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The Pecos River Ecosystem Project
Progress Report

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Background of Situation

Saltcedar (*Tamarix* spp.) is an introduced phreatophyte in western North America. The plant was estimated to occupy well over 600,000 ha of riparian acres in 1965 (Robinson 1965). Saltcedar is a vigorous invader of riparian, rangeland, and moist pastures. Saltcedar was introduced into the United States as an ornamental in the early 1800's. In the early 1900's, government agencies and private landowners began planting saltcedar for stream bank erosion control along such rivers as the Pecos River in New Mexico. The plant has spread down the Pecos River into Texas and is now known to occur along the river south of Interstate 10. More recently the plant has become a noxious plant not only along rivers and their tributaries, but also along irrigation ditch banks, low-lying areas that receive extra runoff accumulation, and areas with high water tables. In addition, many CRP acres in central Texas are being invaded with saltcedar.

Saltcedar is a prolific seeder over a long period of time (April through October). Early seedling recruitment is very slow but once established, seedlings grow faster than native plants (Tomanek and Ziegler 1960). Once mature the plant becomes well established with deep roots that occupy the capillary zone above the water table with some roots in the zone of saturation (Schopmeyer 1974). The plant can quickly dominate an area, out-competing native plants for sunlight, moisture, and nutrients. Mature plants can withstand prolonged drought or periods of inundation. The plant also brings salts to the surface through the plant and excreting it through the leaves dropping onto the soil surface below the canopy. Only extremely xeric or halophytic species of plants can tolerate the understory environment of saltcedar. As a result, the plant commonly forms a near monoculture where it grows.

Probably more important than any other fact about saltcedar is its hydrological implications. An invasion of a flood plain or river bank by saltcedar usually leads to depletion of stream/river flow, lowered water table, an increase in the area inundated by floods, and an increase in sediment production (Blackburn *et al.* 1982). The plant has an extremely high rate of evapotranspiration assists the plant to tolerate saline conditions. Numerous techniques have been used to estimate evapotranspiration rates of saltcedar including Bowen ration, eddy covariance, micro-meteorological data, evapotranspirometer, non-weighing lysimiter, tanks, sap flow, stem-heat-balance, and groundwater monitoring wells. Estimated evapotranspirational water use by saltcedar varied from 1.2 to 10.2 ft. per year. Major factors affecting volume of water transpired by saltcedar include leaf area, plant density and size, depth to water table, and soil type. Two specific studies reported that saltcedar transpired 0.3 cm to 1.0 cm of water per day and from 1.2 m to 3.1 m (3.9 to 10.2 ft.) of water per year (Davenport *et. al.,* 1982), and 2.1 cubic meters/square meter (Carmen and Brotherson 1982).

Monotypic stands of saltcedar have a negative impact on wildlife and livestock. The plant provides little browse and no seed food source for native wildlife species. The wildlife habitat value of saltcedar is limited to screening cover for mammals, nesting sites for some birds, and a pollen source for bees. In most instances, the wildlife habitat value of a saltcedar monoculture is much less than that of its native counterpart that it has replaced (Cohan *et. al.* 1978; Anderson and Ohmart 1977).

Justification of Situation

The management of saltcedar infestations has, more than once, resulted in the return of surface water to an area. Two examples documented include the Eagle Borax Spring in Death Valley National Monument (Neil 1983) and Spring Lake in New Mexico (Duncan 1997). At Spring Lake in New Mexico, saltcedar was treated with Arsenal™ herbicide. Within 34 months after application, the water table had risen to the soil surface from a depth of greater than 6.0 m below the soil surface. This occurred even though the area had experienced a mild drought.

Fires burn easily through dead or green saltcedar and will almost always top kill the plants. However, due to its ability to re-sprout from the base, seldom does fire kill the plant as the root crown area is usually well protected from the fire. Mechanical control practices have shown only slightly greater success when compared to fire. Mowing or shredding have shown similar results to burning, while root plowing or bull dozing have provided some mortality. However, the soil surface is greatly disturbed causing high erosion potential, the plants have a high re-sprouting capability, and the associated costs are prohibitive in most instances. Because of these reasons, use of the root plow or other heavy equipment as a control method for saltcedar has become less frequent (Hollingsworth 1973).

The response of saltcedar to chemical control has historically been variable, with little satisfactory control except under specific conditions or repetitive applications. The most satisfactory control was provided by cut stump or basal bark treatments. These treatments tend to be very time consuming and not practical for larger acreage. Additionally, many of the herbicides historically used for saltcedar control are no longer approved or currently unavailable. Research has been conducted recently (1987 to present) with Arsenal™ (Imazapyr) herbicide. Results indicate Arsenal™ applied alone or in combination with Glyphosate controlled saltcedar to levels of 90% or greater within one year after application when applied in August or September (Duncan and McDaniel 1998). Their recommendations include 0.5 + 0.5 lbs. a.i./acre of Arsenal™ and Glyphosate, respectively, applied with a fixed wing aircraft.

Saltcedar occupies a near continuous buffer along both banks of the Pecos River from Red Bluff Dam southward for the entire area (approx. 180 river miles) of the Red Bluff Irrigation District. The width of the saltcedar band varied from 25 to 500 feet with an average of 150 feet on each river bank. Within this stretch of river, saltcedar occupies about 30 to 40 acres per river mile. Additionally, the Pecos River in Texas is a meandering stream with a ratio of river miles to air miles of about 3 to 1. Another primary concern of the project was to apply the herbicide with minimal contact of off-target vegetation. This situation created a real challenge for aerial application of herbicides.

Project History and Accomplishments

The Pecos River Ecosystem Project was proposed by the Red Bluff Water and Power Control District in 1997, to address saltcedar issues along the Pecos River. The initial objectives of the project were to increase efficiency of water delivery in the river to irrigation districts within the Red Bluff District and improve the quality of the water by decreasing the salinity. After four years of herbicide application on the saltcedar, the project has emerged as the first step to what could be important to the overall statewide plan for water conservation along Texas rivers by managing saltcedar infestations. Success of the Pecos River Ecosystem Project can be attributed mainly to its cooperative effort and organization. Numerous agencies, organizations, and companies were involved in the organizational efforts early in the project development, listed below.

- Upper Pecos Soil and Water Conservation District
- Texas Cooperative Extension
- Texas Department of Agriculture
- USDA Natural Resources Conservation Service
- Red Bluff Water and Power Control District
- Irrigation Districts in Loving, Reeves, Ward and Pecos Counties
- US Environmental Protection Agency
- Pecos River Compact
- International Boundary and Water Commission
- BASF
- Local landowners

The first step undertaken by the group was to develop a section 24(C) special use label to use Arsenal™ herbicide on saltcedar within rangeland and aquatic areas in Texas. The label was prepared by the Pesticide Division of the Texas Department of Agriculture and approved for use in 1999. The project was setup with two major phases, saltcedar treatment phase and debris removal phase. Also of major concern to the project group was the revegetation of the river banks with native plants to complete the ecosystem restoration. Once the label and funding were secured, the project was ready to begin the first phase of herbicide treatments. The Upper Pecos Soil and Water Conservation District Board of Directors were selected to administer the project.

Phase one of the project began in October 1999. During the initial meetings to begin planning the process of saltcedar removal, several major concerns emerged. First, the treatment method selected should provide a high rate of saltcedar mortality while minimizing the detrimental effects on existing native vegetation. Second, this should be accomplished in the most economical way possible. And finally, soil loss from stream banks should be minimized as much as possible. Another daunting task was to obtain permission from private landowners to treat saltcedar along the river. A "spray easement" was developed and used as a contract between the Project and private landowners, allowing access for treatment and follow-up management for a 10 year period. To date, over 800 easements have been signed by private landowners, with a rejection rate of less than 1%. Bids were solicited from aerial applicators in late summer 1999 with the project ultimately being awarded to North Star Helicopters from Jasper, Texas. With funding, landowner permission, and applicator contract in hand by August 1999, initial treatments began in September.

Applications of 4 pints a.i./acre of Arsenal™ were made with helicopter applying the herbicide with large droplets and high total spray volume. The helicopter had the advantage of being able to fly at slower air speeds compared to fixed-wing aircraft, which made the sharp turns of the river much easier to navigate. The helicopter application also provided for much higher precision of application by utilizing specialized nozzle and boom technology. The herbicide was applied in a total spray volume of 15 gallons per acre with a 1500µ droplet. Less than 1% of the droplets were driftable fines (<200µ). The boom was also sectioned into 3 – 15 ft. sections for an overall width of 45 ft. Combinations of the boom could be turned on to allow for a 15, 30 or 45 ft. swath width. This further reduced the amount of herbicide that came in contact with off-target vegetation. Another advantage of the helicopter over fixed-wing aircraft was its ability to land on loader trucks that were positioned near the river and eliminated the need of ferrying to and from a landing strip.

Helicopters were also equipped with GPS navigational equipment to aid in application. The use of on-board GPS allowed for near elimination of skips between spray swaths and allowed the pilot to easily return to the point where they finished spraying the previous batch load. The system was also tied into the sprayers flow control system so that rate of flow through the boom was varied to precisely match ground speed, eliminating the need to maintain a constant ground speed. After completion of treatments, GPS log files were downloaded to a computer to produce maps of the treated area and make calculations about the area treated.

An extensive monitoring program was initiated prior to the beginning of the project in 1999. The specific objectives of the monitoring project are to determine the effects of saltcedar removal on water quality and quantity in the Pecos River. Water quality is monitored through annual and real-time measurements of electrical conductivity. Water quantity is being evaluated through evaluation of historical and current release and delivery data from Red Bluff Water and Power Control District. A study is also being conducted to estimate water use by saltcedar along the river using shallow groundwater monitoring wells. More information on this study can be found in these proceedings in the article by White, et. al. This research currently estimates that saltcedar evapotranspiration along the Pecos River is 5-8 ft. per year. The research is currently attempting to characterize water salvage following control of saltcedar. Estimates of salvage below are calculated using an estimated salvage of 7.7 acre-feet for every acre of saltcedar treated.

The project was privately funded in 1999 and 2000 by money obtained from irrigation districts along the Pecos River. Approximately 66 river miles (Table 1.) or about 1344 acres of saltcedar were treated with an actual spray cost of $253,555. Estimated annual water salvage from applications in 1999 and 2000 are 10,284 acre-feet of water per year. Additionally, native grasses are coming back vigorously on the bare ground that now receives sunlight.

During the 2001 legislative session, $1 million was allocated to the Pecos River Ecosystem Project by the State of Texas. Eight percent of these funds were used for project administration and monitoring with the remaining 92% used for saltcedar treatments in 2001 and 2002. Third year (2001) applications treated approximately 57 river miles or 1440 acres of saltcedar at a cost of $263,000. Estimates indicate 11,102 acre-feet of water salvage per year from the 2001 applications. From 1999 through 2001, 2774 acres of saltcedar were treated at a total cost of $515,635. This acreage treated will potentially release an estimated 21, 386 acre-ft. of water per year at a cost of $7.90 - $8.22 /acre-ft., assuming a mere 3 year treatment life (Tables 2 and 3).

Fourth year applications were completed in September 2002. Approximately 3567 acres were treated including segments of the river between Red Bluff and Grandfalls, TX that were not sprayed during the previous years, from the New Mexico/Texas state line to Red Bluff Lake (including areas around the lake) and 5 miles of Salt Creek from the convergence with the Pecos to the bridge over highway 285. Estimated annual water salvage from this treated acreage is 27,501 acre-ft.

To summarize, from 1999 through 2002, 128 miles of saltcedar along the Pecos River and its tributaries in Texas (6341 acres of saltcedar) have been treated resulting in an estimated 36,743 acre-ft. of water salvaged through 2002. An additional 48,887 acre-ft of water salvage is estimated for 2003 for a total cumulative water salvage estimate of 85,630 acre-ft through five years of the project. Projected water salvage and costs are presented in Tables 2 and 3. Average percent mortality of saltcedar from aerial applications is 90 to 95%. Debris removal and follow-up management continues to be a priority to complete the project. The project directors are currently trying to secure funding to begin this second phase of the project.

Additional information on the project can be obtained from the Internet at the following web site:

http://farwest.tamu.edu/rangemgt/prep.html

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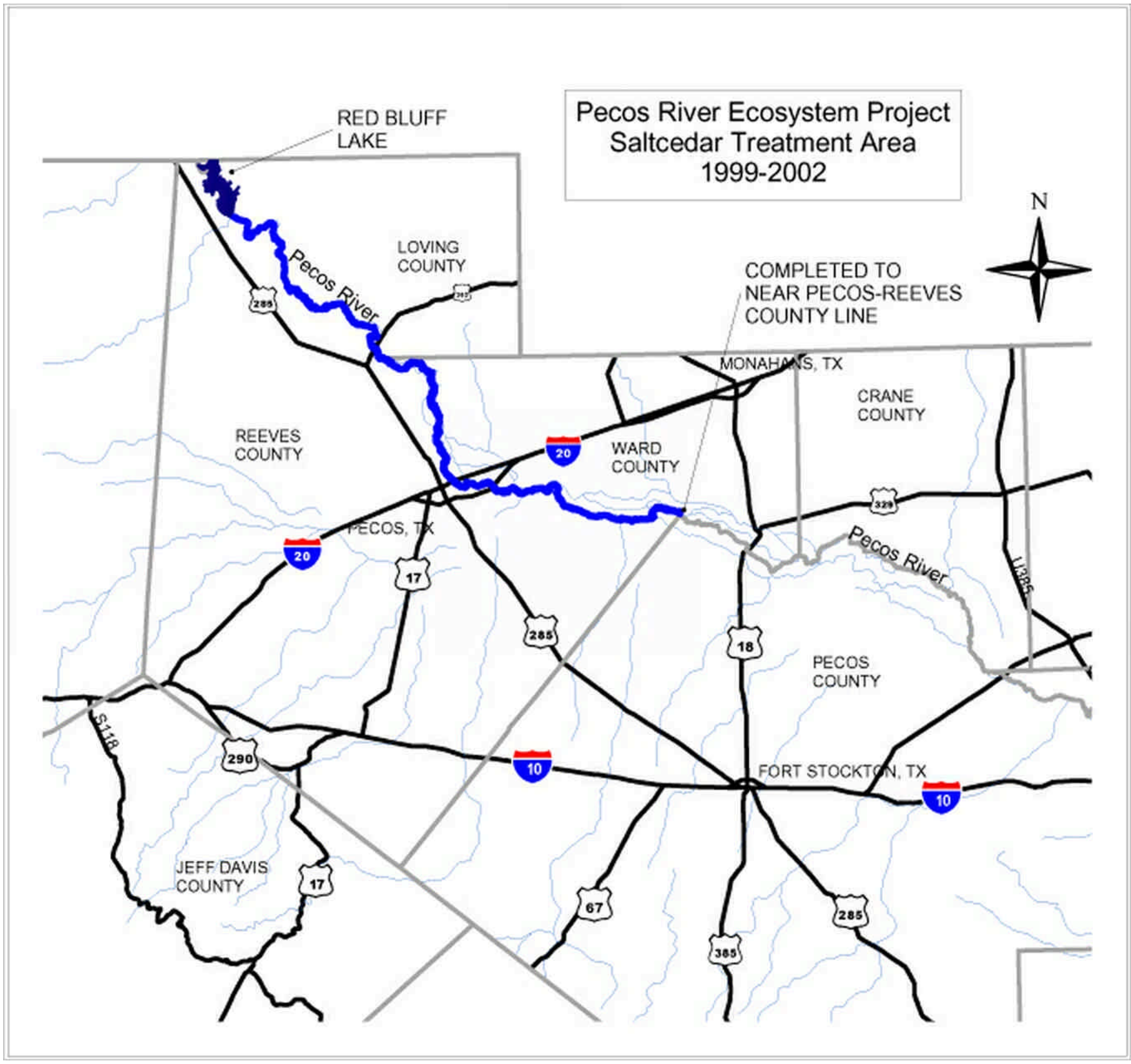
Texas Water Resources Institute
make every drop count

Table 1. Saltcedar acreage treated on the Pecos River Ecosystem Project as measured with GPS log files from helicopter.

Area Treated	Year Treated	Acres Treated	Total Acres	River Miles	Acres/Mile
Red Bluff Lake	2001	22			
	2002	1137			
	Total		**1159**		
Salt Creek	2002	151			
	Total		**151**	**5**	**30.3**
Red Bluff to Mentone	1999	658			
	2000	47			
	2001	240			
	2002	1031			
	Total		**1975**	**40**	**49.4**
Mentone to Barstow	2000	527			
	2002	432			
	Total		**959**	**26**	**36.9**
Barstow to I-20	2000	102			
	2001	301			
	2002	224			
	Total		**628**	**20**	**31.4**
I-20 to Grandfalls	2001	876			
	2002	592			
	Total		**1468**	**37**	**39.7**
Grand Total	1999	658			
	2000	676			
	2001	1440			
	2002	3567			
	Total		**6341**	**128**	**49.5**



Map showing general area of saltcedar treatments along the Pecos River in Texas from 1999-2002. Treatments were completed from the state line north of Red Bluff Lake to the Pecos-Reeves County line.

Table 2. Estimated potential water salvage (acre-feet) from control of saltcedar along the Pecos River in Texas from treatments applied in 1999 through 2002.

Year Treated	Acres Treated	2000 Water Salvage	2001 Water Salvage	2002 Water Salvage	2003† Water Salvage
1999	658	5073	5073	5073	5073
2000	676		5211	5211	5211
2001	1440			11,102	11,102
2002	3567				27,501
Total Annual	**6341**	**5073**	**10,284**	**21,386**	**48,887**
Cumulative		**5073**	**15,357**	**36,743**	**85,630**

**** Estimated water salvage (ac-ft) based on a preliminary estimate of 7.71 ac-ft/acre of saltcedar treated; data from 2001 water monitoring wells along the river. †Projected**

Table 3. Estimated cost of water salvage** from the Pecos River Ecosystem Project, 1999-2002 Treatments.

Year Treated	Acres Treated	Total Treatment Cost	Estimated Annual Water Salvage	Cost/ac-ft. salvaged - 1 year return	Cost/ac-ft. salvaged - 2 year return	Cost/ac-ft. salvaged - 3 year return	Cost/ac-ft. salvaged - 4 year return
1999	658	$125,020	5,073 ac-ft.	24.64	12.32	8.21	6.16
2000	676	$128,535	5,211 ac-ft.	24.66	12.33	8.22	6.16
2001	1440	$263,000	11,102 ac-ft.	23.69	11.84	7.90	5.92
2002	3567	$660,000	27,501 ac-ft.	24.00	12.00	8.00	6.00
Totals	**6341**	**$1,176,555**					
Avg.				**24.25**	**12.12**	**8.08**	**6.06**

** Estimated water salvage based on a current estimate of 7.71 ac-ft/acre of saltcedar treated; data from 2001 water monitoring wells along the river.
* Cost/acre-ft. illustrated based on a 1 to 4 year return.

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2002

Pecos River Ecosystem Monitoring Project

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SUMMARY

The Pecos River Ecosystem Project is attempting to minimize the negative impacts of saltcedar on the river ecosystem, and improve the efficiency of water delivery and stream flow. The project is designed to decrease the number of saltcedar with aerial application of herbicide along the banks of the river. The project is concerned with the effect of saltcedar on both quality and quantity of the water of the Pecos River as a result of mortality of the plant from along the banks. Specifically, the study is monitoring water delivery efficiency and salinity of the river.

The effects of saltcedar on water quality are observed through a series of annual water samples taken along the river from Red Bluff Reservoir to Girvin, hourly electrical conductivity measurements at two sites, and comparison of this data to historical water quality data. Any change in water quantity is determined by comparing historical release/delivery schedules to current schedules from the Red Bluff Water and Power Control District.

OBJECTIVES

Saltcedar is the most widely and evenly distributed phreatophyte in Texas. Saltcedar was introduced to the United States in the early 1800's and in 1925 saltcedar was planted to improve streambank stabilization. Since its introduction, saltcedar has dominated native vegetation and developed into a monoculture along riverbanks. Saltcedar has enormous impacts on river ecosystems including increased salinity of the soil and water, increased flooding from increased sedimentation and decreased channel width, and increased water loss due to high evapotranspiration rates. The specific objectives of this project are to determine the effects of saltcedar removal on water quality and quantity in the Pecos River.

MATERIALS AND METHODS

<u>Water quality</u>

Salinity of river water is measured from water samples taken annually at ten locations from the Red Bluff Reservoir to Girvin (Figure 1). Total Dissolved Solids (TDS) and Total Suspended Solids was measured for each sample taken in 1999-2001. The procedures involved with determining TDS and TSS are described.

> TDS analysis starts with washing the filter disk with 500 ml of reagent-grade water. This is accomplished by placing the filter disk into a filtration apparatus attached to a vacuum. The 500 ml of water is gradually added as the vacuum is applied and suction is continued until all traces of water

are removed. The filter is then transferred to a heat cleaned dish and placed in a drying oven at 180˚C for 24 hours. The filter is cooled in a desiccator and the oven dry weight recorded. The filter is stored in desiccator until needed. The next step is to filter the water sample. The cleaned and dried filter is again placed in the filtration apparatus. A 500 ml sample is then poured gradually onto the filter as the vacuum is applied. Reagent-grade water is then used to rinse the inside of the filtration apparatus to insure all of the sample has gone through the filter. The filtrate is then poured into a 100 ml flask and then transferred into heat cleaned 125 ml flask, for which the weight has ben recorded and placed in a desiccator until needed. A duplicate for each of the ten water samples taken was also prepared, as well as a control using filtered reagent-grade water. The flask is then placed in the drying oven at 100˚C until the filtrate is completely evaporated. Then the flask is dried for an additional 24 hours at 180˚C. The flask is cooled in the desiccator and then weighted. The difference between the original weight and the weight after drying of the flask multiplied by two gives the TDS (g/l) of the water sample.

Total Suspended Solids is determined from the before and after weight of the filter disk following filtration. After filtration, the filter is placed back into the dish and dried in the oven for 24 hours at 103˚ - 105˚C. A filter used in reagent grade water TDS analysis served as a control. The difference between the original weight and the weight after filtration and drying multiplied by ten results in the TSS (g/l) of the water sample.

Electrical conductivity was measured with a conductivity meter from water samples taken in 1999-2002. An unfiltered sample of water in placed in a 50 ml beaker. The conductivity meter is placed in the sample up to the maximum immersion level without touching the bottom of the beaker. The meter is gently stirred around in the solution and then read from the conductivity from the meter when it stabilizes. The reading is in µS/cm. This reading can then be converted to parts per million (ppm) by dividing the reading in µS/cm by 1000 converting it to dS/m. The number is then multiplied by 640 making the number equivalent to ppm. A control using reagent-water was also performed here.

Additionally, electrical conductivity measurements were made at two sites near Mentone, Texas with continuous monitoring loggers placed in the river. Measurements are taken each second and an hourly average (µS/cm) recorded. The loggers were placed in PVC pipe secured to the bottom of the river. Logging began in February 2001 and continued through November 2002. Sensors will be placed in the river again during early 2003.

Water quantity

Water quantity is monitored through release and delivery data from Red Bluff Water and Power Control District. Water released from Red Bluff Reservoir and delivered to seven local irrigation districts along the Pecos River is recorded daily. Release and delivery data is obtained from weirs located at point of release from Red Bluff Lake and at each irrigation turnout point on the river. Historical release and delivery data have also been provided by the Red Bluff Water and Power Control District, with pre-treatment averaged from 1988 through 1999. Flow data is obtained from United States Geological Survey (USGS) Gauging Station 13257 located at Girvin. This gauging station is the southern end of the Red Bluff Water and Power Control District boundary. Water released from Red Bluff Reservoir that is not delivered to upper districts is captured at Imperial Reservoir, located upstream from the USGS gauging station.

RESULTS AND DISCUSSION

Water quality

Water quality data, both TDS and TSS, was determined from samples that were obtained in 1999 through 2001. Electrical conductivity was measured in August 1999-2002 (Table 1). A map showing the area and location of the ten water sampling sites is given (Figure 1). August samples are presented graphically in Figure 2.

Electrical conductivity (salinity) of Pecos River water nearly doubled from 7,300 µS/cm at Red Bluff Lake Dam to 15,460 µS/cm at Girvin, Texas during pre-treatment samples taken in August 1999. Samples taken during August 2000 indicate salinity levels were still increasing down river, but not to the extent of pre-treatment levels. By the August 2001 sampling date, approximately 60 river miles of the Pecos River had been chemically treated for saltcedar control. During this sampling period, similar down river increases were not seen, but salinity levels were higher at Red Bluff Dam. This can be attributed to lower lake levels during the 2001 irrigation season. Samples taken during the 2002 growing season show a high variability among sites. This is due to the fact that no irrigation water was released from Red Bluff during the 2002 growing season. Changes in salinity, then, were influenced by natural inputs into the river at various locations.

Table 1. Electroconductivity (µS/cm) of Pecos River water measured at ten sample sites from 1999-2002.

Sample Site #	1999	2000	2001	2002
1 (Red Bluff)	7300	9610	11820	27550
2	8280	9580	11930	27815
3		6520	12150	17835
4	6890	9650	5080	15210
5	7320	9770	12080	18470
6	10040	12060	14150	1730
7	10250	11080	13230	3035
8	11460	11450	13740	14490
9	12650	11870	14990	13335
10 (Girvin)	15460	16770	11960	12565

Electrical conductivity measurements were also recorded hourly from two sites near Mentone, Texas during 2001 and 2002. Corresponding measurements of river level are taken to explain sudden drops in salinity after rain events swell the river and dilute the salts. Figures 3 through 6 show hourly electrical conductivity and river levels for the two sites during 2001 and 2002. It should be noted that Red Bluff was releasing during 2001 growing season but did not release irrigation water during the entire 2002 growing season. Salinity levels during 2001 were fairly constant with slight increases as releases came down river. The later part of 2002 showed sudden drops and increases in salinity that correspond to rain events or small releases from Red Bluff Lake. This erratic nature helps explain the large fluctuations in the August sampling period during 2002 (Figure 2).

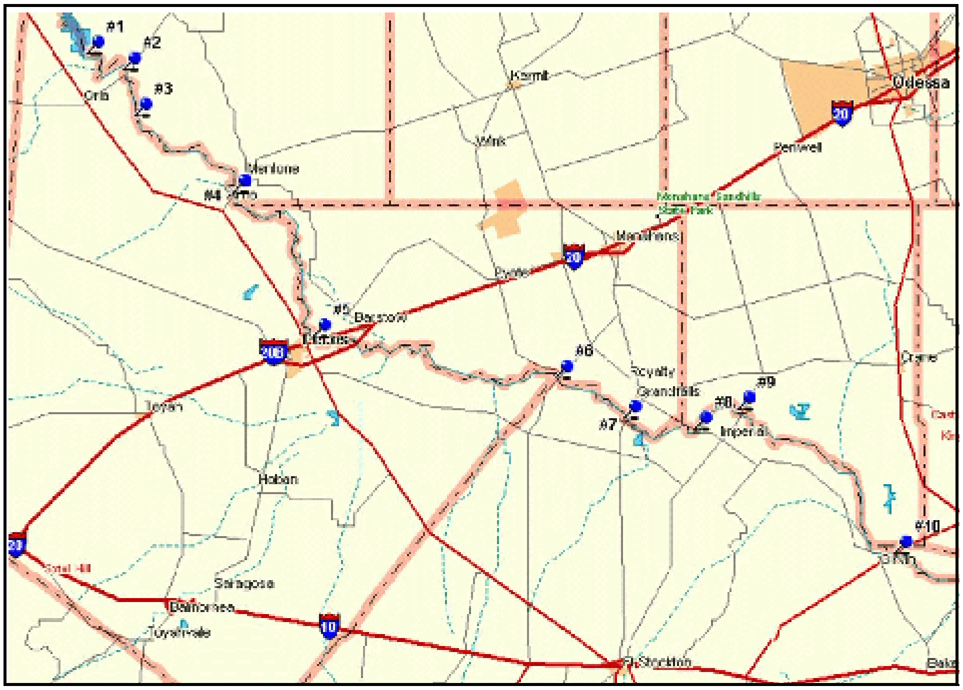

Figure 1. Water sampling sites along the Pecos River.

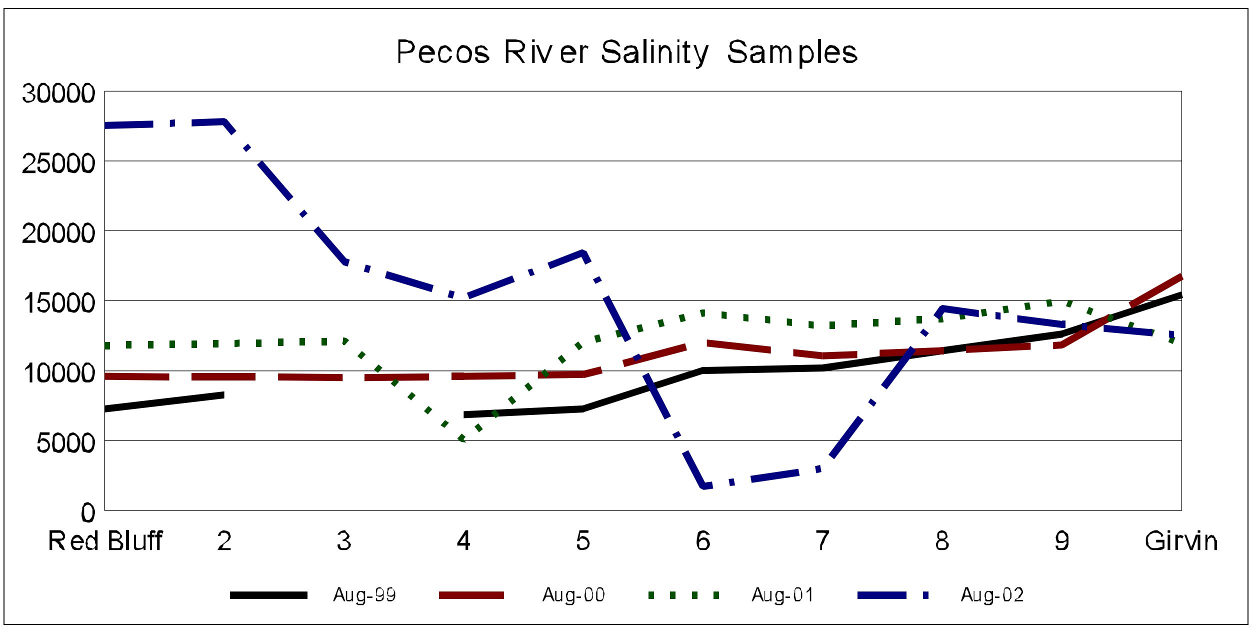

Figure 2. Electrical conductivity (µS/cm) of Pecos River water and 10 sites from Red Bluff Lake to Girvin, Texas sampled annually from 1999-2002.

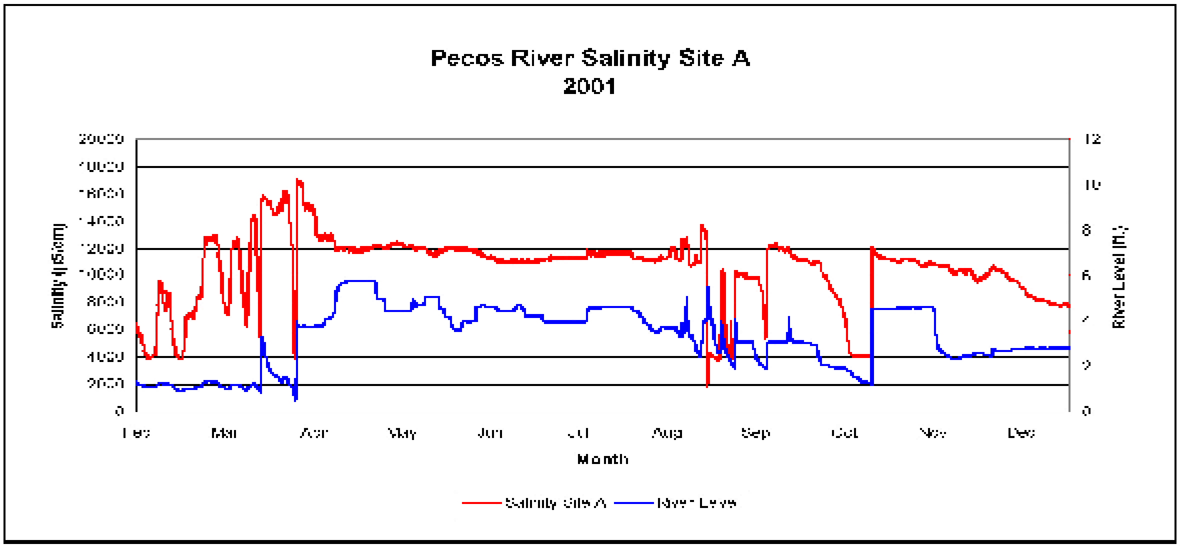

Figure 3. Electrical conductivity (µS/cm) of Pecos River water and river level (ft.) for Site A during February through December 2001.

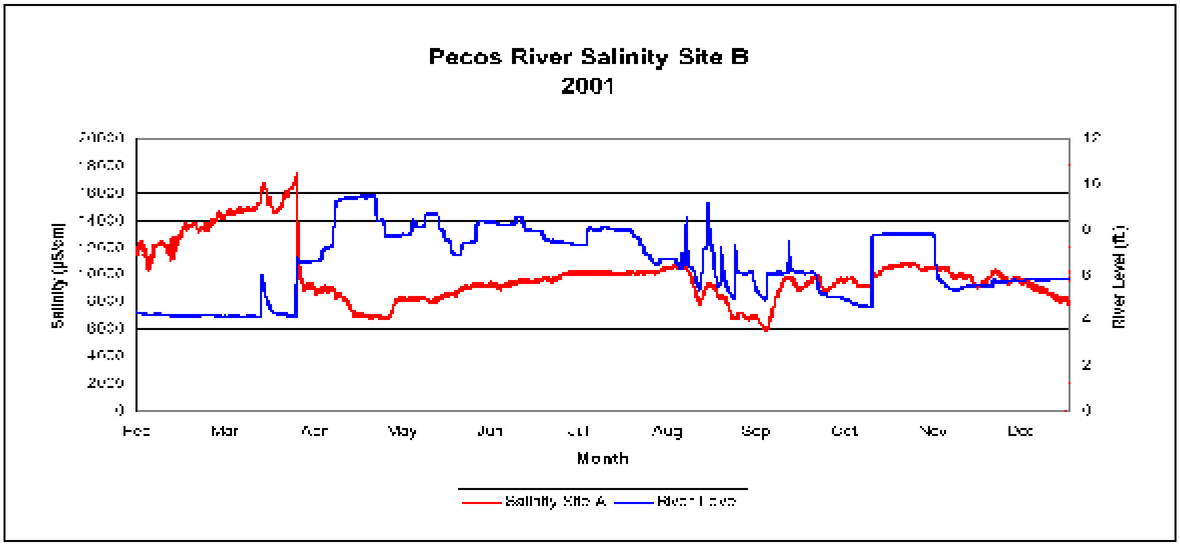

Figure 4. Electrical conductivity (µS/cm) of Pecos River water and river level (ft.) for Site B during February through December 2001.

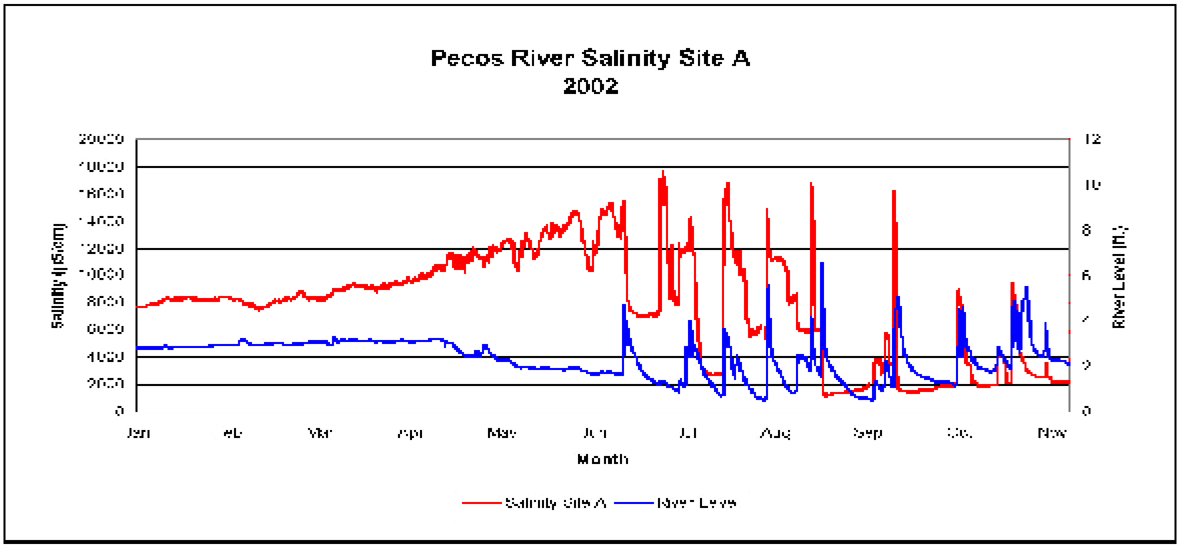

Figure 5. Electrical conductivity (µS/cm) of Pecos River water and river level (ft.) for Site A during January through November 2002.

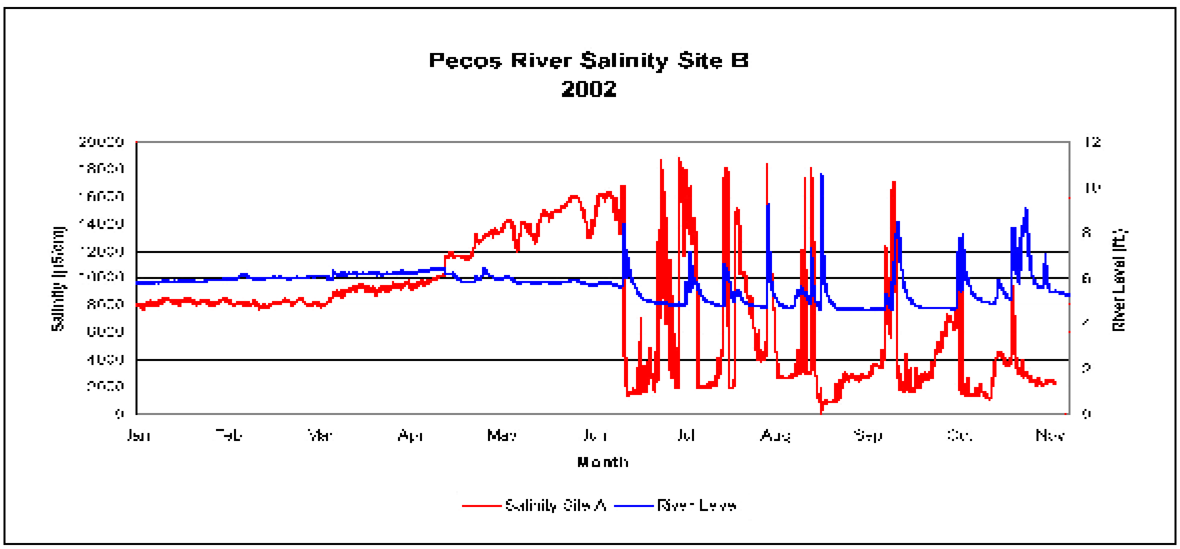

Figure 6. Electrical conductivity (µS/cm) of Pecos River water and river level (ft.) for Site B during January through November 2002.

Water Quantity
The first step taken was to determine if a relationship existed between water released at Red Bluff Lake and the amount of flow measured at Girvin. A coefficient of determination was performed on flow (ac-ft) measured at Girvin and the volume of water (ac-ft) released from Red Bluff Reservoir, where $r^2 = 0.15$ ($p<0.05$). The low correlation provides evidence that release from Red Bluff Reservoir is not related to flow through the USGA station at Girvin.

Once it was determined that loss occurring from release and delivery were not related to Girvin, release and delivery data were analyzed and the Girvin data was not utilized in the analysis. It was observed that during certain time periods within a delivery year, percent loss changes considerably. This pattern precipitated dividing the irrigation delivery year into three categories, first month of release and delivery, release and delivery during the growing season and release and delivery during late season. First month releases during this time period did not occur during the same month each year but varied between March and April. Delivery months were then numbered consecutively from the first month of release each year. The three categories allowed for a characterization of when changes in percent loss occurred during the delivery year.

A monthly average was calculated for each of the three delivery categories (Table 2, Figures 7-9). The first month of release (7,862 ac-ft) with a delivery of 2,927 ac-ft resulted in an average percent loss of 68%. Monthly releases increased during the growing season to an average of 11,015 ac-ft, but losses decreased to 39%. Average release for late season showed to be the lowest, 3,534 ac-ft, and had a loss of 43%. It is obvious that much of the release during the first month is used to "re-charge" the perched aquifer that was naturally "drained" during the non-irrigation winter months. This first month can account for a significant amount of the water lost during the irrigation delivery year (Figure 7).

Table 2. Average monthly release, delivery and percent loss for three release and delivery periods for the Pecos River from 1988-1999.

	Average Monthly		
Delivery Period	**Release**	**Delivery**	**Percent Loss**
First Month	7,862	2,927	68%
Growing Season	11,105	6,648	39%
Late Season	3,534	2,074	43%

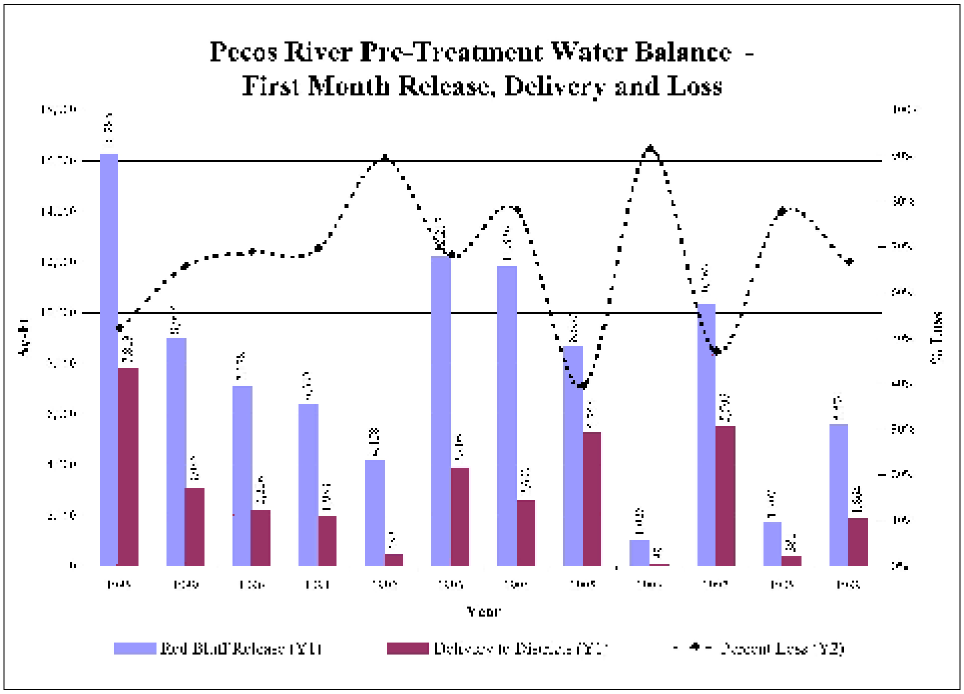

Figure 7. Release and delivery of water from Red Bluff Lake to Irrigation Districts with percent of water lost during the first delivery month for 1988 through 1999.

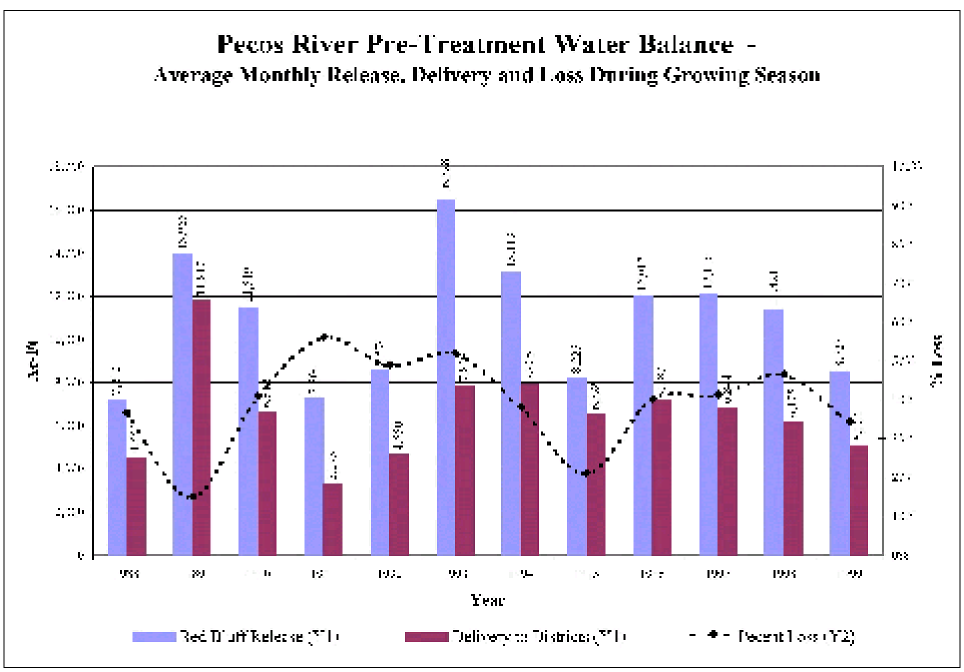

Figure 8. Average monthly release and delivery of water from Red Bluff Lake to Irrigation Districts with percent of water lost during growing season months for 1988 through 1999.

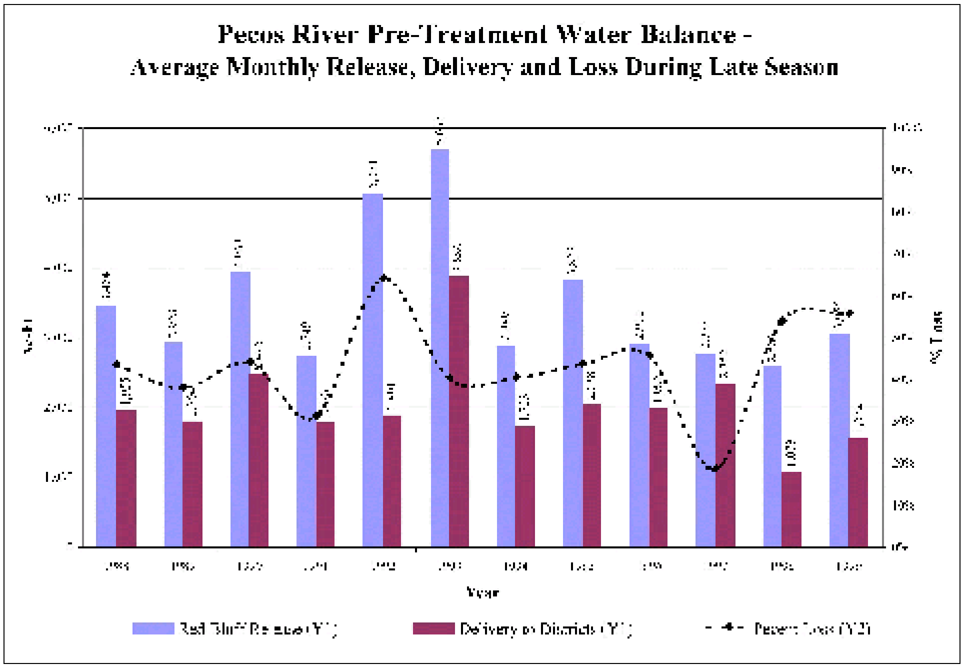

Figure 9. Average monthly release and delivery of water from Red Bluff Lake to Irrigation Districts with percent of water lost during late season months for 1988 through 1999.

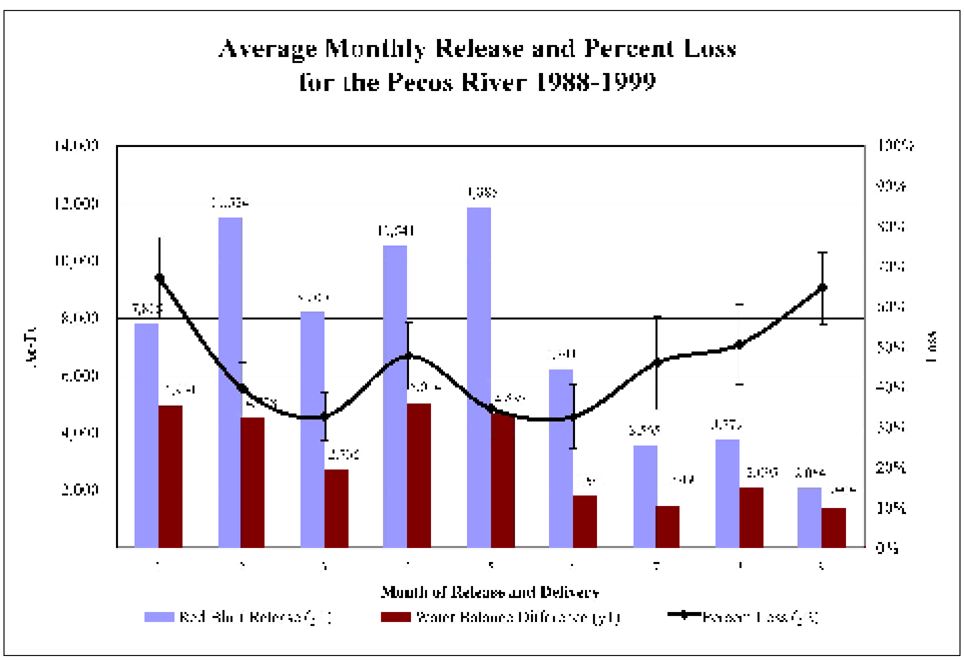

Figure 10. Average monthly release, delivery and percent loss of Pecos River irrigation water during consecutive delivery months from 1988 through 1999. Lines vertical to percent loss for each month is the standard deviation from the mean.

An average pattern of release and percent loss was also determined for each month from 1988 through 1999 during the period of a delivery year (Figure 10). The highest average loss occurred during the first month (67%) of release. Percent loss decreased during the second month of release, and for the next five months of release the loss ranged from 32% to 47%. However, when the amount of water released begins to decrease in month seven, the percent loss begins to increase (46%) and by month nine, the loss increased to 64%.

Ultimately, this release and delivery data from pre-treatment years will be compared to post-treatment years to determine if control of saltcedar increases the delivery efficiency thereby decreasing the loss of water during the irrigation period. While the project is on-going, only two years delivery data post-treatment (2000-2001) is available for comparison. Only a small portion of the Red Bluff District had been treated during those delivery years. During the 2002 delivery season, no water was released from Red Bluff Lake for delivery to irrigation districts. It is uncertain if deliveries will be made in 2003 at this time. As irrigation delivery resumes, comparisons of pre-treatment to post-treatment will be made.

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