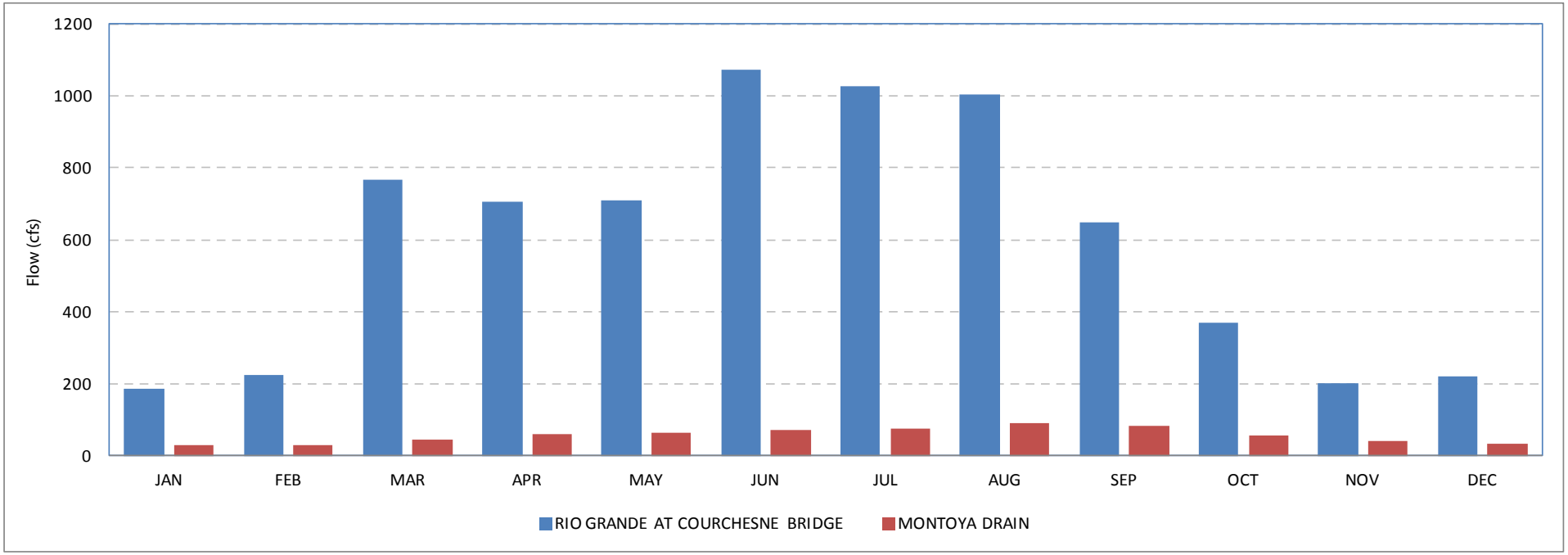


FIGURE 6-9
Montoya Drain
Total Dissolved Solids (mg/L), 1938-1991
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.

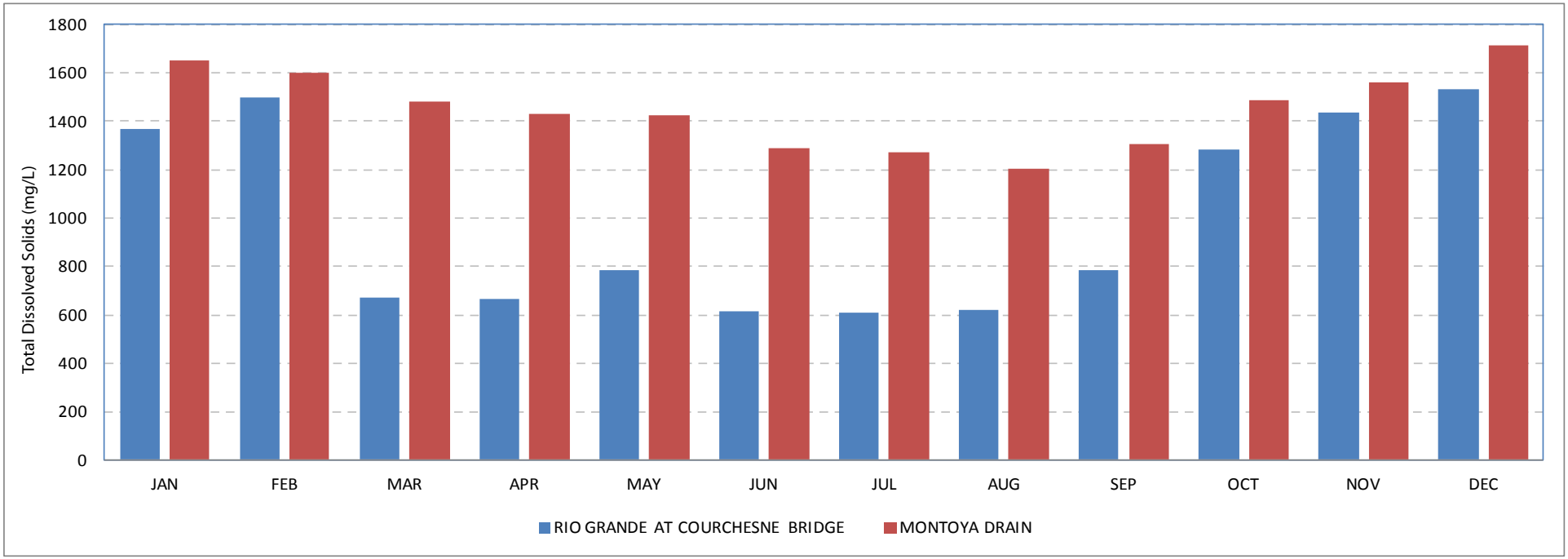


Rio Grande flow records: 1973-2011 and Montoya Drain flow records: 1938-2012

FIGURE 6-10
Rio Grande at Courchesne Bridge and Montoya Drain Flow (cfs), Monthly Pattern

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.



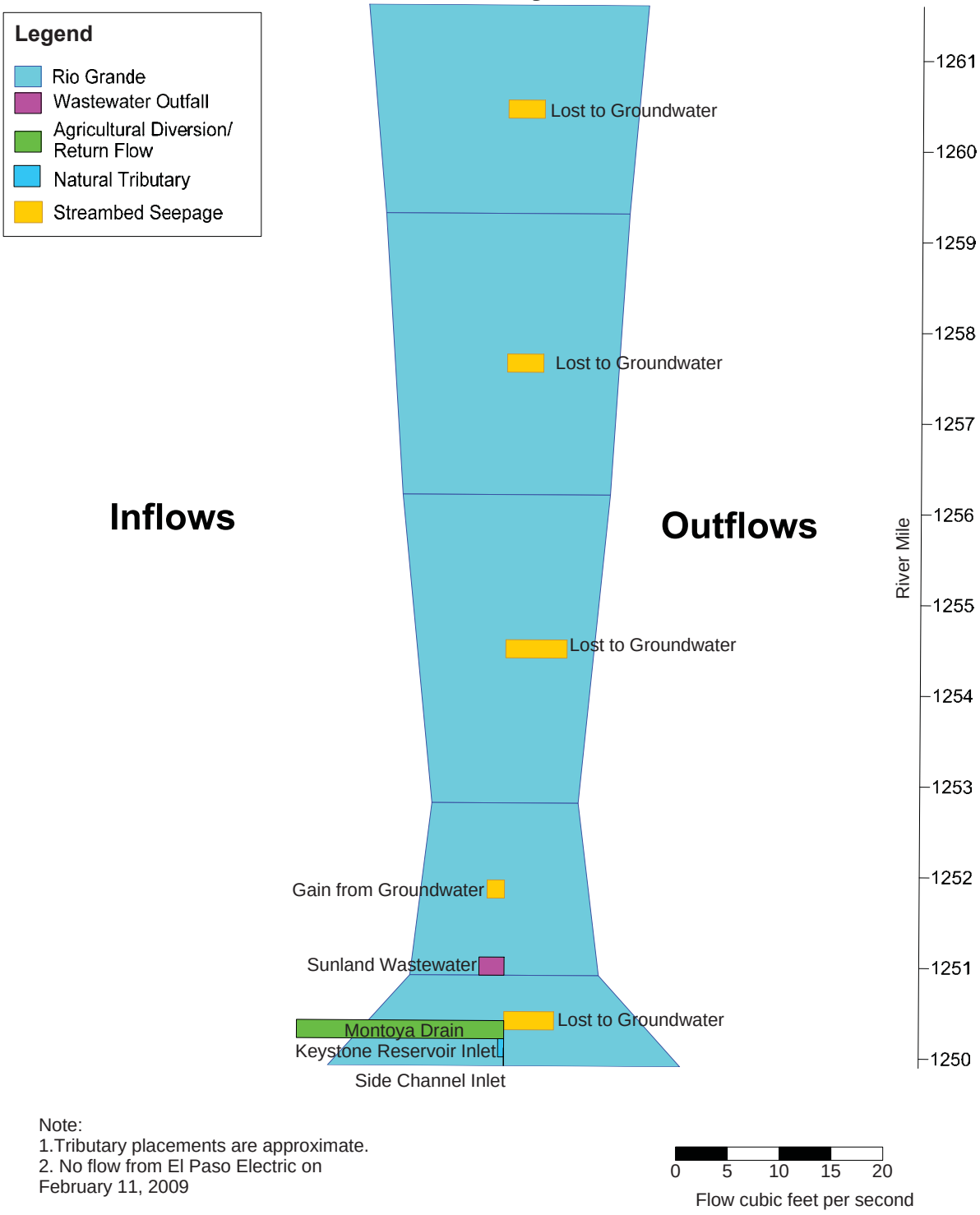
Rio Grande total dissolved solids (TDS) records: 1973-2011 and Montoya Drain TDS records: 1938-2012

FIGURE 6-11
Rio Grande at Courchesne Bridge and Montoya Drain Total Dissolved Solids (mg/L), Monthly Pattern

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL.

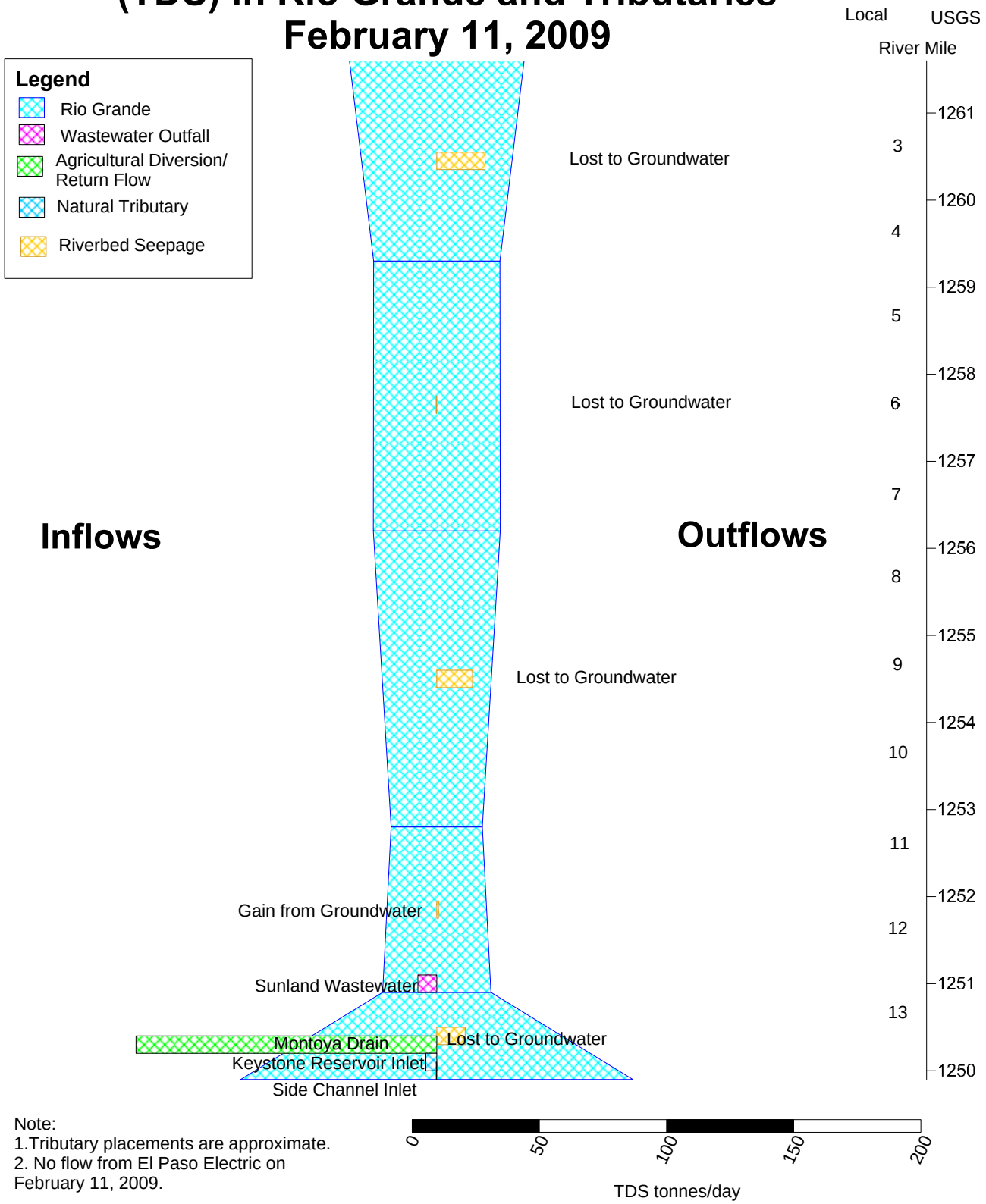
Pipe Diagram of Flow in Rio Grande and Tributaries February 11, 2009



Note:
1.Tributary placements are approximate.
2. No flow from El Paso Electric on February 11, 2009

FIGURE 6-12
Flow Pipe Diagram
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

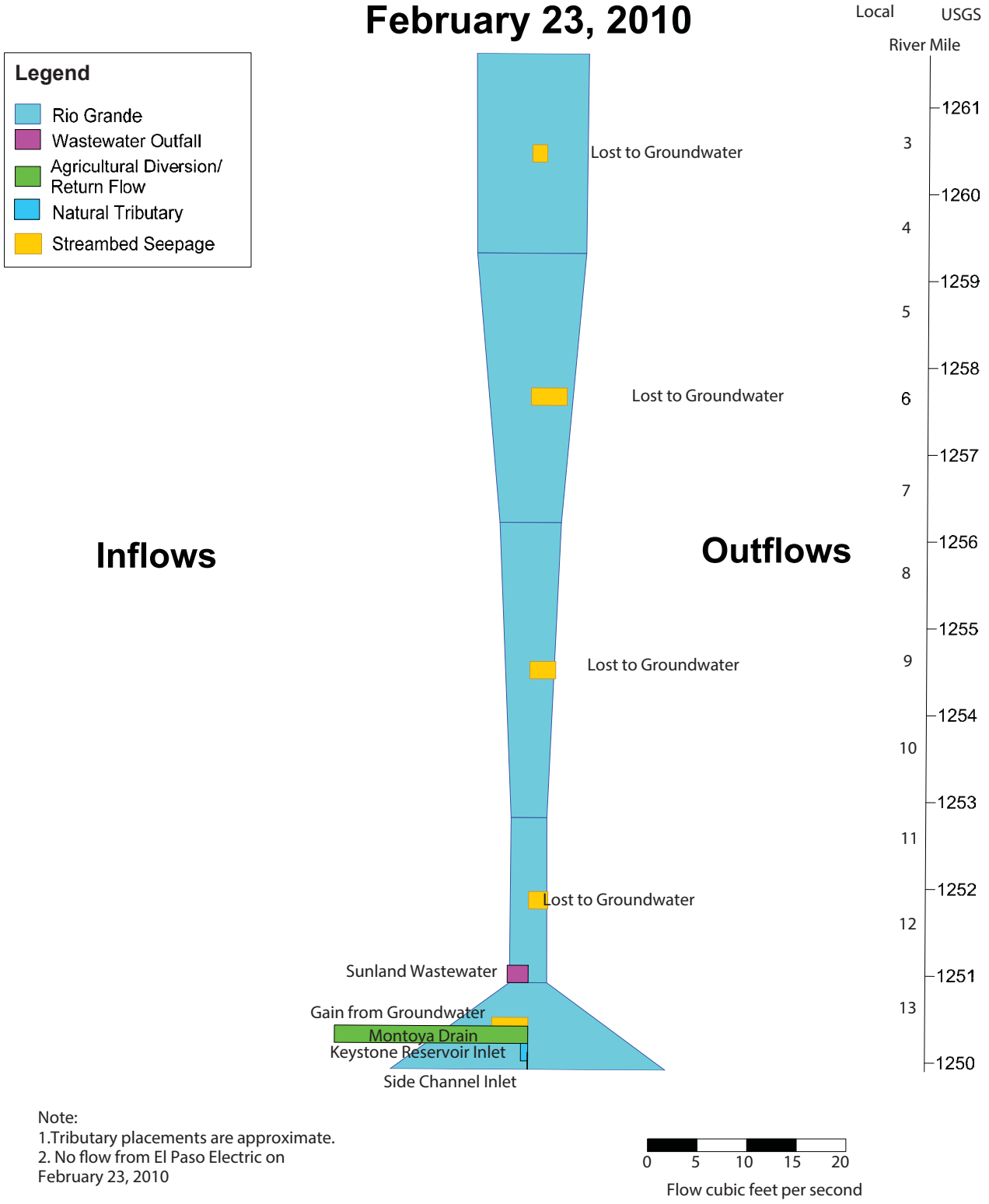
Pipe Diagram of Total Dissolved Solids (TDS) in Rio Grande and Tributaries February 11, 2009



Note:
1.Tributary placements are approximate.
2. No flow from El Paso Electric on February 11, 2009.

FIGURE 6-13
TDS Pipe Diagram
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

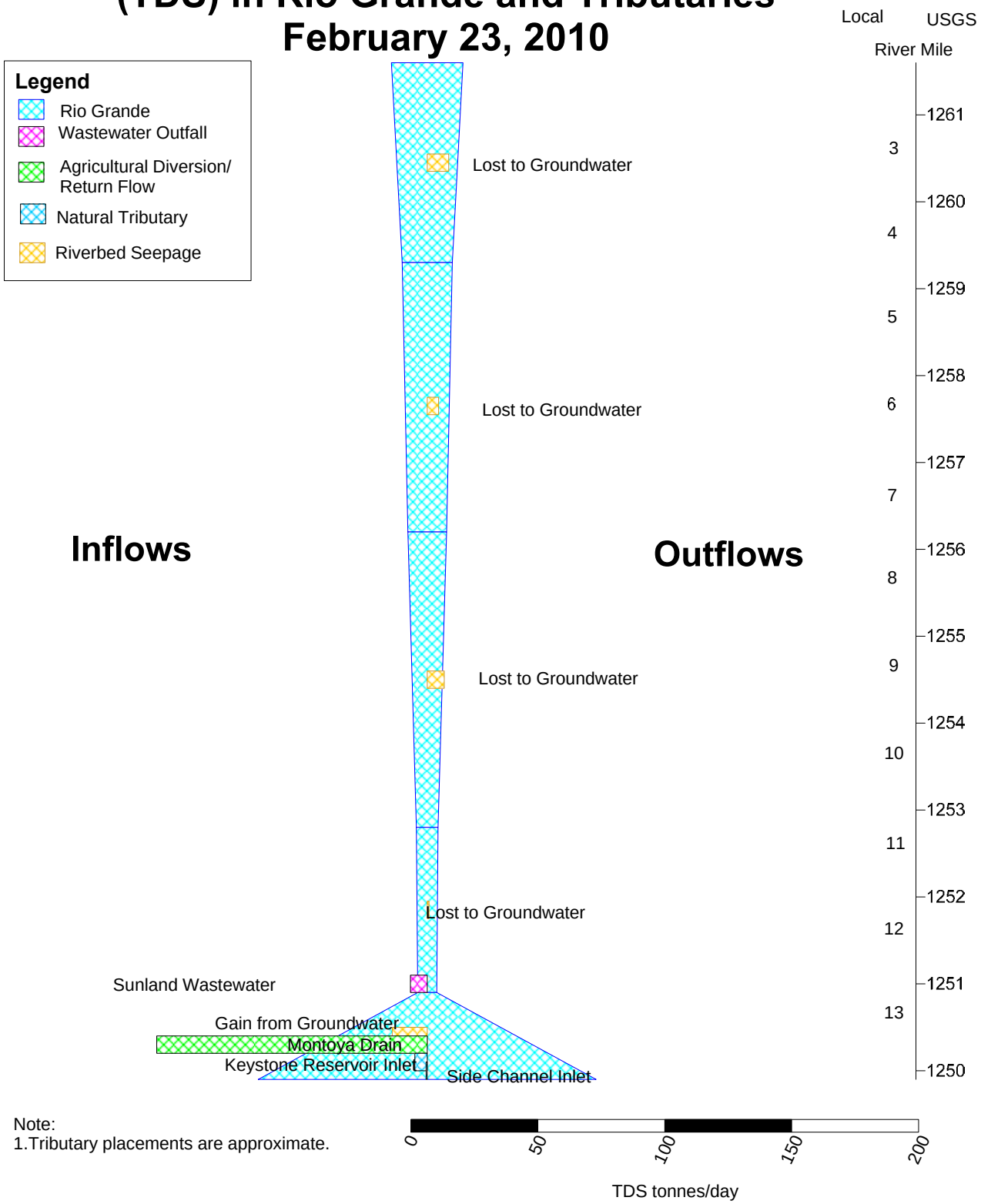
Pipe Diagram of Flow in Rio Grande and Tributaries February 23, 2010



Note:
1.Tributary placements are approximate.
2. No flow from El Paso Electric on February 23, 2010

FIGURE 6-14
Flow Pipe Diagram
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

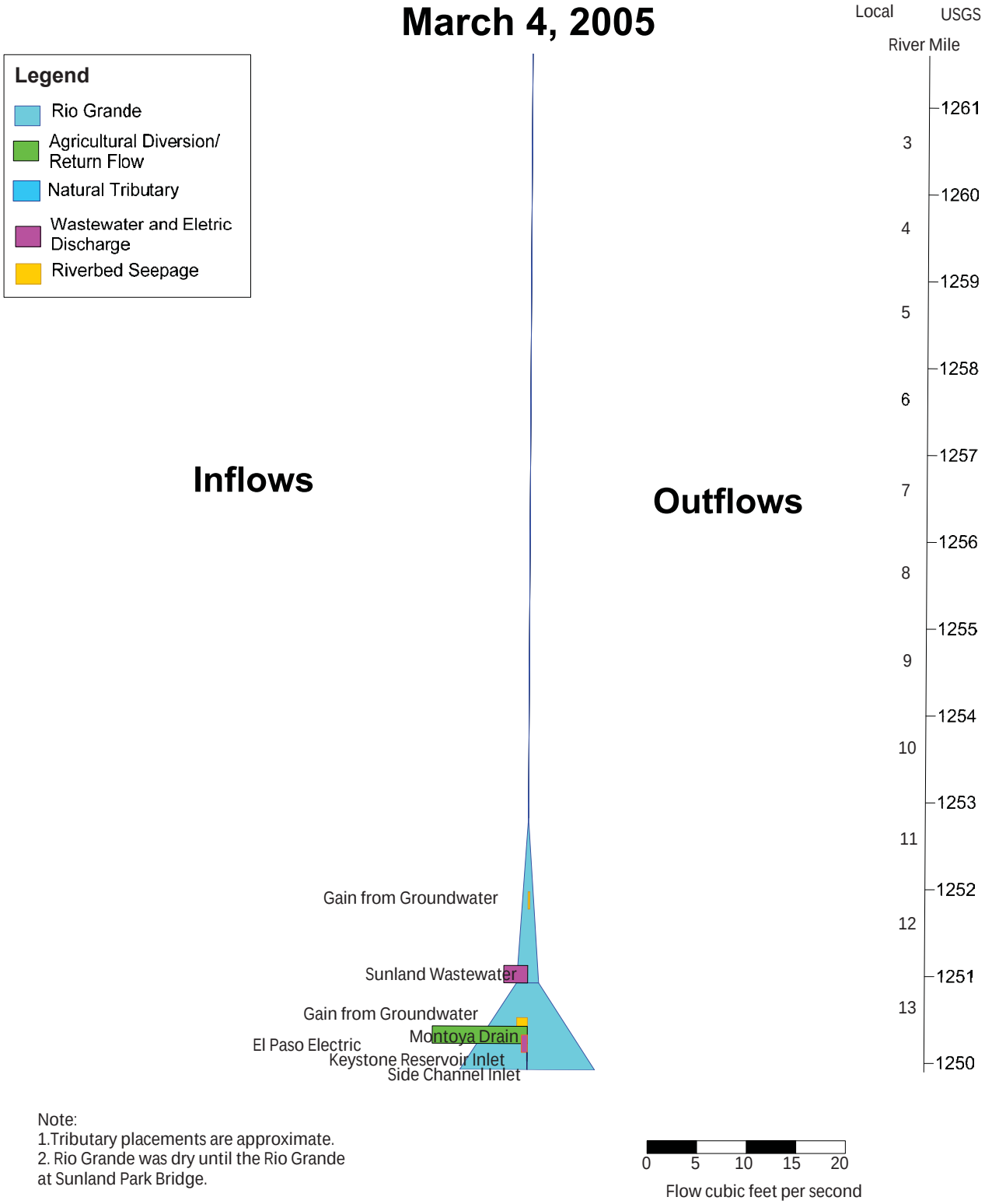
Pipe Diagram of Total Dissolved Solids (TDS) in Rio Grande and Tributaries February 23, 2010



Note:
1.Tributary placements are approximate.

FIGURE 6-15
TDS Pipe Diagram
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

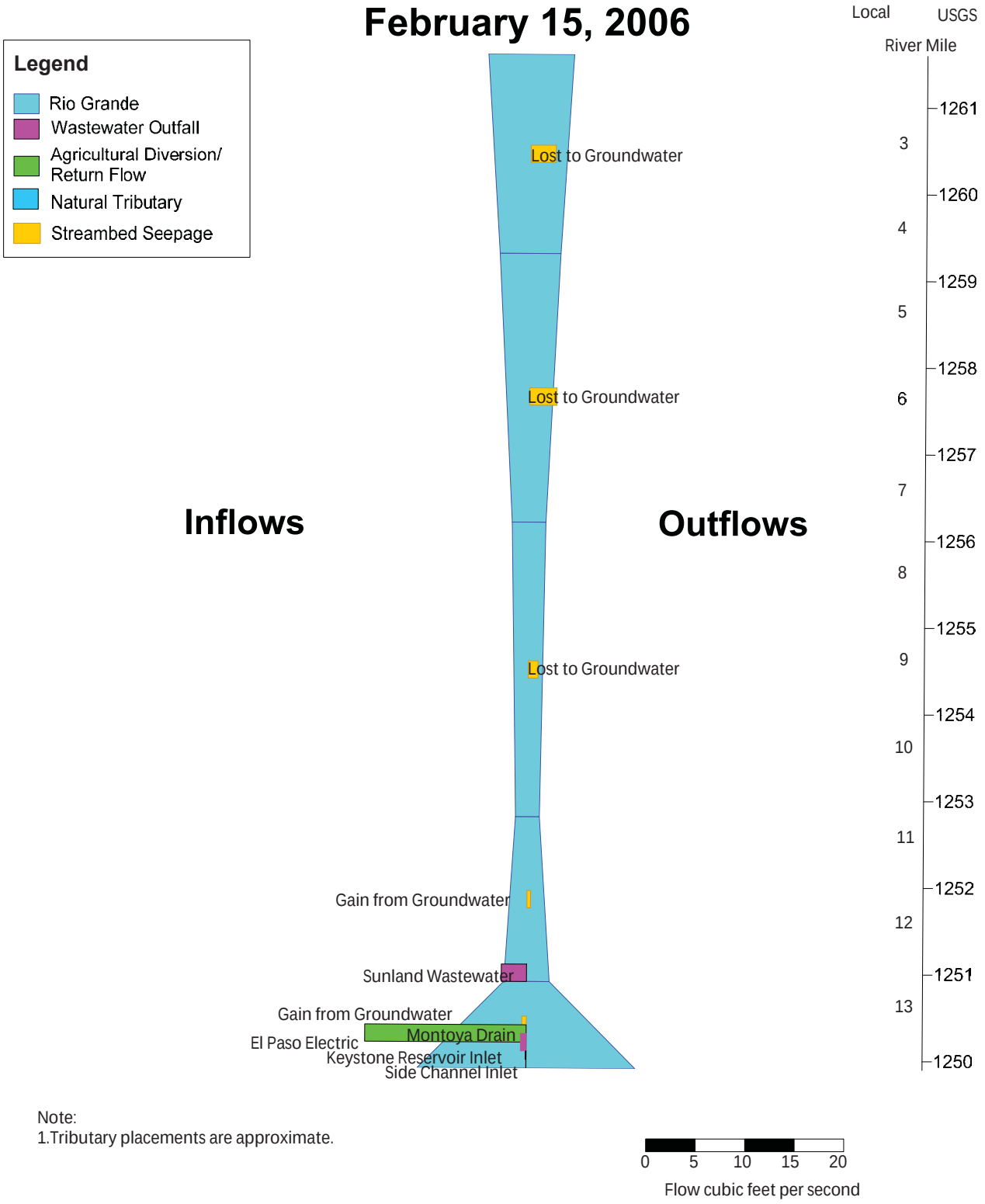
Pipe Diagram of Flow in Rio Grande and Tributaries March 4, 2005



Note:
1.Tributary placements are approximate.
2. Rio Grande was dry until the Rio Grande at Sunland Park Bridge.

FIGURE 6-16
Flow Pipe Diagram
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

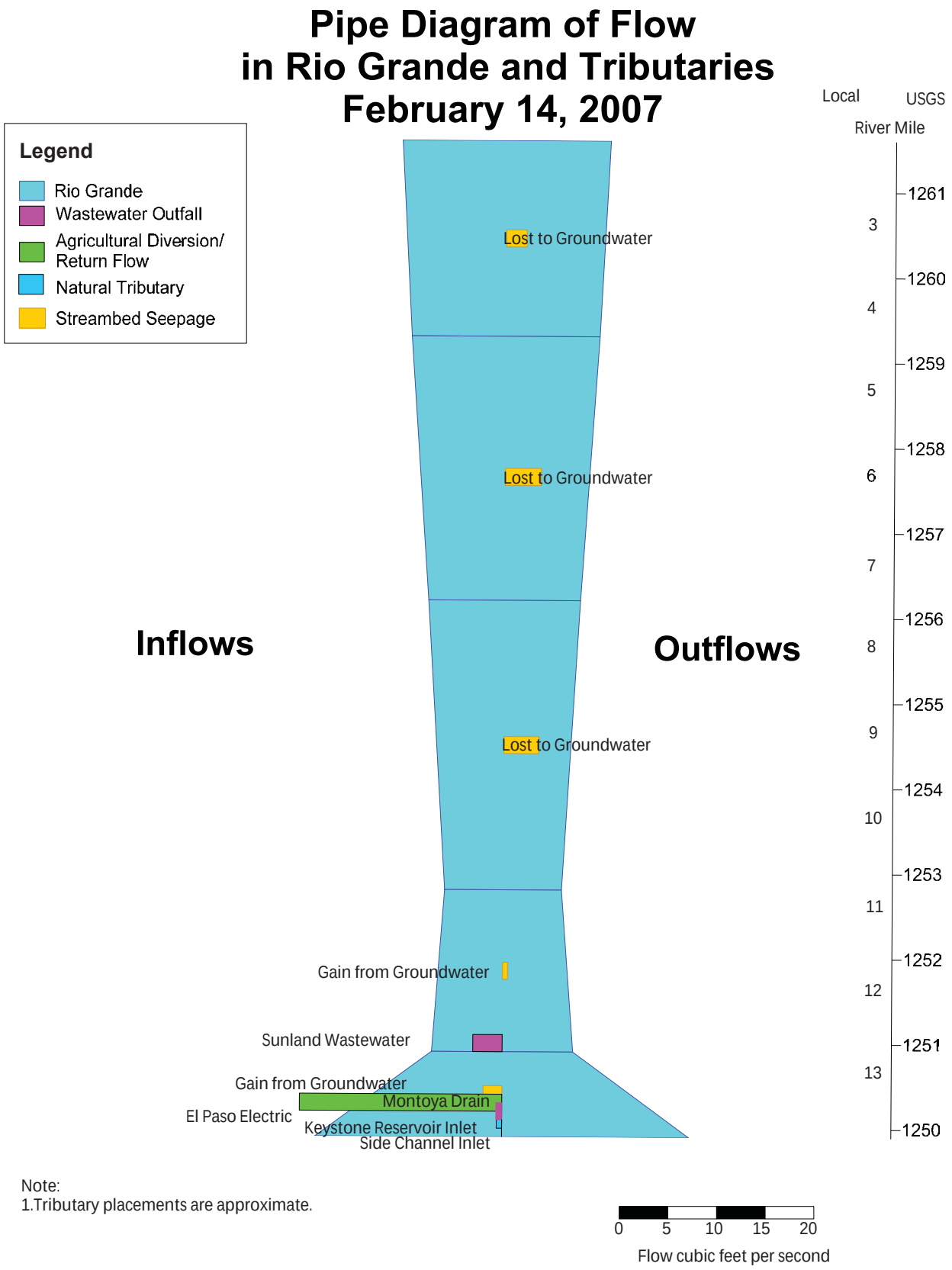
Pipe Diagram of Flow in Rio Grande and Tributaries February 15, 2006



Note:
1.Tributary placements are approximate.

FIGURE 6-17
Flow Pipe Diagram
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

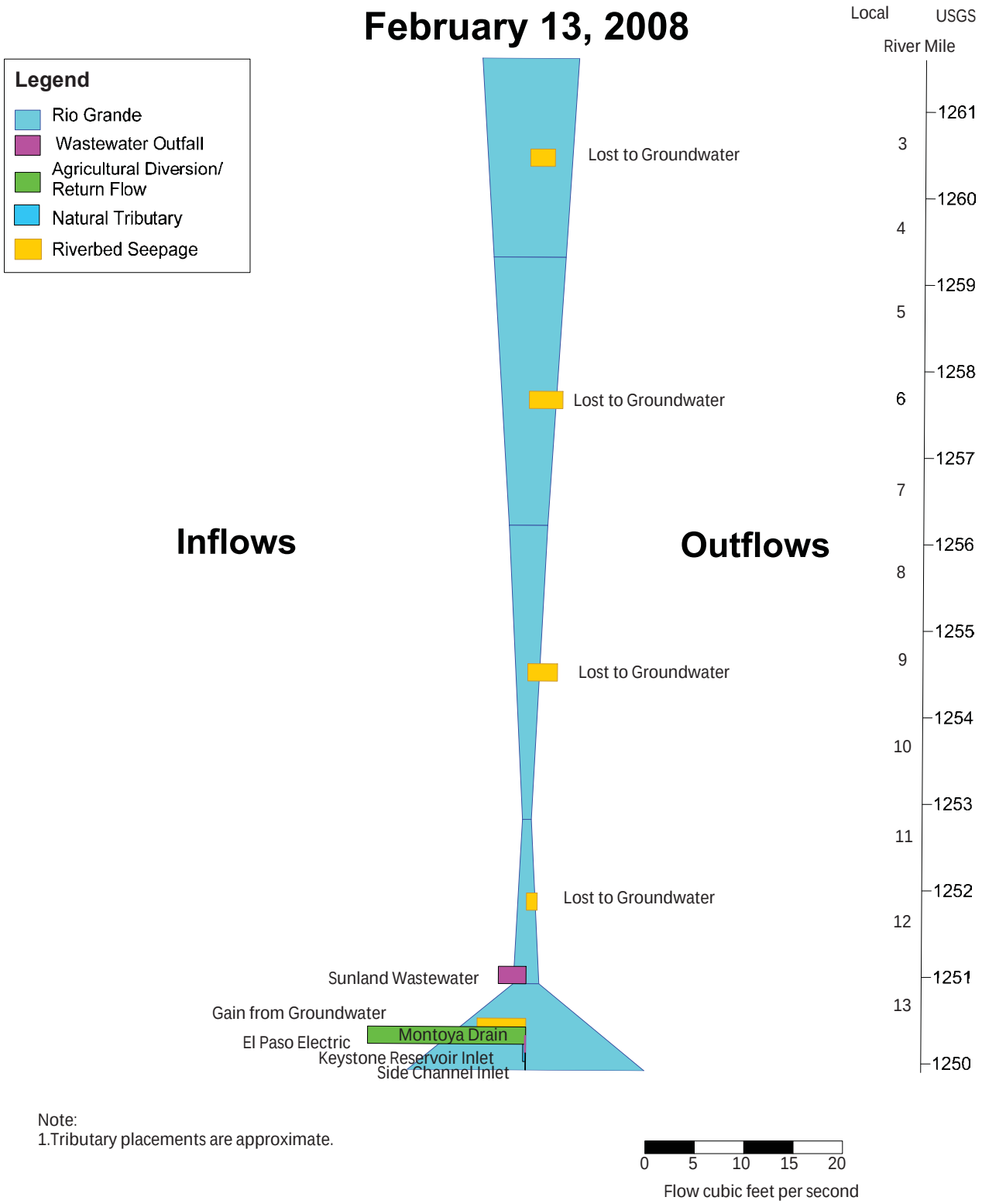
CH2MHILL



Note:
1.Tributary placements are approximate.

FIGURE 6-18
Flow Pipe Diagram
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

Pipe Diagram of Flow in Rio Grande and Tributaries February 13, 2008

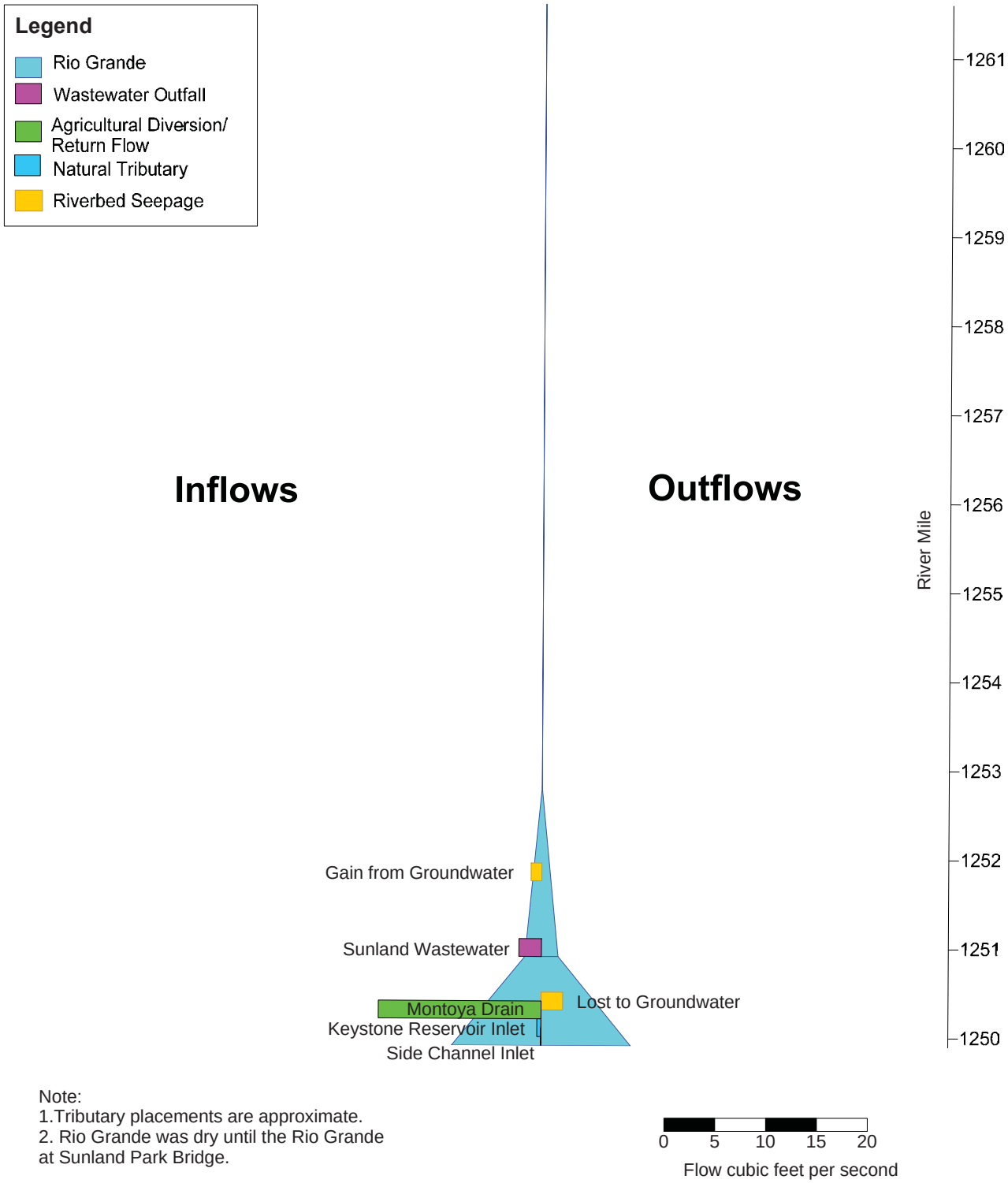


Note:
1.Tributary placements are approximate.

FIGURE 6-19
Flow Pipe Diagram
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

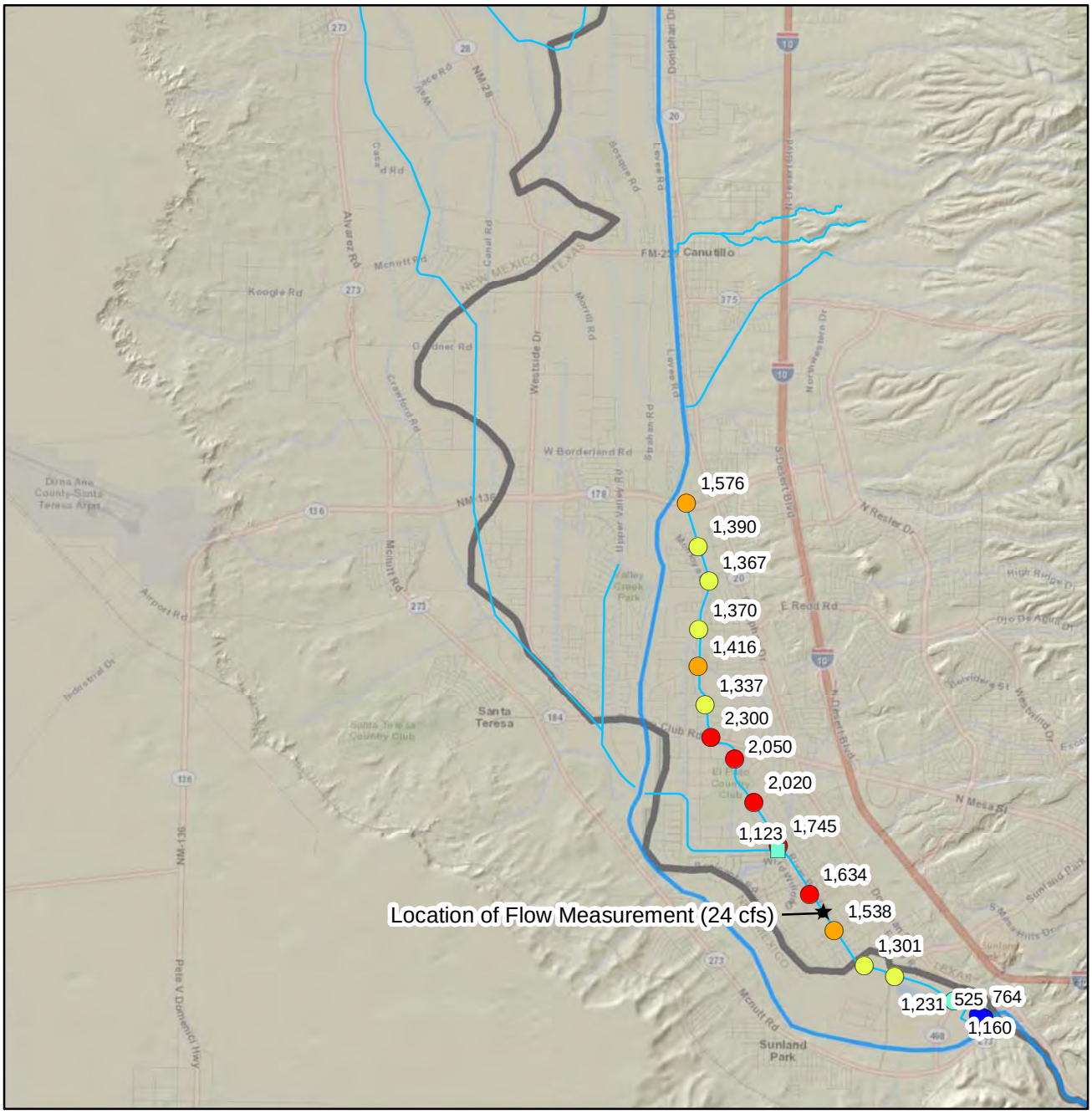
CH2MHILL

Pipe Diagram of Flow in Rio Grande and Tributaries February 15, 2011



Note:
1.Tributary placements are approximate.
2. Rio Grande was dry until the Rio Grande at Sunland Park Bridge.

FIGURE 6-20
Flow Pipe Diagram
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

- Rio Grande
- Drains and Laterals
- State Boundary

TDS_mg_L

- < 800
- 801 - 1,000
- 1,001 - 1,200
- 1,201 - 1,400
- 1,401 - 1,600
- > 1600

Data Source:
Bakker, et al. (2000)

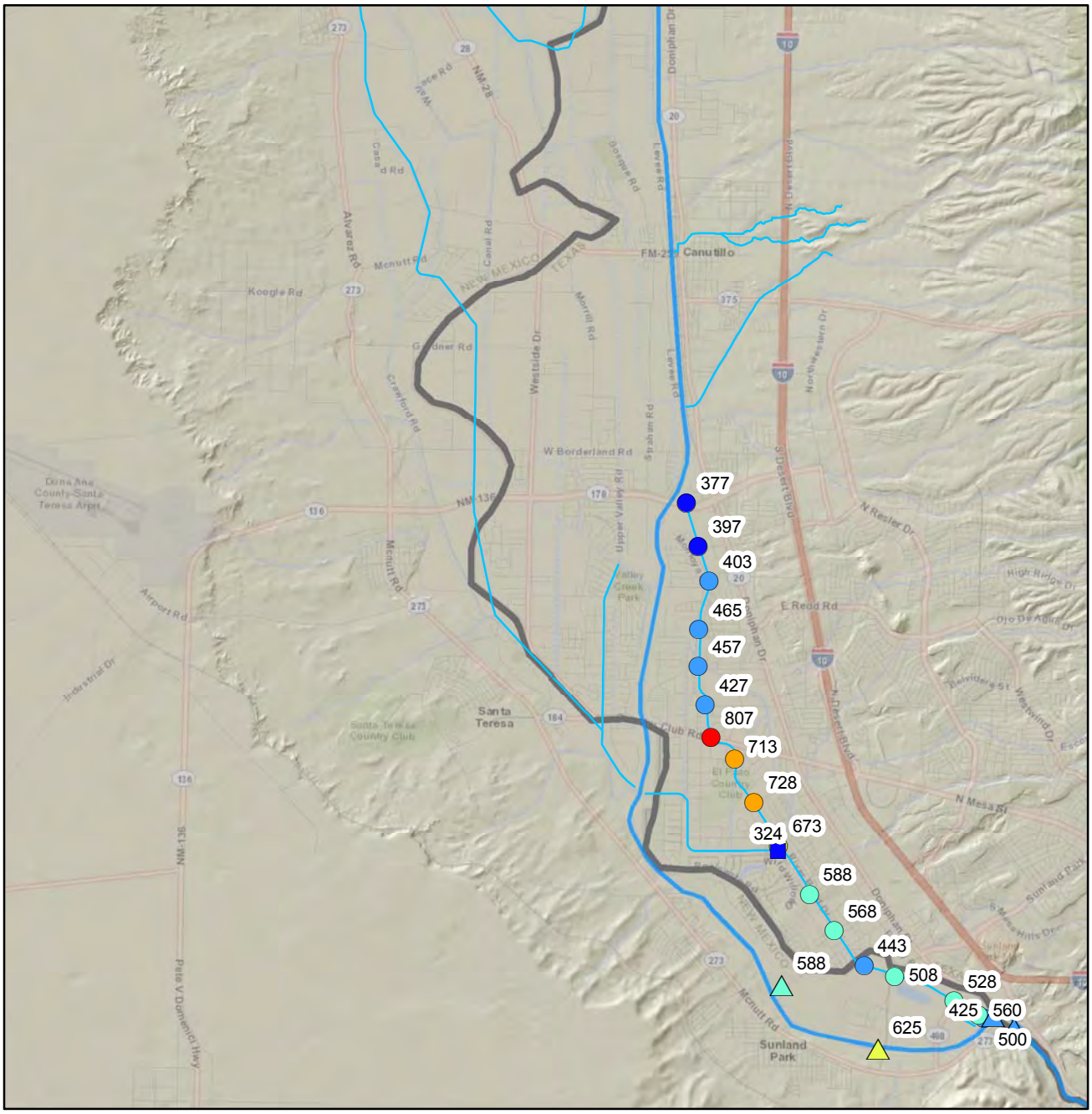
- Circles represent Montoya Drain (2/25/2000)
- Square represents Nemexas Drain (2/25/2000)
- Triangles and blue labels represent Rio Grande (2/2/2000 and 2/3/2000)

0 0.5 1
Miles

N

VICINITY MAP

FIGURE 6-21
Surface Water TDS, Feb-2000
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

LEGEND

Data Source:
Bakker, et al. (2000)

- Rio Grande
- Drains and Laterals
- State Boundary

Cl-Br Ratio

- < 400
- 401 - 500
- 501 - 600
- 601 - 700
- 701 - 800
- > 800

- Circles represent Montoya Drain (2/25/2000)
- Square represents Nemexas Drain (2/25/2000)
- Triangles and blue labels represent Rio Grande (2/2/2000 and 2/3/2000)

0 0.5 1 2
Miles

N

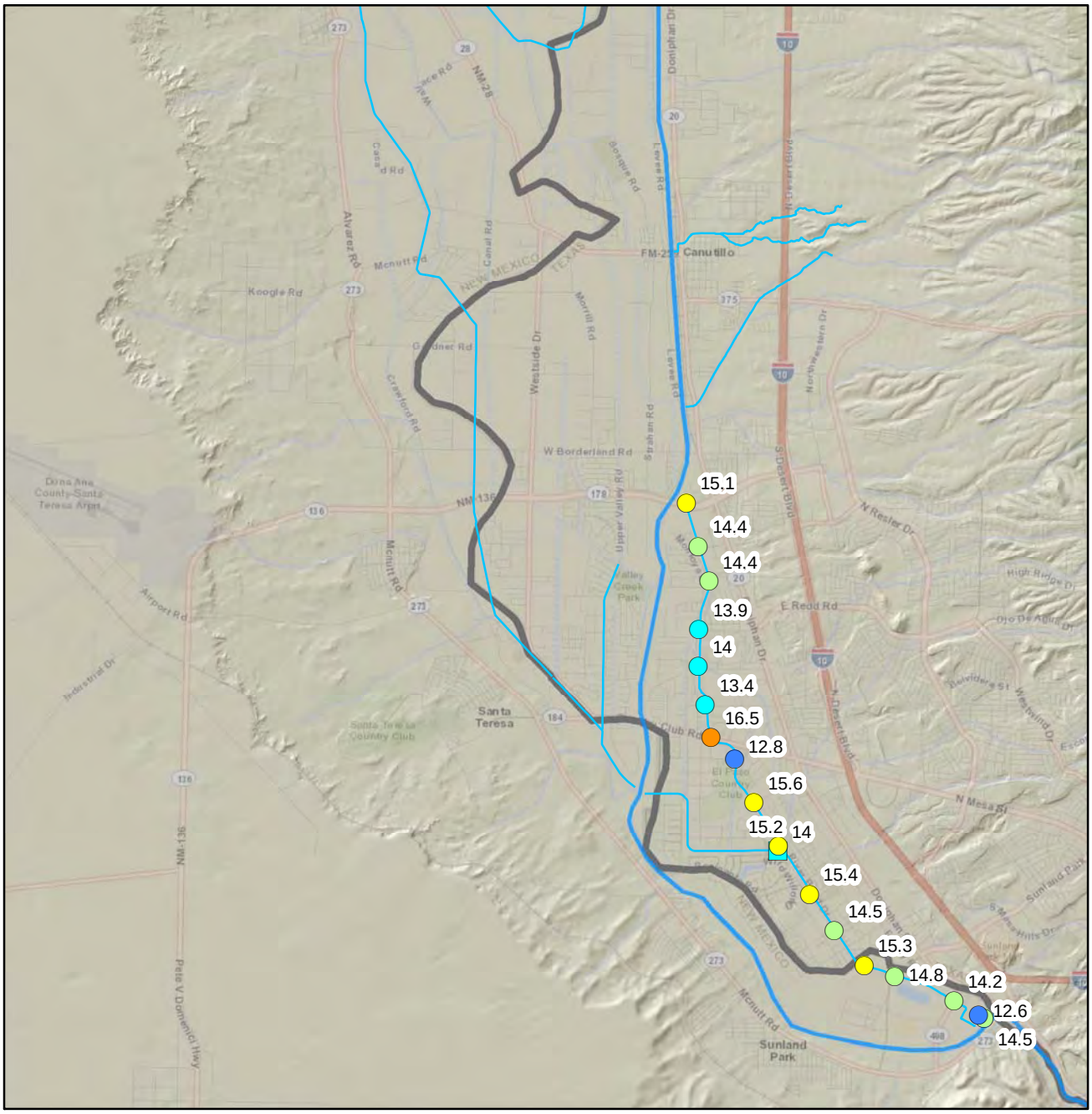
FIGURE 6-22
Surface Water Cl-Br, Feb-2000

Distal Mesilla Conceptual Site Model

Rio Grande Salinity Management Program

CH2MHILL

\\ROSWELL\PROJ\USACE\408366MESILLA\GIS\MAPFILES\DISTALMESILLA\DistalMesilla_Montoya_ClBr.mxd



VICINITY MAP

LEGEND

Data Source:
Bakker, et al. (2000)

- Rio Grande
- Drains and Laterals
- State Boundary

Temperate (degrees C)

- 0.0 - 2.6
- 2.7 - 13.0
- 13.1 - 14.0
- 14.1 - 15.0
- 15.1 - 16.0
- 16.1 - 17.0
- 17.1 - 18.3

- Circles represent Montoya Drain (2/25/2000)
- Square represents Nemexas Drain (2/25/2000)

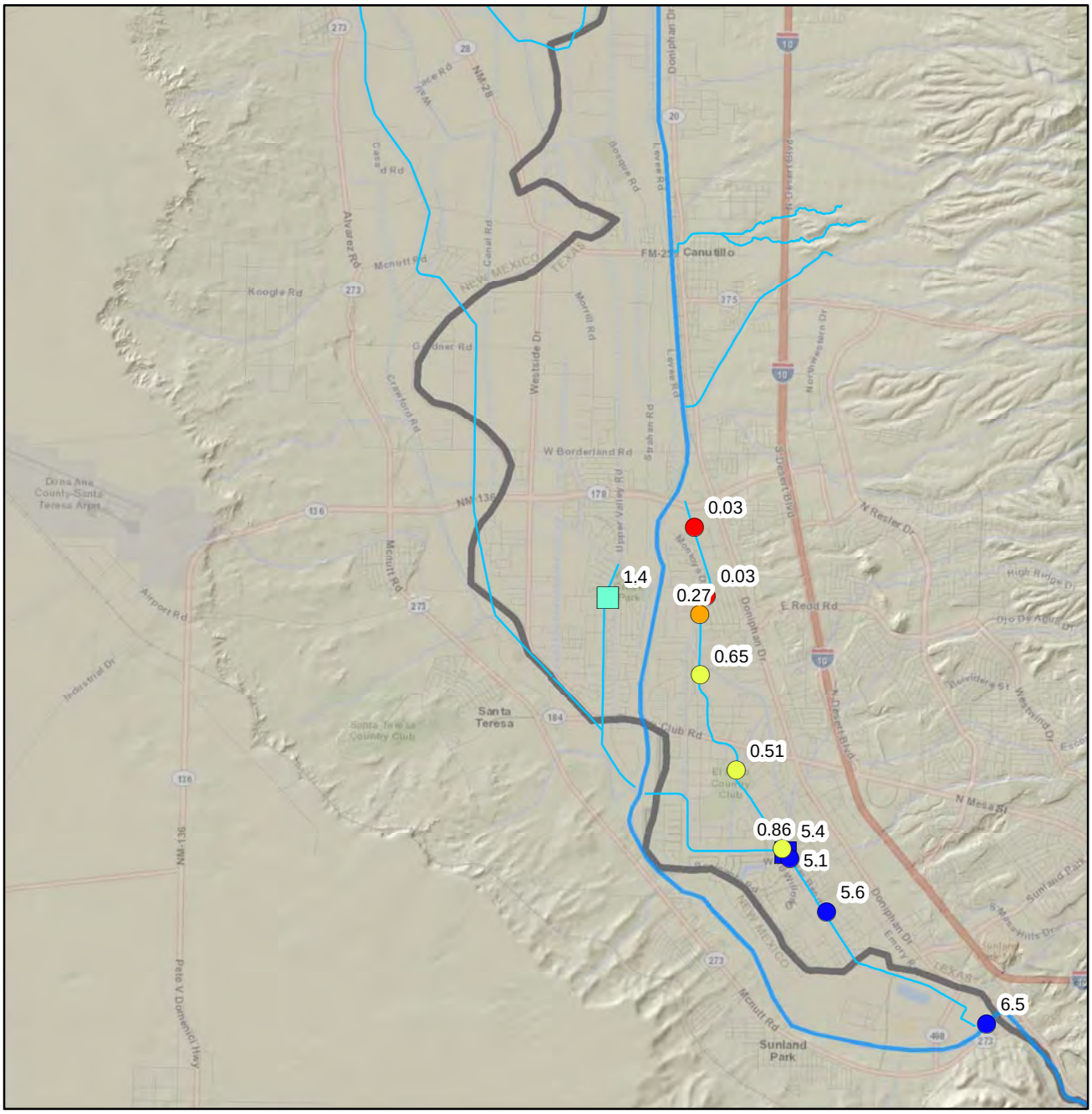
0 0.5 1
Miles

N

FIGURE 6-23
Surface Water Temperature, Feb-2000
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

\\ROSWELL\PROJ\USACE\408366MESILLA\GIS\MAPFILES\DISTALMESILLA\DistalMesilla_Montoya_Temp.mxd



VICINITY MAP

LEGEND

Data Source:
USGS, 2013

- Drains and Laterals
- Rio Grande
- State Boundary

Discharge (cfs)

- 0.03 - 0.25
- 0.26 - 0.50
- 0.51 - 1.00
- 1.01 - 2.00
- 2.01 - 5.00
- 5.01 - 6.49

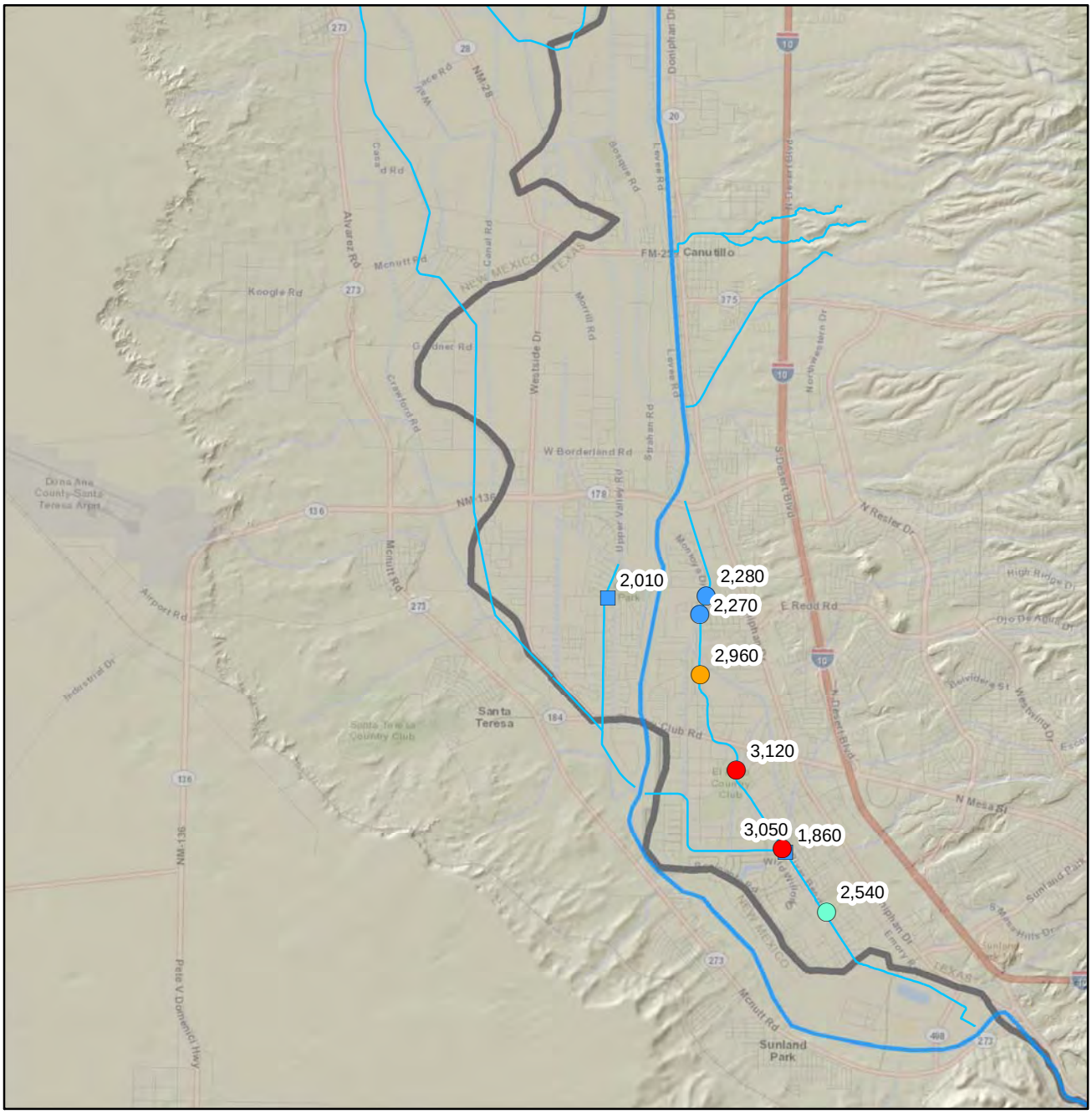
- Circles represent Montoya Drain
- Squares represent Nemexas Drain

0 0.5 1
Miles

N

FIGURE 6-24
Surface Water Flow, Feb-2013

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

LEGEND

Data Source:
USGS, 2013

- Drains and Laterals
- Rio Grande
- State Boundary

TDS (mg/L)

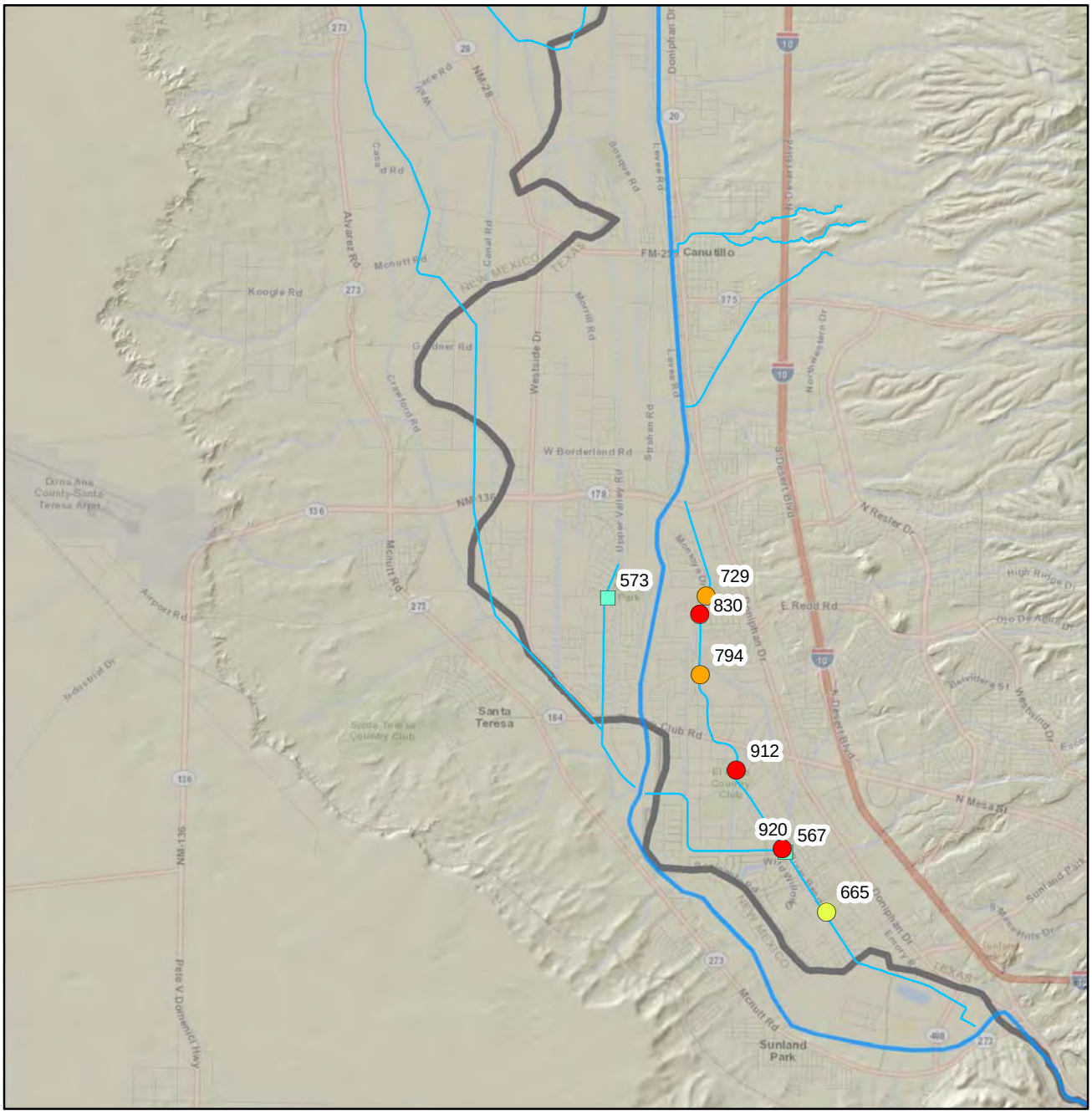
- < 800
- 801 - 2,400
- 2,401 - 2,600
- 2,601 - 2,800
- 2,801 - 3,000
- 3,001 - 5,000

- Circles represent Montoya Drain
- Squares represent Nemexas Drain

0 0.5 1
Miles

N

FIGURE 6-25
Surface Water TDS, Feb-2013
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

LEGEND

Data Source:
USGS, 2013

- Drains and Laterals
- Rio Grande
- State Boundary

Cl / Br Ratio

- < 400
- 401 - 500
- 501 - 600
- 601 - 700
- 701 - 800
- > 800

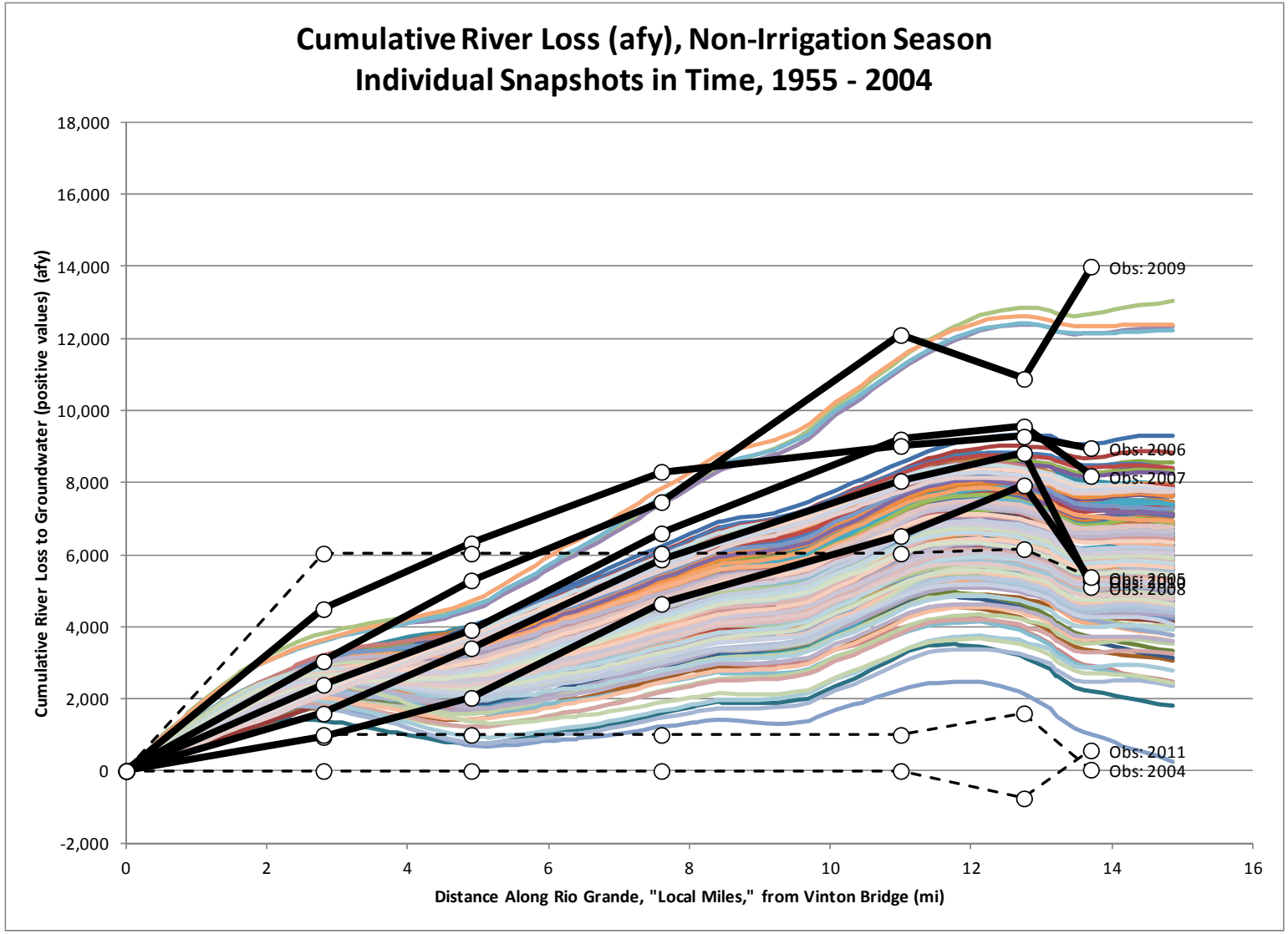
- Circles represent Montoya Drain
- Squares represent Nemexas Drain

0 0.5 1
Miles

N

FIGURE 6-26
Surface Water Cl-Br, Feb-2013

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



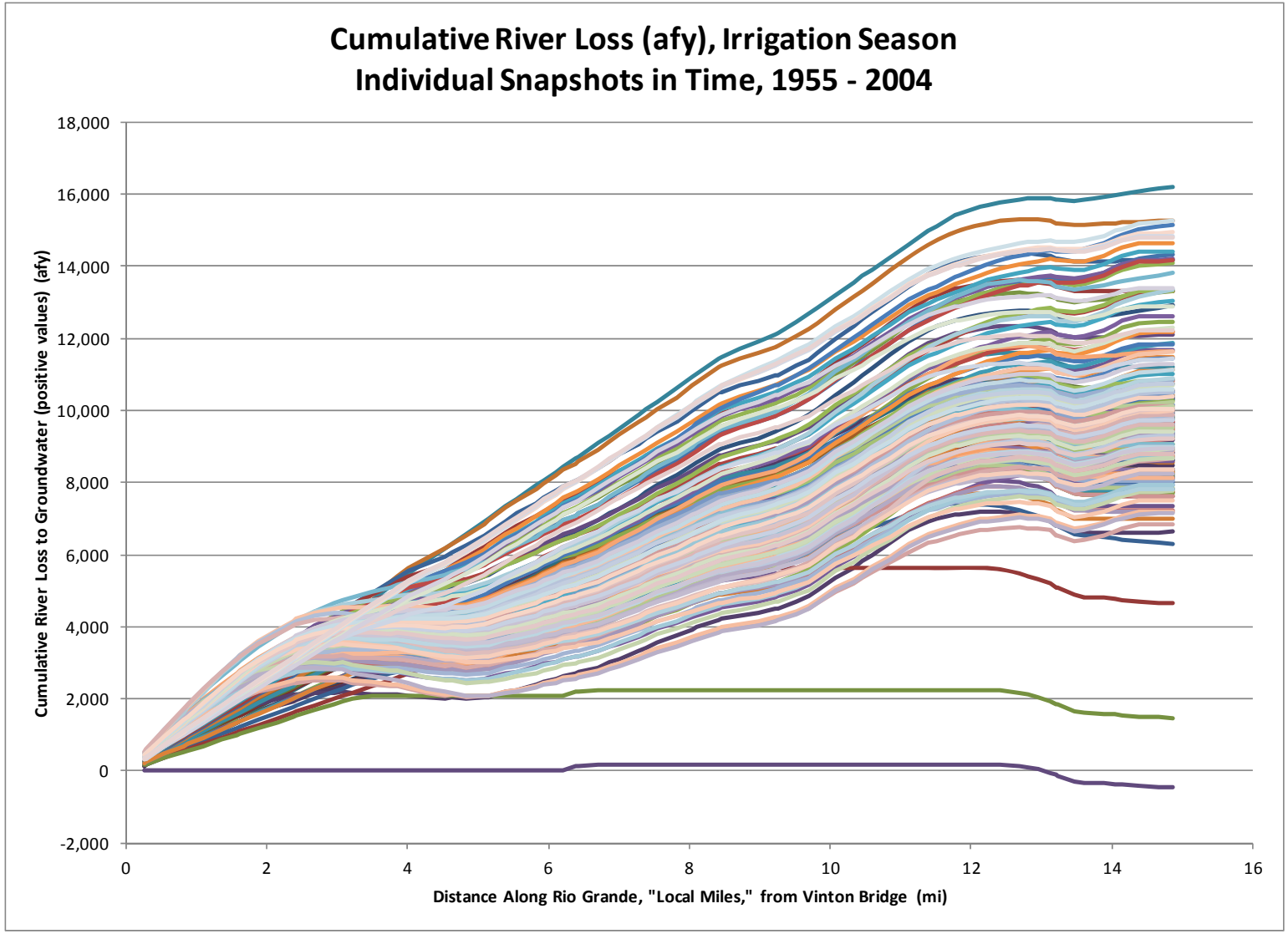
NOTES

1. Colored lines represent modeled data (SSPA, 2007). Each line represents one model stress period
2. Black lines represent USGS seepage studies. During 2004, 2005, and 2011, portions of the Rio Grande were dry. These years are plotted as dashed lines.

FIGURE 6-27
Rio Grande Cumulative Loss, Non-Irrigation Season

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



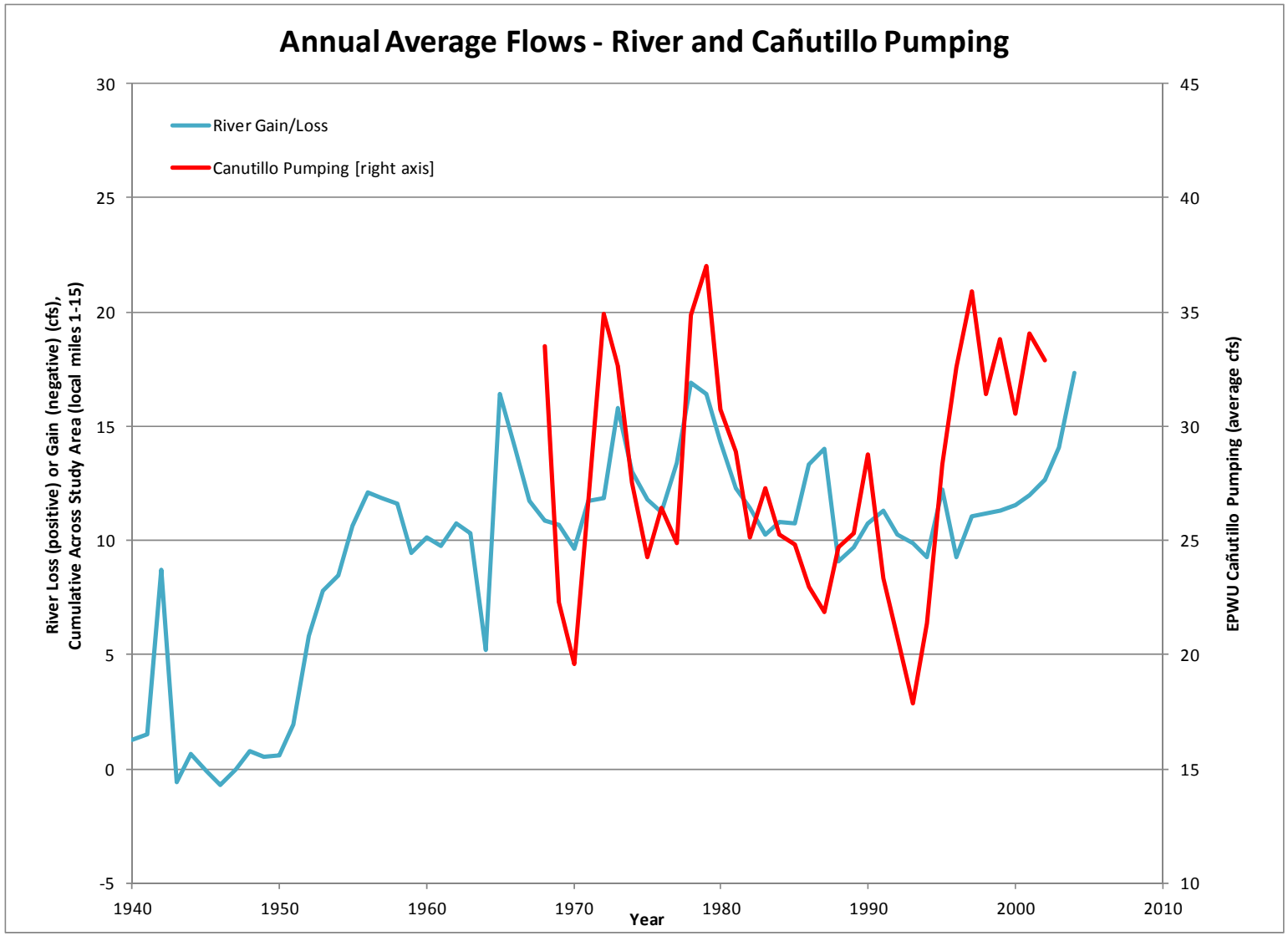
NOTES

1. Colored lines represent modeled data (SSPA, 2007). Each line represents one model stress period

FIGURE 6-28
Rio Grande Cumulative Loss, Irrigation Season

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



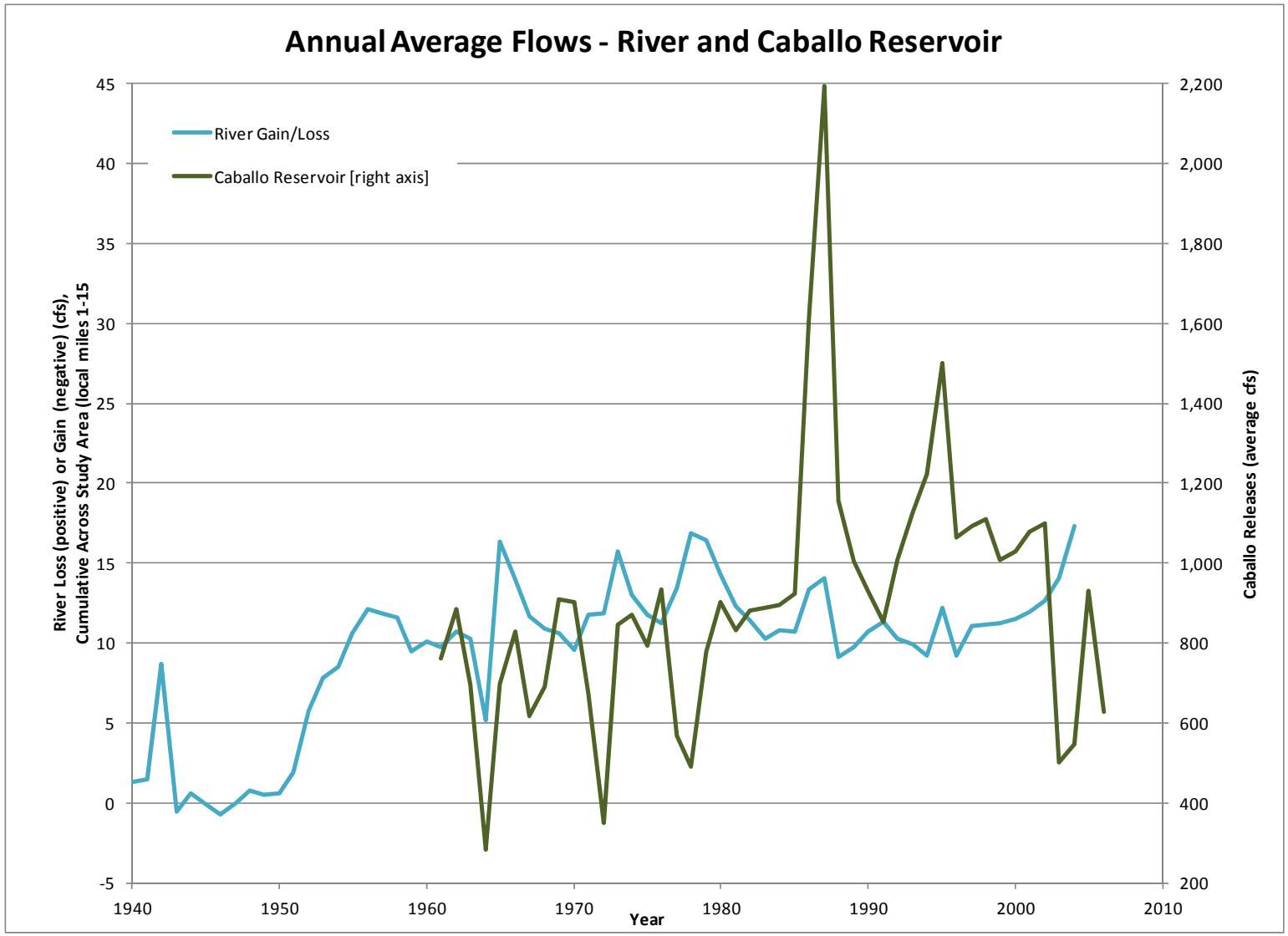
NOTES

1. River gain/loss is simulated, based on NM OSE Administrative Model (SSPA, 2007).

FIGURE 6-29
Rio Grande Cumulative Loss, Compared with EPWU Pumping

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



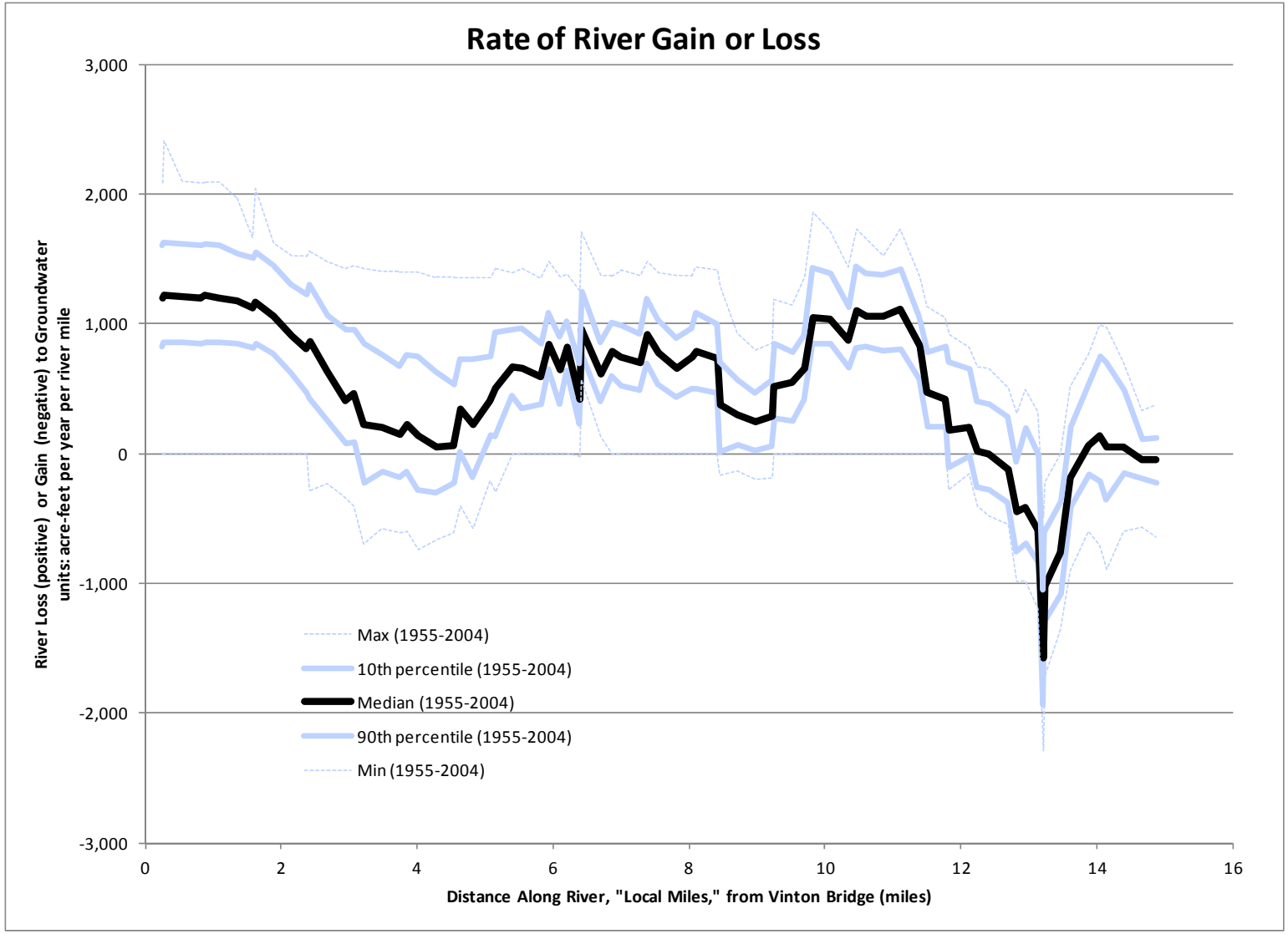
NOTES

1. River gain/loss is simulated, based on NM OSE Administrative Model (SSPA, 2007).

FIGURE 6-30
Rio Grande Cumulative Loss, Compared with Caballo Release

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



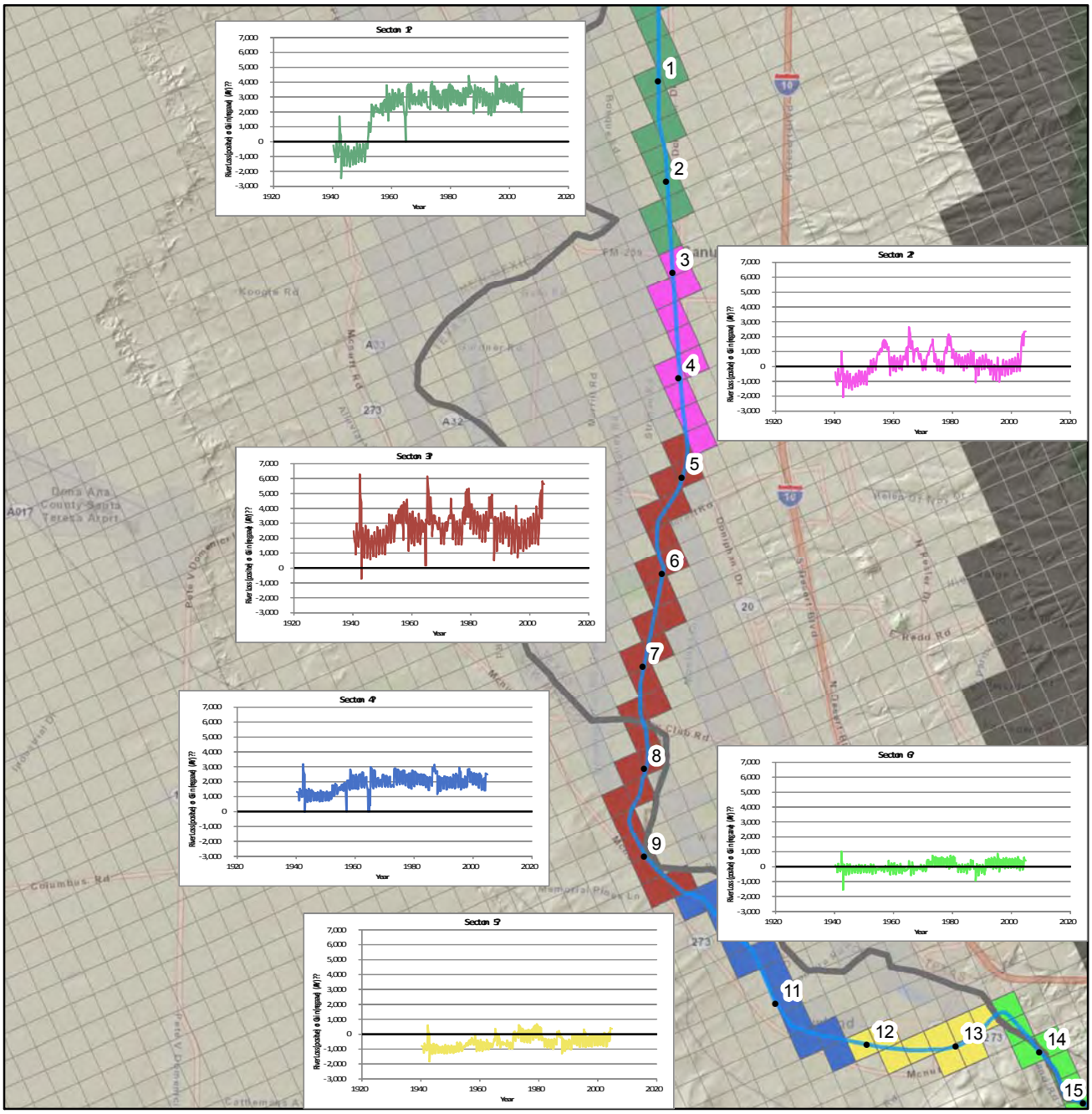
NOTES

1. River gain/loss is simulated, based on NM OSE Administrative Model (SSPA, 2007).
2. Data presented are statistics summarizing all model stress periods between 1955 and 2004.

FIGURE 6-31
Rio Grande Spatial Distribution of Gain and Loss

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



LEGEND

- Rio Grande
- State Boundary
- ModelStreamReaches
- Budget Section
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6

Plots present gain from Groundwater (afy equivalent) (negative value is gain)

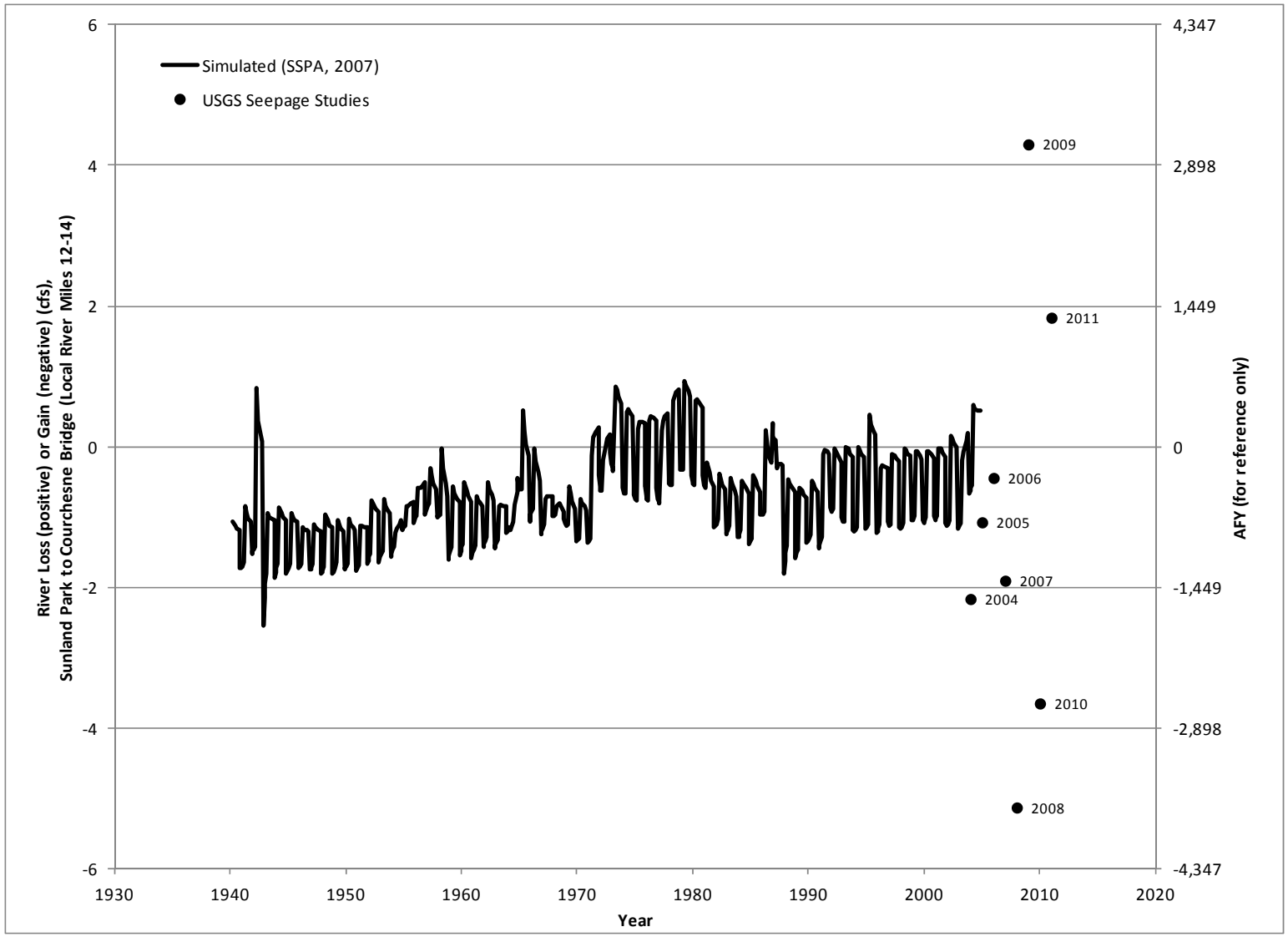
Data Source: (SSPA, 2007)

VICINITY MAP

N

0 0.5 1 2 3
Miles

FIGURE 6-32
Simulated Rio Grande
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

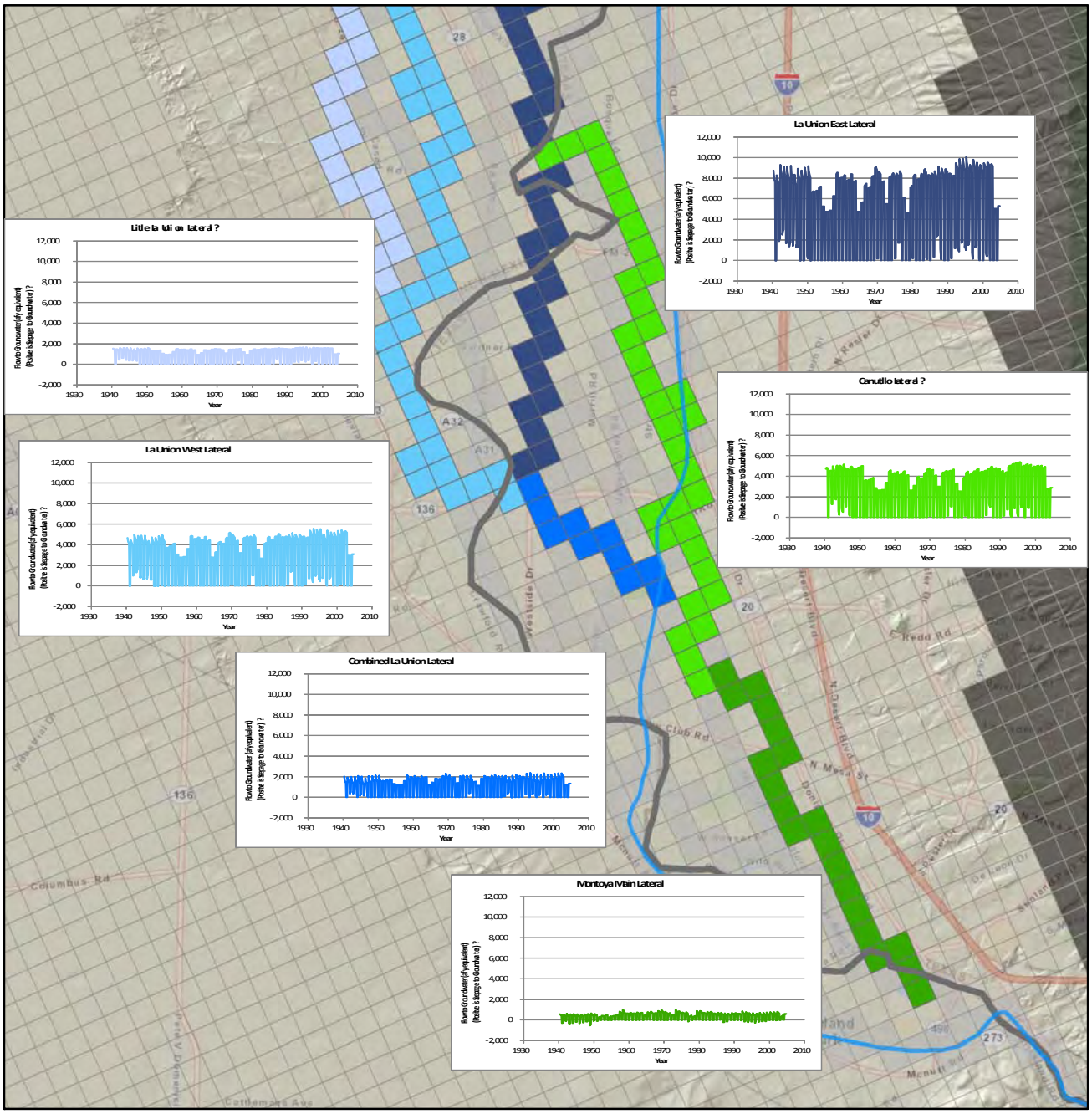


NOTES
1. River gain/loss is simulated, based on NM OSE Administrative Model (SSPA, 2007).
2. Point data based on recent USGS seepage studies.

FIGURE 6-33
Rio Grande Gain from Groundwater, Sunland Park to Courchesne Bridge

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



LEGEND

- Rio Grande
- State Boundary

Surface Water Body

- Little La Union Lateral
- La Union West Lateral
- La Union East Lateral
- Combined La Union Lateral
- Canutillo Lateral
- Montoya Main Lateral

Plots present seepage to Groundwater (afy equivalent)

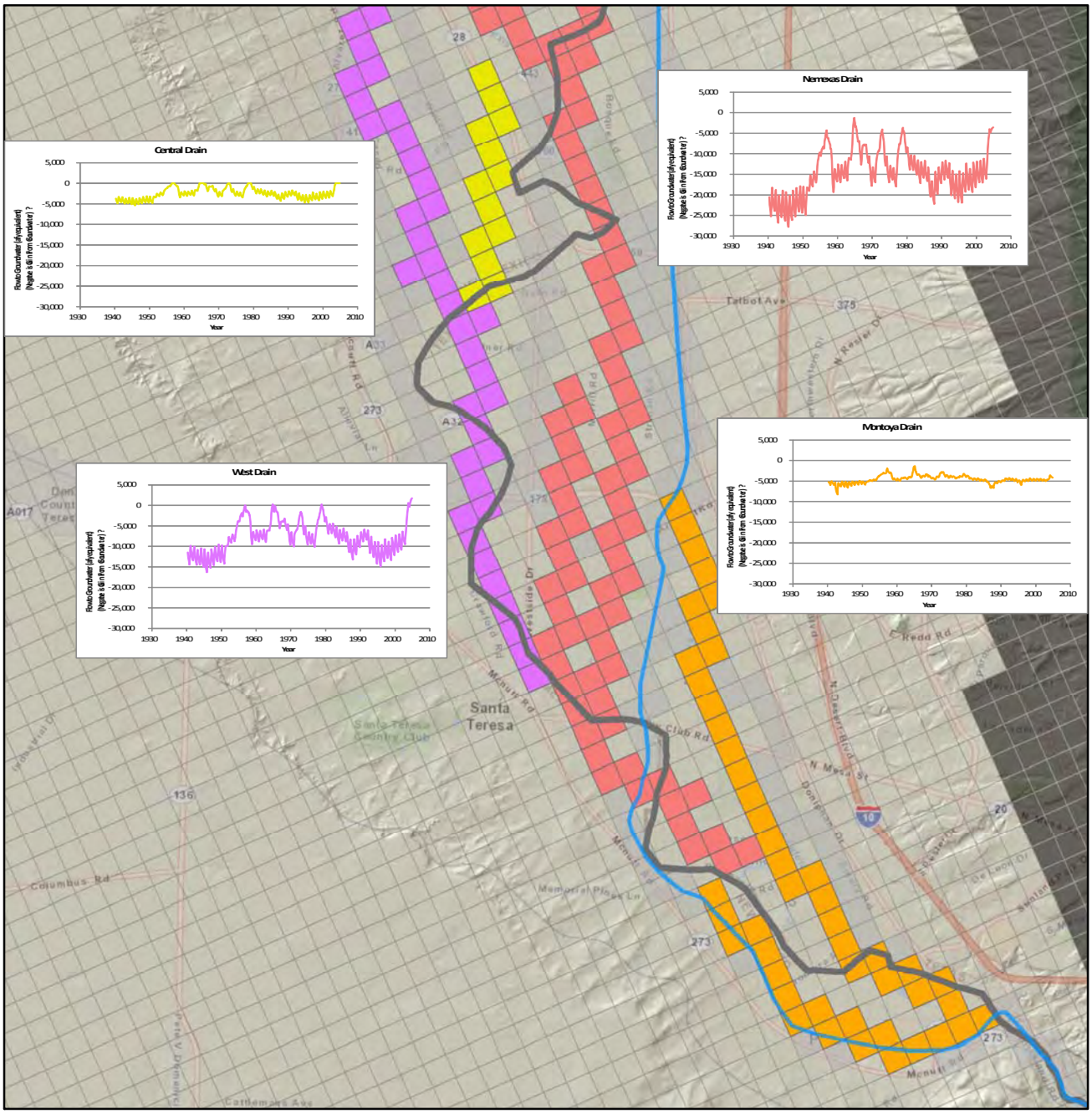
Data Source:
(SSPA, 2007)

VICINITY MAP

N

0 0.5 1 2
Miles

FIGURE 6-34
Simulated Laterals
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

- Rio Grande
- State Boundary

Surface Water Body

- West Drain
- Central Drain
- Nemexas Drain
- Montoya Drain

Plots present gain from Groundwater (afy equivalent) (negative value is gain)

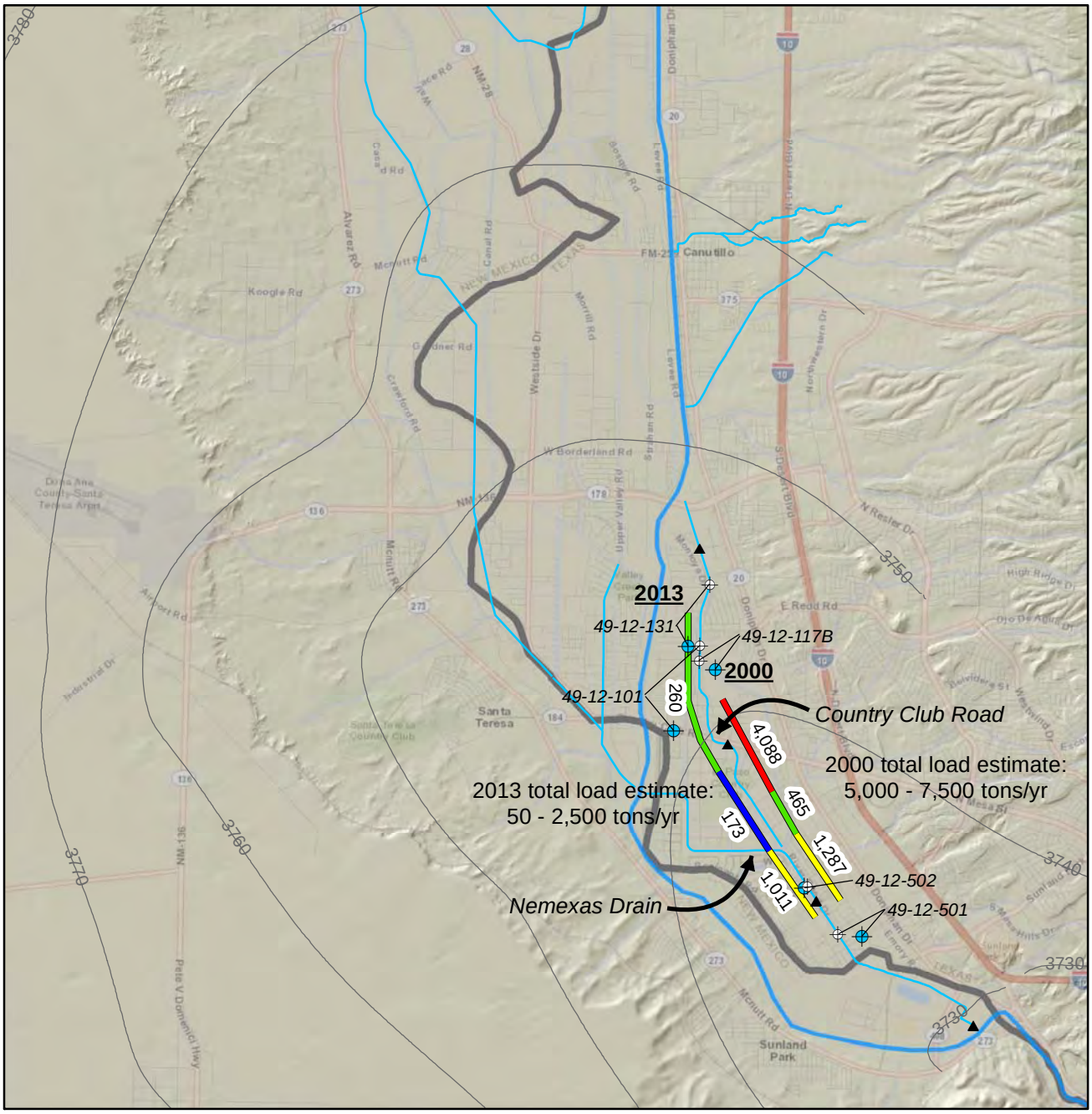
Data Source: (SSPA, 2007)

VICINITY MAP

N

0 0.5 1 2
Miles

FIGURE 6-35
Simulated Drains
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

LEGEND

Data Source:
Bakker, et al. (2000)
USGS (2013)
See Appendix C for calculations

- Rio Grande
- Drains and Laterals

Approx. Chloride Load (tons/year, annualized)

- < 200
- 201 - 1000
- 1001 - 2000
- > 2000
- 2009 Water Level Contour (water table)
- Wells Used in Figure 7-2
- Projected Groundwatwer Location (for Figure 7-2)
- Drain Elevation Survey Location (Tetra Tech, 2004)

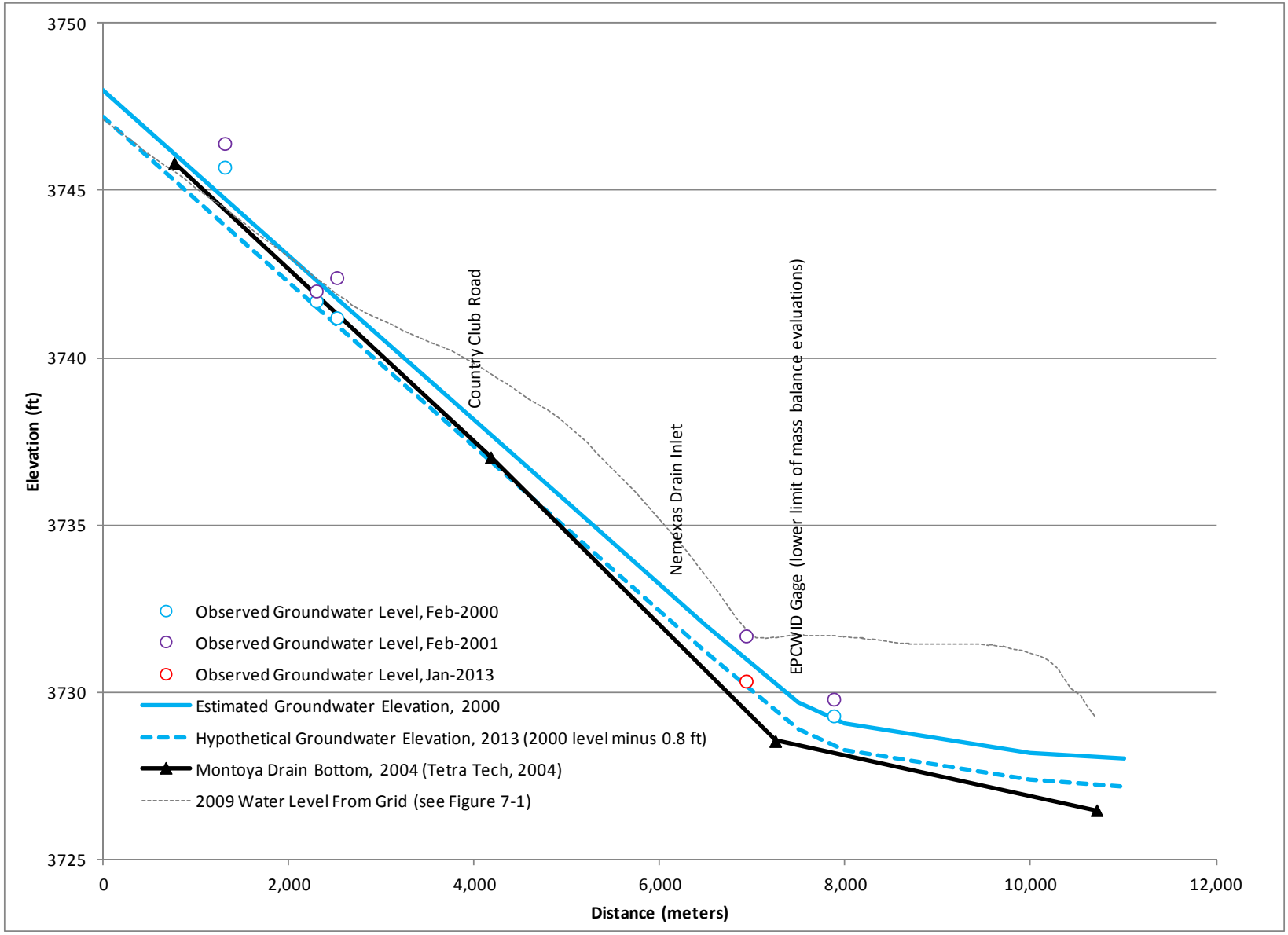
0 0.5 1
Miles

N

FIGURE 7-1
Estimated Chloride Load
From Groundwater to Montoya Drain
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

\\ROSWELL\PROJ\USACE\408366MESILLA\GIS\MAPFILES\DISTALMESILLA\DistalMesilla_Montoya_WQ_Summary.mxd



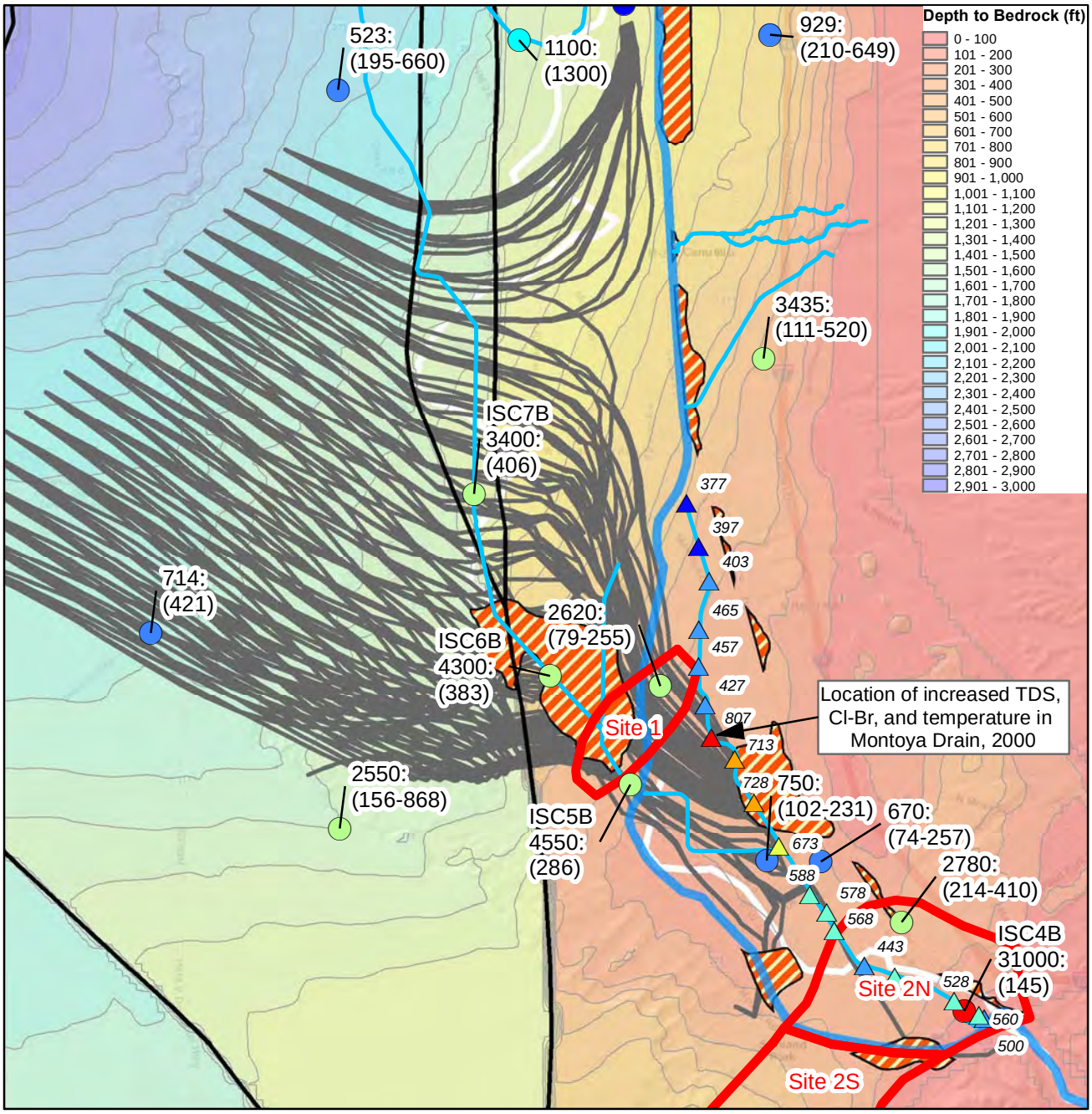
Notes

1. Groundwater elevation lines are uncertain, and are based on projected locations in Figure 7-1. Additional data at or near the drain could better constrain these.

FIGURE 7-2
Elevation of Montoya Drain and Groundwater

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



LEGEND

- Sites for Potential Salinity Control Project
- Rio Grande
- Faults
- Particle Traces
- Alkali Soils, 1912 (Nelsom and Holmes, 1912)

Median TDS in deep groundwater mg/L (label = value: depth)

- <= 500
- 501 - 1,000
- 1,001 - 2,000
- 2,001 - 5,000
- 5,001 - 10,000
- 10,001 - 20,000
- > 20,000

Cl-Br Ratio Montoya Drain

- < 400
- 401 - 500
- 501 - 600
- 601 - 700
- 701 - 800
- > 800

Data Sources:
--Particles: SSPA 2007 model
--TDS: NM ISC compendium Layer: Hawley, pers. comm.
--Cl-Br ratios: Bakker, et al., 2000

0 0.5 1
Miles

N

VICINITY MAP

FIGURE 7-3
Particle Traces
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

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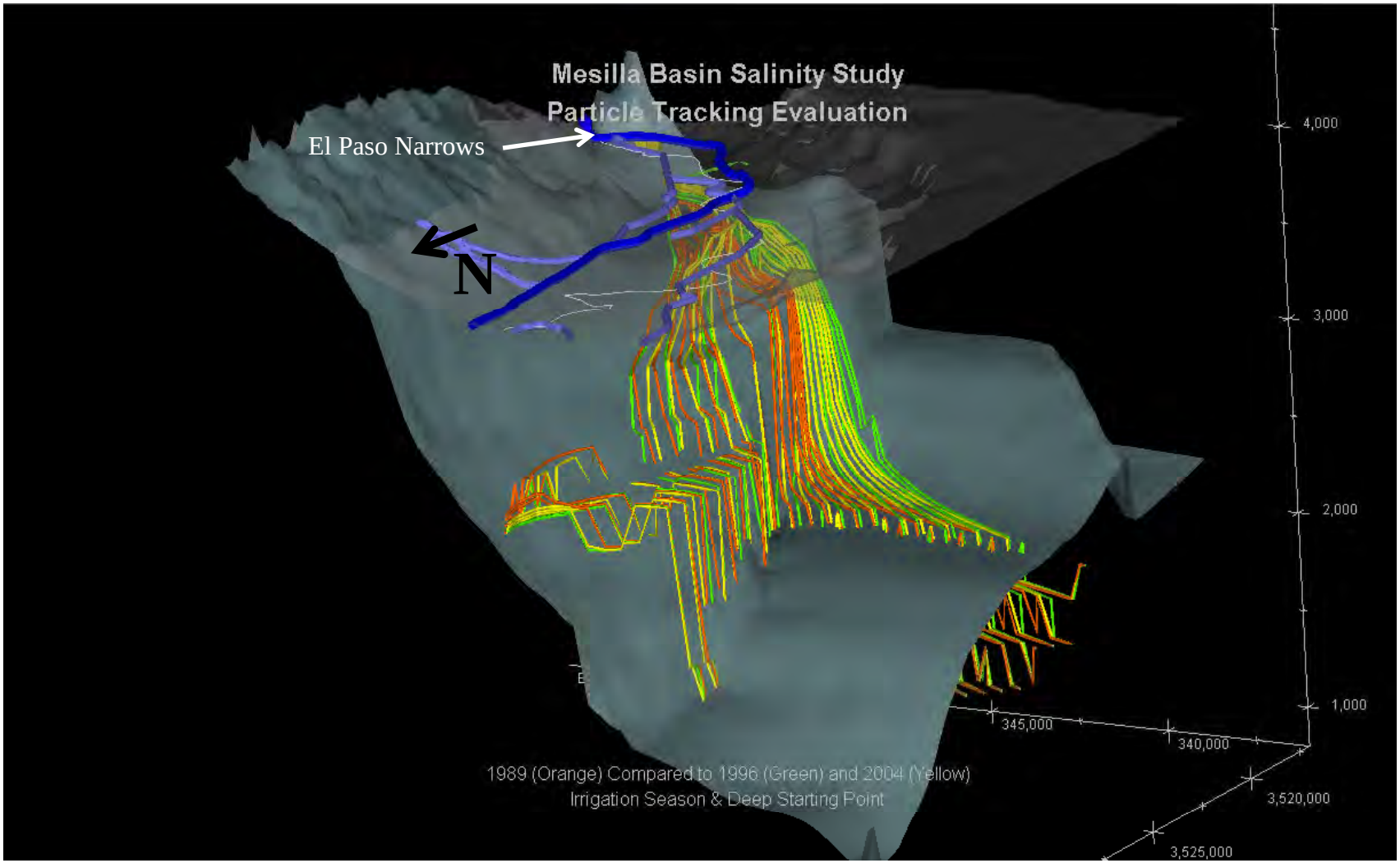
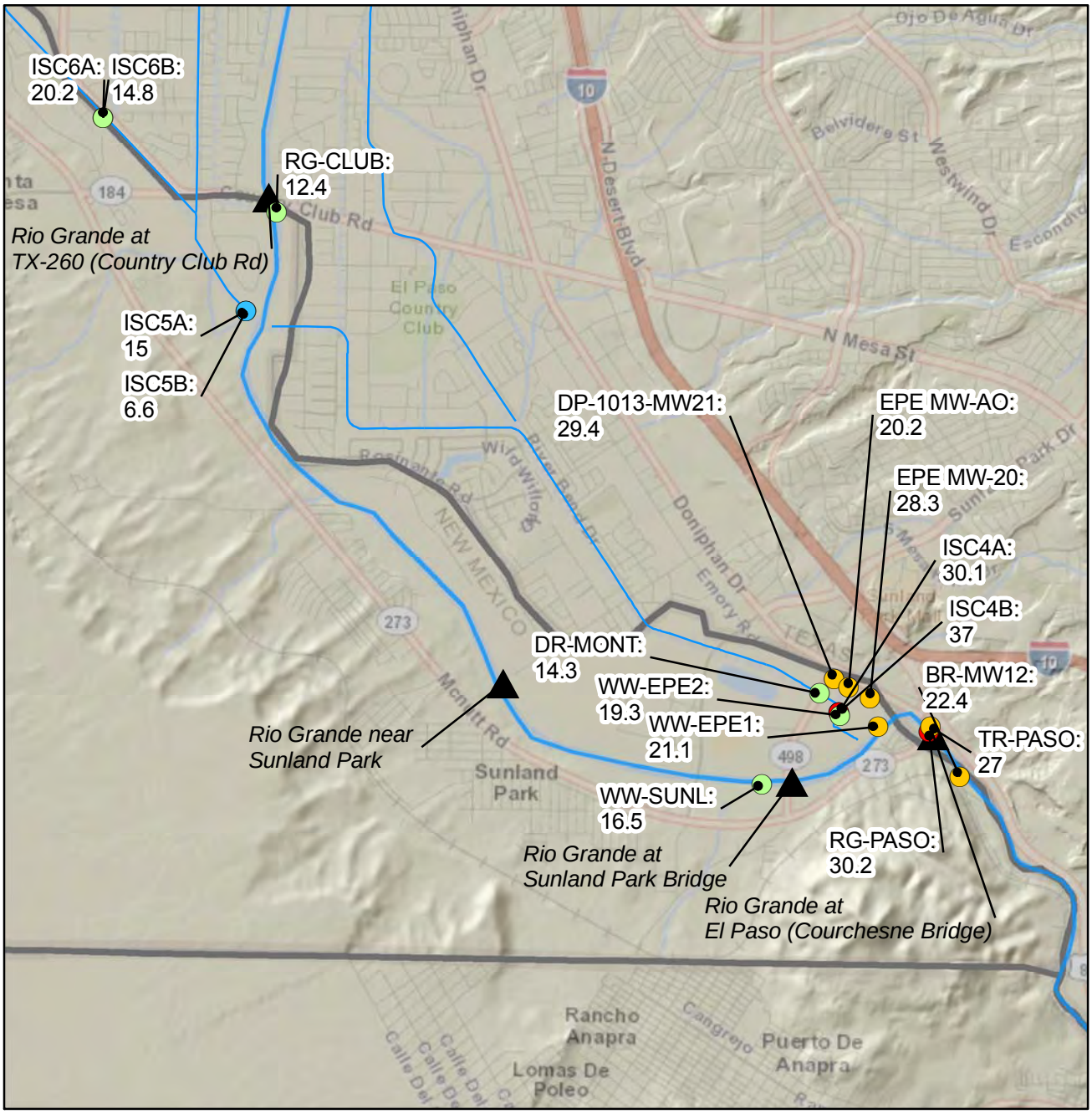


Image is a screen capture from a 3-D file that is available on the CD attachment to this report. The user can "spin," zoom in, etc.

FIGURE 7-4
Particle Tracks,
3-Dimensional View

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



LEGEND

- Drain
- Rio Grande
- State Boundary
- Rio Grande Flow Measurements

Delta Boron-11 (per mil)

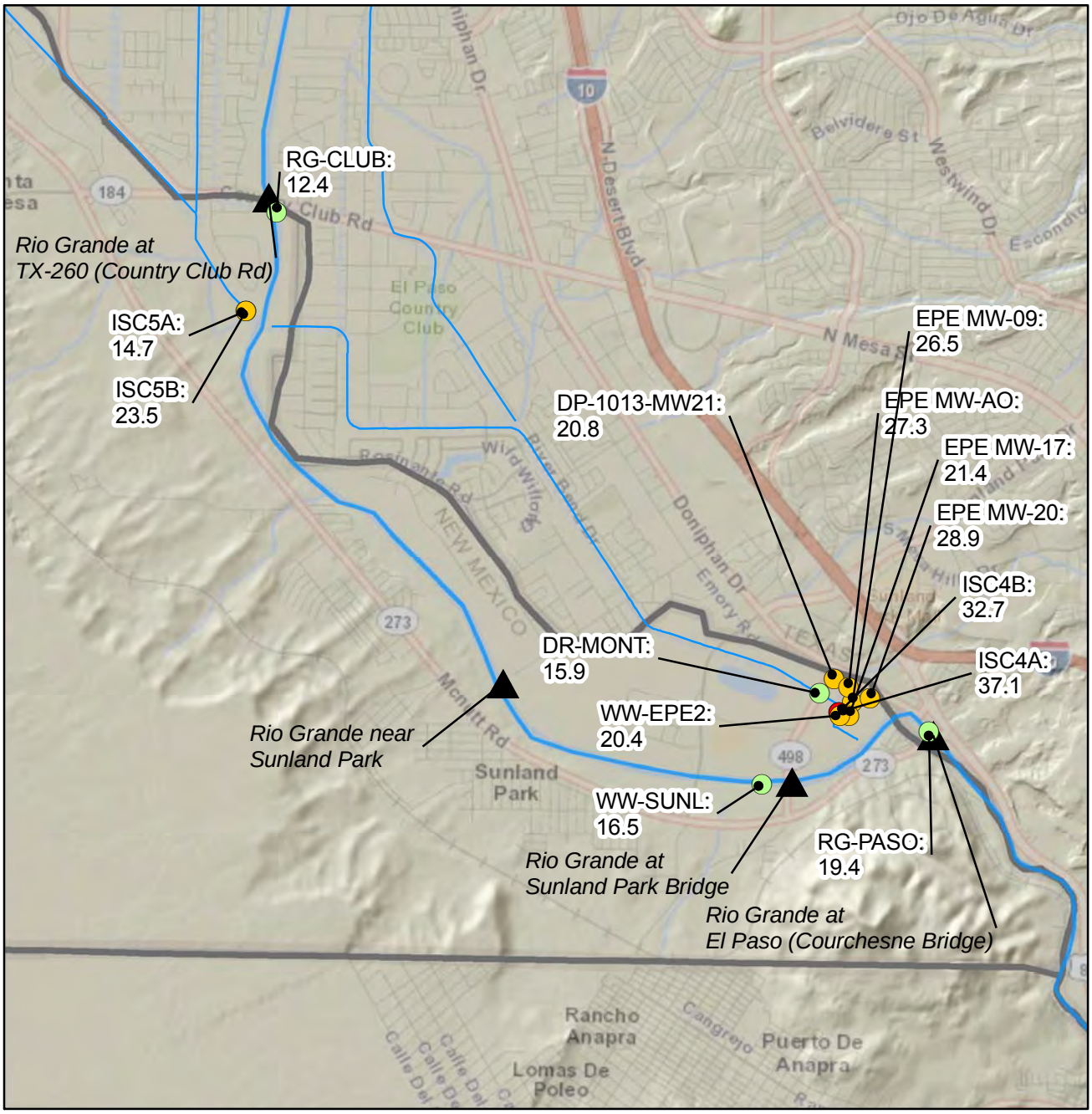
- -7.2 - 0.0
- 0.1 - 10.0
- 10.1 - 20.0
- 20.1 - 30.0
- 30.1 - 40.0

N

0 0.5 1
Miles

VICINITY MAP

FIGURE 7-5
Boron-11, Feb-2007
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

LEGEND

- Drain
- Rio Grande
- State Boundary
- Rio Grande Flow Measurements

Delta Boron-11 (per mil)

- -7.2 - 0.0
- 0.1 - 10.0
- 10.1 - 20.0
- 20.1 - 30.0
- 30.1 - 40.0

N

0 0.5 1
Miles

FIGURE 7-6
Boron-11, Aug-2006
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

LEGEND

- Study Area
- Rio Grande
- Ag Drains
- 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
- 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

N

0 0.25 0.5 1
Miles

Source: USGS National Gap Analysis Program, 2011

VICINITY MAP

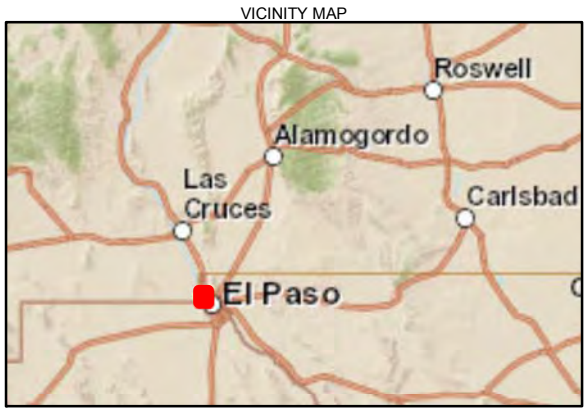


FIGURE 8-1
Vegetation Types at Ecological System Level (USGS GAP)
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

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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

0 0.25 0.5
Miles

N

VICINITY MAP

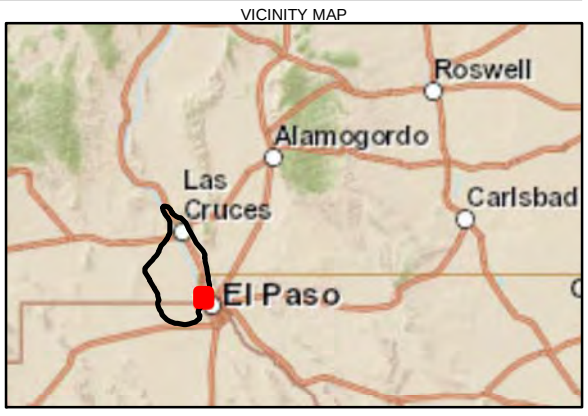


FIGURE 8-2
Potential Jurisdictional Waters of the U.S. and/or in the State in Study Area
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

\\ROSWELL\PROJ\USACE\408366MESILLA\GIS\MAPFILES\DISTALMESILLA\ECOSYSTEM\DistalMesilla_Ecosystem_Wetlands_11x17.mxd

Appendix A
CD Attachment

APPENDIX A

CD Attachment

A CD is included with this report. The CD includes a database of digitized drillers' logs, as well as 3-dimensional "figures" of geology, TDS, and model particle traces.

Digitized Drillers' Logs

173 drillers' logs were compiled and digitized as part of this work. The database is included as an Excel file in the CD. Sources of drillers' logs are as follows.

Source of Key Logs from Hawley Cross-Sections:

Data was digitized from a PDF of a Texas Water Commission document to supplement and expand and produce three-dimensional model of the Hawley stratigraphies.

Leggat, E. R., M. E. Lowrey, and J. W. Hood, 1962. Ground Water Resources of the Lower Mesilla Valley, Texas and New Mexico. Texas Water Commission Bulletin 6203. March.

Source of Key Logs from ISC wells:

Data was digitized from a PDF of a New Mexico Interstate Stream Commission Document for wells providing key water quality information.

Tetra Tech EM Inc., 2003. Final Report for Well Installation Activities within the Mesilla Valley Lower Rio Grande Basin. New Mexico Interstate Stream Commission. May 9.

Source of Historic Logs from TCEQ:

Historic boring logs from the Texas Commission on Environmental Quality website (http://gis3.tceq.state.tx.us/waterwellpublic) were digitized from PDF scans for eastern portions of the study area.

Well identifiers were non-unique and based on township and range location. Log locations were determined by address, survey notes, and maps, and identifiers were assigned by the township and range PDF page.

Source of Recent Logs from TCEQ:

Recent boring logs from the Texas Commission on Environmental Quality were provided in the GWDB database (http://www.twdb.state.tx.us/groundwater/data).

Data was pulled from a Microsoft Access database and parsed to separate large strings of text and code the information into the USCS system.

Source of Lithology codes from other New Mexico wells:

Complete lithologic data was not readily available from the WATERS website. Database managers were contacted directly for additional information.

A table was supplied with four general classes of lithology, and these data was used to help confirm bedrock depths.

3-D Figures

Three 3-dimensional "figures" were developed as part of this work: geology, TDS, and model particle traces. The figures are included in the CD. The CTech "Standalone 4DIM Player," a free software package, is required to view the figures. The software can be downloaded from the CTech website:

http://www.ctech.com/?page=download

Appendix B
Water Budget

APPENDIX B

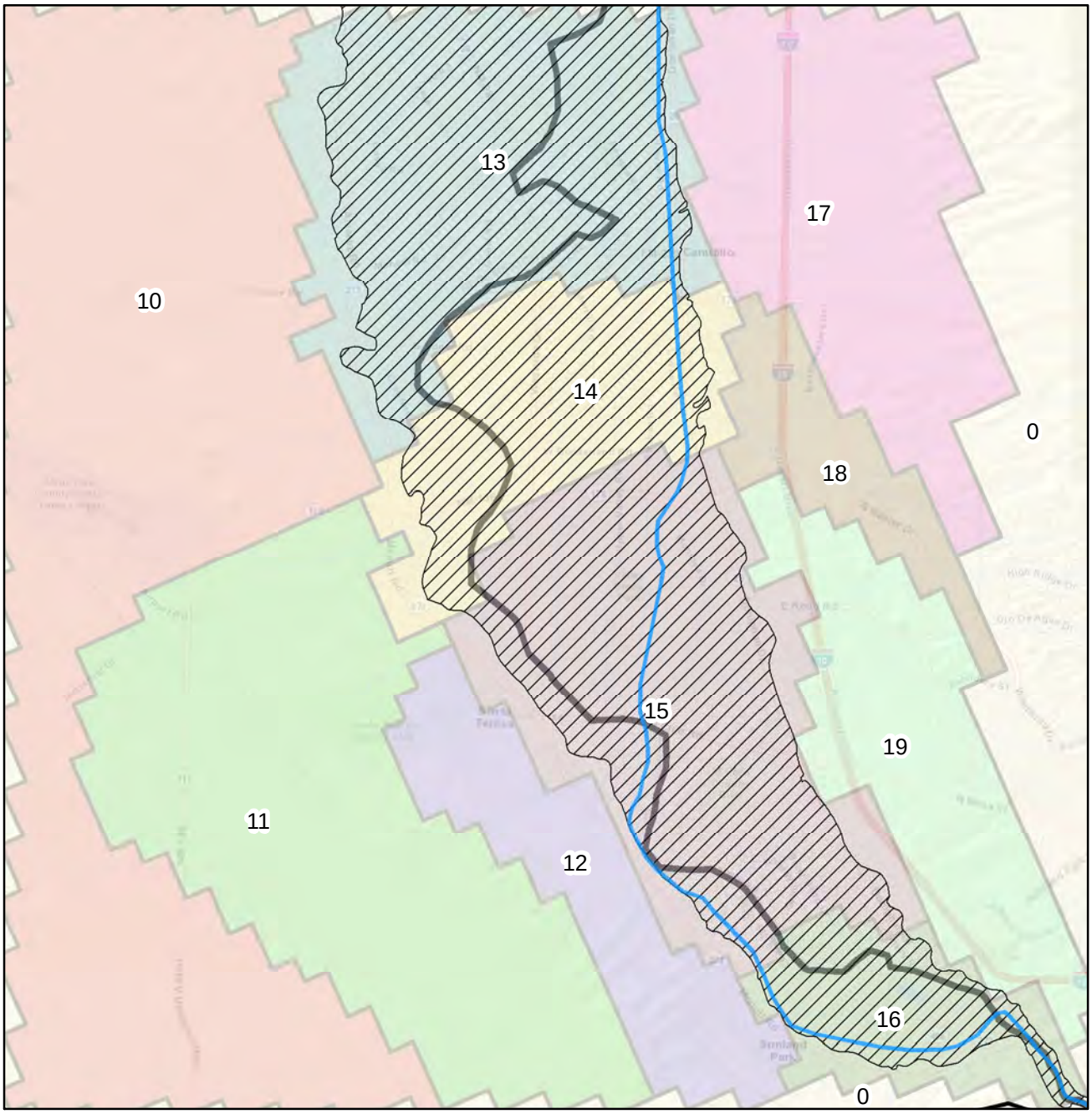
Water Budget

The New Mexico Office of the State Engineer administrative model was used to support evaluation of the study area water budget. The U. S. Geological Survey software "ZoneBudget" (Harbaugh, 1990) was used to process the water budget for 10 spatial zones (Figure B-1). The water budget for each layer was evaluated as a separate zone, for a total of 50 zones evaluated. Average water budgets by layer for the time period 1980-1999 are presented in Figures B-2 through B-6. Transient water budgets for the sum of all layers were also developed for zones 10through 16, along with column plots showing the average water budget for the time period 1980-1999 for each zone.

Reference

Harbaugh, A.W. 1990. A Computer Program for Calculating Subregional Water Budgets Using Results from the U.S. Geological Survey Modular Three-Dimensional Ground-Water Flow Model. U.S. Geological Survey Open-File Report 90-392. 46 p.

Figures



VICINITY MAP

LEGEND

- Rio Grande
- River Alluvium

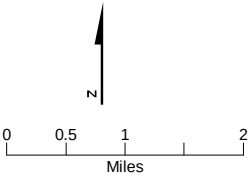
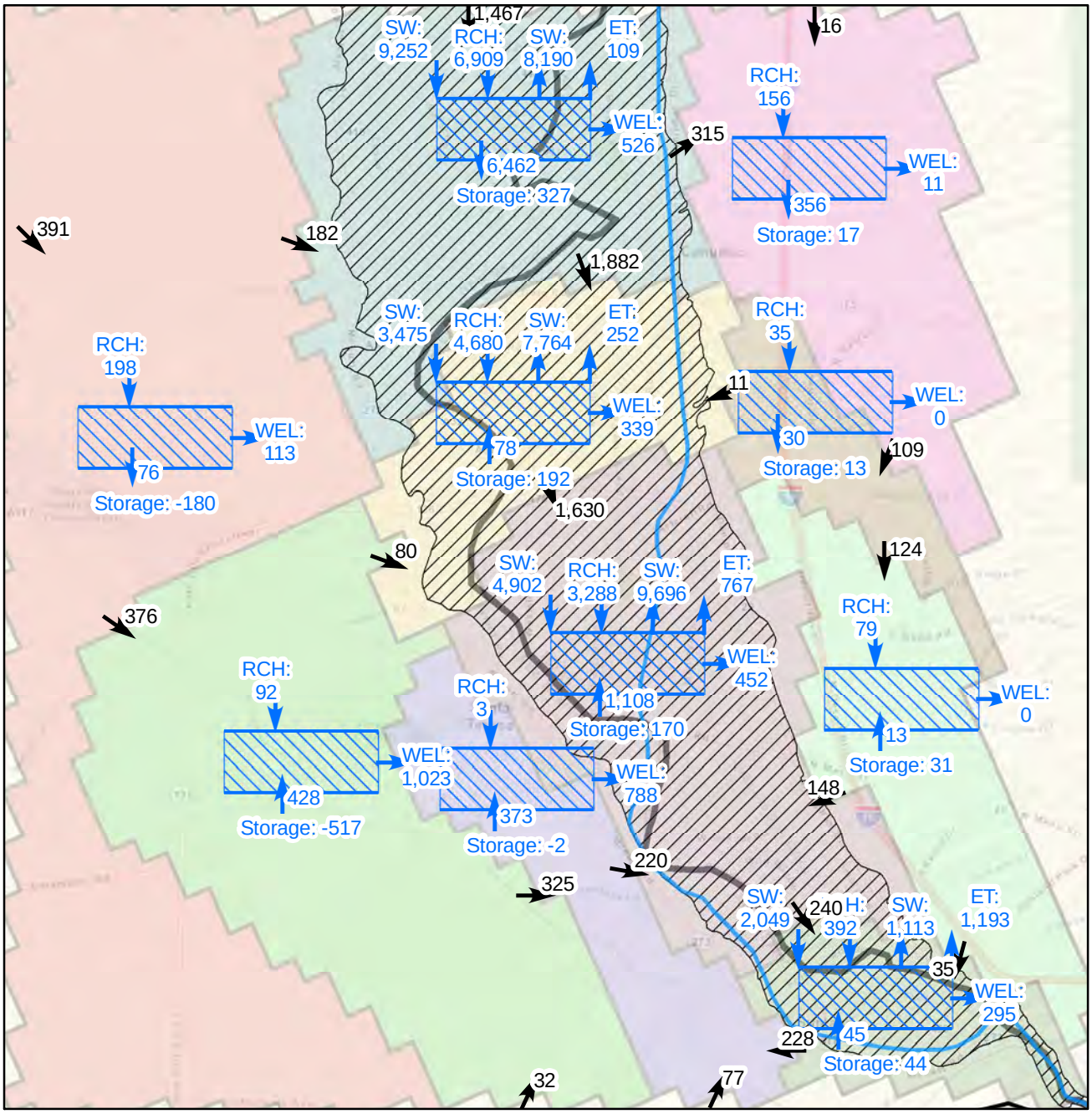


FIGURE B-1
Model Water Budget Zones
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

Rio Grande

Mesilla Basin Boundary

Units: AFY

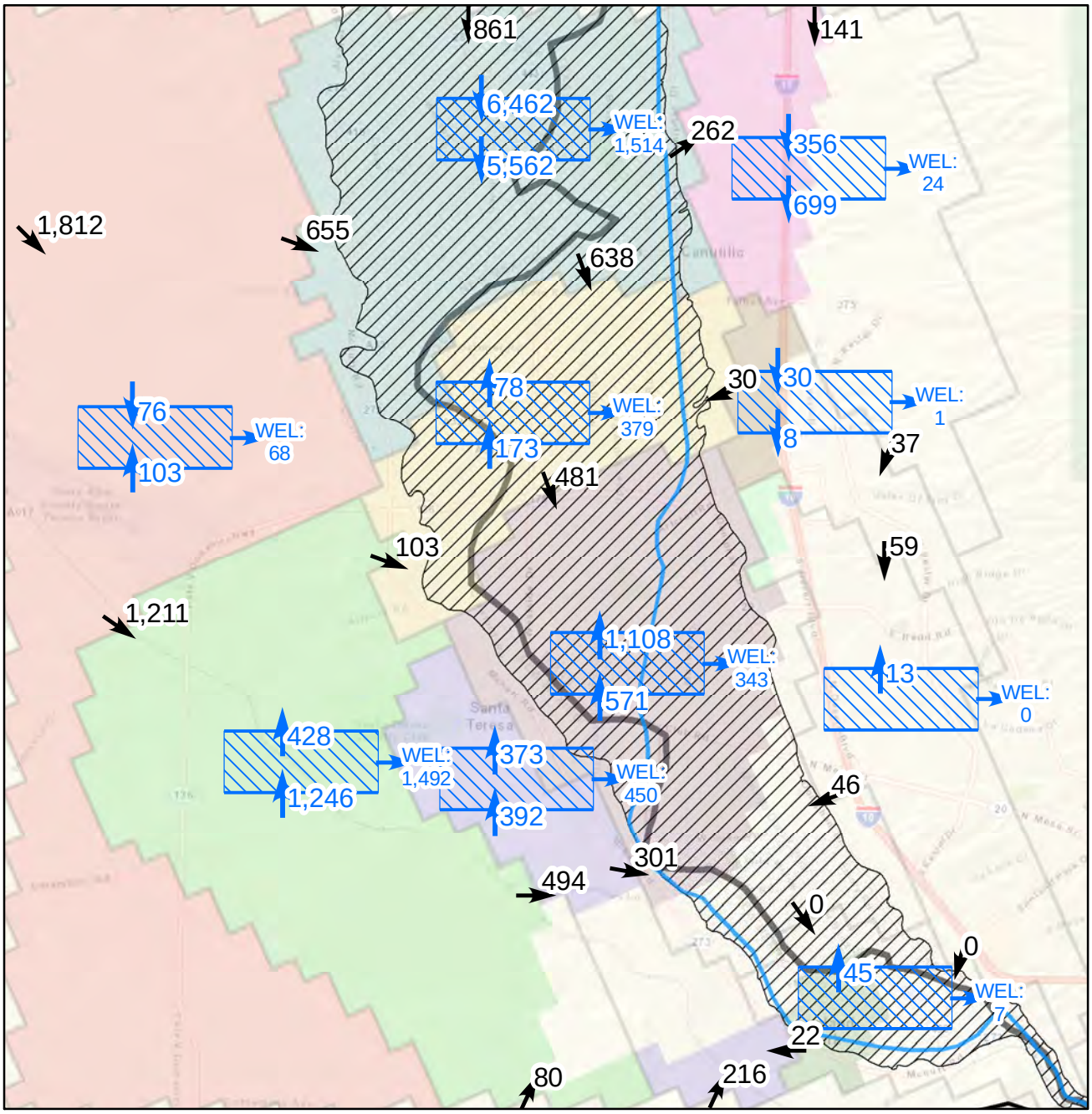
Data Sources:
SSPA 2007 model

VICINITY MAP

N

0 0.5 1 2
Miles

FIGURE B-2
Model Water Budget L1 (1980-1999)
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

Horizontal Flow, arow represents direction (afy)

Layer schematic, with vertical flow (afy)

Rio Grande

Mesilla Basin Boundary

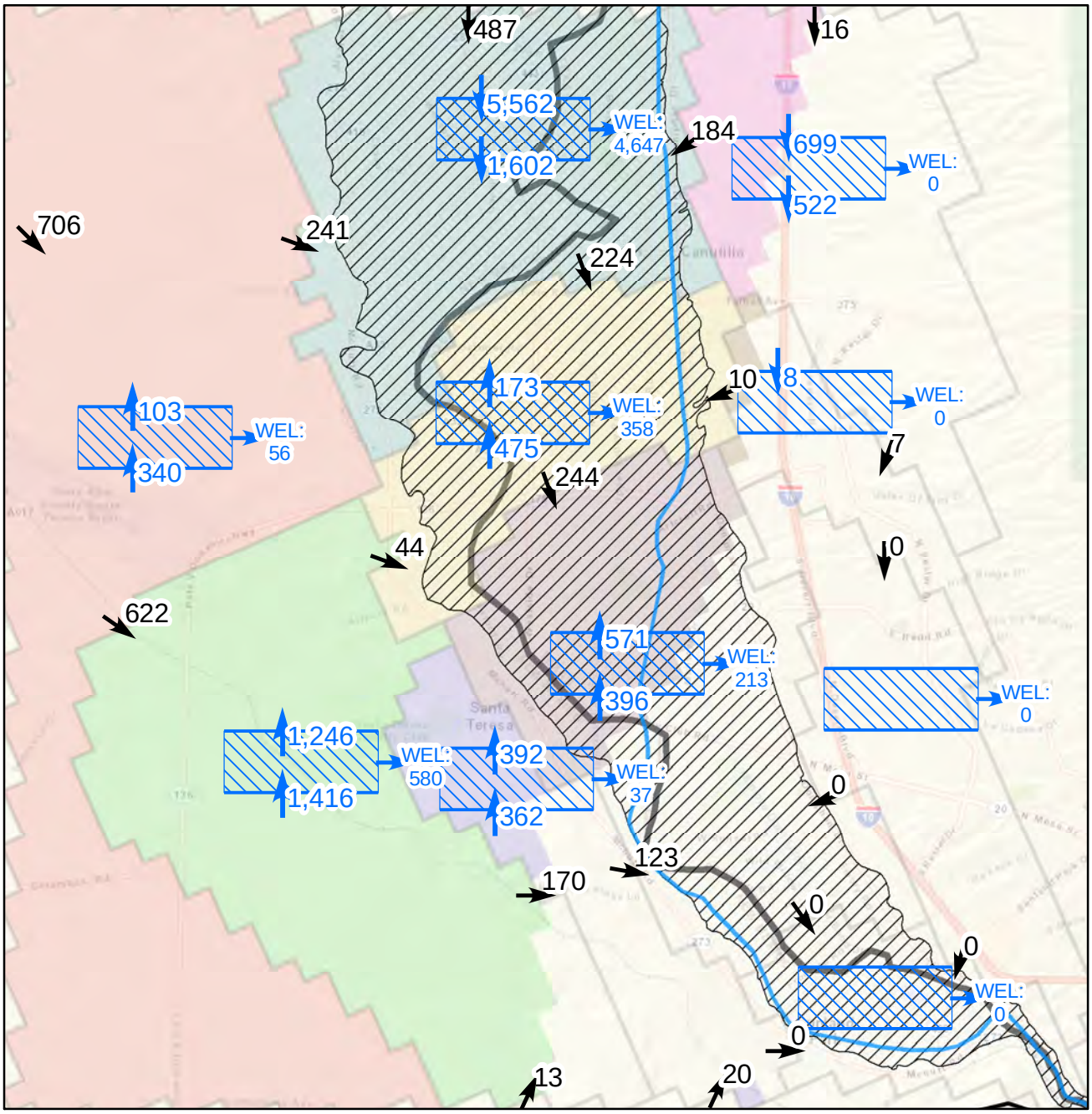
Data Sources:
SSPA 2007 model
Average flow rates, 1980-1999

VICINITY MAP

N

0 0.5 1 2
Miles

FIGURE B-3
Model Water Budget L2 (1980-1999)
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

Horizontal Flow, arow represents direction (afy)

Layer schematic, with vertical flow (afy)

Rio Grande

Mesilla Basin Boundary

Data Sources:
SSPA 2007 model
Average flow rates, 1980-1999

VICINITY MAP

N

0 0.5 1 2
Miles

FIGURE B-4
Model Water Budget L3 (1980-1999)
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

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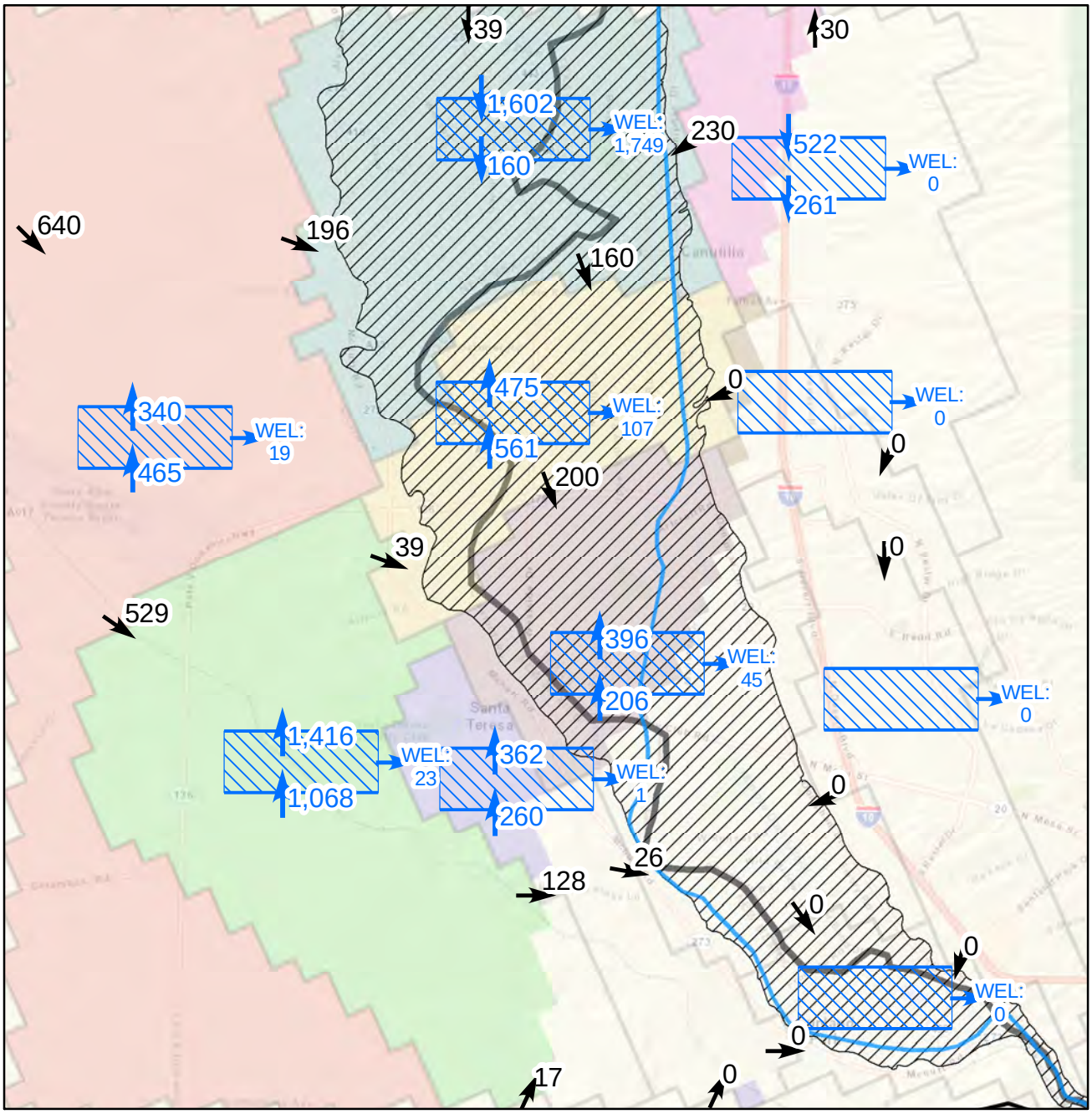
\DISTALMESILLA_MODEL_WATERBUDGET_L2_V1.MXD SSHULTZ 8/7/2012 12:13:



LEGEND

Horizontal Flow, arow represents direction (afy)

Layer schematic, with vertical flow (afy)

Rio Grande

Mesilla Basin Boundary

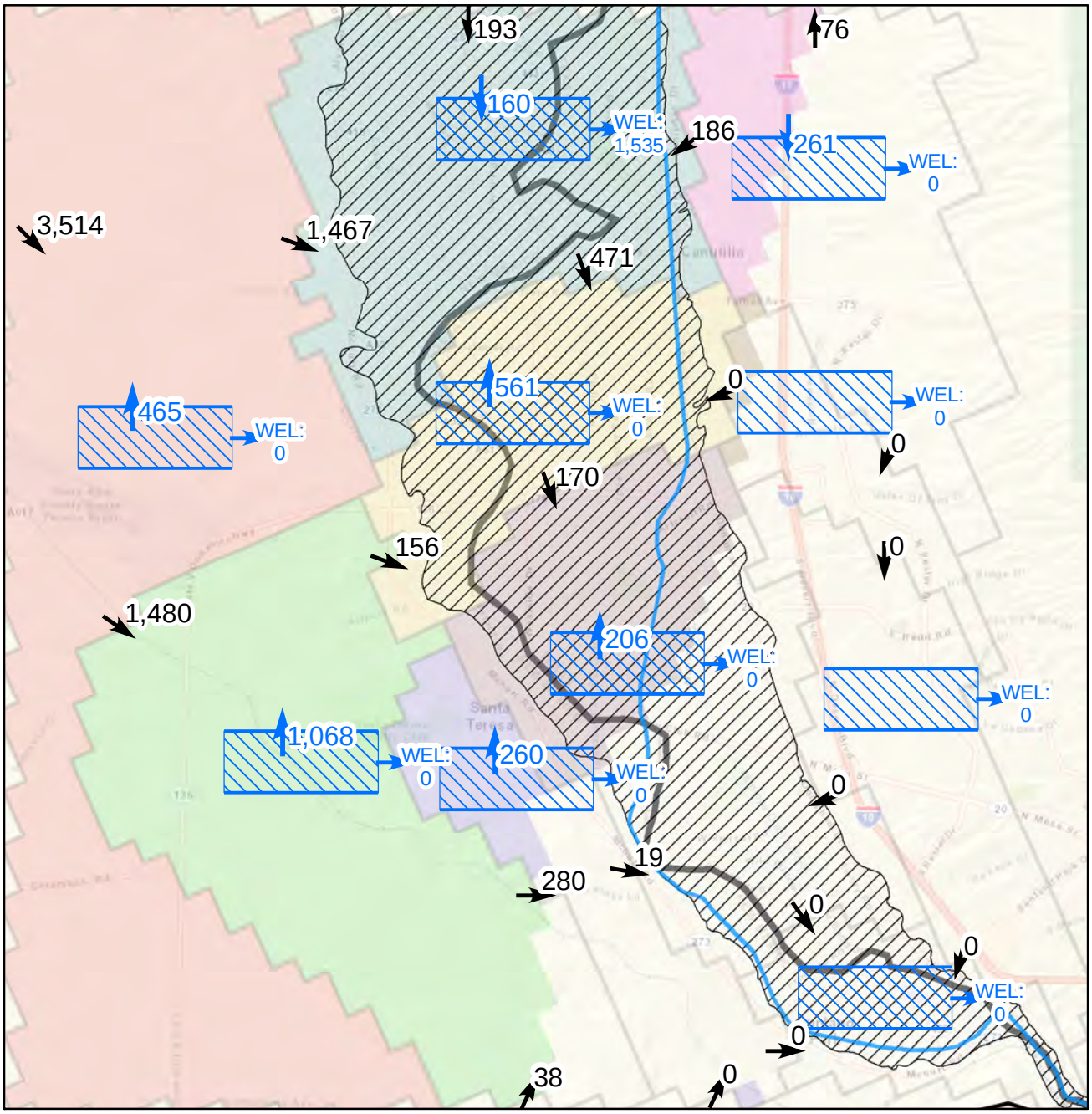
Data Sources:
SSPA 2007 model
Average flow rates, 1980-1999

VICINITY MAP

N

0 0.5 1 2
Miles

FIGURE B-5
Model Water Budget L4 (1980-1999)
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



LEGEND

Horizontal Flow, arow represents direction (afy)

Layer schematic, with vertical flow (afy)

Rio Grande

Mesilla Basin Boundary

Data Sources:
SSPA 2007 model
Average flow rates, 1980-1999

VICINITY MAP

N

0 0.5 1 2
Miles

FIGURE B-6
Model Water Budget L5 (1980-1999)
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

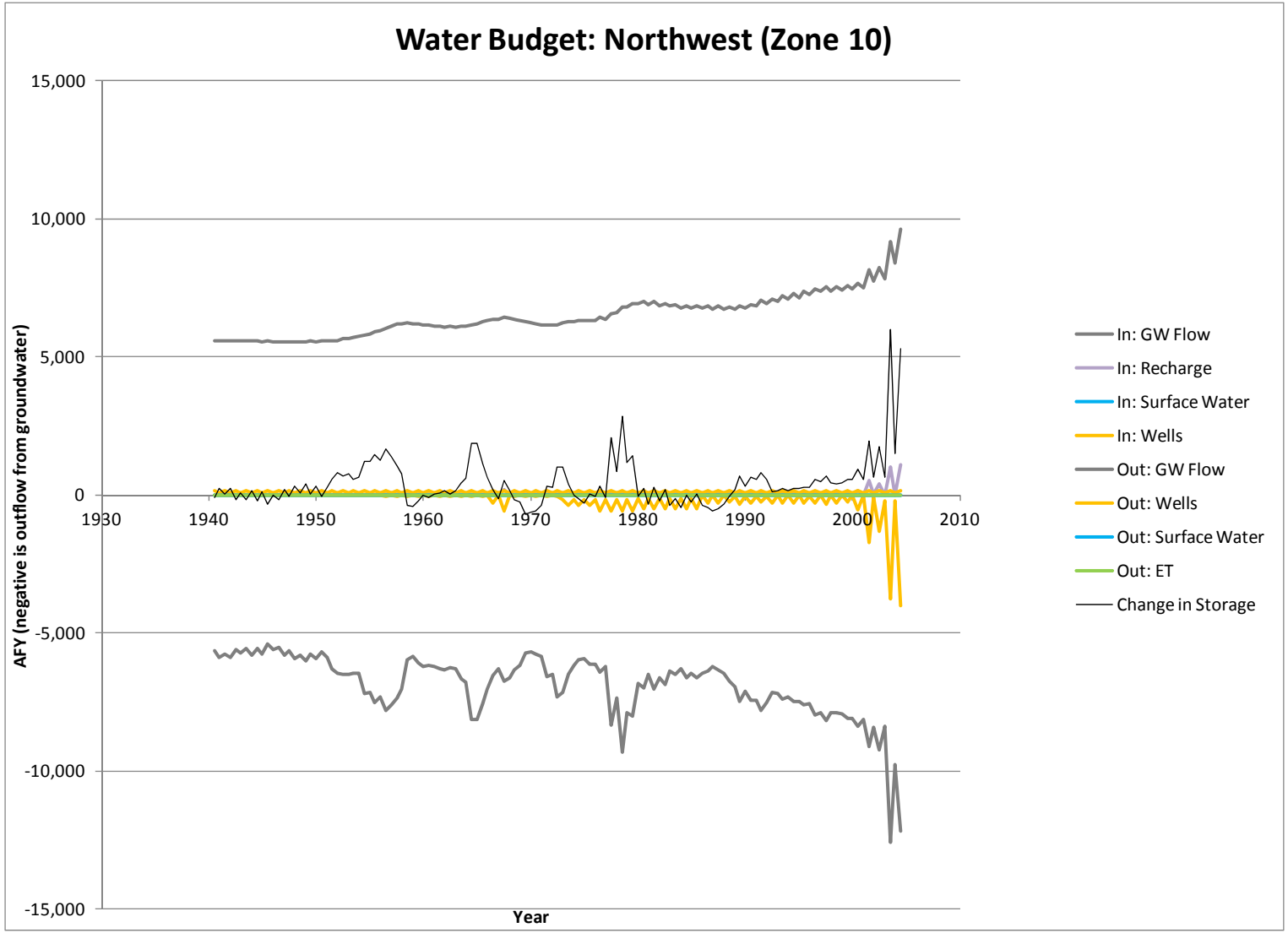


FIGURE B-7
Transient Model Water Budget, Zone 10 (Northwest)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

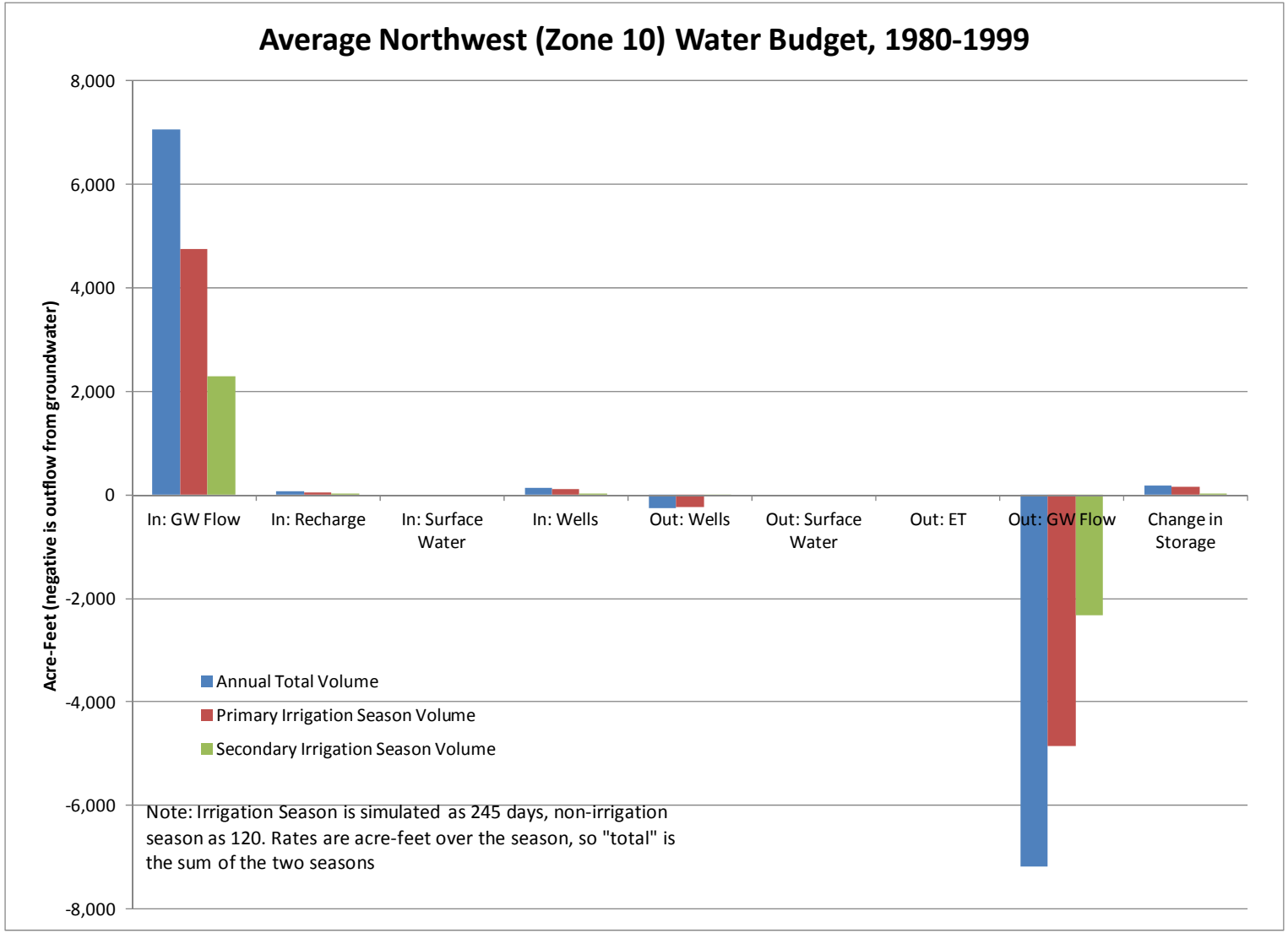


FIGURE B-8
Average Model Water Budget, Zone 10 (Northwest)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

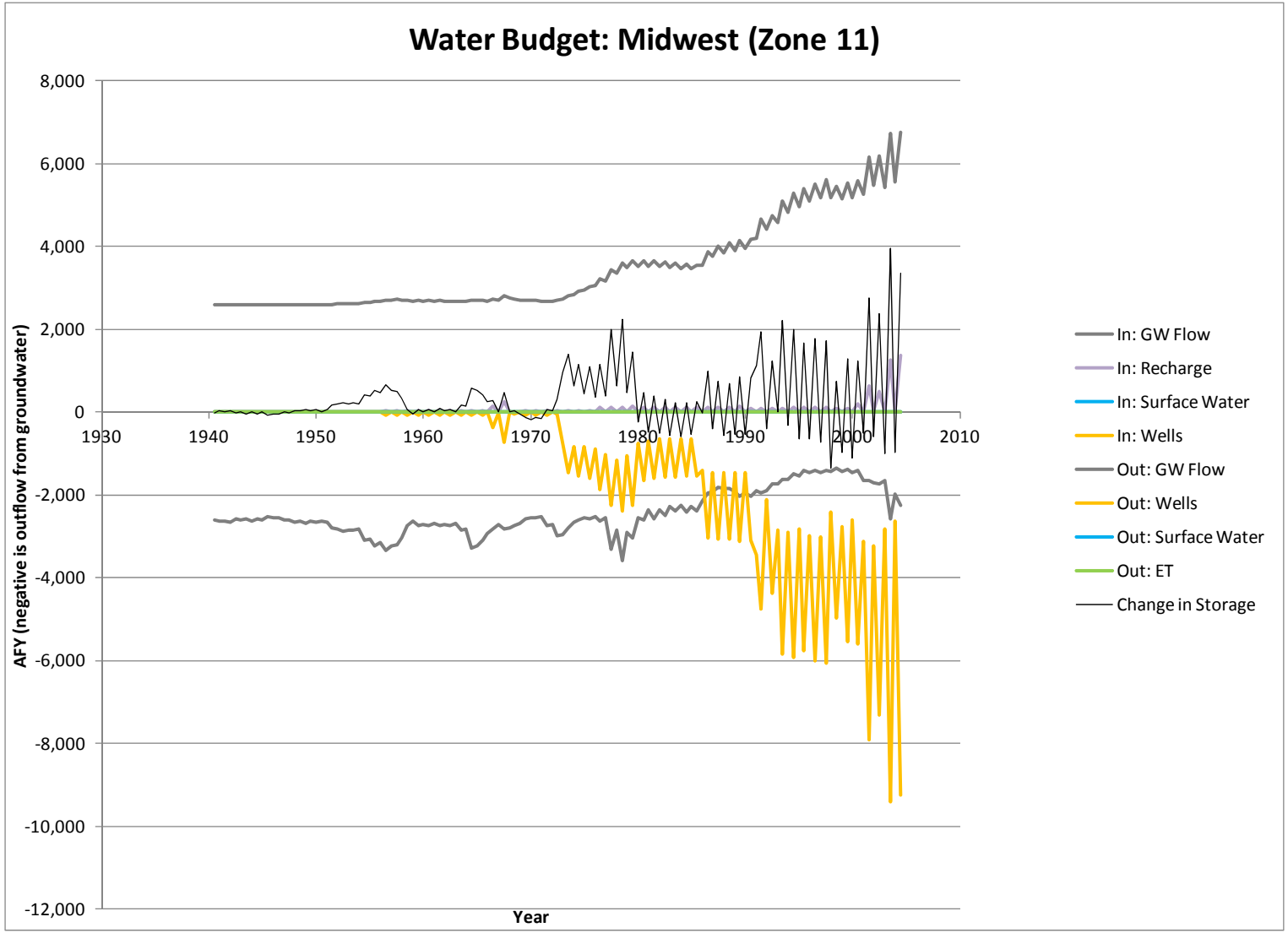


FIGURE B-9
Transient Model Water Budget, Zone 11 (Midwest)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

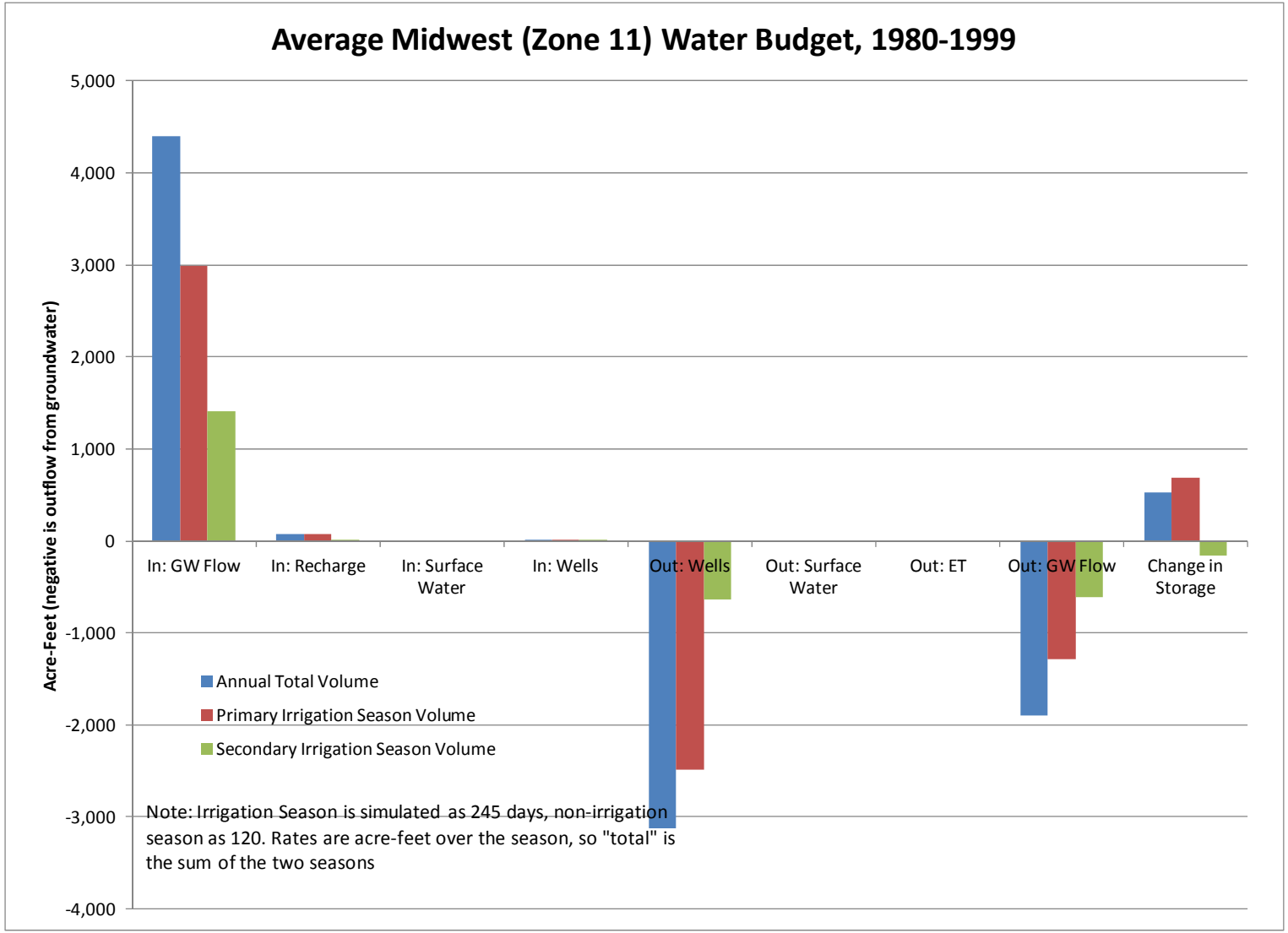


FIGURE B-10
Average Model Water Budget, Zone 11 (Midwest)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

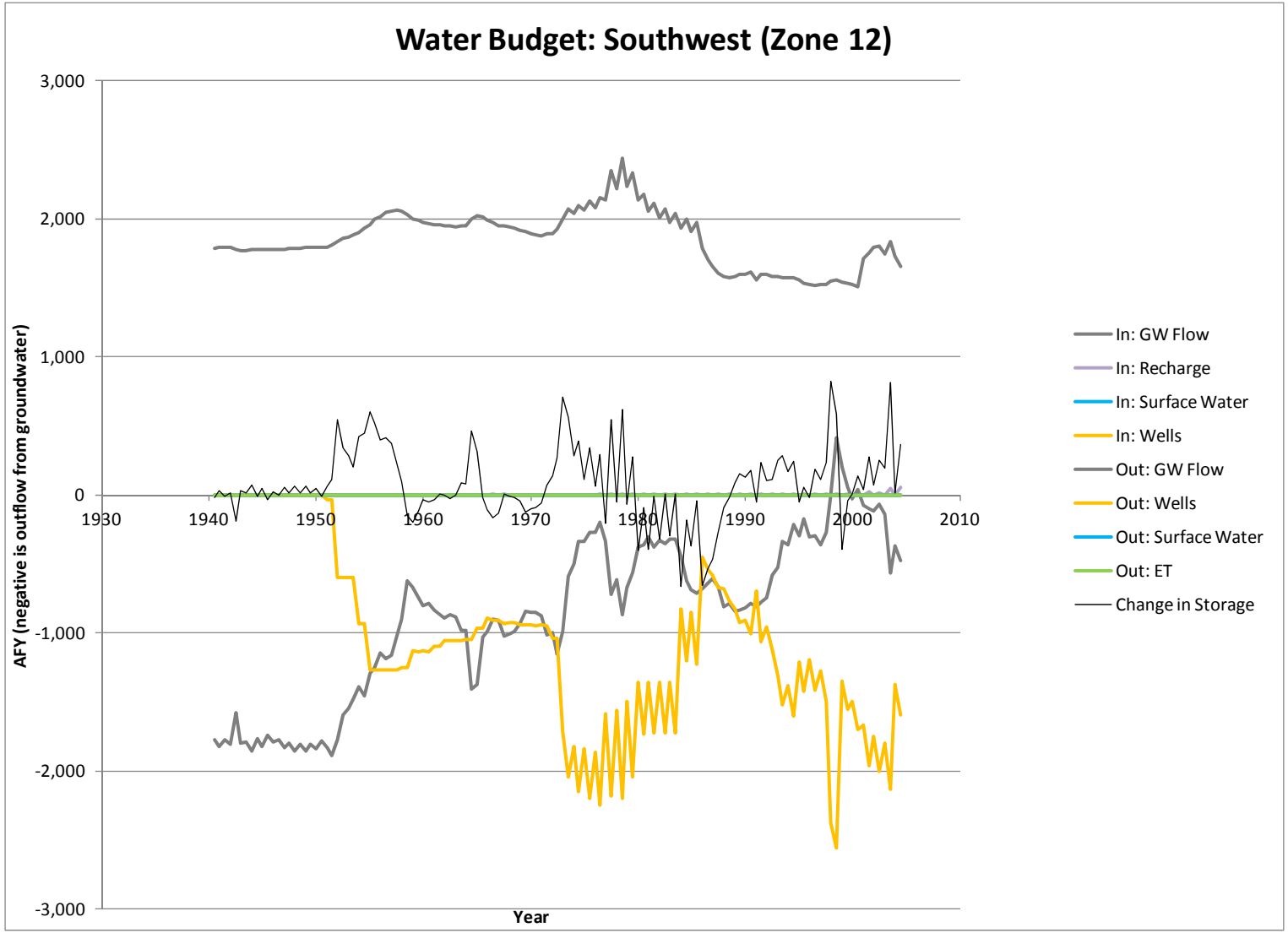


FIGURE B-11
Transient Model Water Budget, Zone 12 (Southwest)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

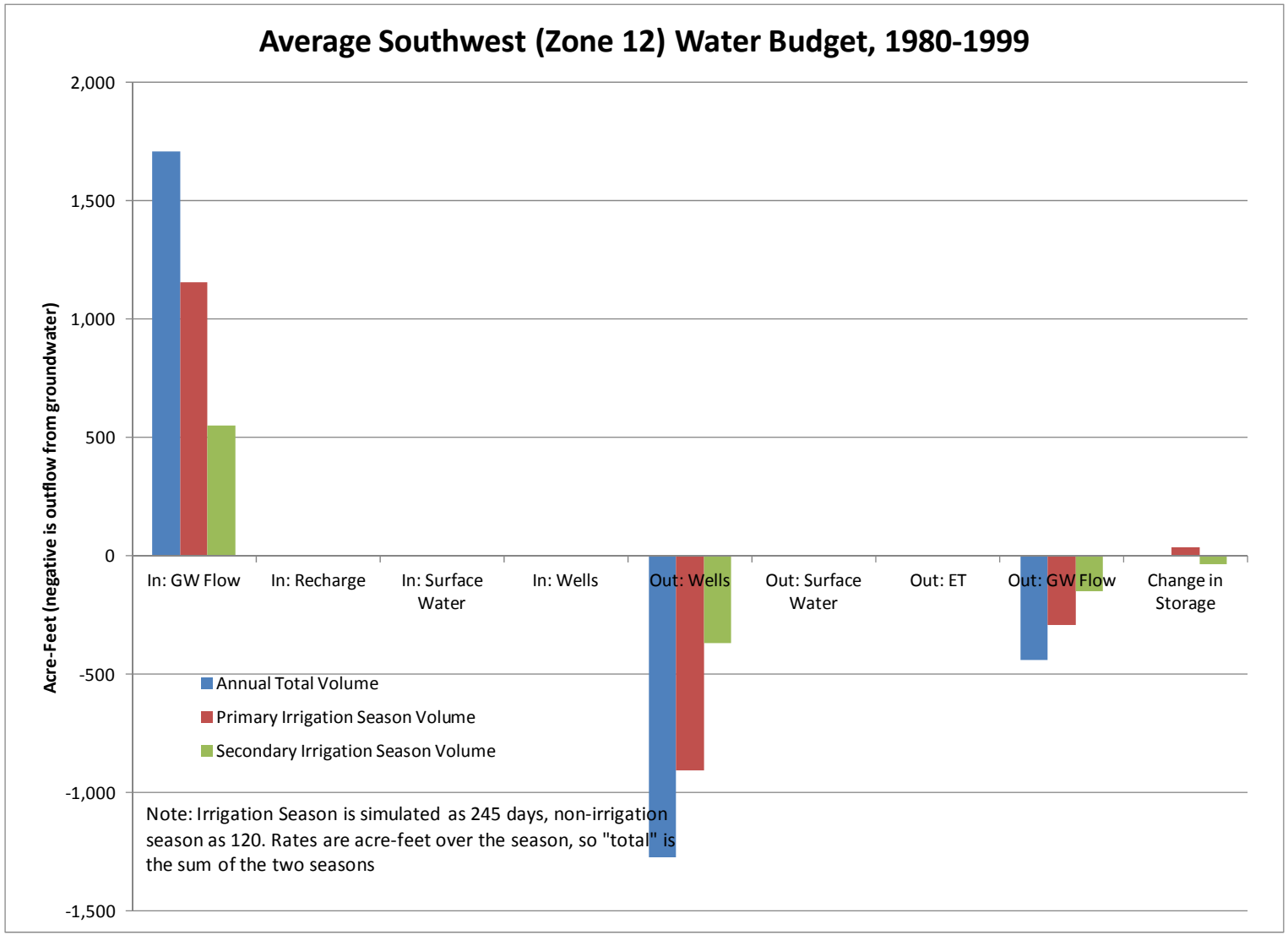


FIGURE B-12
Average Model Water Budget, Zone 12 (Southwest)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

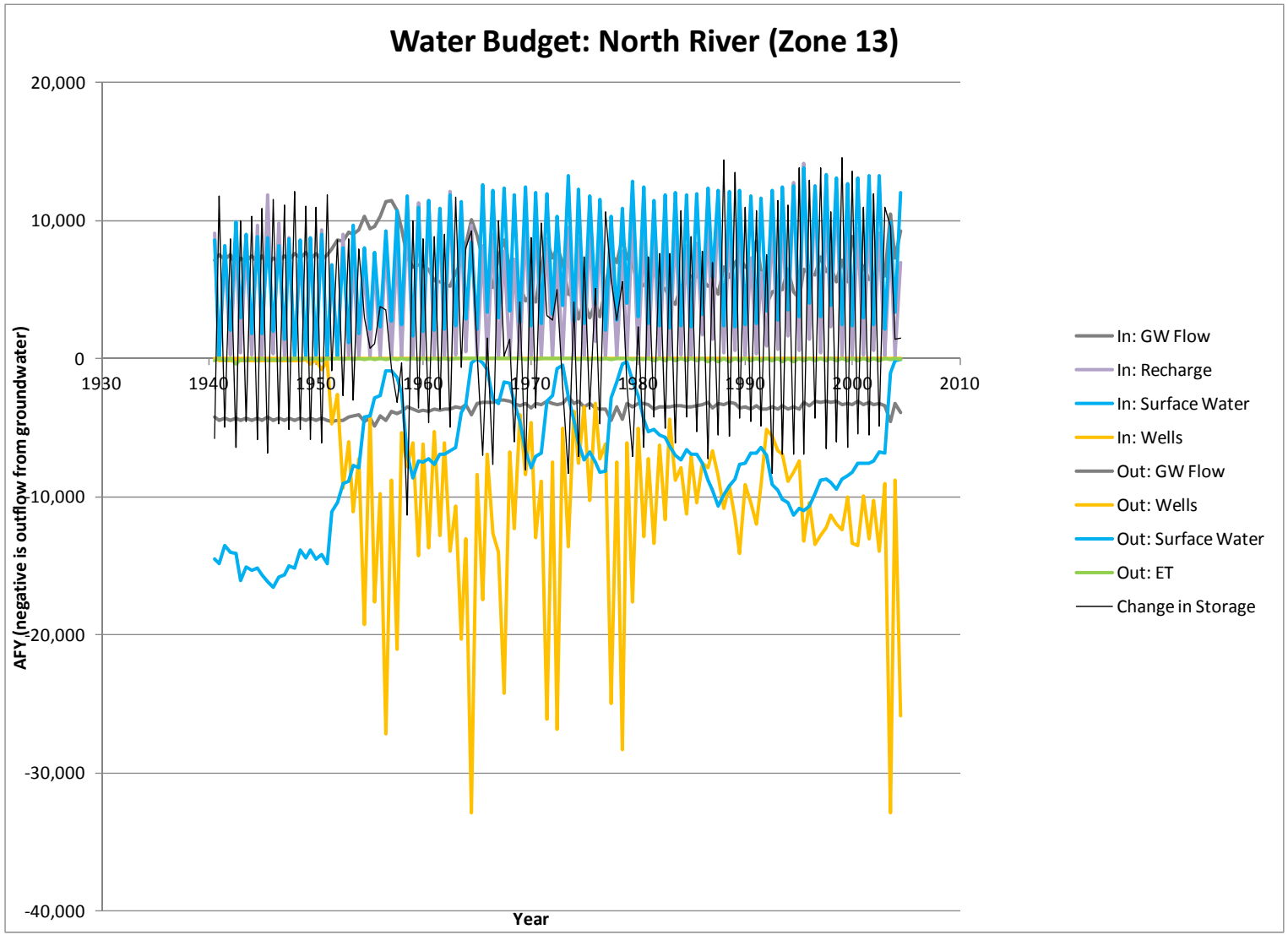


FIGURE B-13
Transient Model Water Budget, Zone 13 (North River)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

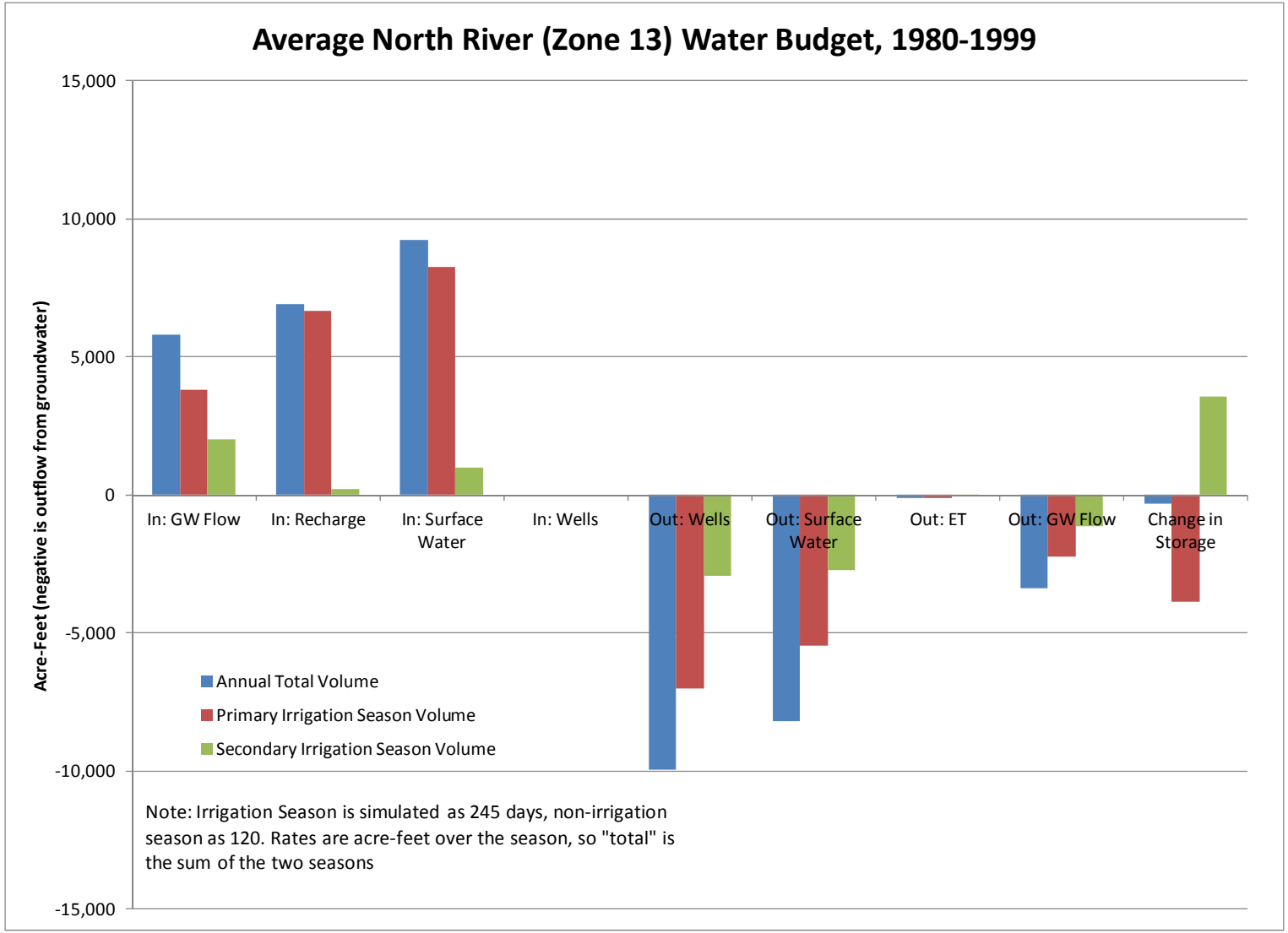


FIGURE B-14
Average Model Water Budget, Zone 13 (North River)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

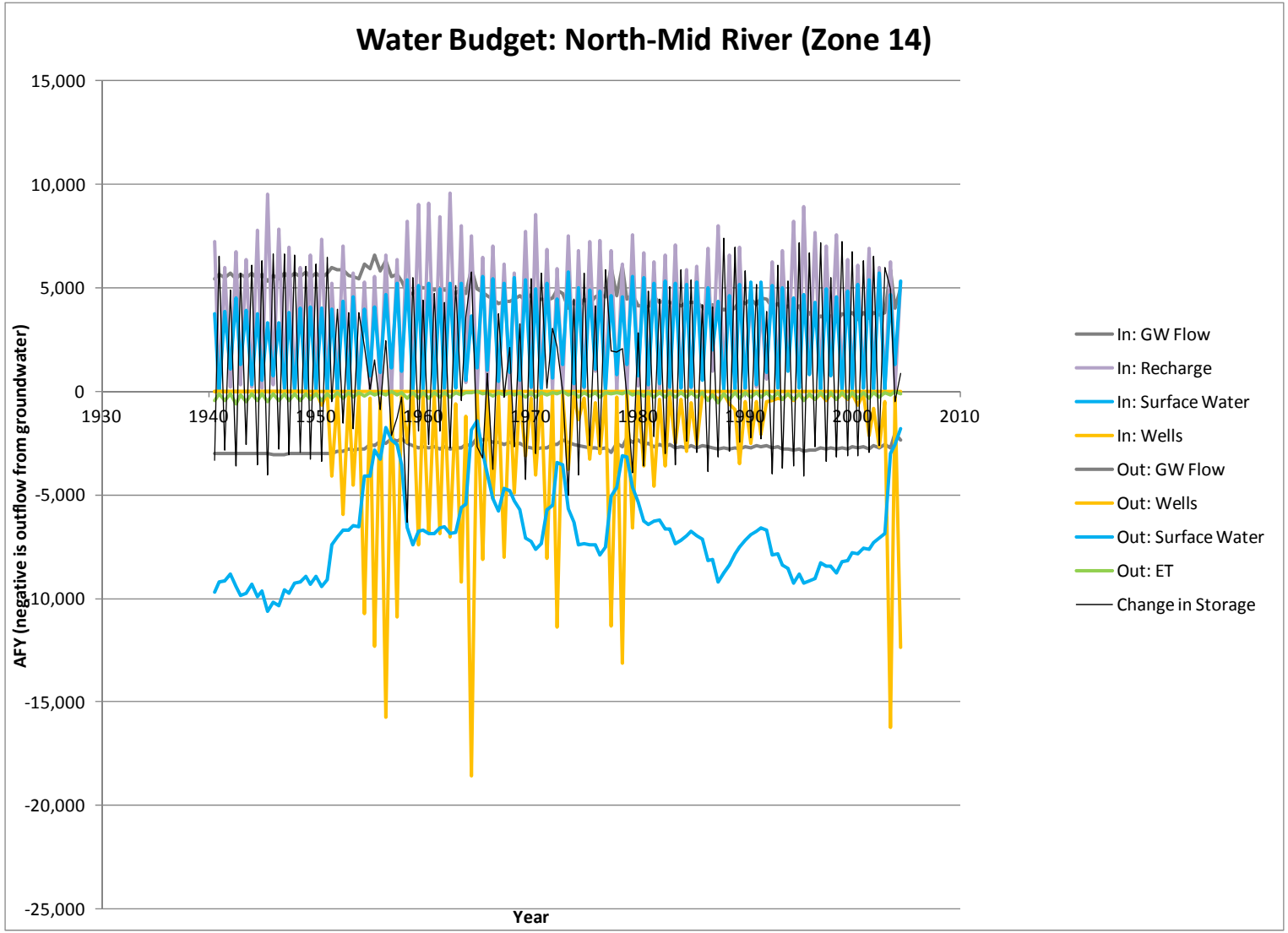


FIGURE B-15
Transient Model Water Budget, Zone 14 (North-Mid River)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

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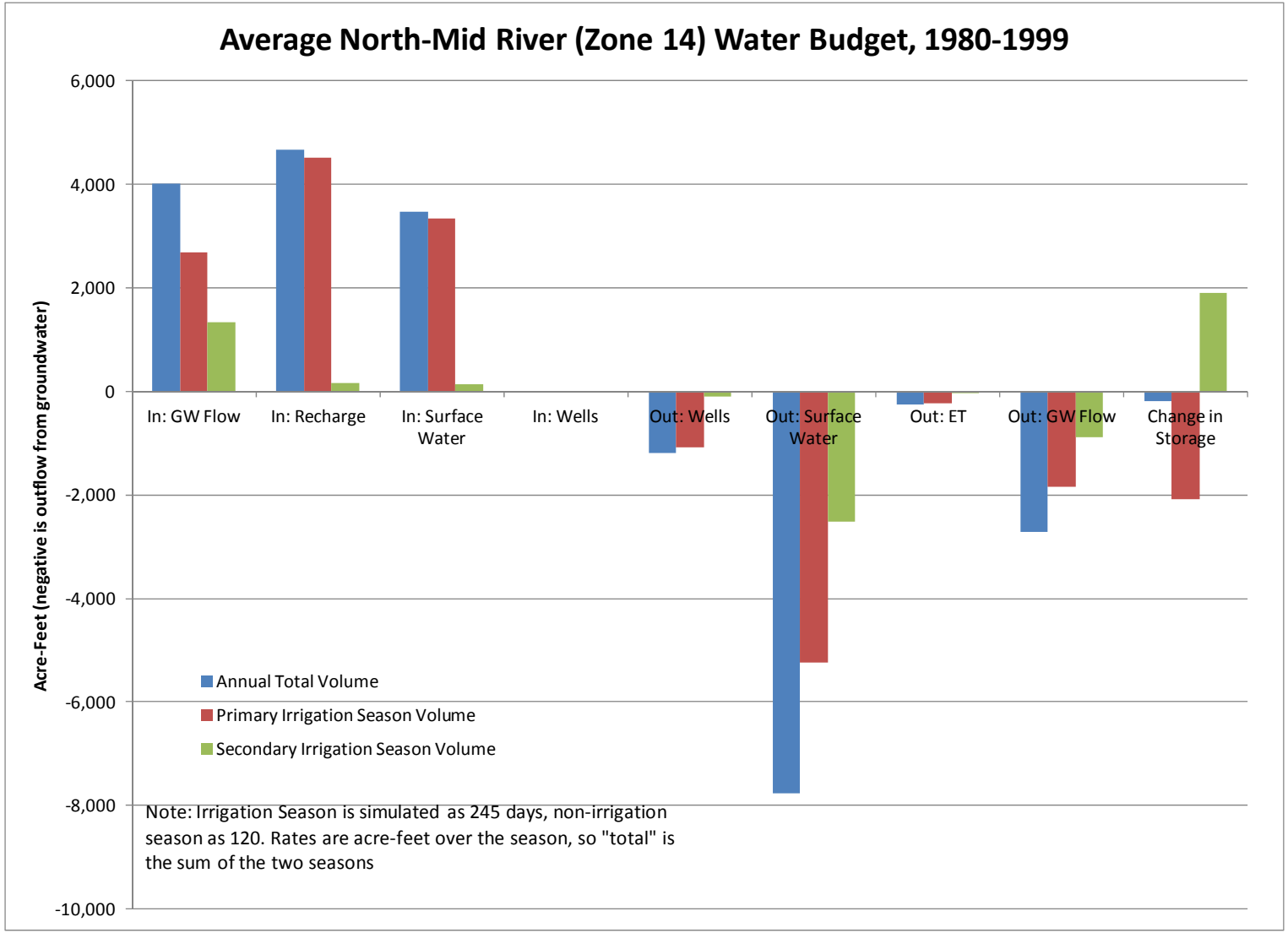


FIGURE B-16
Average Model Water Budget, Zone 14 (North-Mid River)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

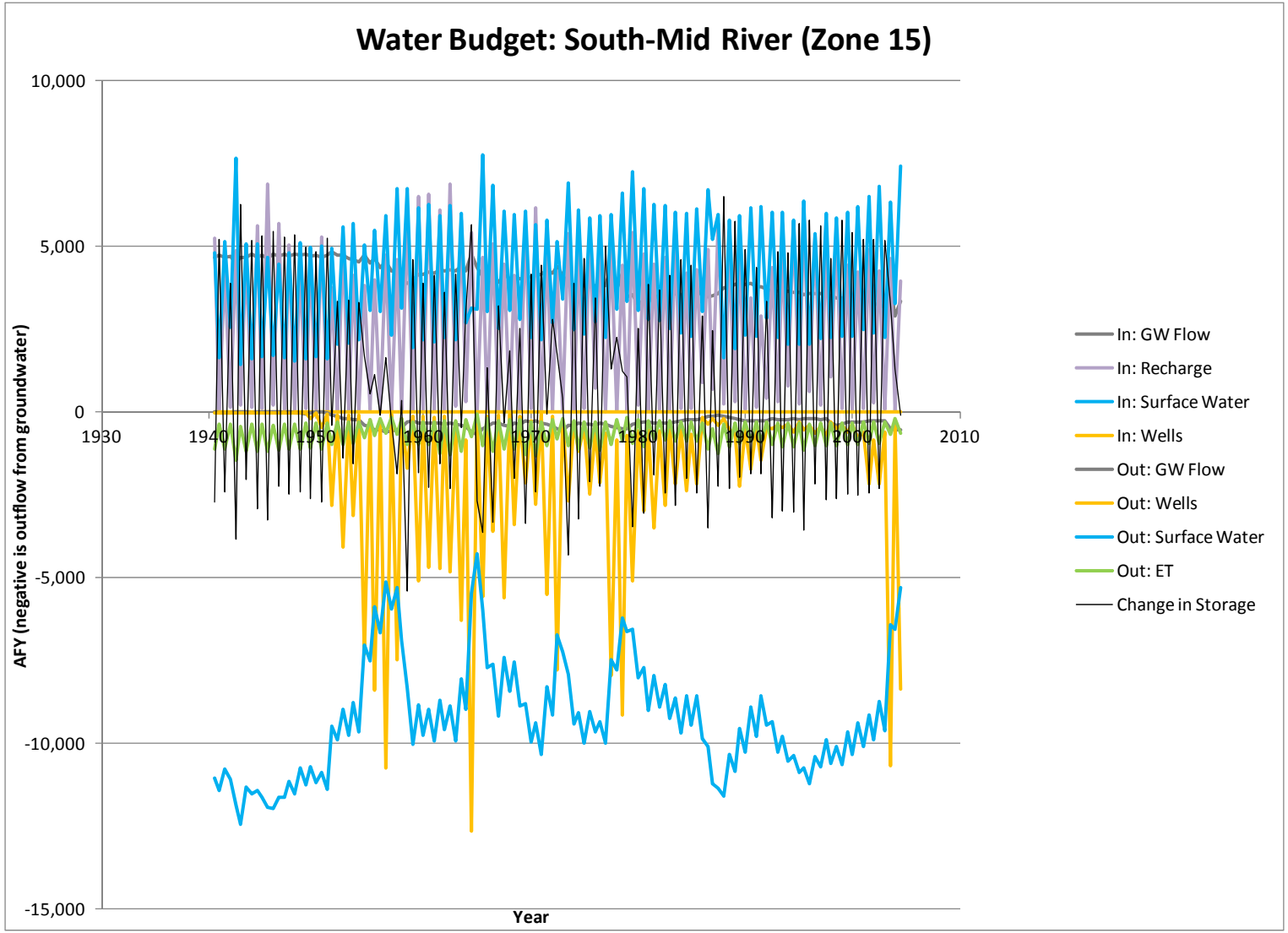


FIGURE B-17
Transient Model Water Budget, Zone 15 (South-Mid River)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

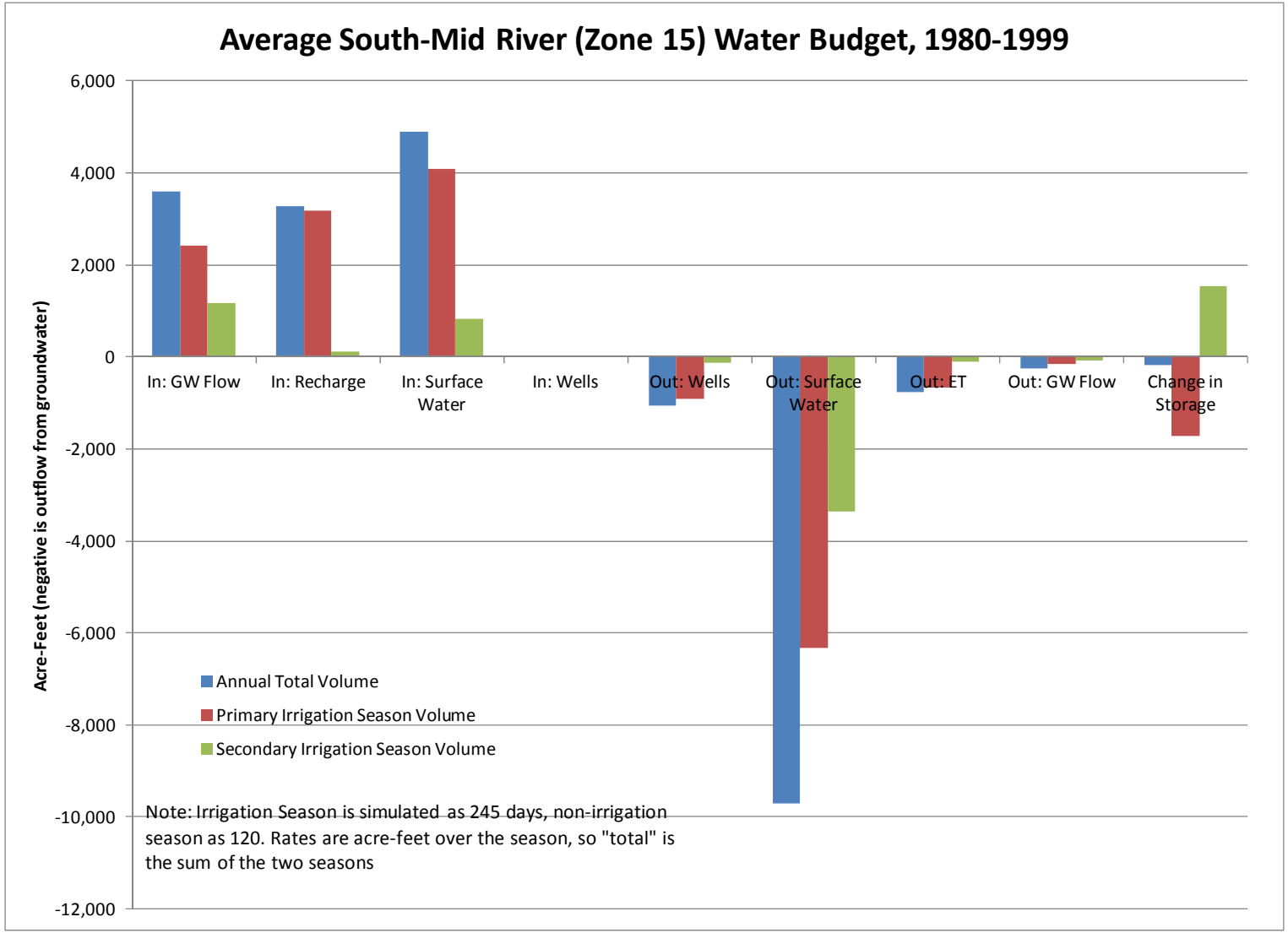


FIGURE B-18
Average Model Water Budget, Zone 15 (South-Mid River)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

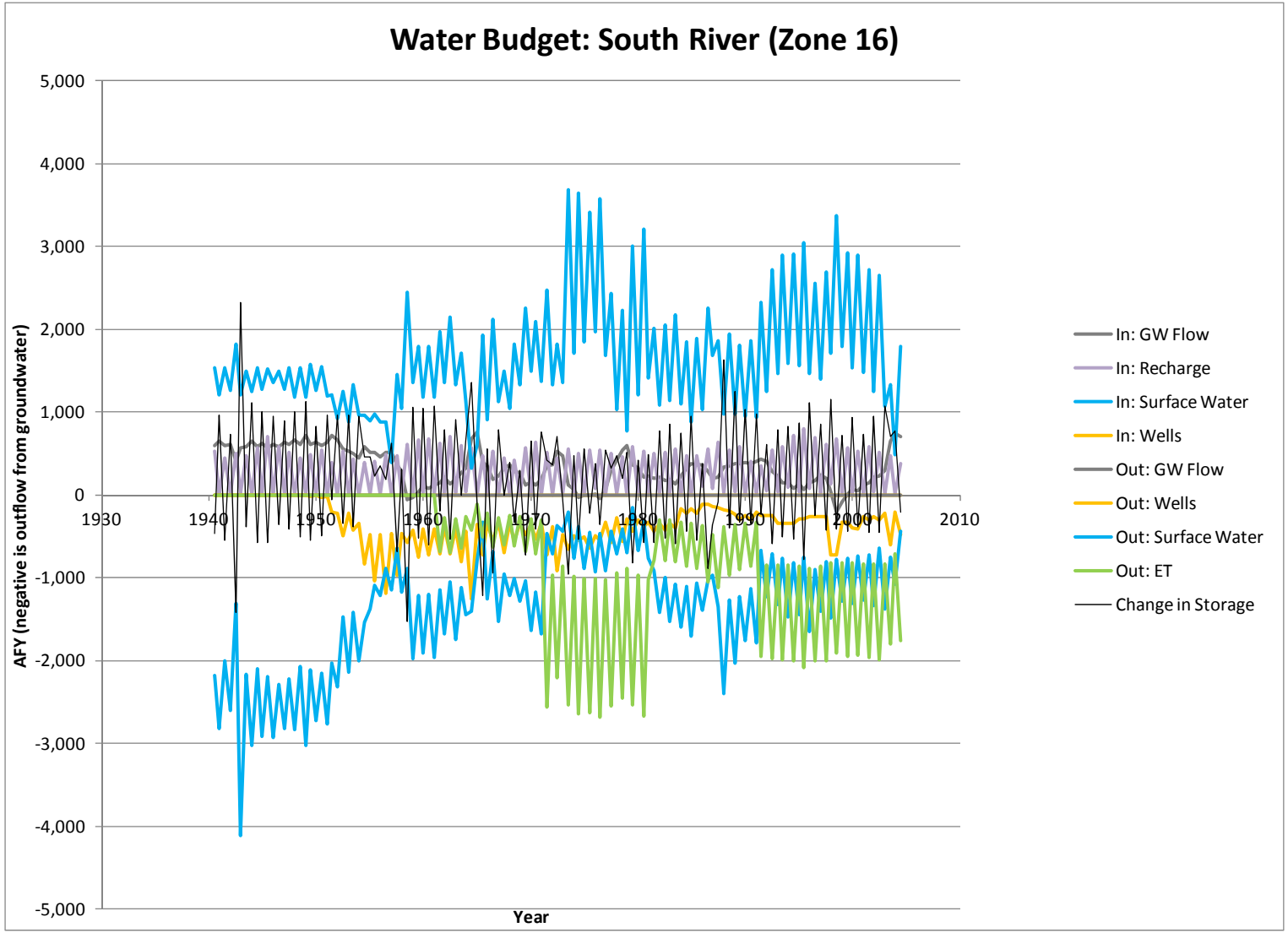


FIGURE B-19
Transient Model Water Budget, Zone 16 (South River)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

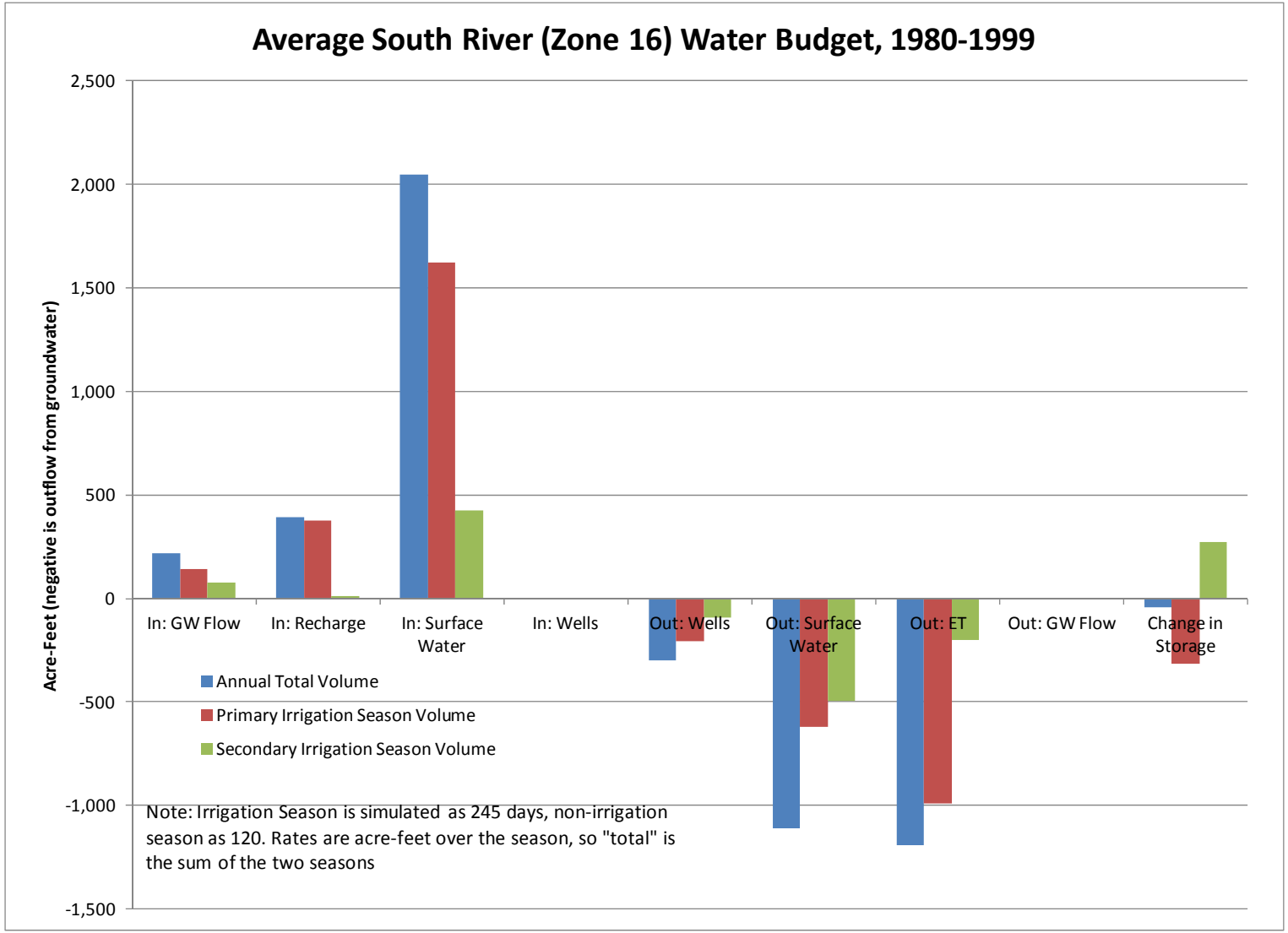


FIGURE B-20
Average Model Water Budget, Zone 16 (South River)

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

Appendix C
Water Quality Mixing Models

APPENDIX C

Water Quality Mixing Models

C.1 Groundwater Inflow to Montoya Drain

Two detailed water quality sampling events were undertaken along the Montoya Drain, one in 2000 and one in 2013. Each is discussed below, with an attempt to quantify potential saline mass loading to the drain.

C.1.1 2000 Sampling Event

Observed data from the first sampling event in February 2000 demonstrate a sharp increase in total dissolved solids (TDS), chloride-bromide (Cl-Br) ratio, and temperature in the Montoya Drain near Country Club Road (Bakker et al., 2000) (see Figure 7-1 and Section 6.2.2), suggesting localized inflow of saline groundwater to the drain in that area. However, drain flow was only measured at one location, approximately 1 mile downstream of the Nemexas Drain inlet (see Figure 6-21). Flow was not measured at the location of the salinity increase, nor was it measured in the Nemexas Drain. Therefore, it is only possible to calculate a range of potential mass loading of saline groundwater to the drain. The range was arrived at by assuming end-member scenarios in a mass balance mixing model. In the mass balance mixing model, unmeasured groundwater inflow rates and concentration were adjusted until both calculated concentrations at selected locations along the drain and flow at the downstream end matched reasonably well with observed data. The following four scenarios were considered, as presented in Table C-1:

1. **Minimum load near Country Club Road**. The minimum groundwater load near Country Club Road was estimated by assuming a reasonable minimum flow in the Montoya Drain in that area of approximately 2 cubic feet per second (cfs). Chloride load near Country Club Road in this scenario could be as low as approximately 730 tons per year (tons/yr) (Table C-1a). However, to obtain mass balance, a potentially unrealistic high rate of groundwater inflow is required further downstream (12 cfs between Nemexas Drain and flow measuring location). Although chloride load from groundwater near Country Club Road in this scenario is only approximately 730 tons/yr, the total chloride load from groundwater is approximately 7,800 tons/yr.
2. **Minimum total groundwater load**. In this scenario, total groundwater load was minimized by maximizing the upstream surface water end-members (Nemexas Drain and Montoya Drain), while still being able to match the observed changes in concentration along the drain. Matching observed changes in concentration required potentially unrealistically low concentration of groundwater inflow near the Nemexas Drain (low concentration coincides with minimum groundwater flow, and therefore maximum surface water flow). The minimum total chloride load from groundwater is estimated to be approximately 4,900 tons/yr (Table C-1b).
3. **Maximum load near Country Club Road**. The measured chloride load downstream of the Nemexas Drain was approximately 9,500 tons/yr(Table C-1c). It is possible to manipulate the mixing model to assume that nearly all of this load comes from groundwater near the Montoya Drain; however, it would require a potentially unrealistically high groundwater discharge rate in that area of nearly 15 cfs.
4. **Best estimate**. The best-estimate scenario uses reasonable flow rates for the upstream end-members (Montoya Drain and Nemexas Drain) as well as groundwater. The best estimate is that approximately 4,000 tons/yr of chloride is discharging from groundwater to the Montoya Drain near Country Club Road, and an additional 1,800 tons/yr in the area near the Nemexas Drain (Table C-1d).

The calculations above suggest that in February 2000, chloride discharged to the Montoya Drain between Country Club Road and approximately1 mile downstream of the Nemexas Drain at an annualized rate of approximately 5,000 to 7,500 tons/yr. Of this amount, approximately 4,000 tons/yr may be localized flow of higher concentration, near Country Club Road. However, these results are highly uncertain and could likely overestimate the actual discharge for the following reasons:

1. Flow was only measured at one location in the Montoya Drain, and was not measured separately in the Nemexas Drain during the 2000 sampling event. Relative contribution of flow from the Nemexas and Montoya Drains had to be estimated.
2. Sampling protocol is unclear—specifically, whether a single sample was collected at each location, or whether an attempt was made to obtain a flow-weighted average sample. During the same study, samples were collected in the Rio Grande by dragging a container across the river, perpendicular to streamflow. However, no description of methodology for sampling the drains is provided.
3. The assumption of relatively high mass load from groundwater to the Montoya Drain is based on the assumption of high flow in the Montoya Drain relative to the Nemexas Drain (an observed increase in concentration at a greater flow rate is indicative of greater mass flux than the same increase in concentration at a lesser flow rate). High flow in the Montoya Drain is necessary to match the observed decrease in concentration in the Montoya Drain downstream of the Nemexas Drain. However, this is highly dependent on (1) the accuracy of the single, relatively low concentration data point in the Nemexas Drain, and (2) the assumption that the water is fully mixed in the Montoya Drain downstream (or that sampling technique was adequate to obtain a flow-weighted average concentration). These assumptions may not be true for the following reasons:
    a. When non-irrigation season flow data were available for both Nemexas Drain at the inlet and nearby locations in the Montoya Drain (February 2001, February 2002, February 2011, and February 2013), Nemexas Drain flow was generally on the order of 5 to 15 times that of the Montoya Drain. However, in this analysis, to maintain saline mass balance, flow in the Nemexas Drain was assumed to be approximately 4 times *less* than flow in the Montoya Drain (in the best-estimate scenario; however, all scenarios have less flow in the Nemexas Drain than in the Montoya Drain).
    b. Measured TDS continues to decrease downstream in the Montoya Drain, from approximately 1,600 milligrams per liter (mg/L) at the flow measurement location, to approximately 1,200 mg/L near the Rio Grande (Figure 6-21). While it is possible this is because of relatively clean groundwater discharging to the drain, it is also possible that these results are due to the samples not being representative of fully mixed flow. That is, the apparent decline in TDS may actually be due to mixing of the Montoya Drain water with Nemexas Drain inflow (TDS = 1,123 mg/L). In this case, the concentration below Nemexas Drain used in the calculation would not be representative of the flow-weighted average, leading to erroneously high conclusions about mass flux from groundwater.

TABLE C-1

Estimated Salinity Loads to Montoya Drain, Based on 2000 Sampling Event

C-1a: Minimum load from groundwater near Country Club Rd

	Measured data				Estimated Discharge and Load							
Location	TDS (mg/L)	Cl (mg/L)	Br (mg/L)	Cl/Br	Discharge (cfs)	TDS (mg/L)	TDS load (tons/yr)	Cl (mg/L)	Cl load (tons/yr)	Br (mg/L)	Cl/Br	NOTES
Montoya drain, upstream end-member (above Country Club)	1,350	350	0.80	438	1.5	1,350	1,810	350	469	0.80	438	
Groundwater inflow, reach 1 (1350 to 2020)					**0.5**	**4,025**	**1,798**	**1,630**	**728**	**1.28**	**1273**	
Calculated mixture, below Country Club					*2.0*	*2,019*	*3,608*	*670*	*1,197*	*0.92*	*728*	
Montoya drain, below Country Club	2,020	670	0.92	728		2,020		670		0.92	728	
Groundwater inflow, reach 2 (2020 to 1745)					4	1,610	5,755	450	1,609	0.71	634	
Calculated mixture above Nemexas					*6.0*	*1,746*	*9,363*	*523*	*2,806*	*0.78*	*671*	
Observed mixture above Nemexas	1,745	525	0.78	673		1,745		525		0.78	673	
Nemexas inflow	1,123	220	0.68	324	6	1,123	6,021	220	1,180	0.68	324	
Groundwater inflow, reach 3 (below Nemexas)					12	1,740	18,659	510	5,469	0.80	638	Unlikely flow rate
Calculated mixture, downstream end-member					*24.0*	*1,587*	*34,043*	*441*	*9,454*	*0.77*	*576*	
Montoya drain, downstream end-member (~1 mile below Nemexas)	1,586	443	0.77	578	24	1,586	34,014	443	9,490	0.77	578	
Total groundwater, above Country Club to Below Nemexas					**16.5**		**26,212**		**7,806**			

C-1b: Minimum total load from groundwater

	Measured data				Estimated Discharge and Load							
Location	TDS (mg/L)	Cl (mg/L)	Br (mg/L)	Cl/Br	Discharge (cfs)	TDS (mg/L)	TDS load (tons/yr)	Cl (mg/L)	Cl load (tons/yr)	Br (mg/L)	Cl/Br	NOTES
Montoya drain, upstream end-member (above Country Club)	1,350	350	0.80	438	15	1,350	18,096	350	4,691	0.80	438	This scenario maximizes load here (to minimize gw flow). Unlikely flow is this high, relative to other inputs
Groundwater inflow, reach 1 (1350 to 2020)					**0.5**	**22,100**	**9,874**	**10,300**	**4,602**	**4.50**	**2289**	
Calculated mixture, below Country Club					*15.5*	*2,019*	*27,970*	*671*	*9,294*	*0.92*	*730*	
Montoya drain, below Country Club	2,020	670	0.92	728		2,020		670		0.92	728	
Groundwater inflow, reach 2 (2020 to 1745)					3.5	530	1,658	50	156	0.15	333	Unlikely groundwater has such low concentration
Calculated mixture above Nemexas					*19.0*	*1,745*	*29,628*	*557*	*9,450*	*0.78*	*716*	
Observed mixture above Nemexas	1,745	525	0.78	673		1,745		525		0.78	673	
Nemexas inflow	1,123	220	0.68	324	2.5	1,123	2,509	220	491	0.68	324	
Groundwater inflow, reach 3 (below Nemexas)					2.5	500	1,117	50	112	0.80	63	Unlikely groundwater has such low concentration
Calculated mixture, downstream end-member					*24.0*	*1,551*	*33,254*	*469*	*10,053*	*0.77*	*609*	
Montoya drain, downstream end-member (~1 mile below Nemexas)	1,586	443	0.77	578	24	1,586	34,014	443	9,490	0.77	578	
Total groundwater, above Country Club to Below Nemexas					**6.5**		**12,649**		**4,870**			

C-1c: Maximum load from Groundwater near Country Club

	Measured data				Estimated Discharge and Load							
Location	TDS (mg/L)	Cl (mg/L)	Br (mg/L)	Cl/Br	Discharge (cfs)	TDS (mg/L)	TDS load (tons/yr)	Cl (mg/L)	Cl load (tons/yr)	Br (mg/L)	Cl/Br	NOTES
Montoya drain, upstream end-member (above Country Club)	1,350	350	0.80	438	1	1,350	1,206	350	313	0.80	438	
Groundwater inflow, reach 1 (1350 to 2020)					**14.5**	**2,065**	**26,757**	**690**	**8,941**	**0.93**	**742**	Unlikely that groundwater inflow here is this great
Calculated mixture, below Country Club					*15.5*	*2,019*	*27,963*	*668*	*9,253*	*0.92*	*725*	
Montoya drain, below Country Club	2,020	670	0.92	728		2,020		670		0.92	728	
Groundwater inflow, reach 2 (2020 to 1745)					4	820	2,931	50	179	0.25	200	
Calculated mixture above Nemexas					*19.5*	*1,773*	*30,894*	*541*	*9,432*	*0.78*	*691*	
Observed mixture above Nemexas	1,745	525	0.78	673		1,745		525		0.78	673	
Nemexas inflow	1,123	220	0.68	324	0.5	1,123	502	220	98	0.68	324	
Groundwater inflow, reach 3 (below Nemexas)					4	550	1,966	50	179	0.70	71	
Calculated mixture, downstream end-member					*24.0*	*1,556*	*33,362*	*453*	*9,709*	*0.77*	*590*	
Montoya drain, downstream end-member (~1 mile below Nemexas)	1,586	443	0.77	578	24	1,586	34,014	443	9,490	0.77	578	
Total groundwater, above Country Club to Below Nemexas					**22.5**		**31,654**		**9,298**			

C-1d: "Best Estimate"

	Measured data				Estimated Discharge and Load							
Location	TDS (mg/L)	Cl (mg/L)	Br (mg/L)	Cl/Br	Discharge (cfs)	TDS (mg/L)	TDS load (tons/yr)	Cl (mg/L)	Cl load (tons/yr)	Br (mg/L)	Cl/Br	NOTES
Montoya drain, upstream end-member (above Country Club)	1,350	350	0.80	438	8	1,350	9,651	350	2,502	0.80	438	
Groundwater inflow, reach 1 (1350 to 2020)					**3**	**3,800**	**10,187**	**1,525**	**4,088**	**1.25**	**1220**	
Calculated mixture, below Country Club					*11.0*	*2,018*	*19,838*	*670*	*6,590*	*0.92*	*727*	
Montoya drain, below Country Club	2,020	670	0.92	728		2,020		670		0.92	728	
Groundwater inflow, reach 2 (2020 to 1745)					4	1,000	3,574	130	465	0.40	325	
Calculated mixture above Nemexas					*15.0*	*1,747*	*23,413*	*526*	*7,055*	*0.78*	*672*	
Observed mixture above Nemexas	1,745	525	0.78	673		1,745		525		0.78	673	
Nemexas inflow	1,123	220	0.68	324	6	1,123	6,021	220	1,180	0.68	324	
Groundwater inflow, reach 3 (below Nemexas)					3	1,700	4,557	480	1,287	0.90	533	
Calculated mixture, downstream end-member					*24.0*	*1,585*	*33,991*	*444*	*9,521*	*0.77*	*575*	
Montoya drain, downstream end-member (~1 mile below Nemexas)	1,586	443	0.77	578	24	1,586	34,014	443	9,490	0.77	578	
Total groundwater, above Country Club to Below Nemexas					**10**		**18,319**		**5,840**			

Note - downstream end-member is at location of flow measurement, between 2 sites. Average concentration of 2 sites assumed.

C.1.2 2013 Sampling Event

The Montoya Drain and tributaries were again sampled for flow and water quality in February 2013. Results are presented in Figures 6-24 through 6-26. A mass balance approach was applied to the data in an attempt to quantify saline influx from groundwater (Table C-2) between Redd Road and EPCWID gage. The difference between observed chloride mass flux between sampling points should be attributable to groundwater influx.

Observed data suggest that the uncertainty associated with the measured data preclude the data from being evaluated directly. Sources of uncertainty as they affect calculation of mass flux include (1) uncertainty of flow measurements, (2) potential that the water quality sample is not representative of the flow-weighted average water quality if water in the drains is not fully mixed, (3) time-variability, in that although the samples were taken within 2.5 hours of one another (Table C-2), they were not timed according to water velocity such that the same water was being sampled, and (4) uncertainty related to lab measurements (assumed to be minor compared with the other uncertainties).

An example of uncertainty can be seen by inspecting measured flow near the confluence of Nemexas Drain and Montoya Drain. Flow measured in the drains above the confluence (both reported as “fair” quality) was 0.86 cfs and 5.4 cfs (total = 6.26 cfs); however, the flow immediately downstream (approximately 650 feet from upstream measurement, and reported as “good” quality) was 5.1 cfs (Table C-2). This error likely represents a combination of timing issues as well as error in the streamflow measurements themselves. While there are a number of ways to adjust the streamflow to obtain mass balance, the best approach is to decrease the upstream “fair” flows by 12 percent and increase the downstream “good” flow by 8 percent. Because upstream flows were both decreased by the same amount, and downstream flow increased by a similar amount, these percentages are assumed to be representative of the minimum uncertainty associated with flow measurements for “fair” and “good” sites. Also, other combinations could be used to obtain mass balance; for example, adjust all by 10 percent, or only adjust downstream by 23 percent.

To evaluate saline groundwater inflow to the Montoya Drain, a range of chloride mass flux was calculated based on uncertainty in both flow and concentration (see Table C-2). Flow uncertainty was assumed to be 10, 15, and 20 percent for “poor,” “fair,” and “good” sites, respectively. These are slightly greater than the minimum uncertainty noted above. Uncertainty associated with flow-weighted average chloride concentration was assumed to be 15 percent, which is consistent with the water quality analysis near ISC-4, summarized in the following section. The result is a range of groundwater contribution to the Montoya Drain of approximately 50 to 2,500 tons/yr, with a best estimate of approximately 1,400 tons/yr. However, it should be noted that uncertainty could be even greater than is noted here, potentially widening the range of chloride flux. The majority of the mass flux appears to occur below the Nemexas Drain.

TABLE C-2

Estimated Salinity Loads to Montoya Drain, Based on 2013 Sampling Event

					Discharge (cfs)				
Type	Site Name	Measured or Calculated	Sample Time	Quality	Measured	Uncertainty	Min	Max	Best Estimate
Montoya	ABV REDD	measured	13:30	Poor (>8%)	0.27	20%	0.22	0.32	0.27
Inflow: Groundwater	Between REDD and "Blw CC"	calculated							0.24
Montoya	Blw Country Club	measured	11:05	Fair (8%)	0.51	15%	0.43	0.59	0.51
Inflow: Groundwater	Between "Blw CC" and Nemexas	calculated							0.25
Montoya	Above Nemexas	measured	12:45	Fair (8%)	0.86	15%	0.73	0.86*	0.76
Inflow: Nemexas	From Nemexas	measured	13:20	Fair (8%)	5.40	15%	4.59	5.40*	4.75
Montoya	Below Nemexas	measured	13:07	Good (5%)	5.10	10%	5.10**	5.61	
		calculated			*6.26*				*5.51*
Inflow: Groundwater	Nemexas to EPCWID	calculated							0.29
Montoya	EPCWID gage	measured	11:00	Good (5%)	5.60	10%	5.04	6.16	5.80
Net Groundwater, ABV REDD to EPCWID							**-0.68**	**1.35**	**0.78**

*To maintain mass balance with "Below Nemexas," assume downward shift only

**To maintain mass balance with two tributaries, assume upward shift only

Yellow = adjusted from observed

		Chloride Concentration (mg/L)					Chloride load (tons/year)		
Type	Site Name	Measured	Uncertainty	Min	Max	Best Estimate	Min	Max	Best Estimate
Montoya	ABV REDD	570	15%	485	656	570	94	190	138
Inflow: Groundwater	Between REDD and "Blw CC"					1,214	98	433	260
Montoya	Blw Country Club	873	15%	742	1,004	873	287	526	398
Inflow: Groundwater	Between "Blw CC" and Nemexas					784	-58	458	173
Montoya	Above Nemexas	844	15%	717	971	844	469	746	571
Inflow: Nemexas	From Nemexas	383	15%	326	440	383	1,335	2,125	1,626
Montoya	Below Nemexas	*(not measured - calculated load only)*					1,804	2,871	2,197
Inflow: Groundwater	Nemexas to EPCWID					3,885	-502	2,115	1,011
Montoya	EPCWID gage	619	15%	526	712	619	2,370	3,918	3,208
Net Groundwater, ABV REDD to EPCWID						**2,077**	**54**	**2,490**	**1,444**

		TDS Concentration (mg/L)					TDS load (tons/year)		
Type	Site Name	Measured	Uncertainty	Min	Max	Best Estimate	Min	Max	Best Estimate
Montoya	ABV REDD	2,270	15%	1,930	2,611	2,270	372	756	548
Inflow: Groundwater	Between REDD and "Blw CC"					4,076	272	1,508	874
Montoya	Blw Country Club	3,120	15%	2,652	3,588	3,120	1,027	1,880	1,422
Inflow: Groundwater	Between "Blw CC" and Nemexas					2,905	-187	1,668	641
Montoya	Above Nemexas	3,050	15%	2,593	3,508	3,050	1,693	2,696	2,063
Inflow: Nemexas	From Nemexas	1,860	15%	1,581	2,139	1,860	6,485	10,322	7,898
Montoya	Below Nemexas	*(not measured - calculated load only)*					8,178	13,017	9,961
Inflow: Groundwater	Nemexas to EPCWID					12,311	-3,294	7,901	3,204
Montoya	EPCWID gage	2,540	15%	2,159	2,921	2,540	9,724	16,079	13,165
Net Groundwater, ABV REDD to EPCWID						**6,787**	**-1,354**	**9,222**	**4,719**

C.2 Groundwater Inflow to Rio Grande Near ISC-4

A quantitative mixing model was used to assess potential groundwater inflow to the Rio Grande near well ISC-4, just upstream of the El Paso Narrows. The mixing model was performed for the two sampling events that had available boron ($\delta^{11}B$) data: August 2006 and February 2007.The mixing model considered boron-11 isotopic signatures; however, the mixing model also was constrained by total dissolved solids (TDS), chloride (Cl), and total boron (B) concentrations.

Observed flows and concentrations did not result in mass balance for all constituents and flow for either of the sampling dates. Accordingly, observed flow and concentration values were adjusted within reasonable bounds. Based on plots of measured flow versus long-term gaged flows (Figures C-1 and C-2), flows were adjusted by as much as 20 percent. Concentrations were adjusted by as much as 15 percent (TDS) to 20 percent (B, Cl) from observed, and $\delta^{11}B$ was adjusted by as much as 25 percent from observed. These adjustments represent a "catchall" that takes into account limitations of sampling and measurement techniques in accurately measuring the flow-weighted average water quality of the entire flow stream.

$\delta^{11}B$ values from the August 2006 sampling event are presented in Figure C-3. During 2006 sampling, the Rio Grande was sampled on August 14, 2006, whereas the other inflows were sampled on August 15, 2006. The upstream site, RG-CLUB, was sampled approximately 3 hours after the downstream site, RG-PASO, was sampled. Flow rates in the Rio Grande were changing somewhat rapidly during this time period (Figure C-1). In addition,

flow was not measured at the upstream site, RG-CLUB. Accordingly, results of this sampling event have such a high degree of uncertainty that they ***should not be used for any evaluation of potential inflow from saline groundwater***. For the purposes of being complete, results of the mixing model for 2006 are presented in Table C-3, even though they are not considered in this analysis.

$\delta^{11}B$ values from the 2007 sampling event are presented in Figure C-4. The observed $\delta^{11}B$ values suggest significant groundwater inflow (as represented by water in ISC-4A and ISC-4B) to the Rio Grande; however, the observed TDS and Cl concentrations suggest minimal groundwater inflow (as represented by water in ISC-4A and ISC-4B) to the Rio Grande.

Results of the 2007 mixing model analysis (Table C-4) suggest that between approximately 1 and 1.5 cubic feet per second (cfs) (between approximately 700 and 1,100 acre-feet per year [afy]) of groundwater was discharged to the Rio Grande in February 2007 between Sunland Park Bridge and Courchesne Bridge. Results suggest that the average water quality of groundwater flowing into the Rio Grande between Sunland Park Bridge and Courchesne Bridge is somewhat similar to that observed at well ISC-4, but that it might contain even higher boron concentration and $\delta^{11}B$, and slightly lower CL (approximately 7,000 milligrams per liter [mg/L]) and TDS (approximately 20,000 mg/L) concentrations, as compared to ISC-4. These concentrations appear to be consistent with a sedimentary brine source, perhaps mixed with some younger, cleaner groundwater. Mass flux of Cl from groundwater to the Rio Grande was estimated to be approximately 7,500 tons/yr.

However, it was necessary to adjust some key values, notably TDS and Cl at upstream Rio Grande (RG-CLUB), downstream Rio Grande (RG-PASO), and Montoya Drain (DR-MONT), to the maximum or minimum of the allowable range. Accordingly, these results are highly uncertain. It is recommended that additional sampling be performed similar to these previous sampling events. Consideration should be given to variability in flows and lag times in flow between sampling locations when developing the sampling plan.

C.3 Reference

Bakker, A., N. Buik, and J.M.H. Hendrickx. 2000. *Water Quality in the Rio Grande and the Mesquite and Montoya Drains During February-March 2000*. A report to El Paso Division of the U.S. Bureau of Reclamation and Executive Board of the Elephant Butte Irrigation District and Department of Hydrology, Free University of Amsterdam. March.

TABLE C-3
Results of Mixing Model (Aug 2006)

		Adjusted					Observed					
Description	**Map Label**	**Flow (cfs)**	**B (mg/L)**	**$\delta^{11}B$ (‰)**	**TDS (mg/L)**	**Cl (mg/L)**	**Flow (cfs)**	**B (mg/L)**	**$\delta^{11}B$ (‰)**	**TDS (mg/L)**	**Cl (mg/L)**	**Notes**
Rio Grande at TX-260 (Country Club Rd) **(upstream end-member)**	RG-CLUB	372.0	0.15	12.4	440	84	460.0	0.14	12.4	510	70	No flow measurement
Seepage to groundwater, "at TX-260" to "Near Sunland Park"		-3.6	0.14	12.4	510	70	-3.6	0.14	12.4	510	70	No flow measurement
Evaporation		-0.5	0.00	0.0	0	0	0.0	0.00	0.0	0	0	
Sunland Park Wastewater Discharge	WW-SUNL	4.2	0.64	16.8	1,468	440	4.1	0.62	16.5	1,500	440	
Seepage to groundwater, "Near Sunland Park" to "at Sunland Park Bridge"		-0.5	0.14	12.4	510	70	-0.5	0.14	12.4	510	70	No flow measurement
Groundwater inflow, "at Sunland Park Bridge" to "at Courchesne Bridge"		5.0	3.10	34.0	26,825	20,000	3.0	3.10	32.7	31,000	17,000	No flow measurement
Montoya Drain	DR-MONT	22.4	0.68	15.6	2,220	650	21.7	0.69	15.9	2,200	600	
Keystone Reservoir Inlet		0.0	1.12	29.2	2,241	448	0.6	1.10	30.0	2,200	440	Values from 2008
El Paso Electric Discharge 1	EPE1	0.0	0.71	21.5	3,871	1,223	0.6	0.70	21.1	3,800	1,200	Not sampled 2007 used
El Paso Electric Discharge 2	EPE2	0.9	1.73	20.7	5,680	1,256	0.9	1.70	20.4	5,800	1,200	
Rio Grande at El Paso (Courchesne Bridge) **(downstream end member)**	RG-PASO	400.0	0.22	17.0	892	376	476.7	0.24	19.4	830	470	
Calculated based on mixing		**400.0**	**0.22**	**17.0**	**892**	**371**	**486.2**	**0.19**	**15.4**	**798**	**205**	
Difference from observed		0.00	0.00	0.0	0	-5	9.54	-0.05	-4.0	-32	-265	
Percent difference from observed		0%	0%	0%	0%	-1%	2%	-20%	-21%	-4%	-56%	

TABLE C-4
Results of Mixing Model (Feb 2007)

		Adjusted					Observed				
Description	**Map Label**	**Flow (cfs)**	**B (mg/L)**	**$\delta^{11}B$ (‰)**	**TDS (mg/L)**	**Cl (mg/L)**	**Flow (cfs)**	**B (mg/L)**	**$\delta^{11}B$ (‰)**	**TDS (mg/L)**	**Cl (mg/L)**
Rio Grande at TX-260 (Country Club Rd) **(upstream end-member)**	RG-CLUB	18.7	0.24	15.5	769	152	15.6	0.27	12.4	840	190
Seepage to groundwater, "at TX-260" to "Near Sunland Park"		-3.5	0.24	15.5	769	152	-3.6	0.27	12.4	840	190
Evaporation		-0.5	0.00	0.0	0	0	0.0	0.00	0.0	0	0
Sunland Park Wastewater Discharge	WW-SUNL	2.9	0.55	20.6	1,472	394	3.0	0.55	16.5	1,500	420
Seepage to groundwater, "Near Sunland Park" to "at Sunland Park Bridge"		-0.5	0.24	15.5	769	152	-0.5	0.27	12.4	840	190
Groundwater inflow, "at Sunland Park Bridge" to "at Courchesne Bridge"		1.2	3.10	40.8	20,738	7,000	1.9	2.40	37.0	31,000	14,000
Montoya Drain	DR-MONT	18.2	0.59	17.9	1,956	456	20.8	0.74	14.3	2,300	570
Keystone Reservoir Inlet		0.6	1.14	34.2	2,197	439	0.6	1.10	30.0	2,200	440
El Paso Electric Discharge 1	EPE1	0.6	0.70	22.1	3,781	1,186	0.6	0.70	21.1	3,800	1,200
El Paso Electric Discharge 2	EPE2	0.6	1.31	21.5	5,448	1,075	0.6	1.30	19.3	5,500	1,100
Rio Grande at El Paso (Courchesne Bridge) **(downstream end member)**	RG-PASO	38.4	0.56	22.7	2,181	564	38.4	0.61	30.2	1,900	470
Calculated based on mixing		**38.4**	**0.56**	**22.5**	**2,181**	**572**	**39.0**	**0.69**	**18.7**	**3,322**	**1,132**
Difference from observed		0.00	0.00	-0.2	0	8	0.61	0.08	-11.5	1,422	662
Percent difference from observed		0%	0%	-1%	0%	1%	2%	13%	-38%	75%	141%

Figures

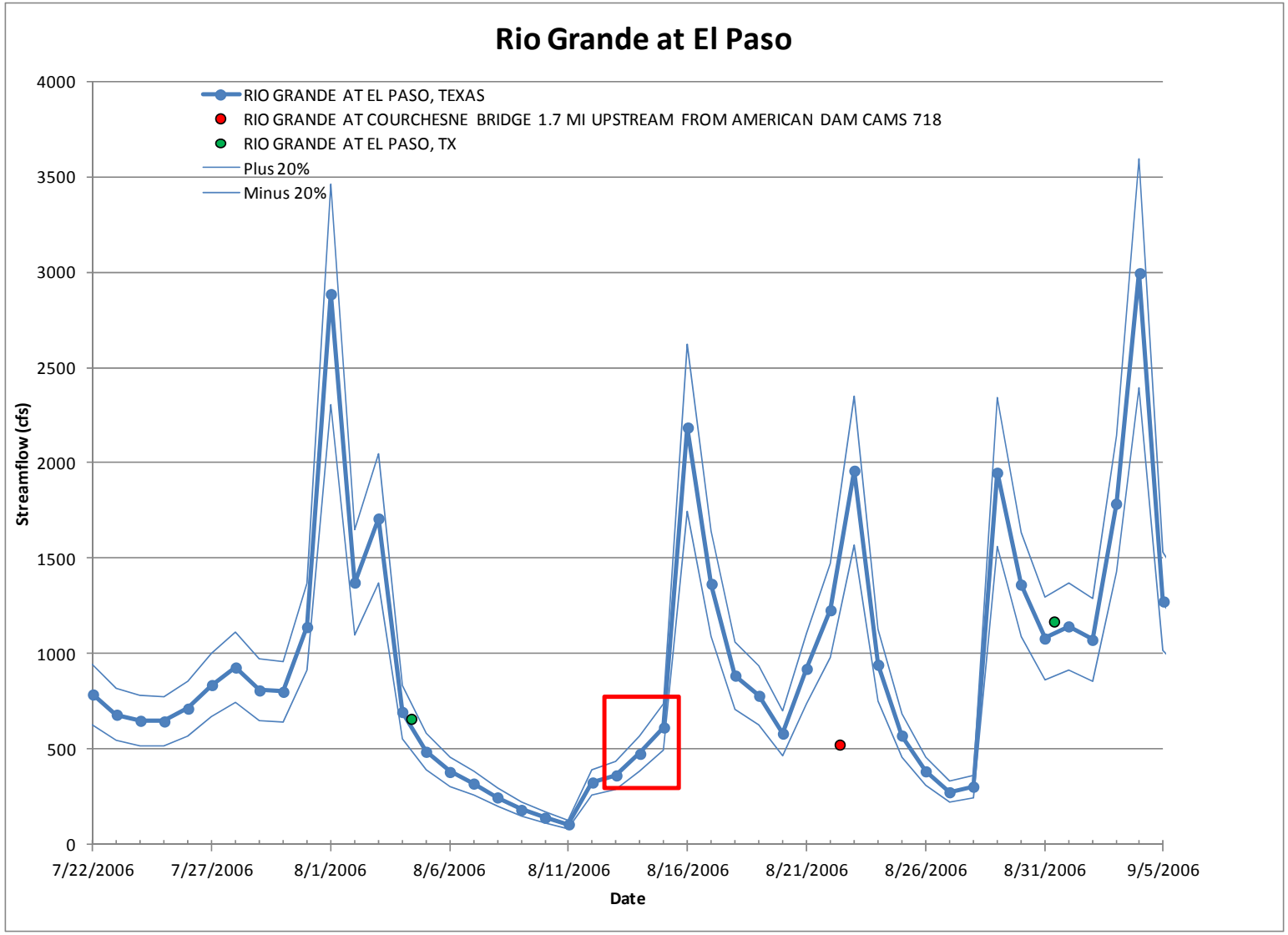


FIGURE C-1
Rio Grande Flow Rates,
August-2006 Sampling Event

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

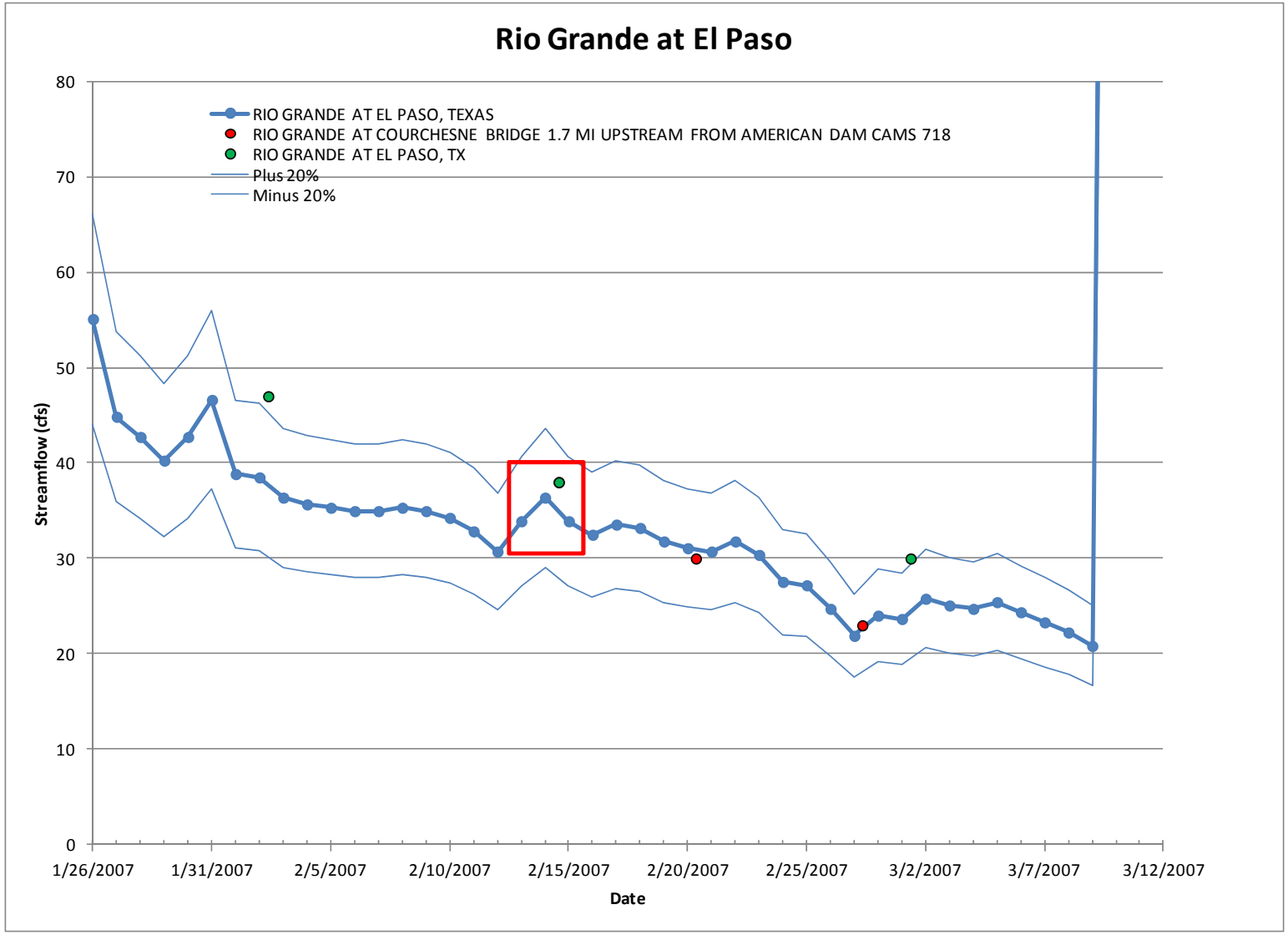
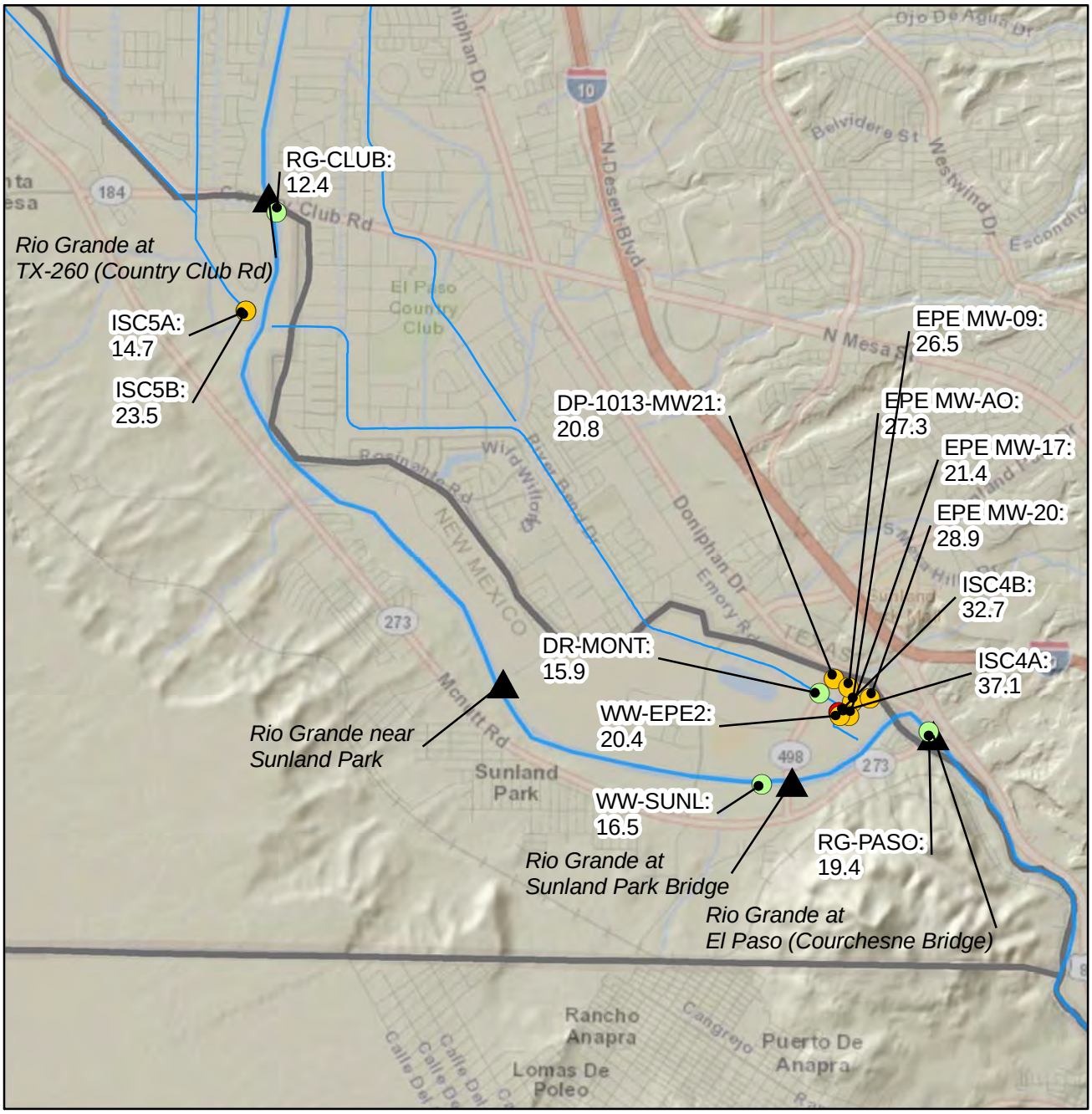


FIGURE C-2
Rio Grande Flow Rates,
February-2007 Sampling Event

Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL



VICINITY MAP

LEGEND

- Drain
- Rio Grande
- State Boundary
- Rio Grande Flow Measurements

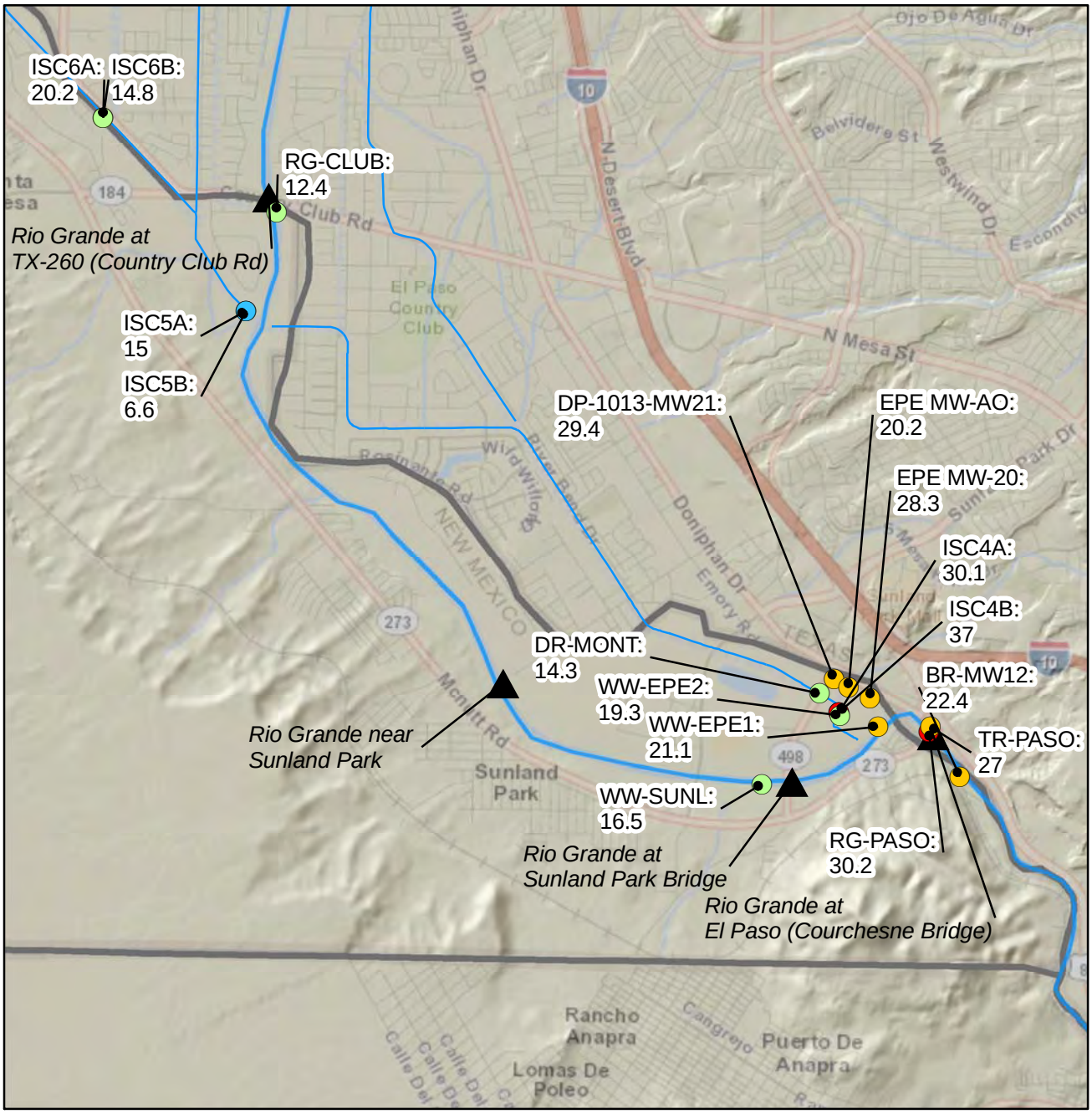
Delta Boron-11 (per mil)

- -7.2 - 0.0
- 0.1 - 10.0
- 10.1 - 20.0
- 20.1 - 30.0
- 30.1 - 40.0

N

0 0.5 1
Miles

FIGURE C-3
Boron-11, Aug-2006
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program



VICINITY MAP

LEGEND

- Drain
- Rio Grande
- State Boundary
- Rio Grande Flow Measurements

Delta Boron-11 (per mil)

- -7.2 - 0.0
- 0.1 - 10.0
- 10.1 - 20.0
- 20.1 - 30.0
- 30.1 - 40.0

N

0 0.5 1
Miles

FIGURE C-4
Boron-11, Feb-2007
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

Appendix D
Ecosystem Framework

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 Smeltertown 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; USIBWC, 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, theses 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.sneedi),* 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 (USIBCW, 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 *Scientific Name*	**USFWS**	**NMRPTC**	**TPWD**	**Habitat Requirements**	**Within Known Distribution**	**Potential Habitat Present**
mescalero milkwort *Polygala rimulicol mescalerorum*		E		Crevices in sandy limestone cliffs in montane scrub at 5,700-6,300 feet.	No	No
desert night-blooming cereus *Cereus greggii var. greggii*		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 *Coryphantha sneedii sneedii*	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 *Opuntia arenaria*		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 *Scientific Name*	**USFWS**	**NMDGF**	**TPWD**	**Habitat Requirements**	**Within Known Distribution**	**Potential Habitat Present**
MOLLUSC						
Doña Ana talus snail *Sonorella todseni*	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 *Notropis simus*			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 *Hybognathus amarus*	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 *Trimorphodon vilkinsonii*			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 *Phyrnosoma hernandesi*			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 *Phyrnosoma cornutum*			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 *Euderma maculatum*		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 *Scientific Name*	Designation or Status			Habitat Requirements	Within Known Distribution	Potential Habitat Present
	USFWS	NMDGF	TWPD			
BIRDS						
southwestern willow flycatcher *Empidonax traillii extimus*	E	E	E	Brushy fields, thickets along streams, and open woodland edges.	Yes	Yes[c]
northern aplomado falcon *Falco femoralis septentrionalis*	E	E		Brushy prairie and yucca flats.	Yes[b]	No
American peregrine falcon *Falco peregrinus anatum*		T	T	Canyons with steep, rocky cliffs, close to water.	Yes	Yes[a]
arctic peregrine falcon *Falco peregrinus tundrius*		T		Canyons with steep, rocky cliffs, close to water.	Yes	Yes[c]
bald eagle *Haliaeetus leucocepalus*		T		Riparian; timbered areas along coasts, large lakes, and rivers.	Yes	Yes[d]
common black hawk *Buteogallus anthracinus anthacinus*		T		Riparian areas.	Yes	Yes[c]
interior least tern *Sterna antillarum*	E	E	E	River sandbars and beaches.	Yes[b]	Yes[e]
broad-billed hummingbird *Cynanthus latirostris magicus*		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 *Calypte costae*		T		Deserts, washes, mesas, sage scrub, and arid hillsides.	Yes[c]	Yes
Bell's vireo *Vireo bellii*		T		Dense shrubby vegetation in riparian, second-growth forests and mesquite brushlands.	Yes	Yes
gray vireo *Vireo vicinior*		T		Riparian willows, thorn scrub, oak-juniper woodlands, pinon-juniper woodlands and mesquite shrublands; potential at Sunland Park.	Yes	Yes
Baird's sparrow *Ammodramus bairdii*		T		Desert grassland and mountain meadows.	Yes[c]	Yes[c]
common ground dove *Columbina passerina pallescens*		E		Farms, orchards, wood edges, and roadsides; xeric riparian areas.	Yes	Yes
yellow-billed cuckoo *Coccyzus americanus occidentalis*	C			Riverine woodlands, thickets, and farms.	Yes	No
Mexican spotted owl *Strix occidentalis lucida*	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 *Scientific Name*	Designation or Status			Habitat Requirements	Within Known Distribution	Potential Habitat Present
	USFWS	NMDGF	TWPD			
whooping crane *Grus americana*	Experi-mental	E		Marshes, wetlands, and pastures.	Yes[f]	No[f]
brown pelican *Pelicanus occidentalis*		E		Occasionally inland in southwestern region.	Yes	No[f]
neotropic cormorant *Phalacrocorax brasilianus*		T		Generally on larger bodies of water; known to occur only in Sierra and Socorro Counties.	Yes[a]	No

[a]Breeding & Migratory
[b]Historic
[c]Migratory only
[d]Winter
[e]Only in dry years
[f]Accidental
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.

References

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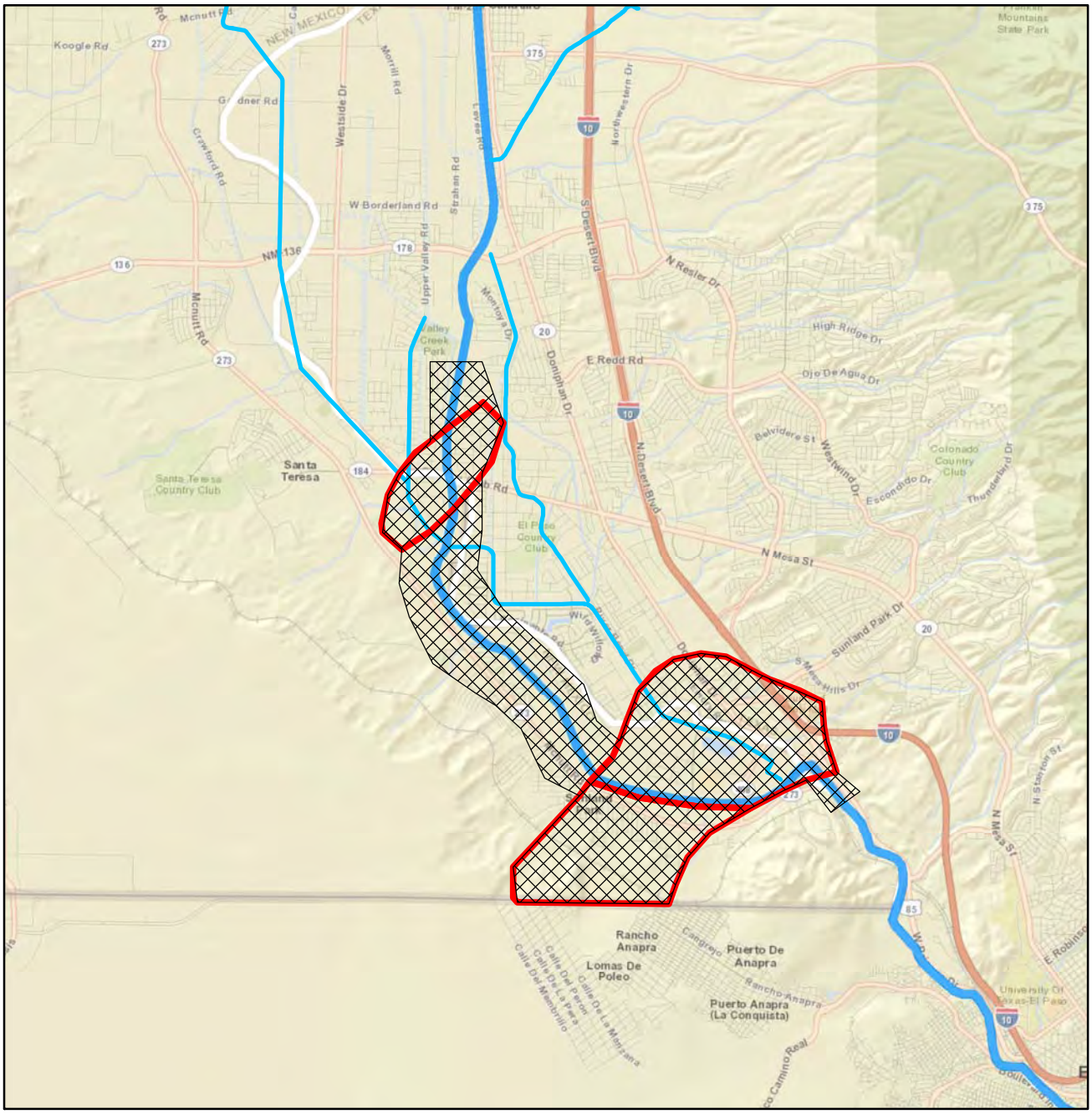
Rio Grande Site Photographs

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)

Figures



LEGEND

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

VICINITY MAP

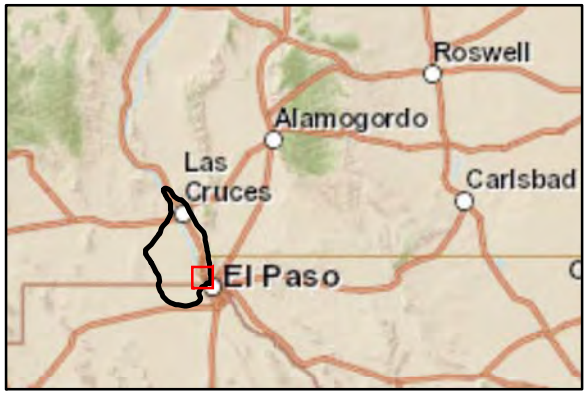


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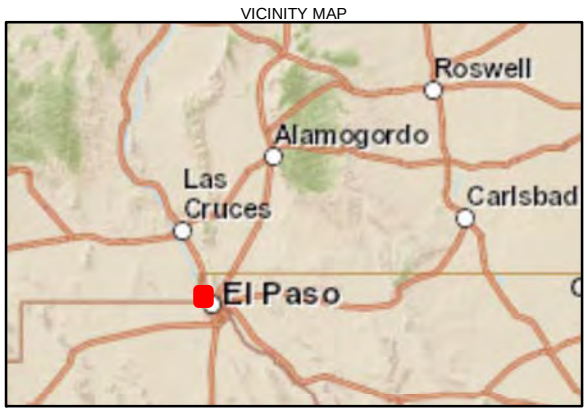
FIGURE D-1
Ecosystem Framework Study Area
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

LEGEND

- Study Area
- River
- Ag Drains
- 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
- 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

N

VICINITY MAP



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Source: USGS National Gap Analysis Program, 2011

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

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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

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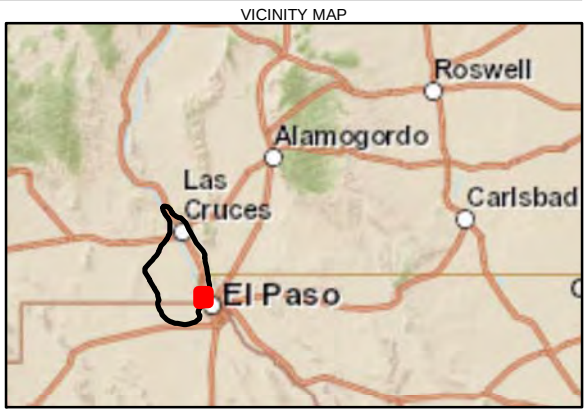

FIGURE D-3
Potential Jurisdictional Waters of the U.S. and/or in the State in Study Area
Distal Mesilla Conceptual Site Model
Rio Grande Salinity Management Program

CH2MHILL

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