Canal Seepage Reduction Demonstration

Using Polyacrylamides in the Ditch and Water

Arkansas River Valley of Colorado

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Abstract

"Salty" describes the Arkansas River in southeast Colorado as salt levels reach 4,000 ppm total dissolved solids. Limited water, limited duration of high flow and numerous drainage systems allowed farmers to irrigate with this water since 1890.

Now two reservoirs restrict snow pack flow from flushing the river and allow water use year-around causing excessive seepage from ditches. 20-30,000 acres of cropland have been lost or yields severely reduced by seepage and high water tables.

PAM, a linear-linked polyacrylamide, was added to "muddy" water causing the sediment to "line" the dirt lateral. Seepage loss was 0.76 gpm/foot of ditch in 1998 before treatment. Four 10-pound applications of PAM in 1998, again in 1999 and one 10-pound application in 2000 reduced seepage loss to 0.01 gpm/foot of ditch.

Key Words: "Salty", seepage, high water tables, PAM

I. SITUATION

The Arkansas River in southeast Colorado is one of the most saline rivers in the United States. The average salinity levels of the canal systems along the river increase from 300 ppm total dissolved solids (TDS) near Pueblo to over 4,000 ppm between Lamar and the Colorado-Kansas border. In fact, more than 200,000 acres along the river are irrigated with Class C4 water, the highest classification for salinity hazard. However, farmers have been irrigating with this water since the late 1800's because of the limited amounts of water available throughout the year, because of the limited duration of high flow and because of the many drainage ditches throughout the area.

In 1948 and 1974, John Martin and Pueblo Reservoirs were built and then, in the 1980's, water users in the Valley initiated a winter water storage program. Now, rather than water being available mostly during the snowpack runoff, water is available year-around as the water is stored and then released as requested by the different canal companies. This allows the users to make more effective use of the water, which substantially increases crop yield. However; the increased duration of water in these dirt canals and ditches caused many of them to begin seeping and these seeps came out in many of the cropping areas. Also, controlled release slowed the flow of the River allowing increased sedimentation of the river channel and, this combination of changes, resulted in raised water tables. These shallow water tables increased the concentration of salts on or near the land surface due to capillary action.

II. OBJECTIVES

The object of this project is to demonstrate the effect of soil and water applied polyacrylamides on seepage from a dirt ditch lateral delivering water to area farms. PAM, a linear-linked polymer, and HYDROGEL, a cross-linked polymer, are being used to determine their effect, if any, on reducing seepage from a dirt lateral.

III. METHODS

Three measuring stations were located at selected sites along the Suburban Lateral of the Catlin Canal, Figure 1, to determine the amounts of water flowing. Because of the changing profile as the dirt ditch banks eroded during 1998 irrigation season, calculation of the velocity was more difficult than on the stable profile of the concrete at Station #2. As a result, in the winter of 1998-99, Station #1 and #3 were replaced with concrete structures.

Cross section areas of each station were measured and velocities of flow were determined using a Marsh-McBirney FLO-MATE Model 2000 Portable Water Flowmeter. By calculating the difference in flow between the three measuring stations, approximate seepage losses could be shown.

HYDROGEL, a cross-linked polymer, can absorb up to 250 times its own weight in water and was used to coat a portion of the lateral ditch before the irrigation season. HYDROGEL was applied at a rate of 0.013 pounds per square foot on the bottom and the sides of the lower 225 feet of the ditch in 1998 only. This amount of material seemed to give good uniform coverage. The HYDROGEL was blown on the perimeter of the ditch using a wall coating applicator prior to water being turned into the ditch. HYDROGEL was applied only once prior to running water in 1998. HYDROGEL was not applied in 1999 or 2000.

PAM, the linear-linked polymer, is being used as a soil stabilizer in furrow irrigation to reduce erosion and increase infiltration but PAM is also a flocculent that causes the suspended soil particles in water to be attracted to each other and settle out, clearing the water, Figure 3. Using PAM as a flocculent is being studied as a means of sealing the ditch. PAM was applied during the later part of the irrigation season.

In 1998, PAM was applied on August 13, August 20, September 1 and October 22. Five (5) pounds was applied at the rate of 1 lb/min, then one hour later a second application of 5 pounds at 1 lb/min.

In 1999, PAM was applied on July 1, July 12, August 31 and October 22 using the same amounts and rates as 1998.

In 2000, because of the already low seepage losses, PAM was only applied once on July 20 again using 5 pounds at1 lb/min, then one hour later, a second application of 5 pounds at 1 lb/min.

The PAM was applied using a funnel with a control petcock that had been timed to apply the above mentioned rates, Figure 2.

Velocities were taken at each of the three measuring stations at different times before and after the PAM application. These measurements were taken at one foot intervals across the ditch at the three sites and at various depths using the 0.2, 0.4 and 0.8 of Depth Profiling Method for Rectangular Channels.

Calculations were made as follows:

1. Measure depth of flow.
2. Calculate the positions on the center line of the interval by:
   - 0.2 x depth
   - 0.4 x depth
   - 0.8 x depth
   - (In manmade channels, measure the 0.2, 0.4 and 0.8 positions from the bottom)
3. At the 0.2, 0.4 and 0.8 positions, measure and record the velocities.

4. Average 0.2 and 0.8 velocities.
5. Average the 0.4 velocity with the 0.2 and 0.8 average for the average Velocity (AV).
6. Calculate segment areas.
7. Calculate the flow, $Q_{1....6/8}$ of each segment by: Segment Area x AV.
8. Sum the flow of the segments for total flow, Q.

Also to determine the effect of seepage on the water level in the field, observation wells were drilled and cased to a depth of four feet at six locations in February 1998.

Sediment levels were determined using tables developed by the USDA-ARS at the Snake River Conservation Research Center in Kimberly, Idaho. These tables were taken from a paper entitled, "Applying Imhoff Cones to Estimate Sediment Concentrations in Runoff Water" by D.L. Carter and R.D. Berg using the 30-minute settling time.

IV. RESULTS AND DISCUSSION

Observation Wells

Salinity in the field was the main reason for doing this demonstration and, as expected, salinity levels in the shallow observation wells were far above the threshold of 2,000 ppm Total Dissolved Solids (TDS) where crop yields are affected. Salinity, as TDS, ranged up to 5,000 ppm in 1998, up to 6,800 ppm in 1999 and lowered to 1,500 ppm in 2000 because of the substantial reduction in seepage from the lateral.

The water levels in the three observation wells 125 feet down slope of the Suburban lateral were significantly affected by the addition of PAM to flowing water and by the excessive amounts of sediment in the lateral during 1999 and 2000.

At the beginning of the demonstration in 1998, all of the observation wells had about 1.0 to 1.4 feet of water. No effect was seen on the observation well in the area treated with Hydrogel. However, after the addition of PAM, the two wells in the treated area dropped to zero (0) and remained empty until an irrigation event. The water level in the untreated remained constant during the remainder of the season at about 1.0 feet, Figure 4.

Then, at the beginning of the 1999 season, all wells were zero until about April 5 when the area was preplant irrigated. The water level in the untreated observation well increased to 4 feet while the water levels in the treated areas only rose 1.25 to 2.1 feet. Between irrigation events, the water levels in the treated areas returned to zero (0) while the water levels in the untreated areas contained some water, Figure 5. Note that after the late April and early May flooding, the water level in the untreated observation well dropped. It is the authors' opinion that the heavy sediment loads in the water partially sealed the untreated area.

In 2000, the water level in all the observation wells remained near zero (0) except during an irrigation event, Figure 6. Water levels varied only slightly during the season even though flow rates in the lateral were similar to 1998 and 1999. Even with the many irrigations on onions and watermelons, water levels in the observation wells in the treated areas stayed very shallow in 2001. Corn was grown on the area of the untreated observation well, which allowed low water levels because of limited irrigation.

Flow and Seepage Loss in Suburban Lateral

Each year of the demonstration, flow tests were conducted and seepage loss for each section of the lateral was determined before the application of PAM into the ditch water. These determinations should indicate the carry-over effect of the sediment sealing from adding PAM combined with sediment sealing due to natural causes.

Flow tests were then taken again between each application of PAM to determine the effect, if any, of adding PAM to the water flowing in the lateral. The initial test in 1998 gave a base determination of seepage loss in each section of the lateral. Tests conducted after the base determination should indicate the effect of each application of PAM on seepage loss. The first flow test in 1999 and 2000 should indicate the carry-over sealing effect of these applications from the end of one irrigation season to the beginning of the next irrigation season.

On August 12, prior to the application of PAM, seepage loss in gallons per minute per foot of ditch (gpm/ft Ditch) was 0.65 between Station #1 and #2, the check or untreated section, and 0.76 between Station #2 and #3, the section to be treated with PAM. Lateral flow was 6-8,000 gallons per minute.

After the application of PAM on August 13, seepage loss between Station #1 and #2 stayed the same at 0.63 gpm/ft Ditch while the seepage loss between Station #2 and #3 dropped to 0.36 gpm/ft Ditch. Lateral flow was 6-8,000 gallons per minute. The seepage loss from Station #1 to #2 stayed at 0.63 gpm/ft Ditch while loss dropped to 0.10 between #3 and #4 with a flow of 4-6,000 gpm on September 2. Lower flows in October of about 3,000 gpm produced lower losses but still the treated area was 0.06 gpm/ft Ditch compared to 0.25 on the untreated ditch area. This reduced loss on the lower flows indicates that seepage was greater on the vertical sides of the lateral than in the bottom of the lateral.

A flood in May 1999 produced heavy amounts of sediment and some natural sealing of the lateral took place. At the first testing on June 30, the lateral from Station #1 and Station #2 showed a seepage loss of 0.44 gpm/ft Ditch, which was about 30% lower that the seepage losses in 1998. This would indicate some natural sealing of the lateral by the heavy sediment load of up to 3.5 tons per acre-foot in the water from flooding. The seepage loss from Station #2 to Station #3 was calculated at 0.07 gpm/ ft Ditch, which would indicate that the PAM treatments from the previous year along with the excessive amounts of sediment in the water from flooding substantially reduced seepage. This was also reflected in the lack of water in the treated area observation wells. Seepage loss remained low on the PAM treated portion of the lateral during testing in the later part of the season. Seepage loss was 0.41 gpm/ft Ditch on the untreated section of the ditch between Station #1 and Station #2 and 0.07 gpm/ft Ditch on the PAM treated section of the ditch between Station #2 and Station #3. Still, after the PAM treatment of 10 pounds on October 26, the seepage loss between Station #2 and Station #3 dropped 71% to 0.02 gpm/ft Ditch.

Just prior to the velocity tests on July 19, 2000, heavy rains increased the sediment load in the Suburban Lateral to 15.0 tons per acre-foot. As a result, seepage losses were lower on the untreated section than in the two previous years measuring 0.16 gpm/ft Ditch. Still, treated sections of the ditch showed the carryover effects of the sealing from 1999 as seepage loss was only 0.04 gpm/ft Ditch, 75% lower than the untreated section of the ditch.

Adding two-5 pound amounts of PAM on July 27 reduced the seepage loss even more, 0.01 compared to 0.13 gpm/ft Ditch, a reduction of 92.3% on the treated sections of the ditch.

Sediment Amounts Deposited

Sediment amounts deposited in the lateral during the PAM application was 16.6 pounds in 1998, 11.0 pounds in 1999 and 21.2 pounds in 2000 for a total of 48.8 pounds of sediment per linear foot of ditch. Assuming an average width of 7 feet, sediment deposited during the PAM applications for the three-year period would equal 7.0 pounds per square foot of ditch. This amount plus the amount deposited during periods of heavy sediment load in the lateral was responsible for substantially reducing seepage loss from the lateral.

IV. CONCLUSIONS AND COMMENTS

The results of the demonstration show that the addition of PAM to the flowing water in a dirt ditch lateral did reduce the amount of seepage loss in 1998, 1999 and 2000. The seepage loss was reduced as much as 84.1% in 1998 with four applications of 10 pounds of PAM. As much as 6,813 pounds of sediment per acre-foot of water or 12.8 pounds per linear foot of ditch was deposited in the area between the Drop Site and Station #3 during one application of PAM. The 450 feet of dirt lateral was partially sealed at a cost of $200, 40 pounds of PAM at $5 per pound, or $0.43 per foot of ditch.

Again, in 1999 as in 1998, four applications of 10 pounds of PAM were applied. The four applications reduced seepage loss as much as 95.1% in 1999. It is felt there was a residual seal on the lateral from the 1998 applications plus the heavy sediment laden waters after the May floods that contributed to this high reduction in seepage loss. As much as 3,875 pounds of sediment per acre-foot of water was deposited in the area between the Drop Site and Station #3 during one application of PAM. Again, the cost of the partial seal was $200 for the 460-foot section or $0.43 per foot of ditch.

In 2000, only one application of PAM was applied because the seepage loss had already been substantially reduced on the treated portion of the lateral. There was also a very marked reduction of the untreated section of the lateral as well indicating that there was natural sealing of the lateral from the excessive amounts of sediment in the flood waters in April and May of 1999 and July of 2000. Even though the seepage loss from the untreated section of the lateral was low, 0.13 gpm/ft of ditch, the seepage loss from the PAM treated section was 0.01 gpm/ft of ditch, 92.3% less with a flow rate of 6400+. Total cost for the 2000 season was $50 or $0.11 per foot.

Total cost of the PAM application over the three-year period, 1998-2000, was $450 or $0.97 per foot of treated dirt ditch lateral when using a cost for PAM of $5 per pound.

On October 18, 2000, when the flow rate dropped to 3400 + gpm, seepage loss on the untreated section of the lateral was 0.07 gpm/ft of ditch and, still, the seepage loss on the PAM treated section was 0.02 gpm/ft of ditch, 71.4% less. This indicates that the sediment seal created by the PAM application was still effective for reducing seepage. It also indicates that water loss due to seepage is much greater at higher flows than at lower flow and increased seepage is coming from the sides of the dirt ditch even though the bottom of the ditch is effectively sealed. Adding 48.8 pounds of sediment per linear foot or about 7.0 pounds of sediment per square foot, assuming an average ditch width of seven feet, did create a seal on the bottom of the ditch and partially on the sides. This amount of sediment should maintain the seal for a minimum of two years.

The high salinity levels in the 125-foot observation wells are part of the reason for this demonstration and show that high water tables, which are caused by ditch seepage at many locations, are contributing to the increased salinity levels. These high salinity levels at these shallow depths are reducing yields of crops and, especially deep-rooted crops, throughout the Arkansas River irrigated cropland in Colorado.

Figure1: Group at Station #3
Suburban Lateral of Catlin Canal

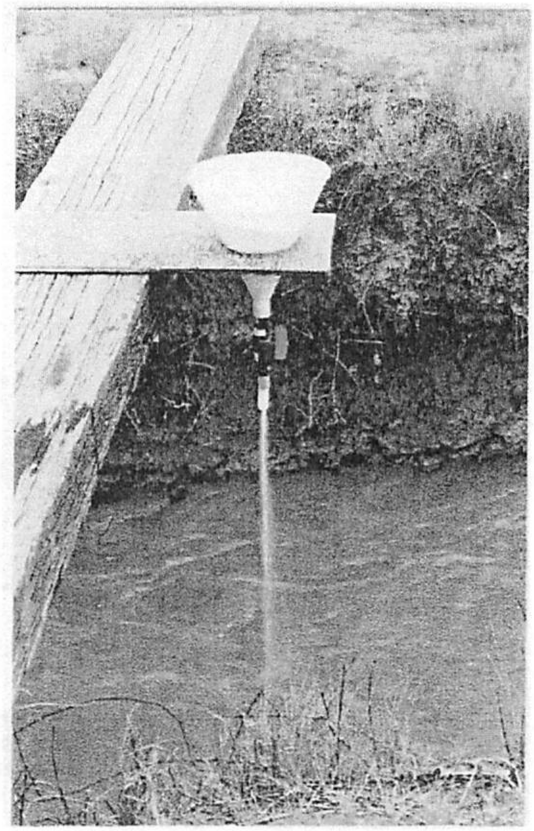

Figure 2: Applying PAM thru Funnel
on Suburban Lateral

Figure 3: Water Samples from Suburban Lateral
Untreated (3-1) and PAM Treated (3-2)

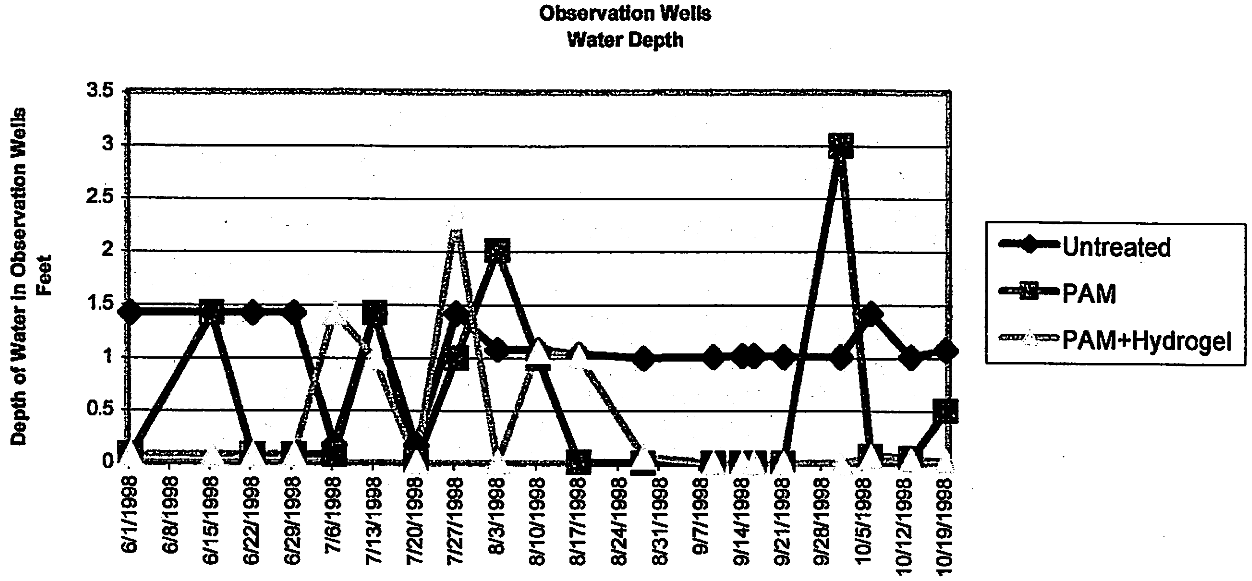

Figure 4. Canal Seepage Reduction Demonstration
Water Depths in Observation Wells
Located 125 Feet North of Dirt Lateral
Suburban Lateral - Catlin Canal - 1998

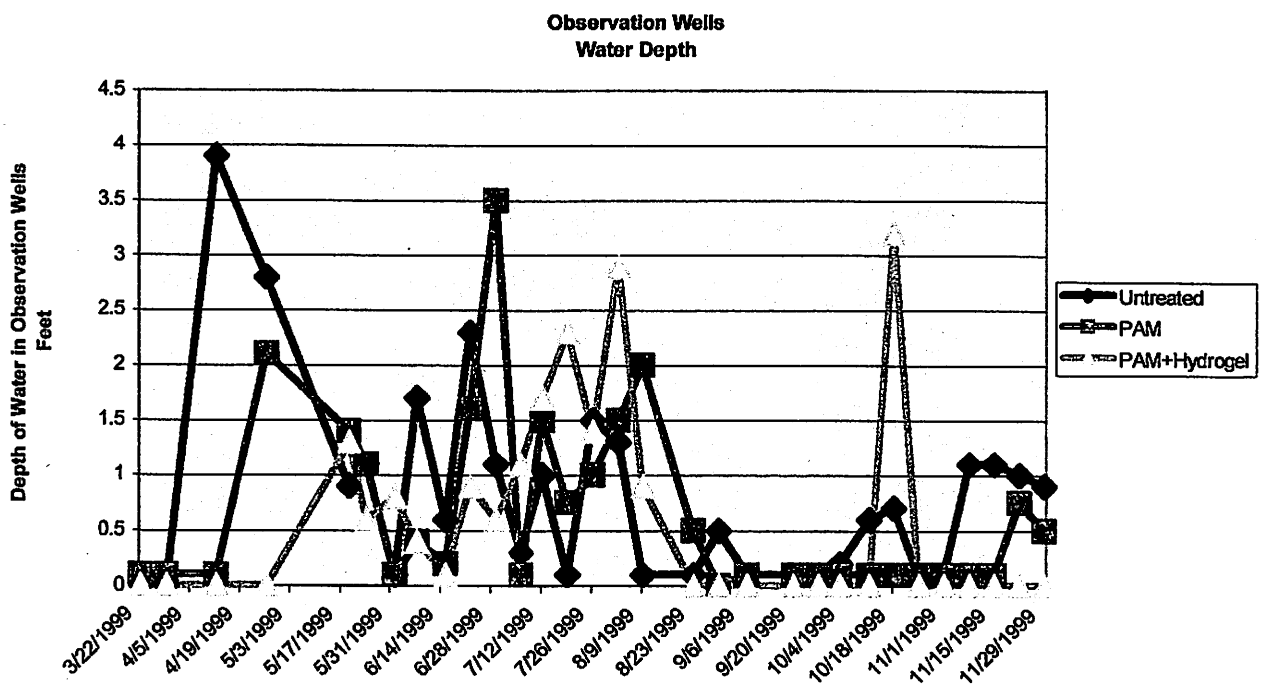

Figure 5. Canal Seepage Reduction Demonstration
Water Depths in Observation Wells
Located 125 Feet North of Dirt Lateral
Suburban Lateral Catlin - 1999

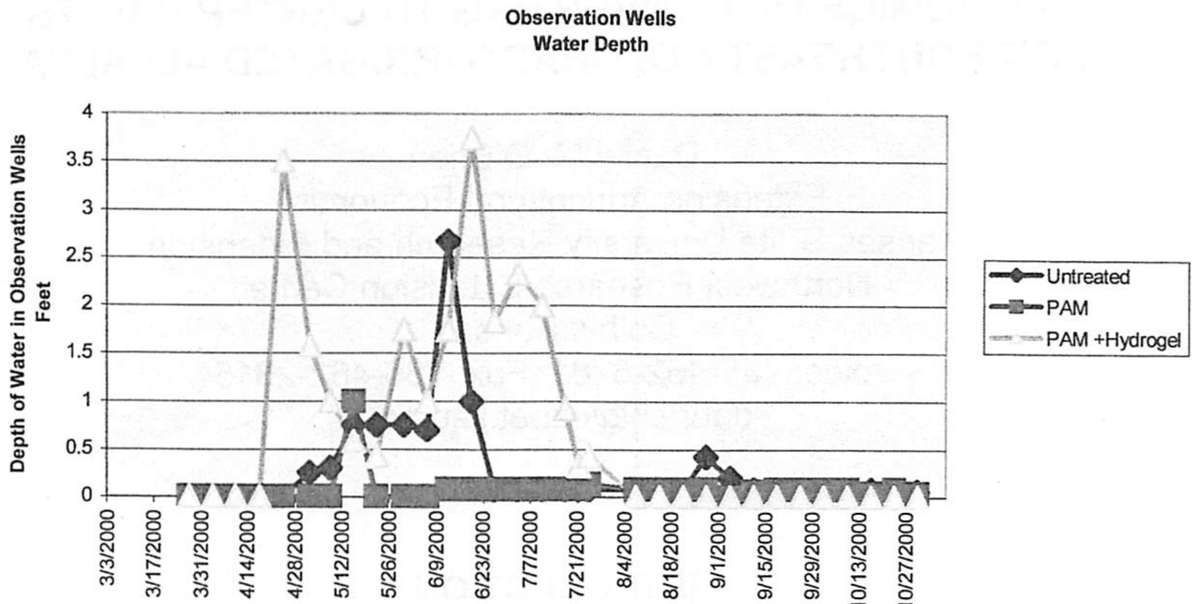

Figure 6. Canal Seepage Reduction Demonstration Water Depths in Observation Wells Located 125 Feet North of Dirt Lateral Suburban Lateral - Catlin Canal - 2000