Evaluation of Irrigation Smart Controller for Salinity Control

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Abstract

The purpose of this paper is to summarize the results of an investigation to determine whether Smart residential irrigation controllers with customized site specific programming, are an effective means of reducing irrigation water usage and the associated deep percolation in arid, salinity-rich soils. A joint effort between the Department of Agriculture (on-farm program) and Department of Interior (off-farm program) in reduce salt loading to the Colorado River has been underway for 25 years. Deep percolation has been quantified for agricultural land converted to residential sites in a previous two-year study. Four residential sites were monitored for a third year to evaluate the performance of Smart irrigation controller irrigating schedules. The results of the investigation provide Bureau of Reclamation and the Grand Valley community with information to support the implementation of best irrigation management practices to reduce ground water salinity loading.

Introduction

Deep percolation of irrigation water has been quantified for agricultural land use in a monitoring and evaluation study by the Natural Resources Conservation Service (NRCS) (U.S. Department of Agriculture, 1986-2003). The U.S. Geological Survey (USGS), in cooperation with the Colorado River Salinity Control Forum and the Mesa Conservation District, quantified the current (2005-2006) deep percolation characteristics of agricultural land that was converted to residential lots and estates, urban parks, and pasture grass fields in the Grand Valley. The two-year study for the years 2005-2006 found that both irrigation water use and deep percolation were lower for he residential lots and estates when compared with traditional surface irrigated fields in the NRCS study.

Purpose and Scope

The purpose of this report is to summarize the results of an investigation to determine whether Smart residential irrigation controllers, which use on-site weather data and customized site specific programming, are an effective means of reducing deep percolation and irrigation-water usage. This report contains the results of a year of data collection for 2007 that used Smart irrigation controllers, with a comparison to the traditional Clock type controllers that were used it the previous two-year study of residential sites in and near Grand Junction, Colorado.

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There are many models of Smart controllers on the market. In this study the Smartline SL 1600 irrigation controller with weather monitor was selected to represent Smart controllers.

The Smart controller determines the daily irrigation-water requirement by calculating a water-deficit using site-specific parameters. The study quantified amounts of irrigation-water use and deep percolation from the use of Smart controllers. The human factors associated with a change to this new type of controller were also evaluated, such as homeowner acceptance of the technology, the homeowner's perceived quality of the lawns during the study, and the success of the homeowners in utilizing the more complex features of the controller. The two-year study quantified irrigation water application and deep percolation for the traditional Clock type controller at each site. The goal of this study is to do the same with the Smart controller. Ideally, a direct comparison of the two types of irrigation controllers might be possible. The results of the investigation provide Reclamation, USGS, and the Grand Valley community with information needed to support the use of Smart controllers for salinity control.

Description of Study Area

The study area is located in the Grand Valley of Mesa County in Western Colorado, near the confluence of the Gunnison and Colorado Rivers (fig. 1). The valley is approximately 30 miles long and 5 miles wide. Geologically, the Grand Valley is underlain by Mancos Shale, which is a non-point source for salt and trace elements such as selenium (Butler and others, 1996). Deep percolations of irrigation waters in the Grand Valley can leach considerable salt and selenium from Mancos Shale-derived soils.

Site Selection and Characteristics

There were four monitoring sites, consisting of two ¼-acre residential lots and two 5-acre estates in the Grand Valley. A summary of site characteristics is listed in table 1. Site numbers are retained from the two-year study. The 2 residential lots were located in two subdivisions (Chipeta Pines and Paradise Hills), one on the north side of the Colorado River, and one on the south side. The estates were both located in the Quail Run subdivision on the north side of the river.

Kentucky bluegrass was the turf studied on the four sites. These residential sites used underground pop-up sprinkler systems. Sprinklers include both impulse and spray types. All sites used irrigation ditch water rather than treated potable water.

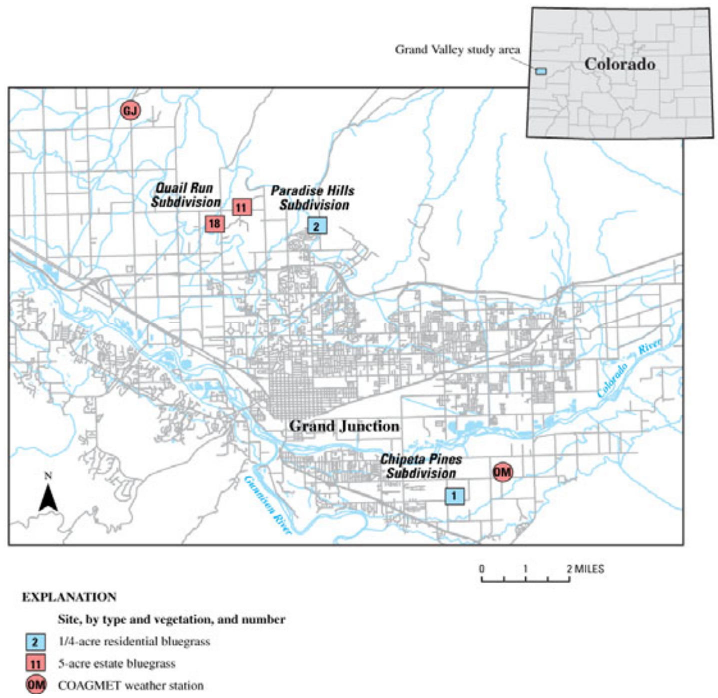

Figure 1: Residential Smart irrigation-controller study site locations in the Grand Junction, Colorado

Table 1. Characteristics of urban study residential ¼-acre lots and 5-acre estates
[Site number, refers to sites published in initial two-year study (Mayo, 2008)]

Site number	Years Studied	Subdivision	Site type	Irrigated turf acreage	Vegetation	Number of irrigation zones	Average gallons per minute flow for all zones	Soil type
1	2005, 2006, 2007	Chipeta Pines	¼-acre residential lot	0.12	Bluegrass	10	12	Loam
2	2005, 2007	Paradise Hills	¼-acre residential lot	0.12	Bluegrass	7	22	Clay loam
11	2005, 2006, 2007	Quail Run	5-acre estate	0.14	Bluegrass	3	27	Clay loam
18	2005, 2006, 2007	Quail Run	5-acre estate	0.82	Bluegrass	7	44	Clay loam

Data Collection Methods

The data collection method used is summarized in table 2. Data collection at the sites included two digital data loggers: (1) to record irrigation- events at the irrigation controller, and (2) to record irrigation-system water pressure. The irrigation events were logged for each sprinkler zone, with a data logger (fig. 3). The water pressure logger recorded the pressure in the irrigation mainline (fig. 4). This provided different information, depending on the type of site water pressure was an indication that the system was actually delivering water, and again served as a cross-check of the sprinkler-controller events.

Table 2. Data collection methods
[CSU, Colorado State University; CoAgMet, Colorado Agricultural Meteorological Network; USGS, U.S. Geological Survey]

Data collection method	Collection frequency	Data source
Irrigation-event log	Every minute	Irrigation-event logger wired to each zone valve at the irrigation controller
Water-pressure log	Every 2 minutes	Data logger with pressure sensor on irrigation system mainline
Flow rate per zone	Twice during two-year study	Field measurement by USGS using acoustic flow-meter
Effective precipitation	Every 60 minutes	Two CSU CoAgMet Weather Monitors, adjusted for runoff
Evapotranspiration	Daily calculation from climate data	Two CSU CoAgMet Weather Monitors
Gravimetric Soil moisture	Monthly	Collection by USGS of 12-inch soil core sample
Irrigation Audit	Each site during the two-year study	CSU Cooperative Extension measurement of distribution uniformity using catch can method

Smart Irrigation Controllers

The existing Clock controllers were removed from all four sites, and Smart irrigation controllers were installed (fig. 2). The Smart controller operates in either of two modes: (1) standard; and (2) auto-adjust. In standard mode, no water deficit calculations are made to adjust the zone run-times of the program. The standard-mode station run-time settings are used to identify the stations used for automatic irrigation. The manual sprinkler run-times are used as default values in auto-adjust mode if communication is lost with the Weather Monitor. In auto-adjust mode, the settings for standard-mode watering days and start time are still used, but the zone run-times are automatically adjusted by the controller. In auto-adjust mode, the controller calculates the water-deficit (ET) for the day just concluded, and sums each day's ET since the last irrigation.

Figure 2: Smart irrigation controller.

Site Visits

Each site was visited at least once a month from June through October, 2007. Data loggers were checked and downloaded, homeowner questions were answered. Soil-moisture core-samples were collected for gravimetric soil-moisture calculation as a cross check against calculated soil-moisture balance.

Figure 3: 22-channel digital irrigation event data logger.

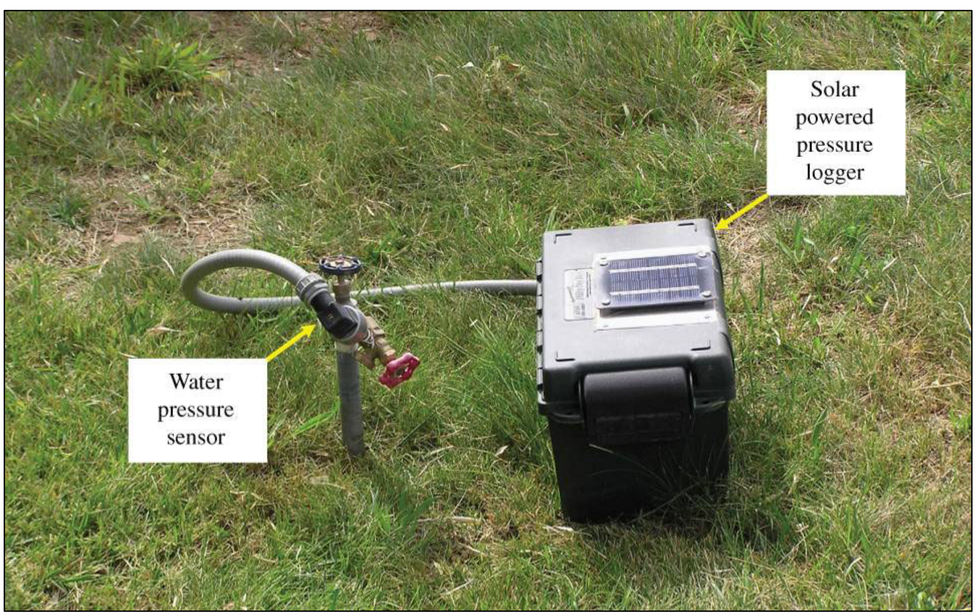

Figure 4: Solar powered digital water pressure logger.

Zone Flow Rate

By knowing the average water flow-rate per zone, a calculation of the total quantity of water delivered during an irrigation event can be made by multiplying the zone flow rate by the zone irrigation duration. Zone flow rates were measured using an acoustic flow meter at each sites. Water pressure was simultaneously recorded during the flow test using water-pressure data loggers to determine the variability in supply pressure and to determine an average pressure.

Irrigation Audits

An irrigation audit of each site was performed. This audit measured the distribution uniformity and application rate of the sprinkler system by placing a grid of catch-cans over a section of the lawn (front, back, side, etc), and running each of the zones in that area for a 5 minute interval. The distribution uniformity and application rate were calculated by area, not by zone.

Climate Data

Two CSU CoAgMet Campbell Scientific Weather Station locations (fig. 1), Grand Junction (GJ) and Orchard Mesa (OM), provide hourly climate data for calculating ETr for the irrigation season (Colorado State University, 2005-2007). Effective precipitations from these weather stations were used for the daily soil-moisture balance calculation.

Data Analyses Method

The two quantitative measures of the effectiveness of the Smart controllers used for the study are: (1) the amount of irrigation water applied to the lawn, and (2) the amount of resultant deep percolation. Irrigation water application for an irrigation event is determined by multiplying the run time (minutes) for each irrigation zone by that zone's flow rate (gallons per minute), then totaling for all zones that were active during the event. Zone run time is recorded by the irrigation event logger. Deep percolation for the study is considered to be any water that infiltrates below the top 12 inches of the soil profile. Gaps in the irrigation event log prevented a continuous daily soil-moisture balance calculation at three of the four sites in the study. To compensate for the lack of continuous daily soil-moisture balance values, a calculation of total-season irrigation water application was made, using estimations of the missing irrigation-water application data. Application efficiency is defined for the study as the measure of irrigation water required (turf evapotranspiration – effective rain), divided by the amount of water applied including precipitation.

Total-season and monthly application efficiency were then used to compare the performance of the Clock and Smart controllers.

Daily Soil-Moisture Balance Graph

To visualize the daily irrigation events and soil-moisture balance for a site, a graph was created for each site showing water inputs and outputs, with resulting changes in the soil-moisture balance (for example, see fig. 11a). The vertical axis represents inches of water, with positive values indicating irrigation and precipitation, and negative values indicating deep percolation. The horizontal axis represents days of the irrigation season.

Total-Season Irrigation-Water Application

Monthly and seasonal water application is the sum of the daily values. For days where daily controller log data are missing, it is not possible to calculate a daily water application value. It is possible to estimate a monthly water application total for a site by assuming that the monthly water applied to the lawn is a function of the cumulative reference evapotranspiration (ETr) for the month. This assumption is based on the fact that the Smart controller determines how much irrigation water to apply each day by calculating a daily estimate of evapotranspiration. After subtracting any effective precipitation, the monthly irrigation-water application can thus be estimated using the ratio of evapotranspiration values between two adjacent months ("missing" and "known").

Total-Season Application Efficiency

Total-season application efficiency is a useful way to compare the performance of irrigation systems from year to year, since it compensates for the quantity of ET in each year. The total-season ET for turf grass can be determined using the total-season alfalfa reference ETr (from CoAgMet) with the standard turf grass crop coefficient Kc (0.66) to calculate ET. A calculation of total-season application efficiency was made by dividing ET by the total water applied including effective precipitation.

The total-season application efficiency may be assumed to be a function of the performance of the irrigation controller. If the Smart controller is making a more accurate determination of the irrigation-water needs of the lawn as compared to the Clock controller, then the seasonal application efficiency should be grater for the Smart controller. By comparing a site's application efficiency month to month and calculating the coefficient of variation of the monthly application efficiency, a judgment of the relative performance of the two controllers can be made. Common sense suggests that as application efficiency increases, irrigation water use should decrease, and deep percolation should decrease. Grass is relatively tolerant of under-watering and over-watering; one can offset the other in the annual application efficiency. By calculating the coefficient of variation of the monthly application efficiency, a look at the monthly variations can be compared, rather than looking at only the annual application efficiencies. In all sites the Smart controller had a smaller coefficient of variation than with the Clock controller. While not a statistically rigorous analysis, the data from this study indicate a possible correlation between application efficiency, irrigation water application, and deep percolation.

Example: Site 18 Results

The daily soil-moisture balance at site 18 for this study is shown in fig. 11a. For comparison, the two-year study soil-moisture graphs are shown for 2006 (fig. 11b).

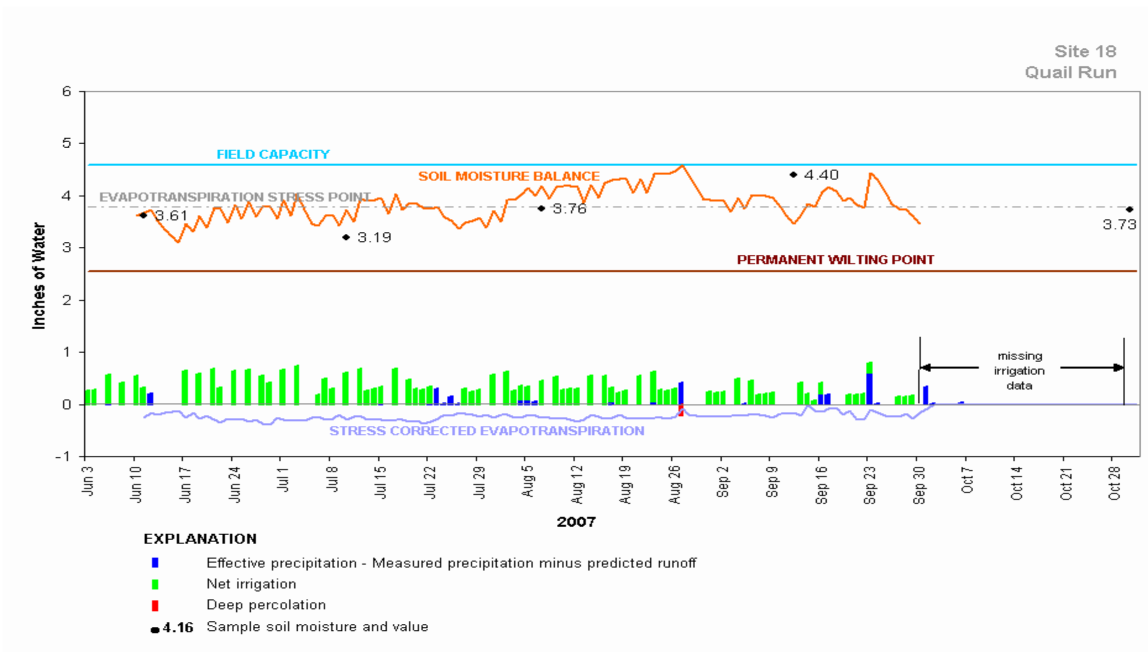

Figure 11a: 2007 Soil-moisture balance for bluegrass for site 18, Grand Valley

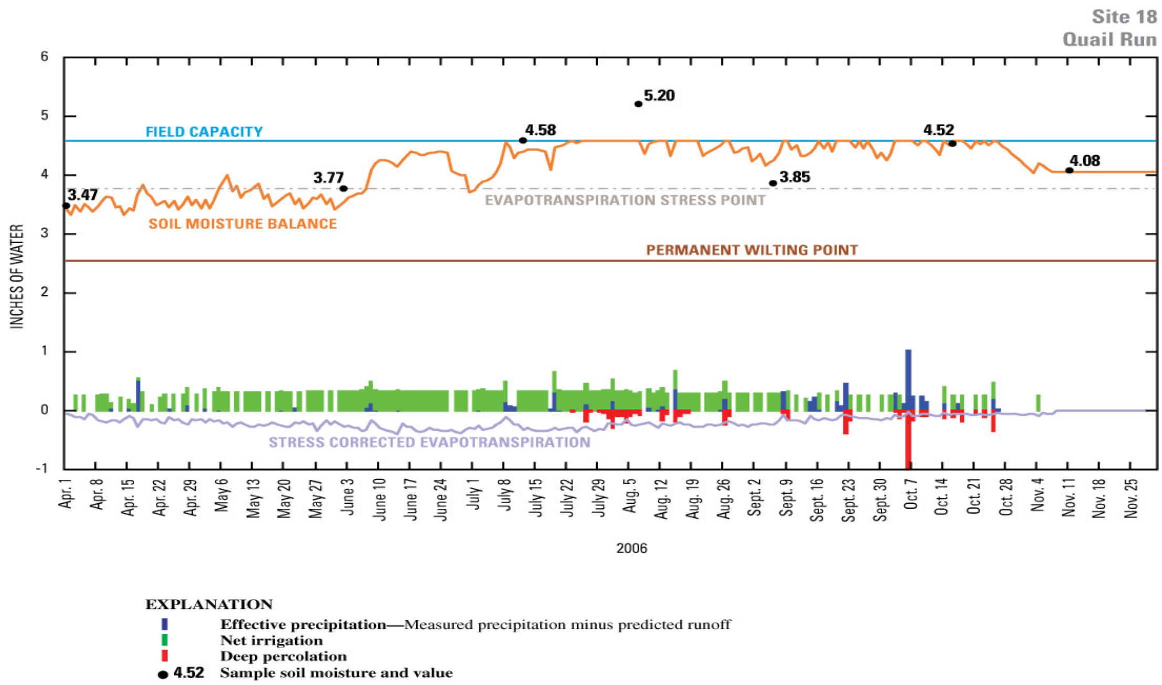

Figure 11b: 2006 Soil-moisture balance for bluegrass for site 18, Grand Valley

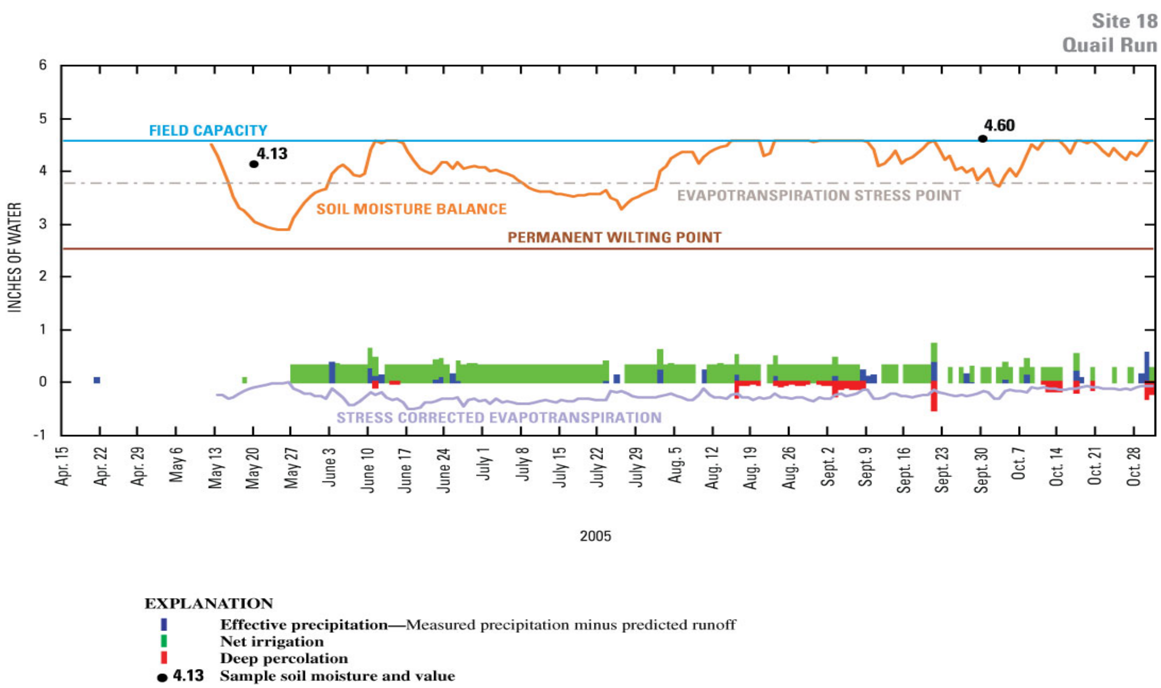

Figure 11c: 2005 Soil-moisture balance for bluegrass on 5-acre estate site 18

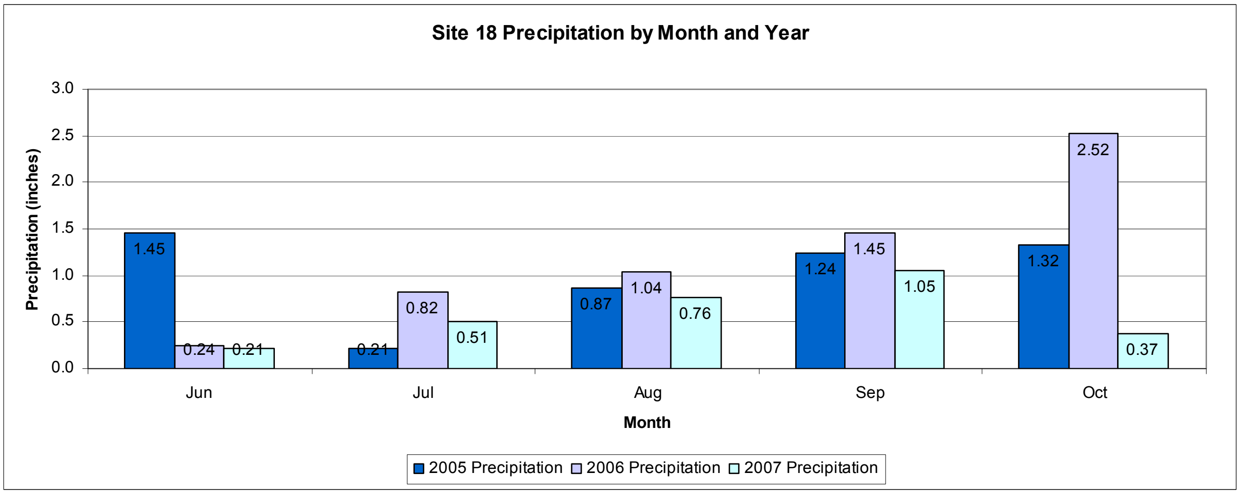

Figure 12a: Three-Year comparison of monthly effective precipitation

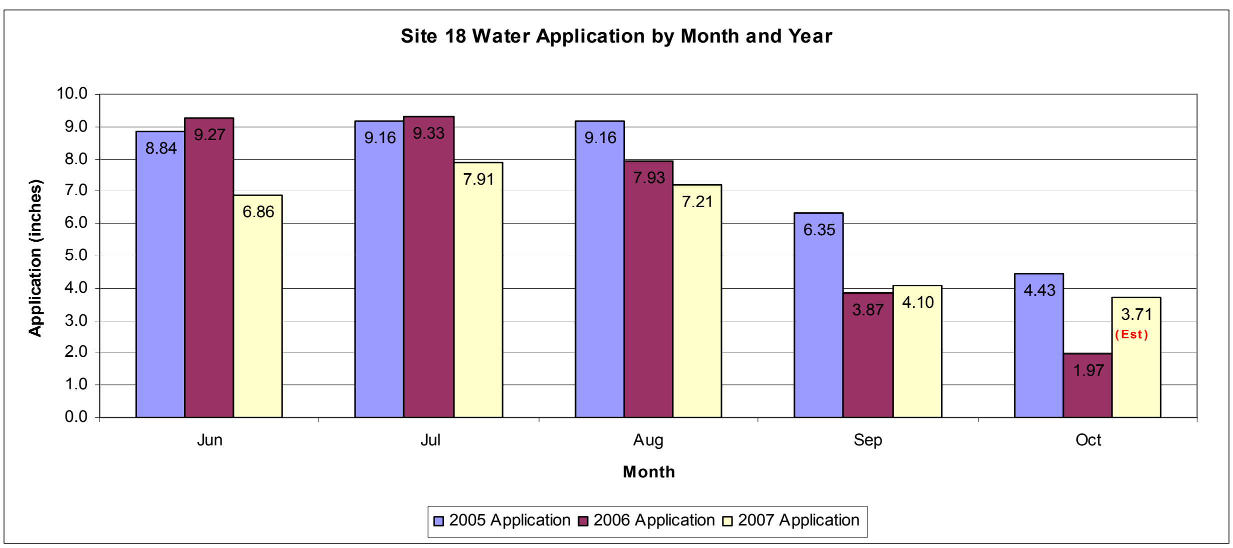

Figure 12b: Three-Year comparison of monthly irrigation-water application on site 18, (est, estimated value)

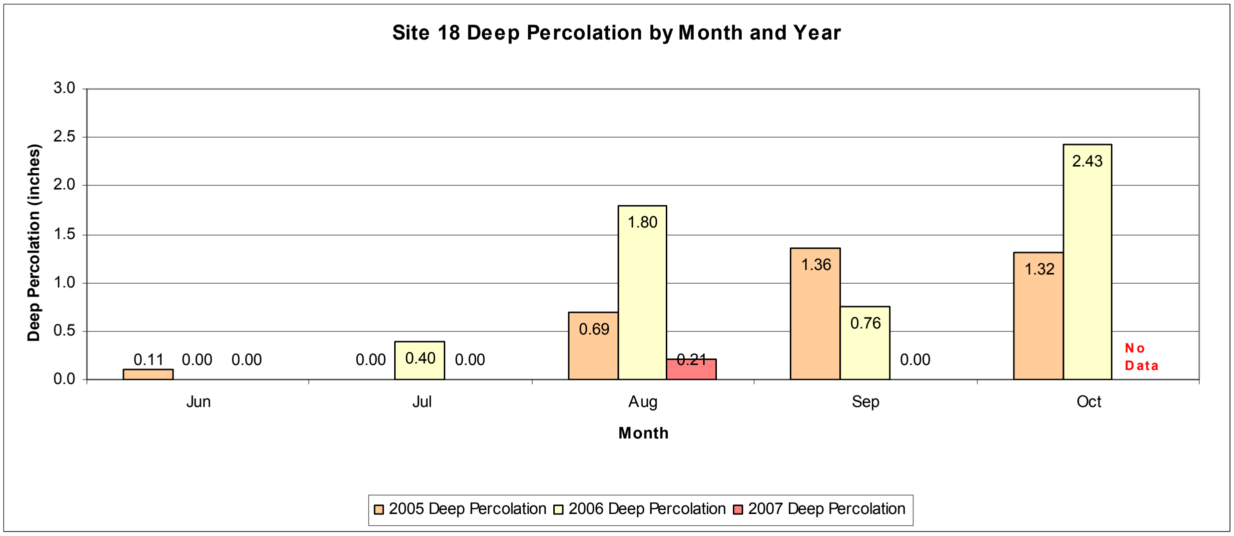

Figure 12c: Three-Year comparison of monthly deep percolation on site 18

Table 11. Monthly precipitation, water applied deep percolation, evapotranspiration, and application efficiency for 2007, 2006, and 2005 on site 18, Grand Valley, Colorado.

Year / Month	Effective Precipitation	Gross Irrigation Water Applied	Deep Percolation	Water Applied + Precipitation	Ref ETr	Crop ETc	Crop ETc - Precipitation	Total Season application efficiency
2007	**2.5**	**26.1**	**0.2**	**28.6**	**35.1**	**23.2**	**20.6**	**72%**
June	0.2	6.9	0.0	7.1	9.7	6.4	6.2	88%
July	0.5	7.9	0.0	8.4	10.1	6.7	6.2	73%
Aug.	0.8	7.2	0.2	8.0	8.4	5.6	4.8	60%
Sept.	1.1	4.1	0.0	5.2	6.8	4.5	3.4	67%
2006	**3.6**	**30.4**	**3.0**	**34.0**	**33.5**	**22.1**	**18.5**	**55%**
June	0.2	9.3	0.0	9.5	10.2	6.8	6.5	69%
July	0.8	9.3	0.4	10.2	9.6	6.3	5.5	54%
Aug.	1.0	7.9	1.8	9.0	8.0	5.3	4.2	47%
Sept.	1.5	3.9	0.8	5.3	5.6	3.7	2.3	43%
2005	**3.8**	**33.5**	**2.2**	**37.3**	**32.4**	**21.4**	**17.6**	**47%**
June	1.5	8.8	0.1	10.3	8.0	5.3	3.8	37%
July	0.2	9.2	0.0	9.4	10.1	6.7	6.5	69%
Aug.	0.9	9.2	0.7	10.0	7.8	5.1	4.3	43%
Sept.	1.2	6.4	1.4	7.6	6.5	4.3	3.1	41%

Post Study Homeowner Interview

Homeowners were interviewed at the end of the study with 15 standard questions to ascertain their experiences and opinions of the Smart controllers. The questions are listed in table 3. All the homeowners were impressed with the automatic operation of the controller. The advantages of the controller were stated as: (1) water was not being wasted; (2) the controller shut off after a rain; and (3) the homeowner did not have to adjust the settings throughout the season. Disadvantages of the controller were mostly stated as the complexity of learning how to use the controller, and not entirely understanding the automatic watering decisions being made by the controller. The reliability of the Smart controller was judged to be good, but several homeowners were concerned about the life of the battery in the Weather Monitor. Smart controller technical support states that the Weather Monitor battery should last 4 years.

Table 3. Homeowner interview questions.
[USGS, United States Geological Survey]

Question Number	Question
1	Overall, how did you like the Smart controller during the study last year?
2	What did you like most about this irrigation controller?
3	What did you like least about this irrigation controller?
4	Did the controller keep your yard adequately watered throughout the irrigation season? How would you rate your lawn?
5	Did you operate the controller in auto adjust, or manual mode?
6	Did you have to call USGS for help with the controller? If so, what did USGS need to do to help you?
7	Have you needed to change the Weather Monitor battery on the roof yet? Do you know how to change the battery?
8	What kind of adjustments, if any, did you make to the controller settings during the irrigation season?
9	Did the controller respond in the way you expected it to?
10	What is your judgment of the quality and reliability of the controller?
11	Do you plan to use the controller next year?
12	Do you think your neighbors would like to use the Smart controller? If so, what would convince them to do so?
13	Do you think the controller saved any water for the season, compared to years past?
14	Why did you decide to keep the controller after the study was over?
15	Are there any other comments or questions that I haven't asked you?

Conclusion

Based upon the data collected, using Smart controller technology reduced excess deep percolation. Troubles with data collection prevented a more firm conclusion. However, it appears that Smart controllers would help reduce salinity loading in the Grand Valley. The annual application efficiencies results are summarized in table 13.

Table 13. Three-year summary of application efficiency by site number and study year.
[N/A, site not studied that year, data not available]

	Annual application efficiency			
Study Year	Site 1	Site 2	Site 11	Site 18
2007	54%	52%	92%	73%
2006	48%	N/A	54%	55%
2005	54%	43%	69%	47%

Acknowledgements

The U.S. Geological Survey, Colorado Water Science Center, Grand Junction Office, Grand Junction, Colorado, for conducted the initial two-year and the controller study.

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