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Automation of Border and Basin Irrigation

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Abstract

Various methods and types of control equipment for automating border and basin irrigation are described. Mechanical gates include dual function turnout gates that both open and close and a trapezoidal center-of-pressure check gate for a lined ditch. Cablegation systems are used to irrigate either borders or basins with or without cutback. Field tests and systems using feedback are described.

Introduction

Automation can alleviate a number of water management problems associated with border and basin irrigation. The most common justification for automating is to provide greater convenience for the irrigator and to save labor. Although conditions often differ in other countries from those in the U.S., many of the problems are universal. Relatively large streams are commonly used with narrow set widths. Thus, frequent attention by the irrigator is required because of the short set times and large number of set changes. This is particularly inconvenient at night. Consequently, set times are often longer than needed. Shallow soils, particularly those with high intake rates, require short, precise set times to optimize irrigation efficiency. Surface irrigation for frost control, practiced in some areas, requires very short set times and continued irrigator presence during the night unless the system is automated. Variable farm deliveries often make precise application and timing difficult; irrigation based on volume of water delivered is needed. In some locations, irrigation runoff must remain on the field or farm where it is produced and, by law, is not permitted to leave the farm. Erosion in some areas is related to irrigation inefficiencies caused by excess runoff and deep percolation. Precise timing by automation can control or prevent runoff and increase irrigation efficiency. Older systems and those in many countries often either do not have permanent structures or they are in need of repair and upgrading. An additional benefit of automation for these conditions would be improved system facilities and water control.

Methods of Automating Borders and Basins

Most automated border and basin systems are semiautomatic and employ both automatic and semiautomatic components. Semiautomatic systems or control devices require some degree of manual operation, either to turn water into the system or to reset or reposition the structures and/or control devices.

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Open channel systems utilize different modes or system configurations and these often determine the type of structures used. Field supply or head ditches with average slopes exceeding 0.002 to 0.003 can often be stair-stepped to provide an elevation difference of 100 to 150 mm (4 to 6 in) between borders/basins or groups of borders irrigated together. Systems with stepped ditches are widely used in New Zealand. Semiautomatic drop-closed check gates are installed in the head ditch with concrete or wooden sills, or weir crests, in the side of the ditch at the head of each border (Taylor et al, 1982). Water normally flows at a level below the crest of the sills except in the set being irrigated immediately upstream from the semiautomated check gate. This type system is usually the most economical because only one simple gate with a clock is required for each set.

Systems with less slope sometimes use gates in pairs--a check gate in the ditch and a turnout gate in the side of the ditch for each irrigation set. Gates for these systems usually consist of a drop-open type gate used with a companion drop-closed type gate. Various gate styles and configurations are used (Haise et al, 1980, Humpherys, 1969, Humpherys, 1986). A new style drop-open gate built into the side of a concrete lined ditch is being used on the Muddy Creek project in Montana with a conventional drop-closed gate (Andrews, 1985).

Most border and basin systems have relatively flat head ditches such that check gates in the head ditch can be located some distance apart with multiple irrigation sets in between. For this condition, dual function turnout gates are used. These gates serve two functions by first opening to admit water to the field and then closing to terminate irrigation of the field segment. Dual function gates as used in Australia, consist of both rectangular metal slide gates mounted on concrete headwalls and metal flap gates on the inlet end of pipe turnouts. They are manually reset and are released from closed-to-open-to-closed positions by a pneumatic release system. Energy for operating the gates is derived from falling counterweights (Merryless et al, 1985). Both gates have more recently been automated with an electromechanical gate controller. The controller is a portable, battery-powered, electric motor-driven, linear actuator which raises and lowers the gates. An electronic timer controls the operation. Various types of pneumatically and hydraulically operated gates and valve closures, some of which are used for automating borders and basins, were described by Haise et al, 1980. Systems and equipment for automating level basins in Arizona where irrigation streams of 400 to 560 L/s (15 to 20 cfs) are used, was described by Dedrick and Erie, 1978, and Erie and Dedrick, 1978.

Field Tests with Semiautomatic Gates

Pipe turnouts. A dual function structure for open channel turnouts is shown in Fig. 1. This structure consists of a pipe outlet with a drop-closed gate on the inlet and a flexible drop-tube on the outlet. The first structures of this type used prefabricated commercial concrete pipe headgates with a head wall. They were modified by replacing the original slide gate with a drop-closed gate and by attaching a drop-tube on the outlet. The tube, made from either nylon reinforced butyl or hypalon, is clamped onto the outlet end of the pipe and supported in its raised position by a bracket and trip release mechanism. A separate mechanical timer is used to release the inlet gate and outlet tube. The timers are portably mounted so that they can be moved from the structures of one set to those of another. Thus, the total cost is minimized since, if the timers are moved every 12 hours, timers are needed for only a half day's sets; or, if moved once per day, they are needed for only one day's sets.

Eight 250 mm (10 in) diameter semiautomated pipe outlet gates were tested in a border irrigated alfalfa field near Rigby, Idaho (Fig. 1). Overall, the turnout gates performed very well. Vegetative growth near the inlet drop gates sometimes lodged under the gates and caused them to leak slightly; however, this can be prevented by controlling weed growth in unlined ditches. The mechanical timers, which are no longer available, occasionally malfunctioned; electronic timers are now more reliable. The primary operational constraint was estimating the time to complete irrigation of a border. The variable soil texture at that location made irrigation time prediction difficult. An automated system with feedback to control the turnout structures is needed.

Eighteen semiautomated turnouts which used 375 mm (15 in) diameter PVC pipe were tested near Fairfield, Montana. Sheetmetal headwalls fastened to the inlet end of the pipe (Fig. 2) were sealed with caulking. Expansion and contraction of the PVC pipe made sealing difficult. Concrete pipe may be more satisfactory than PVC for this size turnout which is the largest tested and perhaps the largest size practical.

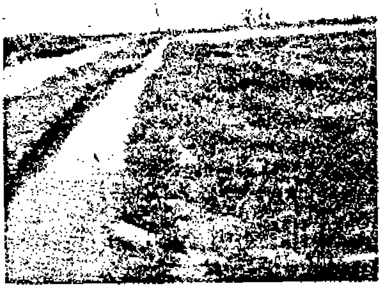

Fig. 1. Dual function semiautomated pipe turnouts for border irrigation.

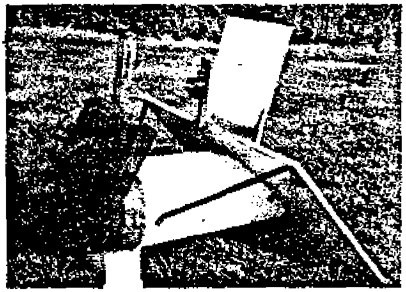

Fig. 2. PVC pipe turnout with an inlet gate and drop-tube outlet.

Drop-closed and center-of-pressure turnout gates. These gates were tested in a pilot study as companion gates in a level basin system near Delta, Utah (Figs. 3 and 4). They were designed for installation in the existing turnout openings of a concrete lined ditch. Four outlets from the ditch are used to discharge approximately 230 L/s (8 cfs) into 4 Ha (10 ac) basins. Four drop-closed gates were installed at the first basin to be irrigated while four center-of-pressure gates (pressure gates) were installed to serve the next basin in sequence.

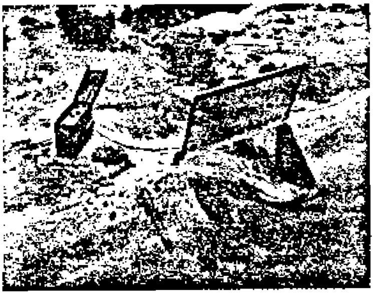

Fig. 3. Drop-closed gate in a ditch turnout to a level basin.

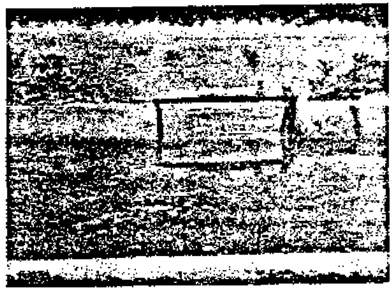

Fig. 4. Center-of-pressure gate being used to irrigate a level basin.

The drop-closed gates were reset manually and closed when released by electric solenoids controlled by a 24-hour mechanical timer. Interconnecting wires were used between gates. The solenoids were powered by the electrical discharge from capacitors through an electronic "switch" or SCR.

The pressure gates use hydrostatic water pressure to open either automatically, or when a gate latch is released after the water level in the ditch reaches a predetermined depth. When counter-balanced, they automatically return to their closed position following irrigation. When irrigation of the first basin was terminated by the drop-closed gates, the water level in the supply ditch rose and an electrical circuit similar to that used for the drop-closed gates was activated by a float to open the pressure gates leading to the next basin. This trip arrangement was used to assure simultaneous opening of the pressure gates. In a completed system, the remaining basins would be equipped with pressure gates which would sequentially open when tripped by a timer to begin irrigation and then automatically close to terminate irrigation of a basin.

During two years operation of the pilot system, the drop-closed gates worked well, but the pressure gates did not always close when irrigation of the next downstream basin began. The low water depth behind the gate in some basins combined with the small water level drop in the ditch was a constraint and did not always allow the gates to automatically return to their closed position. Consequently, the pressure gates were replaced by butterfly type gates.

Butterfly turnout gates. A new style butterfly type gate was designed and tested in the laboratory. Four of these gates were installed to replace the pressure gates in the level basin pilot system. This gate, shown in Fig. 5, consists of two panels which rotate about a horizontal axis at the top of the turnout opening. In its initially closed position, the downstream or backside panel is latched on the downstream side of the gate frame. When the first latch is released by a solenoid, the gate is pushed open by water on its upstream side and rotates 90 degrees where it is restrained by a second latch. In this open position, both gate panels are horizontal. The panel on the upstream side is counterweighted so that it is a little heavier than the backside panel. Thus, when the second latch is released, the gate acts similar to a drop-closed gate and rotates another 90 degrees to its second closed position with the gate panel on the upstream side of the gate frame. Water pressure holds the gate panel tight against the gate frame.

An infrared transmitter/receiver telemetry system which utilizes feedback from the downstream end of a basin is used to provide a control signal to open the gates of succeeding sets. A control signal is received by the receiver when water reaches a transmitter/sensor unit located about 0.8 of the basin length downfield. The infrared receiver in turn activates the gate-tripping circuitry for the next set of butterfly gates downstream. A mercury switch mounted on the upstream-most gate of the set provides the control signal to close the gates of the previous set. This operation is repeated for all sets in that section of the stepped supply ditch between ditch checks.

Trapezoidal ditch check gate. The center-of-pressure check gate shown in Fig. 6 was designed for the 46 cm (18 in) bottom width ditch used in the level basin system. When the system is complete, one of these check gates will be located at each step or drop in the level supply ditch. Several basins located on both sides of the ditch are irrigated from outlets in the section of ditch between checks. Using hydrostatics, a generalized procedure was developed for designing pressure gates for relatively large trapezoidal-shaped ditches near this size. The gate was designed to be released by either a timer or water spilling into a container from an overflow. The gate being tested uses the overflow method. When the last series of butterfly gates close, the water level in the ditch rises to the gate's overflow lip and water spills into a container mounted on the downstream side of the gate. The weight of water in the container trips or releases the gate to its open position. This type gate release also serves as a positive release for safety purposes and, thus, will prevent overtopping of the ditch.

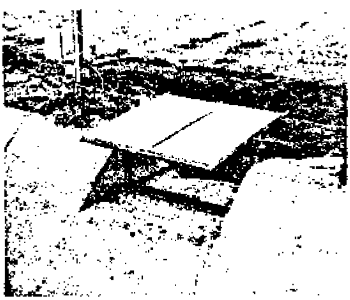

Fig. 5. Dual function butterfly type semiautomatic gate.

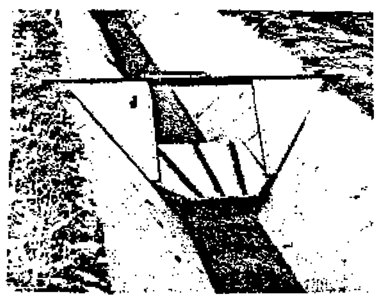

Fig. 6. Trapezoidal center-of-pressure check gate in lined ditch.

Cablegation on Borders and Basins

Cablegation utilizes a moving plug in a sloping pipe to transfer water sequentially from outlet to outlet along the pipe. The cablegation concept was originally developed for use with gated pipe type delivery systems to furrows (Kemper et al, 1981). By using buried pipes and large riser outlets, it has been adapted for water delivery to borders and basins.

A border cablegation system, Fig. 7, uses a pipe buried along the upper end of the borders with a large-diameter riser(s) for each border. The tops of the risers are installed to a design grade and left open. A water-tight plug inserted into the pipe acts as a dam so that when water is introduced, water accumulates behind the plug and spills from the upstream riser. The risers are sized large enough to discharge the desired flow under the available head, which is equal to the elevation drop between risers minus the pipe friction loss between risers. Consequently, all of the water will flow out of the riser on the border immediately upstream from the plug. The riser outlet is sometimes flared outward to increase capacity. Multiple risers are also commonly used on each border to achieve the required capacity.

The plug is constructed to slide through the pipe under the force of the water pressure behind it. The system is automated by regulating plug movement with a speed controller. A cable attached to the plug extends back through the pipe, through a pulley, and is wrapped around a reel. The reel is attached to a speed controller such as a waterbrake (Kincaid 1985). The plug speed is set such that the plug advances the distance between borders during the desired irrigation time for each border. When the plug passes a downstream riser, the head drops below the level of the upstream riser and all of the flow is transferred to the next border. Irrigation duration and, thus, water quantities (at a given flow rate) are consequently determined by the controller's speed setting.

Cablegation can also distribute water to more than one border and provide a cutback irrigation by sizing the risers such that only a portion of the design flow is discharged under the available head. Under these conditions, the water backs up further in the pipe and spills from one or more additional risers upstream. Consequently, when the plug passes the next riser (or set of multiple risers), the pressure head at the upstream riser(s) drops, but still remains above the elevation of the top of the riser; thus, the flow rate is reduced. When water discharges from two sets of risers, typically about three fourths of the water will flow from the downstream set and one fourth from the upstream set of risers. This type of cutback water distribution is represented in Fig. 8.

The primary constraint to the use of cablegation for borders is the lack of sufficient field side slope or gradient from border-to-border to operate the system. Border irrigation is typically used in areas where the cross slope is small so that it can be economically eliminated with land leveling. Generally, 75 to 100 mm (0.25 to 0.35 ft) elevation drop from riser to riser is required to discharge the size flow required for border irrigation with a reasonable number of risers. The effective grade on a cablegation system can be increased beyond the land slope by elevating the risers at the inflow end of the pipeline. This type of layout, shown in Fig. 9, requires additional available water supply head at the field inlet point.

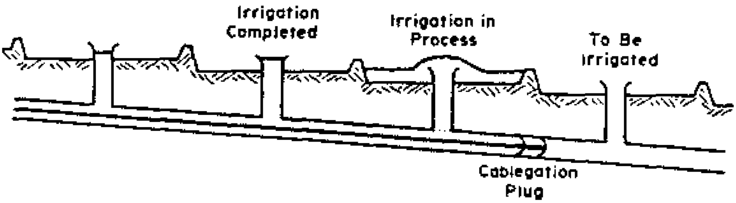

Fig. 7. Cablegation on borders.

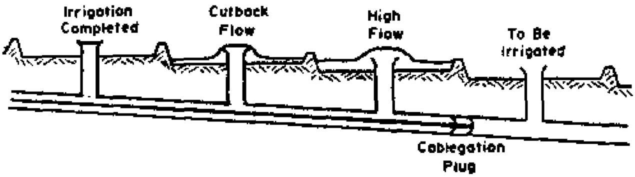

Fig. 8. Cablegation on borders with cutback flow.

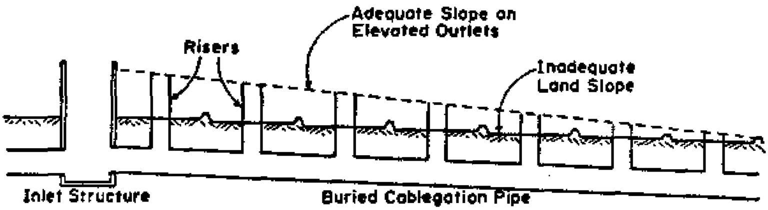

Fig. 9. Elevated risers used to increase riser outlet gradient.

As noted previously, border cablegation applications are generally controlled by adjusting the controller speed. Border cablegation systems have also been successfully controlled by using feedback. In this more fully automated mode, moisture sensors installed near the tail end of the border sense the arrival of the surface flow and send a signal back to the controller. This signal releases a latch on the controller and allows the plug to advance to the next riser where a float-activated switch closes the controller latch to stop the plug. The plug then remains stationary until water arrives at the sensor in the border being irrigated; whereupon, a signal is again sent to release the latch and advance the plug to the next border. Information from the tail of the field to the controller can be transmitted by wire, radio telemetry, or with an infrared transmitter and receiver. Placement of the field sensors depends upon the desired irrigation criteria.

Twelve border cablegation systems were in use in 1986 in three western states. The operators have been pleased with the simplicity and reliability of the systems. System costs depend upon the layout of the field, but have ranged from \$400 to \$600/ha (\$150 to \$240/acre). Most of the cost is for pipe, risers, and installation. Controllers, structures, plugs, and cable typically cost less than one thousand dollars.

Summary

Automation can improve the management and efficiency of border and basin irrigation. Drop-closed, dual function, and center-of-pressure turnout and check gates were developed and field tested on border and basin irrigation systems. An infrared telemetry feedback system is being developed to control the gates for more efficient operation. Twelve cablegation border systems were used in three western states during 1986. These systems can be designed to irrigate either with or without cutback and have been successfully tested with feedback from sensors located at the tail end of the field.

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