Appendix C. Hydrology Modeling Report for Settlement Agreement

New Mexico Interstate Stream Commission

Model Evaluation of the Adjudication Settlement Agreement

Re: State *ex rel* State Engineer v. L.T. Lewis, et al.
Pecos Settlement

Expert Report

Prepared by:

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March 10, 2003

Revised: September 27, 2004

Introduction (March 10, 2003)

As part of the Pecos River Adjudication Settlement Negotiations, Hydrosphere was asked to perform model simulations of the proposed Pecos River adjudication settlement terms. The parties to the adjudication negotiations were interested in understanding how the settlement terms would translate into actual water operations, and how those modified operations would impact water supply to the various water users in the Pecos River basin.

This report provides a brief background on the modeling tools, discusses how the adjudication settlement terms were translated into modeling assumptions and rules, outlines the analysis process including definition of the resources of interest, and presents the results of the analysis.

Introduction (September 27, 2004)

During the summer of 2004, the Interstate Stream Commission (ISC) asked Hydrosphere to re-evaluate the terms of the Adjudication Settlement using updated versions of the modeling tools used in the original report of March 10, 2003. The rationale for these additional modeling activities was set forth in Section 3 of the Settlement Agreement.

The original modeling tools have been updated and enhanced as part of several ongoing efforts, including two NEPA EIS programs and the Adjudication Settlement program itself. The models and associated data management tools have been reviewed by several entities involved in these processes, including the Bureau of Reclamation, U.S. Fish and Wildlife Service, the New Mexico State Engineer's Office and Interstate Stream Commission, and various private contractors to these and other interested parties.

Modeling Tools and Processes

A suite of models was used to evaluate the impacts of the proposed settlement terms. The models include a RiverWare model of river and reservoir operations between Santa Rosa Reservoir and Avalon Dam, two MODFLOW groundwater models of the

Roswell and Carlsbad groundwater basins (the RABGW and CAGW models, respectively), a Pecos River Compact accounting model, and various pre- and post-processing tools for performing data input/output functions and post-run analyses. A schematic of the spatial extent of the Pecos basin represented by the models is shown in Figure 1.

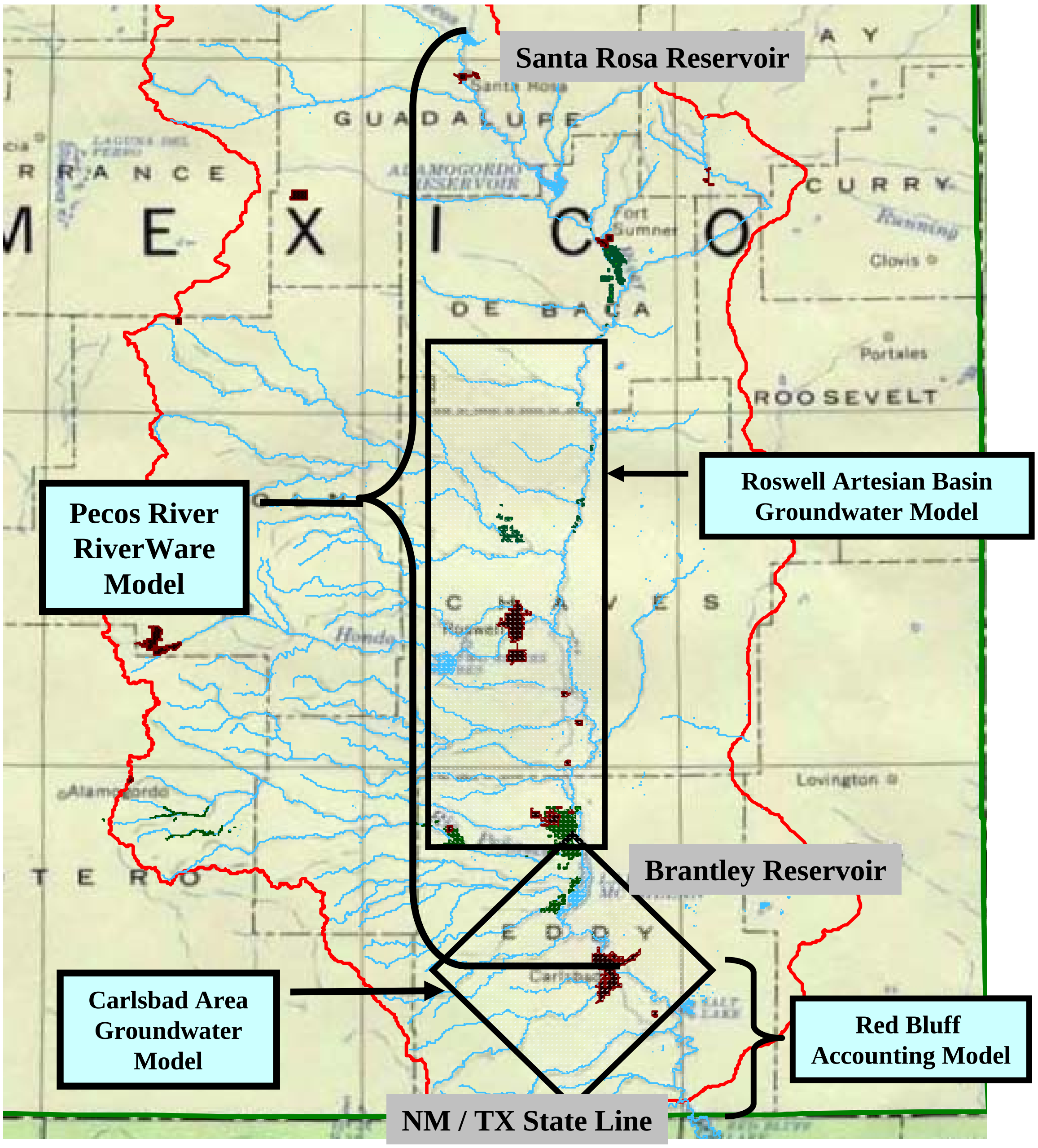

Figure 1. Spatial Extent of the Pecos River Modeling Tools.

Model Objectives and Assumptions

The purpose of this modeling exercise is to evaluate the impact of the Pecos River Adjudication Settlement agreement. The agreement anticipates a combination of land retirement and groundwater pumping with the objectives of: a) permanent compliance with the Pecos River Compact and Amended Decree and, b) avoiding the need for priority administration of water in the basin. Central to achieving these objectives is meeting certain threshold levels of water supply for the Carlsbad Irrigation District (CID). Maintaining these threshold levels is important because of CID's seniority in the basin (the need to avoid a water rights "call") and because water supply shortfalls have a direct impact to stateline flows, and hence Compact compliance.

Two model scenarios were developed for this evaluation. The Baseline scenario, as the name suggests, represents a baseline condition against which proposed actions may be evaluated. However, it only represents those conditions or activities in the basin which are permanent; thus, ongoing temporary leases of water by the ISC and bypass operations for ESA compliance are not considered part of the baseline. The second scenario - termed the Settlement scenario herein - simulates the operation of the system under the Pecos river Adjudication Settlement agreement (the Settlement). The Settlement scenario is essentially a translation of the Settlement agreement into model rules and data. Simulation of the two scenarios, and evaluation of their results, provides an estimate of the changes in water supply that is expected when the Settlement agreement is implemented.

The models rely on historical hydrology for inputs, with current or proposed operational rules superimposed on the hydrologic record. The models are reliable for estimating the long-term impact of implementing a proposed action, but they should not be used in any sense to predict water supply conditions at specific times and locations.

As stated previously, the Baseline scenario is intended to reflect the current operations of the system, minus any ongoing short-term leases or modified operations.

The Settlement scenario is based largely on the Baseline scenario, with certain modified operations. Model assumptions common to both scenarios include:

- Models are based on current / proposed operations and historical hydrology (1967-1996).
- January 1, 2004 reservoir storage levels are used as initial condition for all simulation runs.
- January 1, 2000 aquifer heads are used as initial conditions in the Carlsbad Area Ground Water model.
- January 1, 2000 aquifer heads are used as initial conditions in the Roswell Artesian Basin Ground Water model.
- No augmentation / bypass flows are allocated for the Pecos Bluntnose Shiner.
- Effects of permanent land retirements previously made through the PVACD conservation program and NM ISC are included.
- Acme to Artesia base inflows are generated by the RABGW model, and are based on combinations of historical and statistically generated pumping rates.
- No FSID lands were retired or leased for model runs.
- Total river pumper diversion rates are set at their combined decreed limit of approximately 4,800 acre-feet per year.
- CID allotments are based on 25,055 acres.
- Willow Lake, Harroun, ISC purchased River Pumpers are retired.

The Baseline scenario includes all of the above assumptions, plus:

- The baseline scenario employs 1967 - 1996 historical pumping for the artesian aquifer and alluvial pumping based on statistically-derived estimates using data from 1991-2000.
- CID allotments are based on 25,055 acres. Delivery of CID water to 18,000 acres of irrigated land.
- CID supplemental well pumping limited to 3.0 acre-feet per acre at farm headgate. Model assumes that 14,506 acres may be irrigated by supplemental wells, per latest Hydrographic Survey of decreed lands.
- Avalon releases are due to conservation storage spills only.

The Settlement scenario is modified from the above as follows:

- The settlement scenario assumes the retirement of 11,000 acres in the Roswell Basin; 3,000 acres irrigated by shallow aquifer, and 8,000 acres irrigated by artesian aquifer.
- The settlement RABGW model uses modified stress files; retirement of 11,000 acres and augmentation pumping are distributed uniformly across both the artesian and alluvial aquifers throughout Pecos Valley Artesian Conservancy District (PVACD). Land retirement and augmentation pumping is split between the artesian and alluvial aquifers in an 8:3 ratio (8,000 acres artesian; 3,000 acres alluvial).
- Augmentation pumping in the Roswell basin, from retired PVACD lands, up to 35,000 AF/year and 100,000 AF per 5-year accounting period, occurs when CID divertable supplies at Avalon Reservoir are less than the prescribed target supply volumes defined in the table below.

Table 1. CID Surface Water Supply Thresholds for Augmentation Pumping.

Target Date	Target Supply
March 1	50,000 acre-feet
May 1	60,000 acre-feet
June 1	65,000 acre-feet
July 15	75,000 acre-feet
September 1	90,000 acre-feet

- The model accounts for the purchase of 6,000 acres in CID (by ISC), and delivered or redistributed based on the logical rules below.
- CID allotments are based on 25,055 acres with delivery to 18,000 CID acres.
- CID supplemental well pumping limited to 3.697 acre-feet per acre at farm headgate, per Settlement agreement. Model assumes that 14,506 acres may be

irrigated by supplemental wells, per latest Hydrographic Survey of decreed lands.

- If there is a Compact delivery shortfall, remedy pumping occurs in the Roswell basin and that water is delivered directly to the state line. This pumping occurs in the fall and winter. A 10% transit loss is assumed for all remedy water.
- The distribution of water from 6,000 acres of CID land purchased by ISC is conditioned on the cumulative Compact credit and current water supply (ISC water "yield" = 1.176 x allotment):
  a. If CID irrigators' supply < 50,000 acre-feet, ISC water is reallocated to actively irrigated CID lands up to a total supply of 50,000 acre-feet. Once the 50,000 acre-foot supply level has been reached, ISC may take delivery of water until its allotment is equivalent to that of the irrigators.
  b. If Compact credit < 50,000 acre-feet, and CID irrigators supply > 50,000 acre-feet, deliver ISC water to stateline 5x annually.
  c. If 50,000 acre-feet < credit < 115,000 acre-feet, AND current supply < 90,000 acre-feet, ISC shall make its CID water available for re-distribution to CID irrigators.
  d. If 50,000 acre-feet < Compact credit < 115,000 acre-feet, AND current CID supply > 90,000 acre-feet, ISC may take delivery of additional water over 90,000 acre-feet until its allotment is equivalent to that of the irrigators. Once ISC's allotment is equal to the irrigators, water is alloted to all 25,055 acres equally.
  e. If credit > 115,000 acre-feet, ISC shall make its CID water available for re-distribution to CID irrigators up to the decreed limit (3.697 acre-feet/acre); If CID irrigators have their full allotment, excess water is held over in storage.

Model Analysis and Resource Indicators

Several key resource indicators were identified to evaluate and compare the results of the simulations. These include:

- Pecos river flows at Acme and Artesia.
- Augmentation pumping in the Roswell basin.
- Roswell basin aquifer storage.
- Base inflows in the Acme to Artesia reach.
- CID allotment and Main Canal deliveries.
- CID supplemental well pumping.
- Releases from Avalon Dam.
- Pecos River flow at the Red Bluff gage and total stateline deliveries.
- Pecos River compact obligations and departures.

The results of the model simulations, based on the above resource indicators, are discussed below.

Resource Indicator: Pecos River flows at Acme and Artesia

Flow statistics are generated from the RiverWare model at nodes representing the "near Acme" and "near Artesia" gages (Figures 2 and 3). Augmentation pumping is assumed delivered directly into Brantley Reservoir in the RiverWare model (with a 15% transit loss). Previously, we had estimated the impacts of augmentation pumping on flows at Artesia (Carron, 2003). However, it appears that much of the augmentation pumping will occur below Artesia. In early drafts of the Settlement agreement, there was a clause requiring a minimum flow at Artesia. This clause was not included in the final agreement. We have therefore not included estimates of augmentation pumping on flows at Artesia in this revised report.

Acme Flow Statistics (cfs)		
	Baseline	Settlement
Maximum	7356	6862
Average	114	118
Minimum	0	0
Acme Exceedence Values (cfs):		
50%	19.2	18.7
75%	10.0	9.7
90%	5.5	5.3
95%	3.4	3.3
99%	0.0	0.0

Figure 2: Flow Statistics at Acme.

Artesia Flow Statistics (cfs)		
	Baseline	Settlement
Maximum	10230	10224
Average	165	170
Minimum	9	7
Artesia Exceedence Values (cfs):		
50%	75.9	75.9
75%	50.5	49.2
90%	30.1	29.0
95%	23.2	22.1
99%	15.9	14.1

Figure 3: Flow statistics at Artesia.

Resource Indicator: Roswell Basin Aquifer Storage

Aquifer storage levels are derived from the RABGW model, and represent departures in storage from a pre-development condition. Figures 4 and 5 show the aquifer storage levels for both the artesian and shallow alluvial aquifers as a normalized percentage of the estimated pre-development aquifer storage. Note that the general trend for both aquifers is one of increasing storage throughout the simulation period, due to the combined effects of retired PVACD lands and lower augmentation pumping requirements. The simulations indicate that over the first 30 years following implementation of the Settlement, the alluvial and artesian aquifers would recover approximately 10% and 20%, respectively, compared to the baseline.

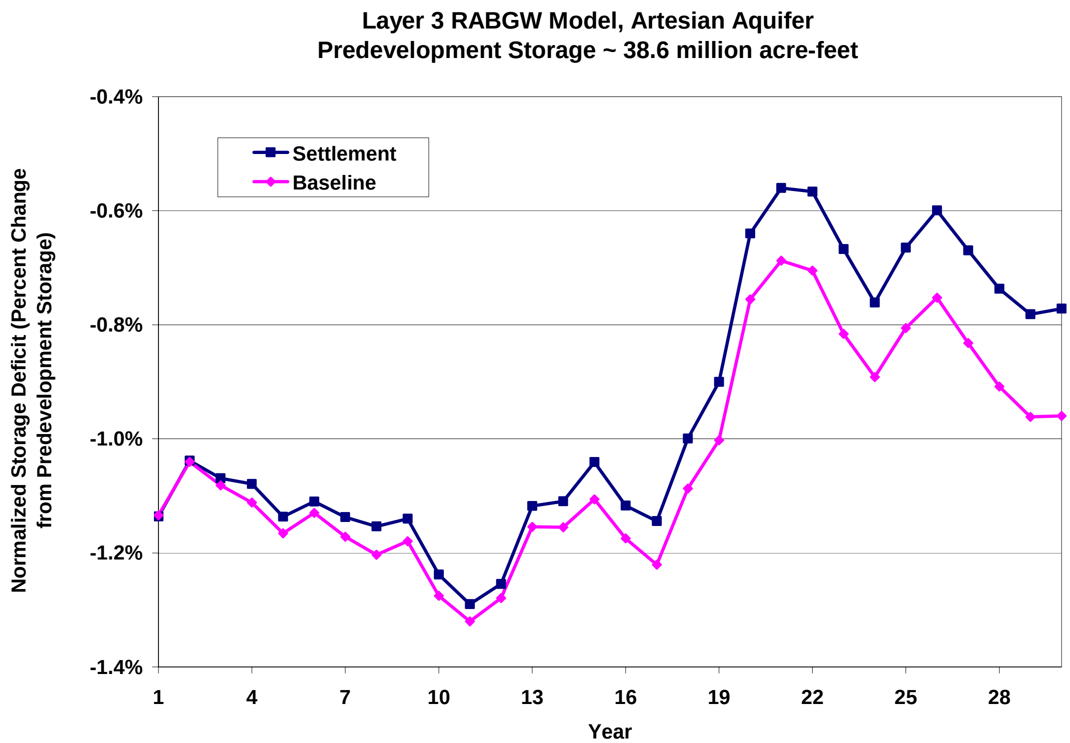

Figure 4: Artesian Aquifer Storage. (Comparison of storage deficit for the baseline and settlement scenarios, normalized against pre-development storage conditions.)

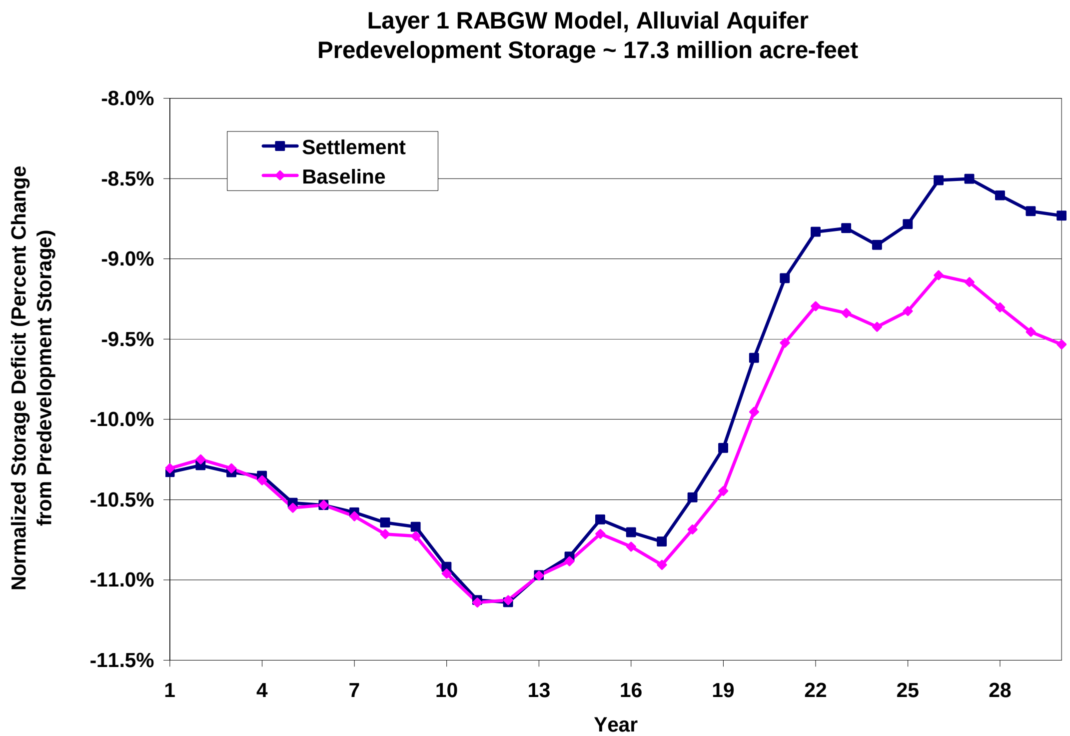

Figure 5: Alluvial Aquifer Storage. (Comparison of storage deficit for the baseline and settlement scenarios, normalized against pre-development storage conditions.)

Resource Indicator: Base Inflows in the Acme to Artesia Reach

Base inflows between Acme and Artesia are generated from the RABGW model and input to the RiverWare model as daily values. RABGW generates monthly average flows, which are distributed evenly over the month when converting from monthly to daily flow values. Annual volumes of baseflows from the RABGW model are shown in Figure 6. The Settlement results indicate an initial reduction in baseflows as compared to the baseline, due to significant augmentation pumping early in the simulation period, followed by a recovery of baseflows to levels equal to and then greater than the baseline. Over the long-term (i.e., beyond the 30-year simulation), we expect the baseflows to continue to increase above what would be seen under the baseline.

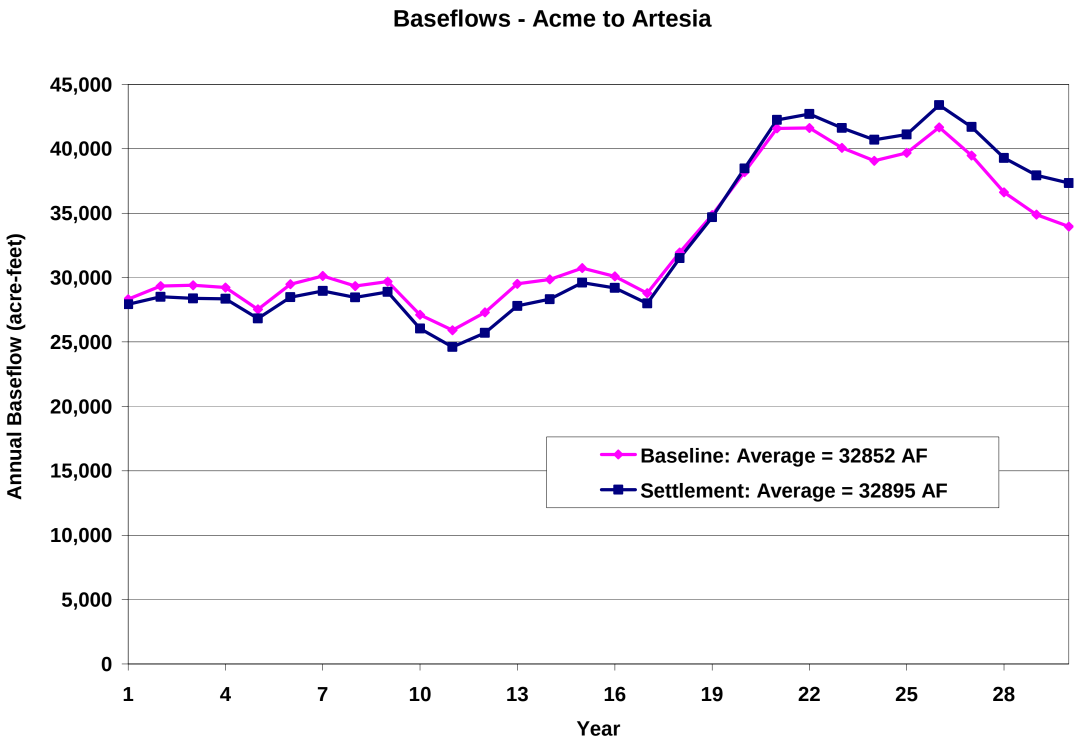

Figure 6: Acme to Artesia Base Inflows.

<u>Resource Indicator: CID Allotment and Main Canal Deliveries</u>

Under the Settlement, ISC would use its purchased PVACD water rights to augment CID's surface water supply it times when the natural CID surface water supply is less than the prescribed thresholds (refer to Table 1). Figure 7 illustrates the amount of augmentation pumping required to provide CID with 50,000 acre-feet of water on March 1 for each year of the simulation.

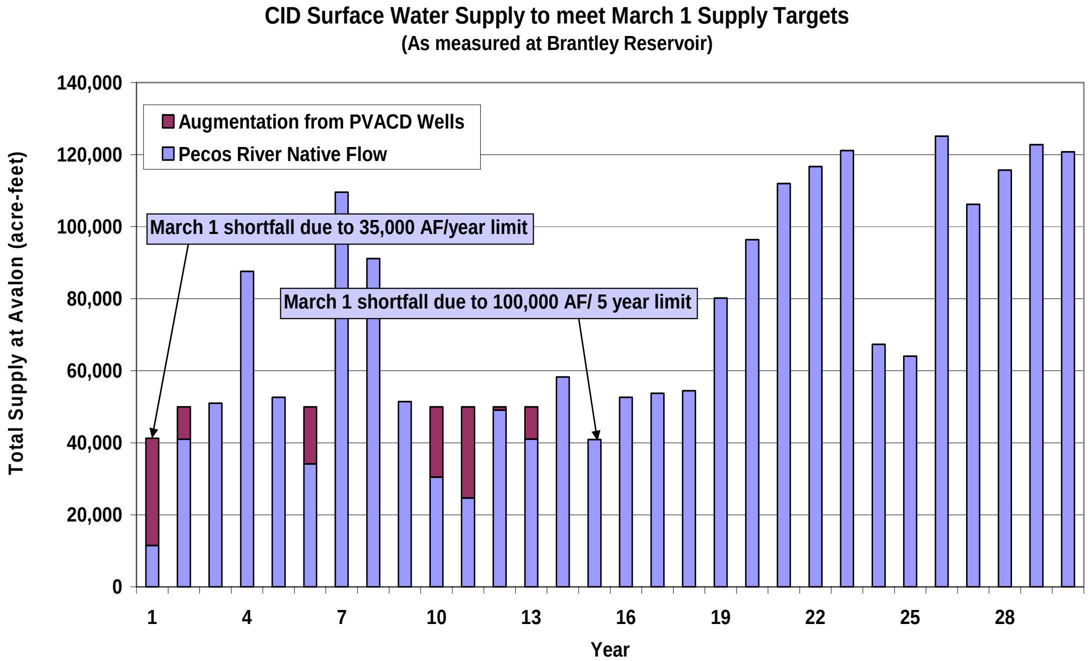

Figure 7. Augmentation Pumping required to meet 50,000 AF March 1 Supply Target.

Total annual water supply, including augmentation pumping, is shown in figure 8. The augmentation component of that supply is shown in figure 9. Note that in many years, there is augmentation pumping even though the total supply exceeds 90,000 acre-feet (Figure 8). In these years, the supply typically is low early in the year, which triggers augmentation, but later increases due to large precipitation and flood events. From figure 8, the impacts of the 35,000 acre-foot annual limit and 100,000 acre-foot 5-year limit can clearly be seen. In years 1 and 11, for example, the 90,000 acre-foot supply target cannot be met due to the annual augmentation pumping limit. Also compare the values to targets for years 10, 14, and 15 where the total supply is less than 90,000 acre-feet because augmentation pumping is constrained by the 5-year 100,000 acre-foot limitation.

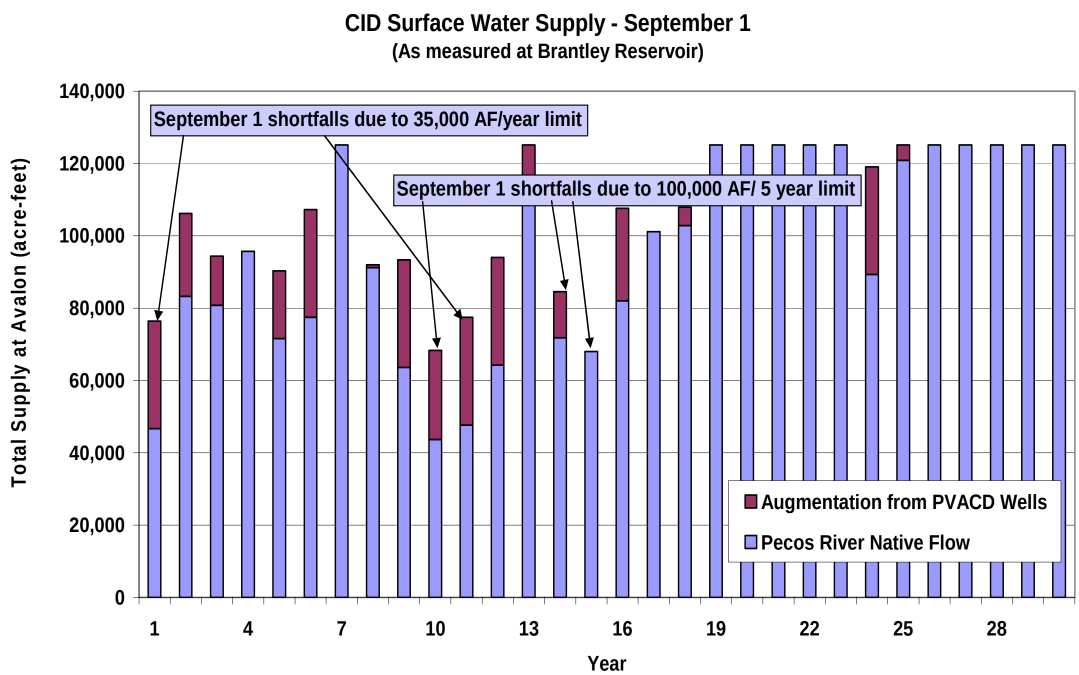

Figure 8. Total CID Supply from "Natural" and Augmentation Sources.

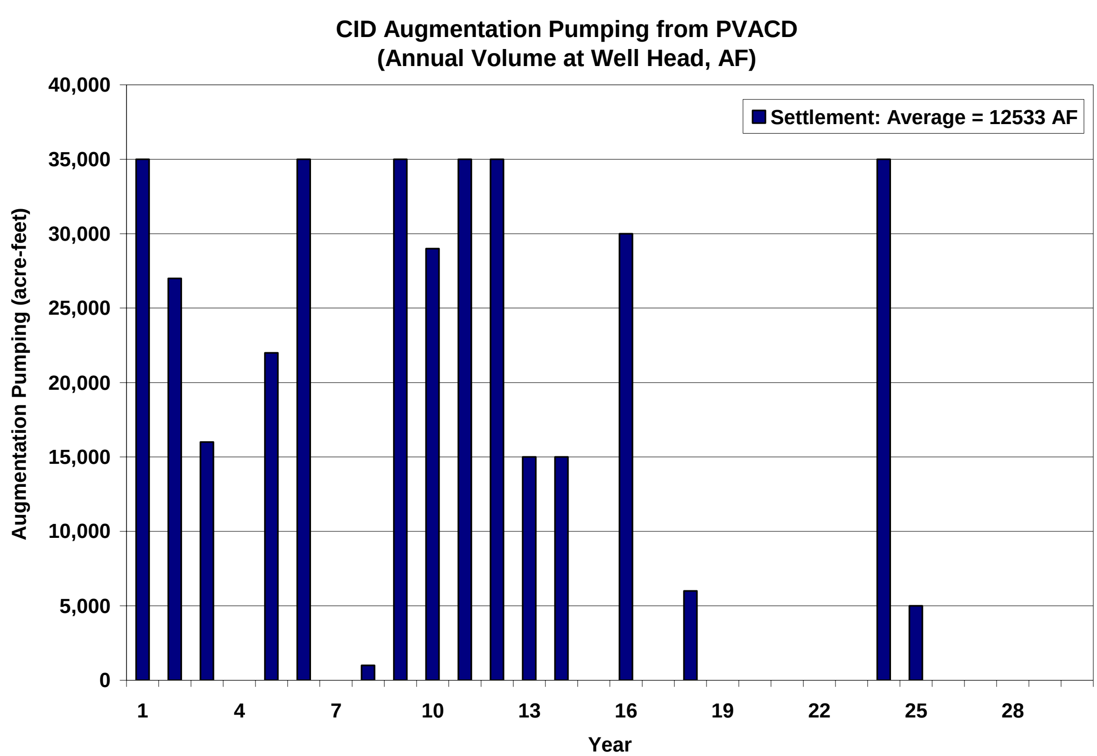

Figure 9: Settlement Scenario Augmentation Pumping from PVACD.

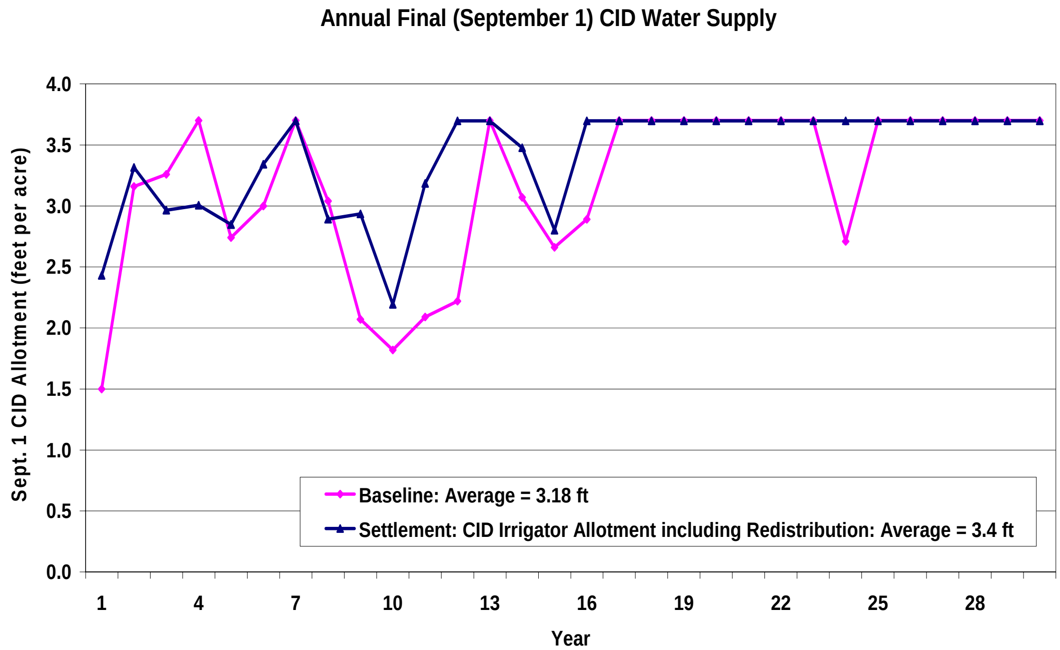

Figure 10: Comparison of CID Allotments under Baseline and Settlement Scenarios.

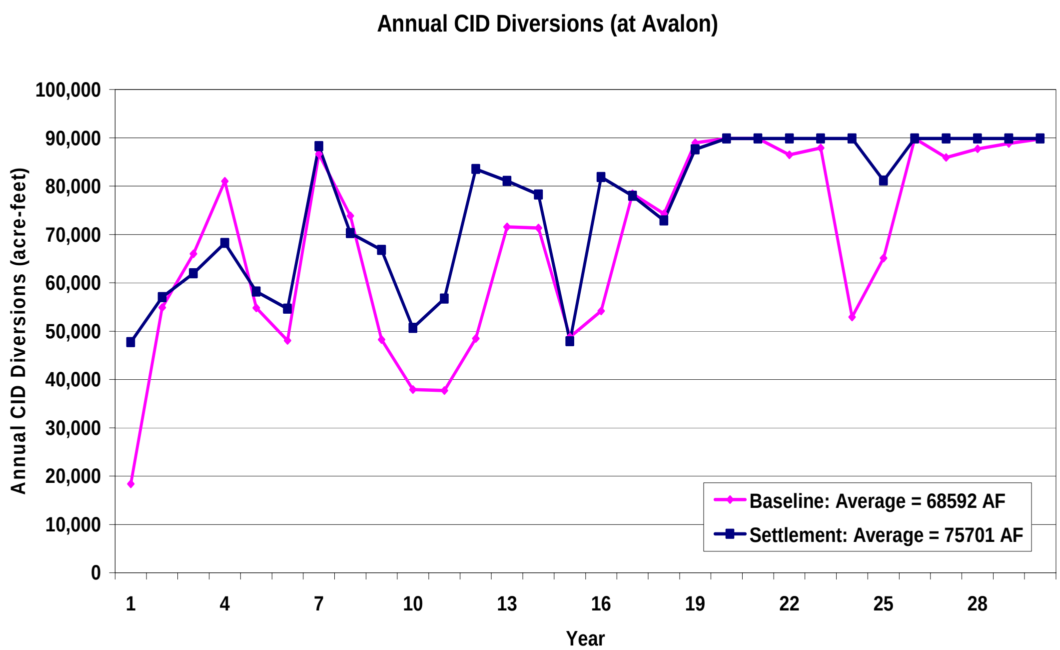

Figure 11: Comparison of Actual Diversions to CID Main Canal. Both scenarios assume 18,000 acres actively irrigated.

Another significant feature of the Settlement is the re-distribution of ISC's CID rights under certain water supply and Pecos River Compact conditions. Figure 10 shows the change in allotments under the two scenarios. The increase in total allotment reflects the combined impact of land retirement, augmentation, and redistribution. The average increase in water available for irrigators due to implementation of the Settlement is 0.22 feet per year. Notice also that the Settlement tends to significantly benefit CID in dry years. Under the baseline scenario, the minimum final allotment was 1.5 feet per year, while under the Settlement, the minimum was about 2.2 feet per year. This benefit extends into the early part of the irrigation season as well. The minimum March 1 allotment increased from 0.55 to 1.21 under the Settlement scenario. This increase in early-season allotment translates into a higher proportion of early-season irrigation water coming from surface supplies as opposed to supplemental wells.

Figure 11 shows the total actual diversions from Avalon Reservoir into the CID Main Canal. Total annual diversions increase by about 7,100 acre-feet annually, or about 10%. This is equivalent to about 0.29 feet per irrigated acre.

Supplemental well pumping results are shown in Figure 12. Under the proposed settlement, supplemental well pumping limits would be increased from 3.0 to 3.697 feet per acre, to offset any potential under-deliveries of surface water. Total supplemental well pumping is increased under the settlement scenario by about 1,800 acre-feet per year. It is worth noting that as much as 12,500 acre-feet per year of supplemental pumping is due to the increase in the decree limit for the supplemental well rights, and not because of a reduced CID water supply. If the 3.0 feet per acre limit was in place under the Settlement, supplemental pumping would in fact be significantly reduced.

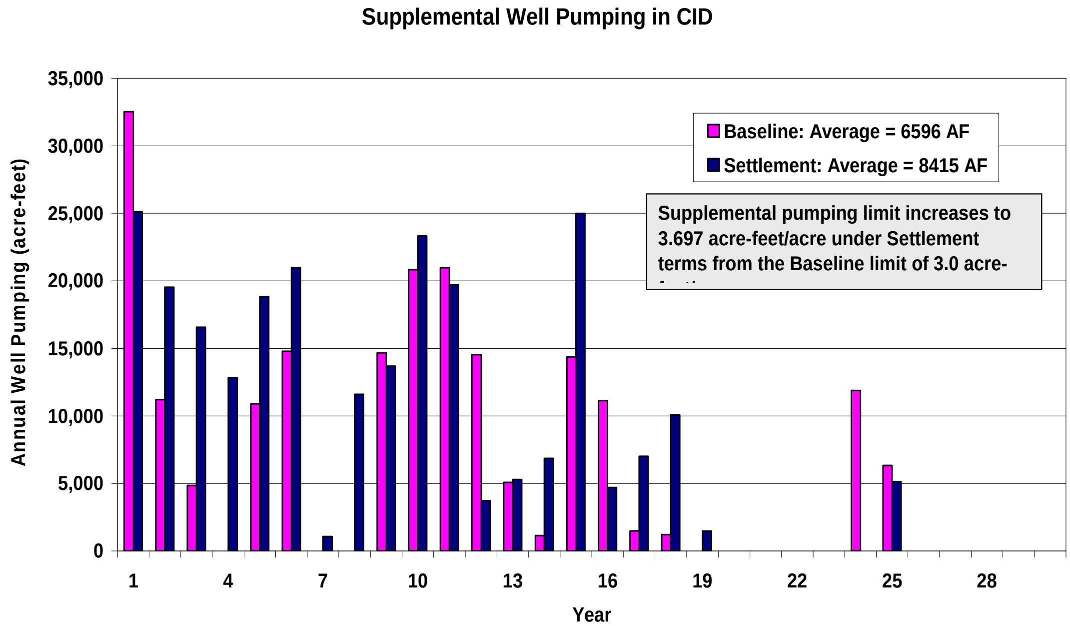

Figure 12: Comparison of CID Supplemental Well Pumping. (Increase in pumping under settlement is due to increase of pumping limit from 3.0 to 3.697 acre-feet per acre.)

<u>Resource Indicator: Releases from Avalon under Settlement Terms</u>

Under baseline operations, the only releases from Avalon dam, other than to the CID main canal, are due to conservation spills. The Settlement agreement includes provisions that allow ISC to release its share of the CID allotment directly from Avalon dam for purposes of complying with the Pecos River Compact. Figures 13 through 15 illustrate the impacts of the Settlement on Avalon Dam releases. Total releases from Avalon increase by about 6,600 acre-feet annually (Figure 13). This average does not include the remedy water bypasses totaling about 30,000 acre-feet in years when there is a Compact delivery shortfall (see below for details on the Pecos River Compact). Conservation spills decrease under the Settlement, on average, although the majority of the changes occur late in the simulation period after a sizeable Compact credit has been accumulated (Figure 14). Release of ISC's CID water averages about 10,500 acre-feet annually (Figure 15). Notice that the bulk of the ISC releases occur early in the simulation period, when the stateline Compact credit is small. Additional deliveries of

ISC water occur later in the model run only in years when CID's water supply is high (again, see discussion on Compact departure in the next section).

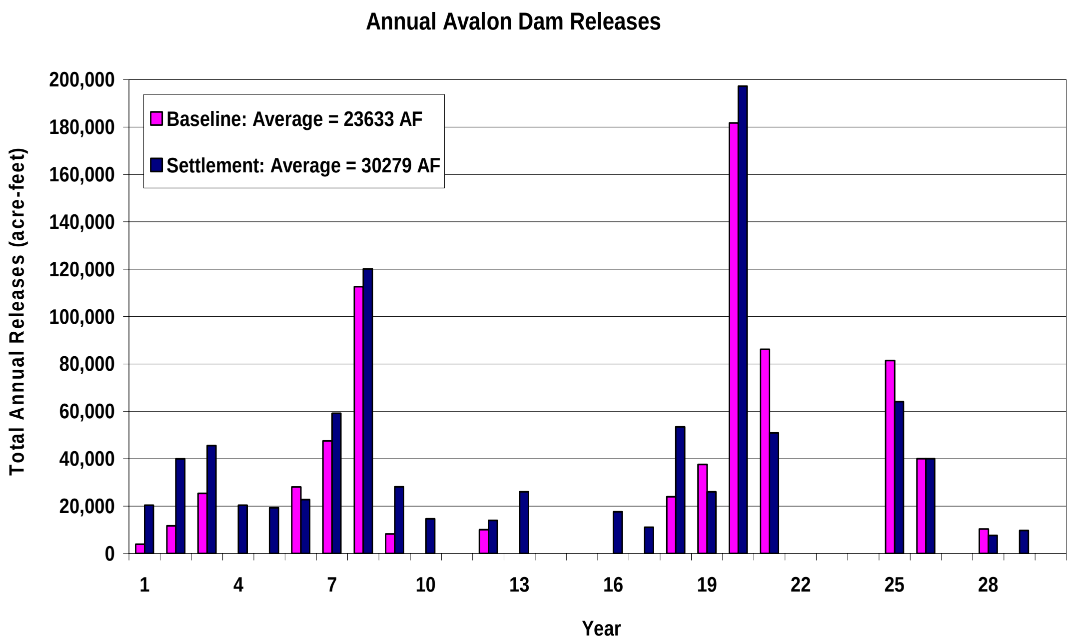

Figure 13: Total Avalon Releases to Pecos River.

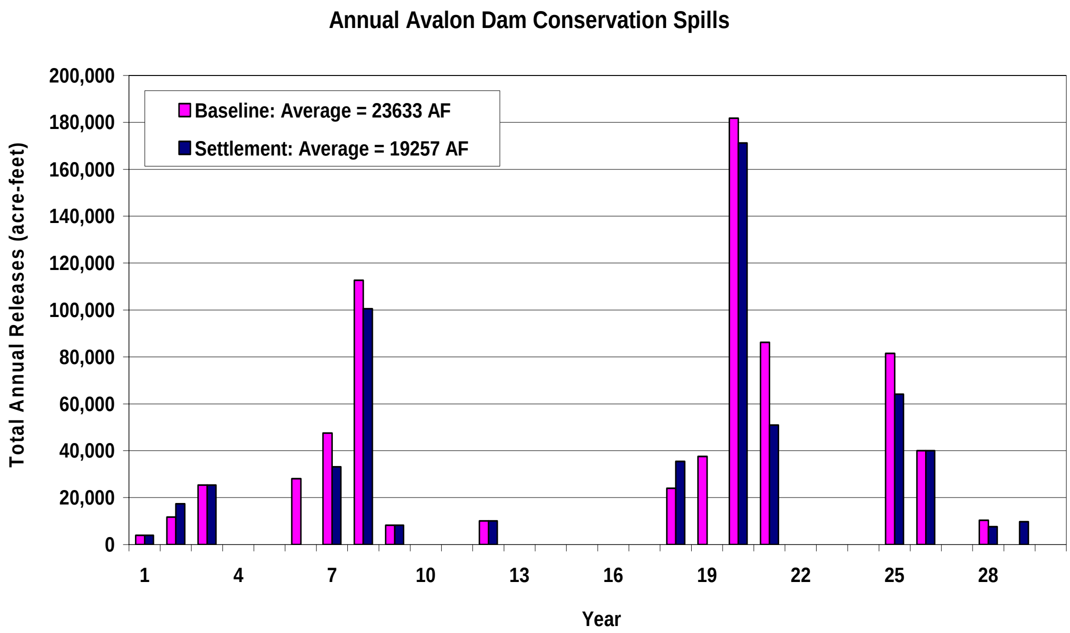

Figure 14: Avalon Releases to Pecos River due to Conservation Spills only.

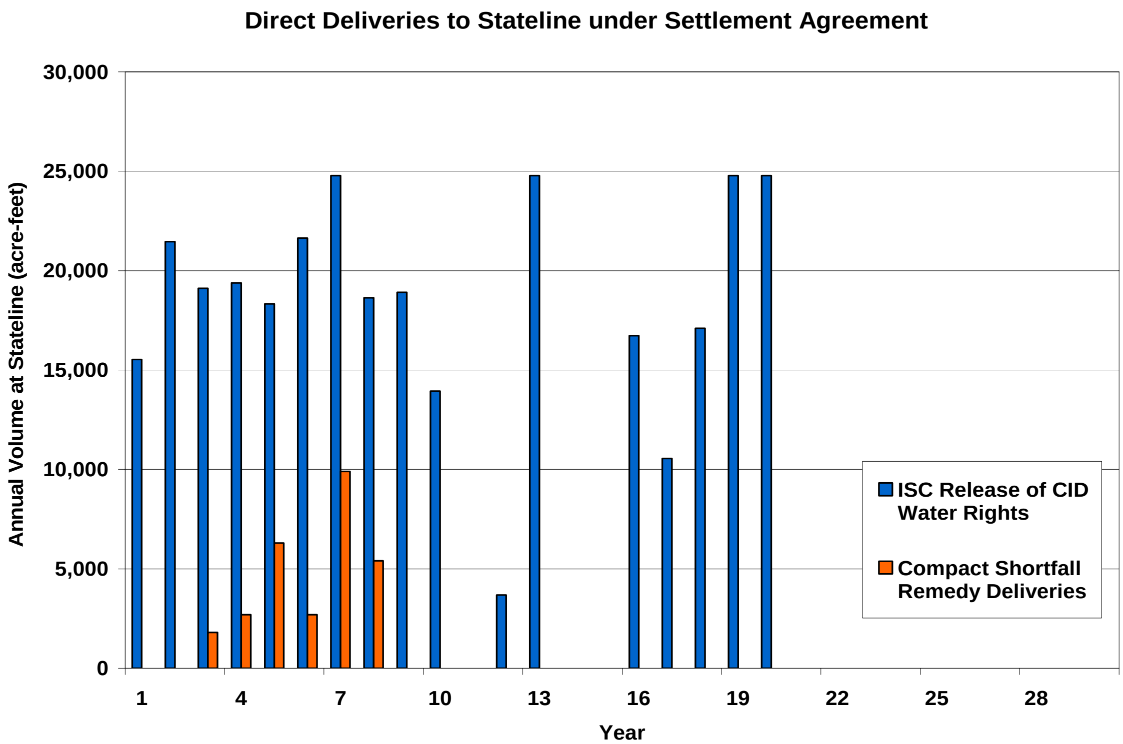

Figure 15: Stateline Deliveries of ISC's CID Water Rights and Remedy Water.

Resource Indicator: Red Bluff Flows, Stateline Deliveries, and Pecos River Compact

The final set of resource indicators pertain to New Mexico's obligations under the Pecos River Compact and Amended Decree. One basic tenet of the Settlement agreement is that by keeping CID's water supply whole as much as possible (which increases return flows to the Pecos River), and by direct delivery of a portion of the CID allotments which would be purchased by NM ISC, New Mexico can increase its Compact credit to a level that will allow it to more comfortably weather drought years without severely damaging the region's economy. The net impacts of the proposed settlement terms on stateline flows are shown in Figure 16. Average annual flows at the stateline would increase by about 9,500 acre-feet annually based on the model simulations. Additional water delivered to the stateline as a result of remedy pumping total almost 30,000 acre-feet (Figure 15). Corresponding to the increase in stateline flows is an increase in the average annual and cumulative departure from the Compact obligation, as shown in Figure 17.

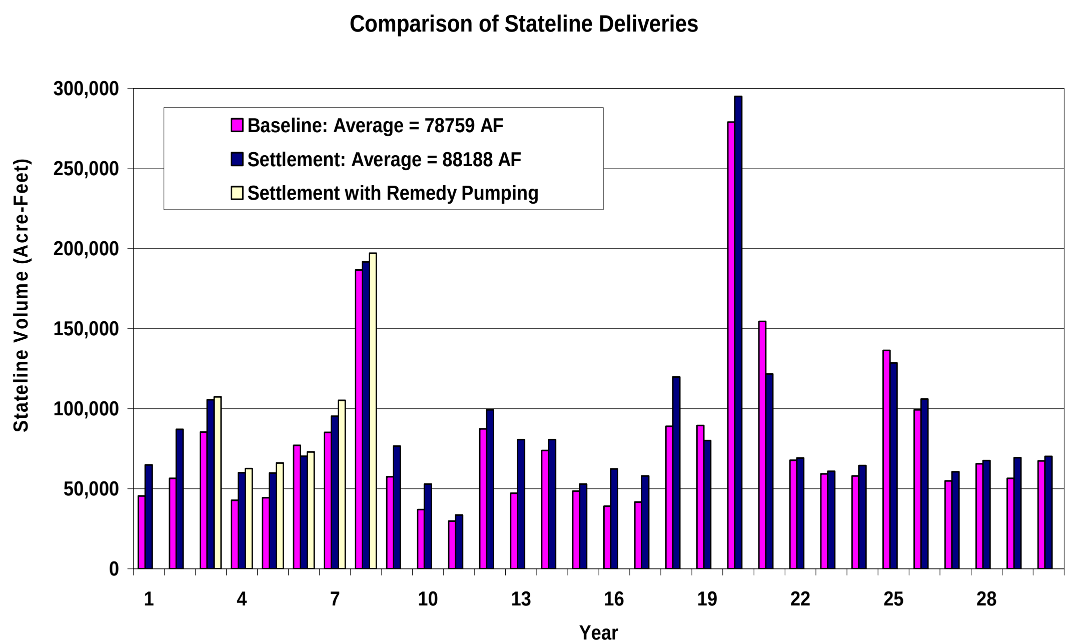

Figure 16: Total Flows at the Stateline (includes Red Bluff and Delaware).

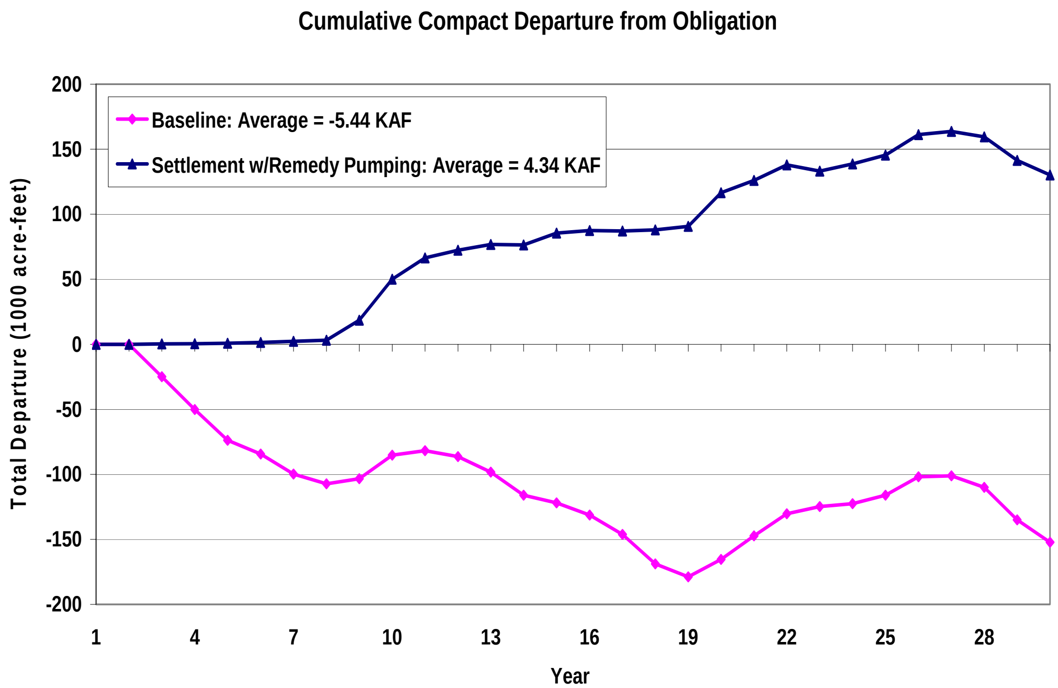

Figure 17: Comparison of Cumulative Compact Departure under the Baseline and Settlement Scenarios.

Finally, Figure 19 provides a breakdown of the additional sources of water that lead to the additional stateline flows. The graph shows the cumulative gain in stateline flows (in acre-feet) as the blue line, using the y-axis on the right. Using the left-hand y-axis, the columns show year-by-year changes under the settlement scenario for Avalon spills, baseflow gains, and ISC releases from Avalon, as compared to the baseline scenario. Early in the simulation period, deliveries of ISC's CID water directly from Avalon account for much of the gain in stateline flow. In the later two-thirds of the period, in addition to ISC releases, additional return flows and baseflow gains from the CID area account for much of the gain.

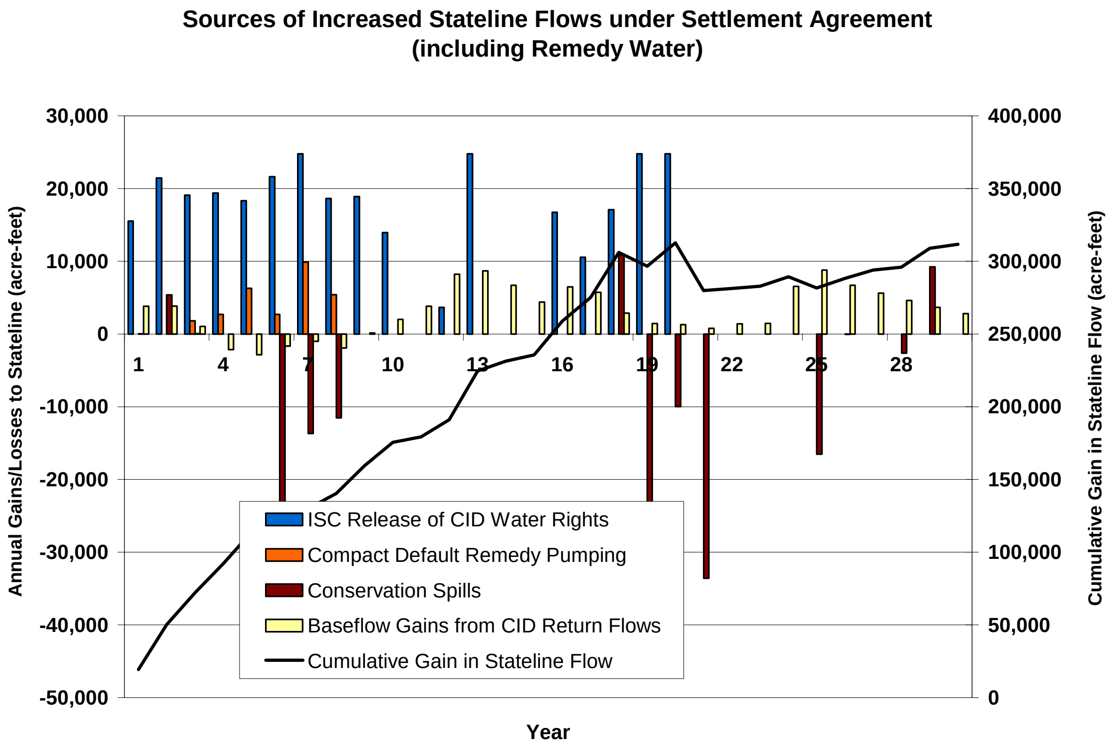

Figure 18: Sources of increased state line flow, and cumulative gain in state line Flow, Settlement scenario vs. Baseline scenario.

Summary and Conclusions

This report has presented results of two model simulations intended to evaluate the impacts of the proposed Pecos River Adjudication Settlement Terms. The model results indicate that implementation of the Settlement agreement will:

1. Have no significant impact to Pecos River flows at Acme and Artesia.
2. Increase the total annual surface water supply available to CID irrigators.
3. Significantly increase the CID system's resiliency to dry years.
4. Minimize the chances of a priority call by CID, through augmentation pumping to meet supply targets.

5. Over time, reduce total depletions in the Roswell basin and increase baseflows to the Pecos River.

6. Increase baseflows / return flows from the Carlsbad basin to the Pecos River.

7. Provide for the direct delivery of water from Avalon dam to the stateline.

8. Minimize the possibility of the State of New Mexico defaulting on its Pecos River Compact obligations, and most likely result in a cumulative credit over the long-term.

References

Barroll, Peggy. 2002. The Carlsbad Area Groundwater Flow Model. Hydrology Bureau, New Mexico Office of the State Engineer.

Carron, John. 2003. Pecos River Adjudication Settlement: Model Evaluation of Adjudication Settlement Agreement. Final Report. March 10, 2003. Hydrosphere Resource Consultants, Inc.

Hydrosphere Resource Consultants, Inc. 2003. The Carlsbad Area Ground Water Model Data Processing Tool: User's Manual and Technical Reference. Prepared for the New Mexico Interstate Stream Commission.

The Hydrology/Water Operations Work Group for the Carlsbad Project Water Operations and Water Supply Conservation NEPA Process (HWG). 2004. Volume 2: Pecos River RiverWare Model Report. Referred to herein as (HWG Volume 2, 2004).

The Hydrology/Water Operations Work Group for the Carlsbad Project Water Operations and Water Supply Conservation NEPA Process (HWG). 2004. Volume 3: Roswell Artesian Basin Groundwater Model Documentation. Referred to herein as (HWG Volume 3, 2004).

The Pecos River Adjudication Settlement Agreement, dated March 25, 2003, as entered into by the state of New Mexico ex rel. the State Engineer; The New Mexico Interstate Stream Commission; the United States of America, Department of the Interior, Bureau of Reclamation; the Carlsbad Irrigation District; and the Pecos Valley Artesian Conservancy District. Referred to herein as (Settlement Agreement, 2003).