TECHNOLOGIES FOR AUTOMATION IN SURFACE IRRIGATION

Khaled Bali, Thomas Gill and Dale Lentz[1]

ABSTRACT

Surface irrigation systems (mainly furrow and border irrigation) are the primary method of irrigation for field crops in California. The majority of water losses through these systems are either by surface runoff or through leaching or a combination of both. Various irrigation cutoff methods are used by irrigators to reduce surface runoff; however, the cutoff time can vary from 60 to 90% of the field length depending on irrigation flow rate, crop roughness, and field characteristics. Determining the time of irrigation to reduce surface runoff and increase irrigation efficiency could be achieved by automating surface irrigation systems. Surface irrigation automation involves the use of wetting front advance sensors, flumes, and electronic timing control gates to determine the irrigation cutoff time. Automation of surface irrigation systems increases irrigation efficiency and reduces the cost of labor and water. In addition to water conservation, reduced surface runoff and deep percolation reduce erosion, off-site movement of pesticides/phosphorous, and nitrate leaching.

Key Words: surface irrigation, automation, irrigation efficiency, surface runoff

INTRODUCTION

In 2010, major field crops in California accounted for more than 3.67 million acres (USDA, 2012) or approximately 40% of the 9.2 million acres of irrigated crop area in California (California Water Plan Update, 2009). The water use on these major field crops exceeds 10 million acre-ft/year. As part of Senate Bill x7-7 (enacted in November 2009), all large water suppliers in the state are required to increase water use efficiency. Alfalfa alone is the single largest crop water user in the state requiring more than 5 million acre-ft of water/year. Major field crops in the Imperial Valley use approximately 2.5 million acre-ft of Colorado River water. As part of the Quantification Settlement Agreement (QSA), California is required to reduce its water use by approximately 0.8 million acre feet. Research conducted by University of California researchers (Bali et al., 2001 and Grismer and Bali, 2001) in the low desert region showed that improvements in surface irrigation systems by reducing surface runoff could yield up to 15% in water savings with no significant impact on alfalfa or sudangrass yield. The “reduced-runoff” surface irrigation method is a simplified version of the volume-balance model approach and could be used to calculate the irrigation cutoff time based on advance time and distance (Bali et al., 2001). The simplified approach was tested first to improve water use efficiency but then later was used on an 80-acre commercial field in the Imperial Valley as part of management practices to improve the quality of surface runoff water in the Salton Sea Watershed. The method was effective in reducing phosphorus and sediment loads in drainage water (SWRCB, 2008).

---

[1]Khaled Bali (kmbali@ucdavis.edu), UCCE Farm Advisor, Imperial County, 1050 East Holton Road, Holtville, CA 92250; Hydraulic Engineer, US Bureau of Reclamation, Denver CO; Hydraulic Engineer, US Bureau of Reclamation, Denver CO
In: Proceedings, 2014 California Alfalfa, Forage, and Grain Symposium, Long Beach, CA, 10-12 December, 2014. UC Cooperative Extension, Plant Sciences Department, University of California, Davis, CA 95616. (See http://alfalfa.ucdavis.edu for this and other Alfalfa Symposium Proceedings.)

In 2006 Bali and USBR engineer developed an irrigation slide chart based on the above method. The chart was designed for irrigators to determine the irrigation time needed to reduce runoff by less than 5% of applied water. The irrigator needs only two sets of information; flow rate and advance/time at any point after 25% of the length of the fields. To implement the method effectively, flumes were installed in several commercial fields and irrigators were trained to use the method. However, we encountered problems related to variable inflow rates in irrigation canal which made it more difficult for irrigators to precisely determine the appropriate cutoff time to achieve 5% or less runoff. In 2009 more collaborative work between Bali and USBR Engineers focused on automation for more precise way to conserve water.

AUTOMATION DESIGN

A field at UC Desert Research and Extension Center (UCDREC) was selected to test the automation process. A border irrigated plot made available at the DREC farm has initially been set up with five border sections, each served by a single turnout from the concrete lined field canal. Run length of the border sections is approximately 1200 ft. and border width is 60 ft. Figure 1 shows the field site layout that.

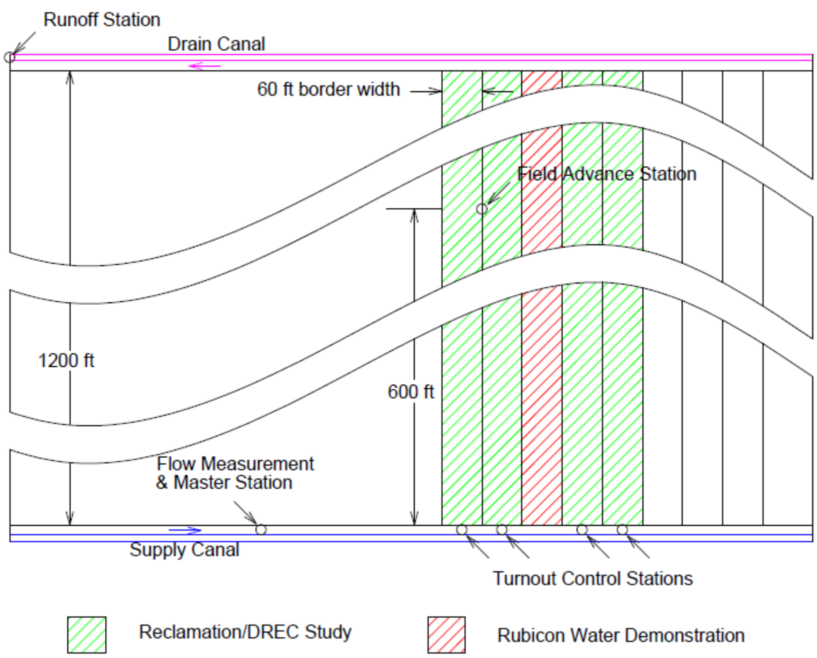

Figure 1. Sketch of the Field Demonstration Site Layout

Multiple border sections are available for use by the project at the site. In the initial configuration equipment has been installed by the Reclamation/DREC team in four of the border sections – each featuring a different turnout control device. Along with the Reclamation/DREC project is a border section equipped with a turnout control device and an automation system developed by Rubicon Water. The Rubicon Water equipment is operated independently from the Reclamation/DREC system. Only the Reclamation/DREC prototype system is discussed in this paper. The Reclamation/DREC prototype features 4 types of stations. All stations are equipped with similar programmable control units with integral data radios. The master unit is located along the supply canal and measures discharge being delivered to the flow at a long-throated flume. The master station is also able to measure water level in the canal downstream from the flume. This measurement is utilized to determine whether the canal has filled before flow is turned out to the first border section.

Turnout control stations are located at each border station turnout. The master station directs each turnout station to open the flow control device in the border section when irrigation of a border station is being initiated, then to close the flow control device when sufficient water has been applied to complete the irrigation of the border section. Turnout control stations are also equipped with two toggle switches. An On-On toggle is a selector switch which allows an operator to select automated or manual operation. When the selector switch is in the manual position, the turnout may be manually operated using the second toggle switch. The manual operation toggle is a momentary (On)-Off-(On) switch that defaults to the off position when not being in the open or close positions.

The field advance sensing station is located at the midpoint of the field length in the direction of travel of irrigation water but could be moved to any location along the border. The primary function of the field advance station sensing station is to determine when the irrigation water has reached the half-way point of the traverse from upper to lower end of the border section. This is accomplished by linking a conductivity "water sensor" placed near the center of the width of the border section with the radio/control unit. A secondary function of the advance sensing station is to monitor soil moisture conditions between irrigations. Soil moisture sensors installed at one or more depths in the border section are linked to the radio/control unit at the stations. Soil moisture readings may be taken at user-defined intervals and logged on-site. Software loaded on a PC linked to an office base at a DREC office then retrieves this data and writes it to a file on the PC hard drive. At a minimum, one field advance station is required for the system to monitor the advance rate of water applied to the first border section being watered. In the DREC layout, a field advance station is located on the ridged boundary of two border sections. Water sensors located in both adjacent border sections are linked to the station radio/control unit.

The fourth type of station in this system is a field runoff measurement station. For the test site layout, field runoff from all border sections enters a concrete lined runoff canal and is conveyed to the edge of the field where it passes through a standard Imperial Irrigation District (IID) runoff weir box into the IID drainage collection network. A water level sensor monitoring water level at the weir box is linked to a radio/control unit at this site. Flow over the weir is calculated at 60 second intervals and logged on-site. Logged information from this site is also retrieved via wireless communications by the office base unit and written to a file on the PC hard drive.

AUTOMATED SITE

Irrigation of the Reclamation/DREC equipped border sections is initiated by turning flow into the field supply canal. The master unit at the measurement flume will determine when a measurable flow is passing the flume and will monitor flow rate plus the water level downstream from the flume until the downstream level reaches a target level for starting flow into the first border section. The time, as read from the on-board real-time clock at the time flow is started in the first border section, is coded into a time stamp and written to an on-board data register in the master unit.

To initiate the irrigation a message is wirelessly transmitted to the radio/control unit at the flow control station in the first border section directing it to open. A second message is transmitted almost simultaneously to the radio/control advance station directing it to begin monitoring the surface water advance sensor. After flow into the first border section has been initiated, measurements of flow crossing the flume are taken at a user defined interval. The measured flow rate is multiplied by the time interval to calculate an incremental volume for the time interval which becomes the initial value for a totalized volume variable which is also logged and updated with each measurement cycle.

At the border section flow control station a relay that opens the flow control device is turned on when directions have been received from the master unit. Depending on the type of flow control device installed at the border, the "open" relay may be energized for a specified time interval, or may be energized until a position indicator on the flow control device provides feedback that the device is fully open. After switching off current to the "open" relay, the flow control station will be taken until a command to close off flow to the border section is received from the master station, at which time a second "close" relay will be energized for a pre-set time interval or until feedback from a position sensor indicates that the flow control device is closed.

When the field advance sensing station has received direction from the master unit, the station begins to monitor the surface water sensor at 60 second intervals until the arrival of irrigation flow is detected. The field sensing station then transmits an indicator to the master station that the surface water advance has arrived at the border section mid-point. At the time feedback from the field advance station is received, the master station program will note the totalized volume delivered to the border section up to that point in time and calculate the additional applied volume needed to fully irrigate the border section. The additional volume is added to the totalized volume already applied to determine a target total volume which, when reached, would trigger initiation of flow in the next border section and shut off of flow into the first section. For sites where only one border section is equipped with an advance sensing station, the applied volume total target value derived during irrigation of the initially irrigated section would be used as the target for remaining border sections. In the Reclamation/DREC prototype configuration, the advance sensing station is positioned and instrumented to monitor advance on two adjacent border sections. For the prototype, irrigation of the second border section is essentially a repeat of the process described for irrigation of the initial border section. The volume total target derived for irrigation of the second section would be volume target used for additional border sections. The rest of the field is irrigated using the same logic described above and the volume of runoff is determined and used to compare the actual runoff volume with the predicted one.

AUTOMATION LOGIC IN CLAY SOILS

The cracking clay soils at DREC which are prevalent in much of Imperial Valley experience minimal infiltration after initial wetting. The volume of water retained in the soil during an irrigation event thus approximately represents the volume of the cracks that have formed in the soil, (Grismer and Tod, 1994). For a near constant inflow rate delivered at the border section turnout, an appropriate cut-off time for the border section may be calculated as a function of the time measured for the irrigation front to travel a known distance (i.e. to a field advance sensing station). The minimal infiltration after initial wetting associated with the clay soil means the volume water requirement needed to fully irrigate a border section would be minimally impacted by varying turnout flow rate. For sites where the available inflow rate may be subject to variation, the inflow rate measurement capability inherent in the Reclamation/DREC prototype allows the automation scheme to be operated as a function the delivered volume needed to reach the field advance sensing station. Field research has shown that runoff can be reduced to as little as two percent of the infiltrated volume by stopping application of water to a border section when the appropriate amount of water has been applied (Bali et.al. 2001).

SUMMARY

Automation of surface irrigation systems could be used to improve irrigation efficiency and reduce operating costs (savings in water and labor). The automation process could also reduce scalding on alfalfa grown on heavy soil by eliminating standing water at the end of the field. The automation process could also improve the quality of drainage waters due to reduction in both deep percolation and surface runoff.

REFERENCES

Bali, K.M., Hanson B.R., and Sanden B.L. (2010). "Improving Flood Irrigation Management in Alfalfa". Proceedings, 2010 California Alfalfa and Forage Symposium and Corn/Cereal Silage Conference, Visalia CA, 1-2 Dec, 2010. UC Cooperative Extension, Plant Sciences Department, University of California Davis, CA 95616

Bali, K., Grismer, M., and Tod, I. (2001). "Reduced-Runoff Irrigation of Alfalfa in Imperial Valley, California." Journal of Irrigation and Drainage Engineering, 127(3), 123–130.

Grismer, M. E. and Tod, I. C. (1994). "Field Procedure Helps Calculate Irrigation Time for Cracking Clay Soils" California Agriculture, 48(5), 33-36.

California Department of Water Resources, California Water Plan Update 2009. State of California. http://www.waterplan.water.ca.gov/Grismer M. E. and Bali, K. M. 2001. Reduced-Runoff Irrigation of Sudan Grass Hay, Imperial Valley, California. American Society of Civil Engineers, Journal of Irrig. & Drain. Engr. Vol. 127, No. 5, 319-323.

SWRCB, 2008. CALIFORNIA POLLUTED RUNOFF REDUCTION or NONPOINT SOURCE (NPS) SUCCESS STORIES. Agricultural Management Practices Reduce Phosphorus in the Salton Sea Watershed.
http://www.waterboards.ca.gov/water_issues/programs/nps/success.shtml

USDA Statistics, 2012. The National Agricultural Statistics Service. http://www.nass.usda.gov/