AUTOMATED CABLE CONTROL IRRIGATION SYSTEM

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Introduction

Rapidly rising energy costs have emphasized the need for applying irrigation water with gravity methods whenever it can be effectively done with good efficiency. Rising labor costs and the lack of skilled irrigators has led many growers to move away from gravity systems when upgrading their systems in recent years. Now the rising spiral of energy costs, together with a smaller margin between production costs and crop market returns is bringing renewed interest in applying up-to-date methods of gravity irrigation. These methods reduce labor requirements and increase water application efficiency to levels similar to sprinkler methods. One of the newest of these methods has been developed and tested during the last year and a half at the Snake River Conservation Research Center of the Agricultural Research Service, USDA, near Kimberly, Idaho. This report will review the development and testing of this method which is often called "Cablegation."

Description

The method has been used principally for furrow and corrugate irrigated crops, but one evaluation has shown that it can be modified to use on graded borders as well.

The basic system, first installed in August 1980, is similar to a gated pipe system in which the outlets are near the top of the pipe (Figure 1). The inside diameter of the pipe is sized so that it can carry the irrigation flow for the field across the upper edge of the field when only

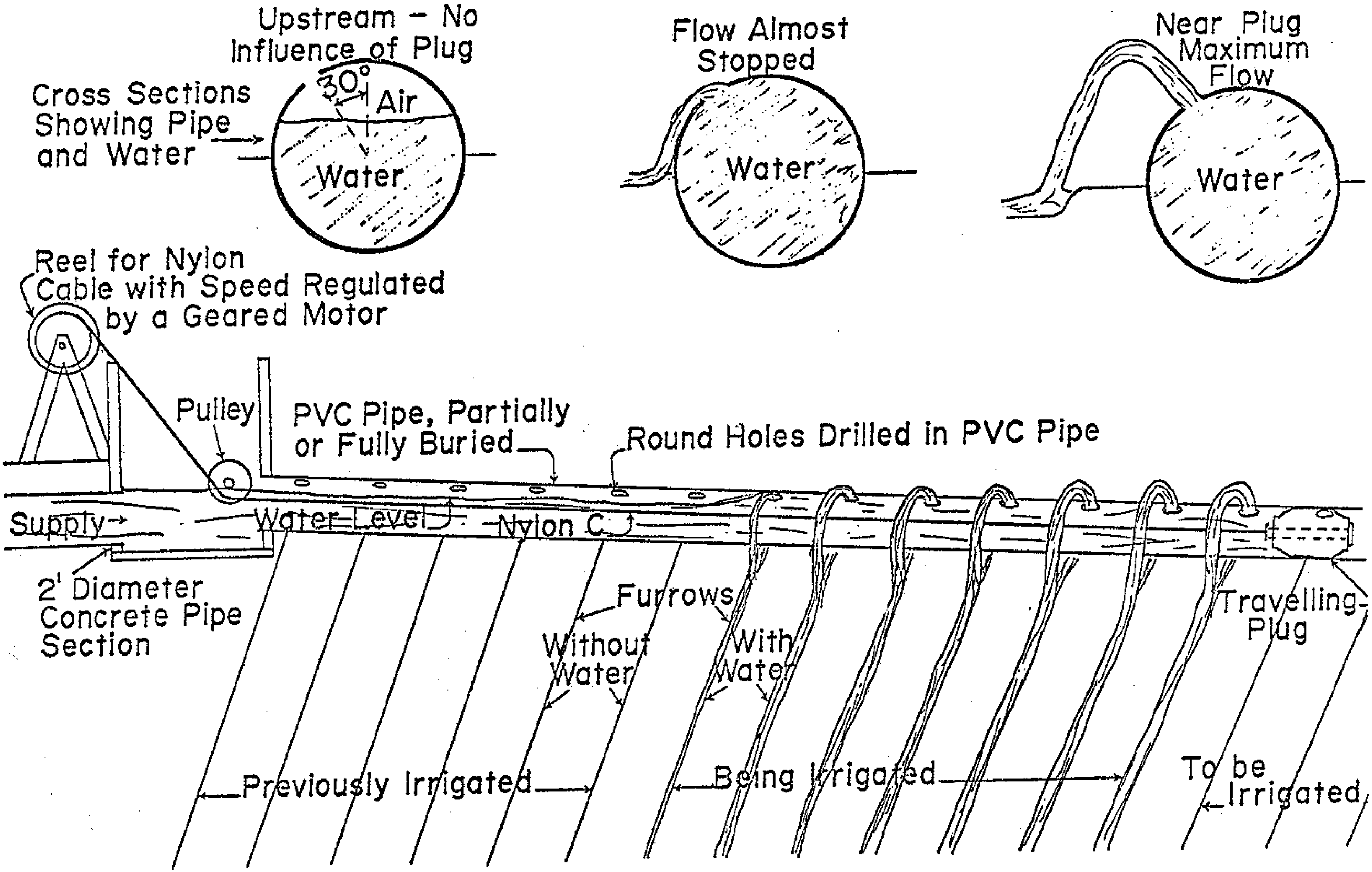

Figure 1. Schematic of Cablegation

filled to about 85 to 90% of its cross sectional area. Thus, the size of the pipe depends on the flow required for the field and the slope across the upper edge of the field. The outlets near the top of the pipe are above the level of the water flowing freely in the pipe until flow is obstructed to reduce its normal velocity.

The water is delivered from the pipe to the field by placing a "plug" in the pipe. As the flow in the pipe approaches the plug, the velocity decreases and the pressure head increases until water is delivered from the pipe to the field. The pressure head is greatest near the plug where the velocity in the pipe approaches zero. Thus the maximum flow from the pipe outlets occurs near the plug and the delivery rate decreases up slope from the plug as shown in the curve in Figure 2. The plug is fabricated from two plastic salad bowls that are clamped between round aluminum plates which are spaced about 10 inches apart by a 2-inch diameter aluminum tube, welded to the plates clamped to the bowls. The outside circumference of the bowls is trimmed so they just slip inside the pipe.

The plug's position in the pipe is controlled by a cable which is attached to the center of the plug. Water pressure against the plug tends to force the plug down slope in the pipe and the cable resists this force. When the cable is reeled out at a controlled rate, the plug moves through the pipe across the upper edge of the field to automatically apply a complete irrigation. The reel's rate of rotation is controlled by a small 12-volt, DC, 1/35 hp motor which operates from an automobile battery, or other DC power supply (Figure 3). The speed of the motor is reduced through two speed reducing units so the cable is reeled out to control the plug's travel rate between approximately 8 and 24 feet per hour. A rheostat in series with the motor is used to adjust the plug's rate of advance to achieve the desired duration of water supply to the furrows. Additional details of the cablegation system may be obtained from reference #1.

Testing by Computer Model

Early in the design phase of development, a computer model of cablegation was developed. Full details of this model are presented in reference #2. This model is based on the physical and hydraulic relationships that are involved when water flows in a partially filled pipe line on a slope as well as the soil intake function that prevails when water flows in a furrow. Evaluation of the performance of the 1980 installation showed that this model satisfactorily predicted the rates and duration of flow from the orifices.

The model has been used to compare the effects of several different operating conditions. It was first used to analyze the water applied at the starting and ending positions of the plug in the pipe. The plug must remain at these points for an extended time to adequately irrigate the rows at the edges of the field. In order to apply more uniform application, the outlets must be modified in these portions of the pipe and the computer model permitted optimization of the sizes of these outlets to improve the uniformity of application.

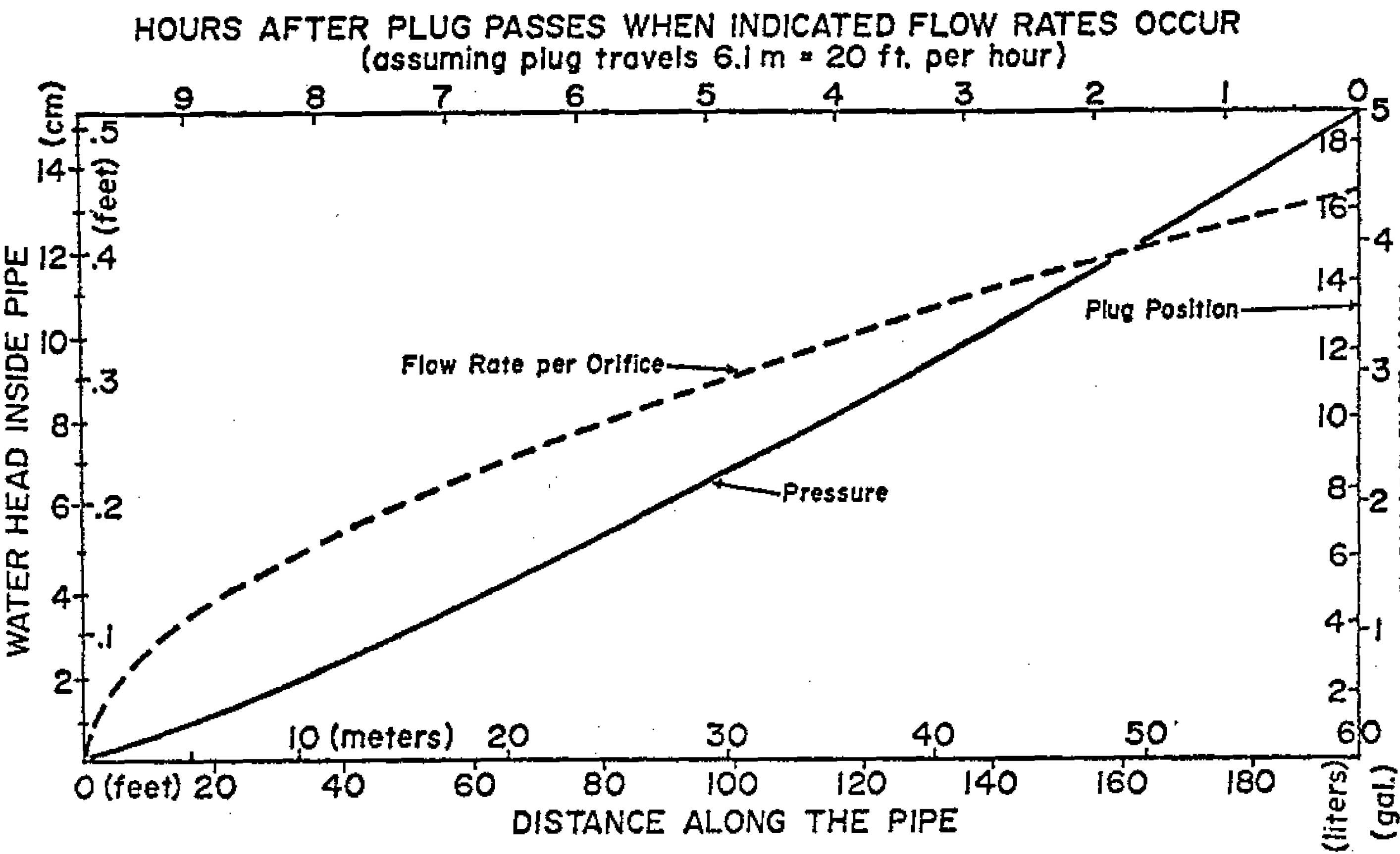

Figure 2. Distribution of Flow Rates Along Cablegation Pipe

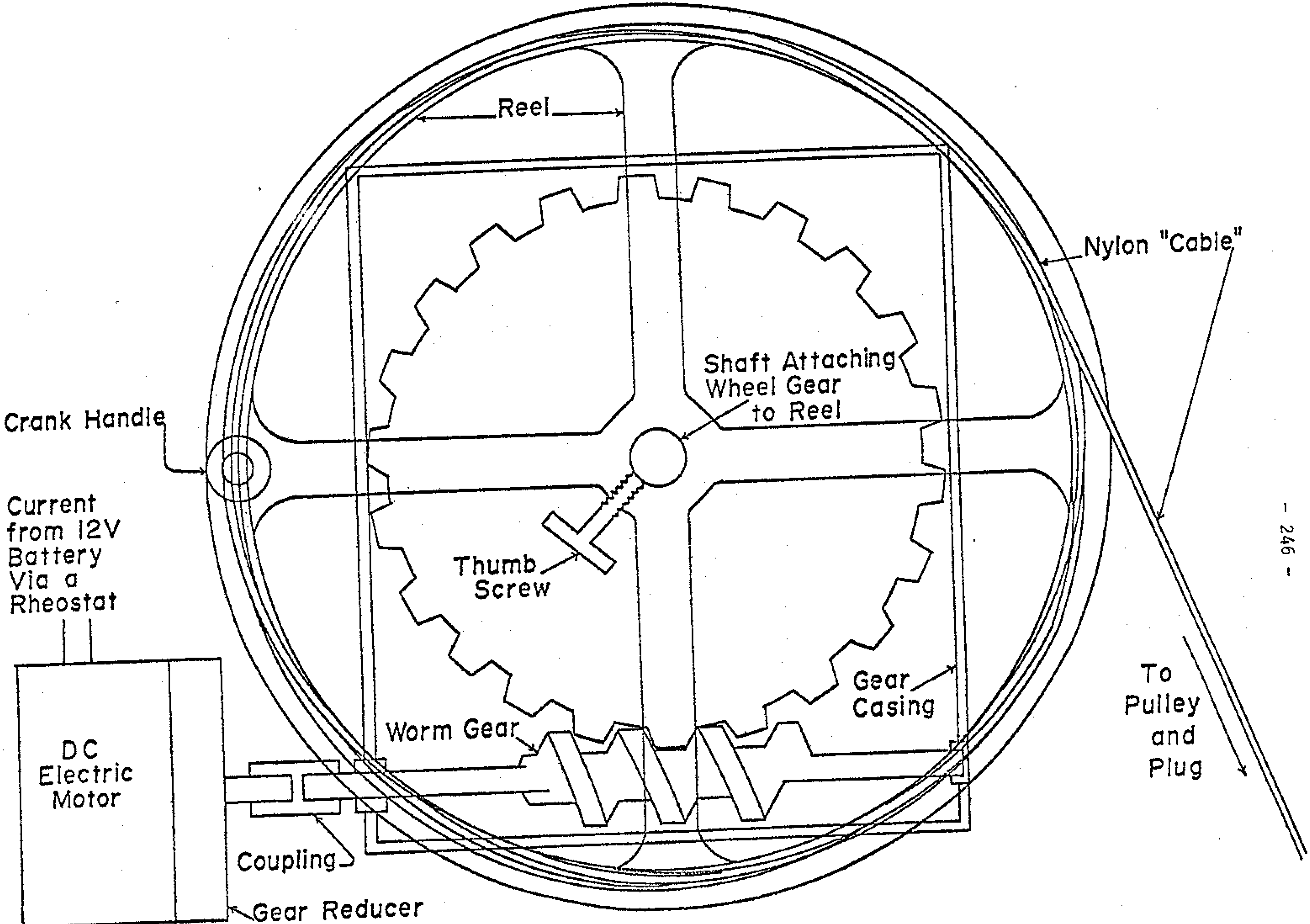

Figure 3. Schematic of Reel, Motor and Gearing

Figure 4 shows the general cutback nature of the supply and the effect of changing outlet size while holding the system's supply rate and the plug's travel rate constant. Larger outlets deliver larger flows for shorter time periods so fewer outlets are flowing at any given time. In this way the system can be adjusted for different intake rates.

Figure 5 shows the effect of changing the plug travel rate while holding the outlet sizes and the system supply rate constant. The initial flow is the same, but the water remains in the rows for a longer time to apply more water at the slower travel rate.

Figure 6 shows the effect of using different total flow rates in a system while the other parameters are held constant. At the lower flow rate, the maximum discharge is somewhat lower but the duration of delivery to the furrows is shortened even more noticeably. The middle curve represents an optimum condition. When the input flow is increased above the design level, the pipe fills to a higher level and the outlets tend to "dribble" water for an extended time which over-irrigates the upper ends of the rows. Variations in pipe slope aggravate this condition--especially on pipelines with slopes less than 0.4%.

Figure 7 shows the results obtained from the computer model when three plugs were used in series. Part of the flow was passed through an orifice in the center of the upper two plugs. The lower plug was of conventional design. The computer model also has the capability of closely estimating the amount of infiltration into the corrugates across the field when rates of infiltration versus time functions are available.

Figure 8 shows a comparison between the measured inflow and runoff rates on a furrow (reference #3). The area between the inflow and runoff curves is proportional to the water infiltrated and the vertical distance between the two curves represents the soil intake rate for the total length of furrow at any time after runoff starts. The computer model has been most useful in bringing a quick understanding of the interaction of the parameters of the system design and in making preliminary tests of new innovations.

Installations and Testing - 1981

Six field size installations were made and partially evaluated during the 1981 irrigation season. These included three in southcentral Idaho, one near Emmett, Idaho, one in the Uintah Basin of Utah, and one in the Grand Valley of Colorado. The field sizes varied between 40 and 80 acres. The crops grown were beans, beets, corn, grain, and alfalfa hay. The growers were generally well pleased with their systems and are presently planning to install cablegation systems on other fields in the near future.

Each of these systems was installed to test one or more new innovations which can be used to make cablegation more versatile. Problems encountered and their solutions are outlined in Table 1.

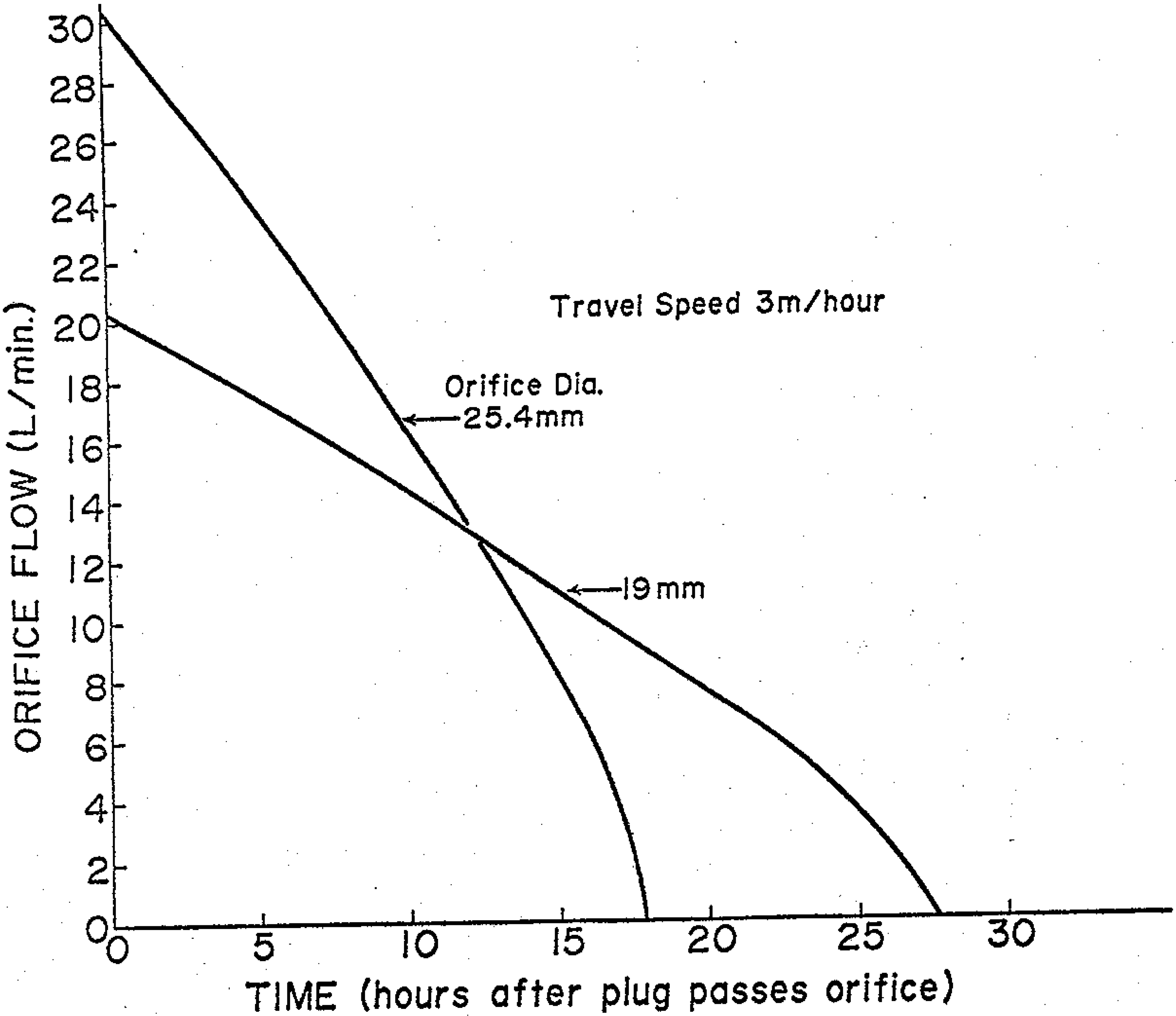

Figure 4. Effect of Orifice Size on Orifice Flow Rates and Times

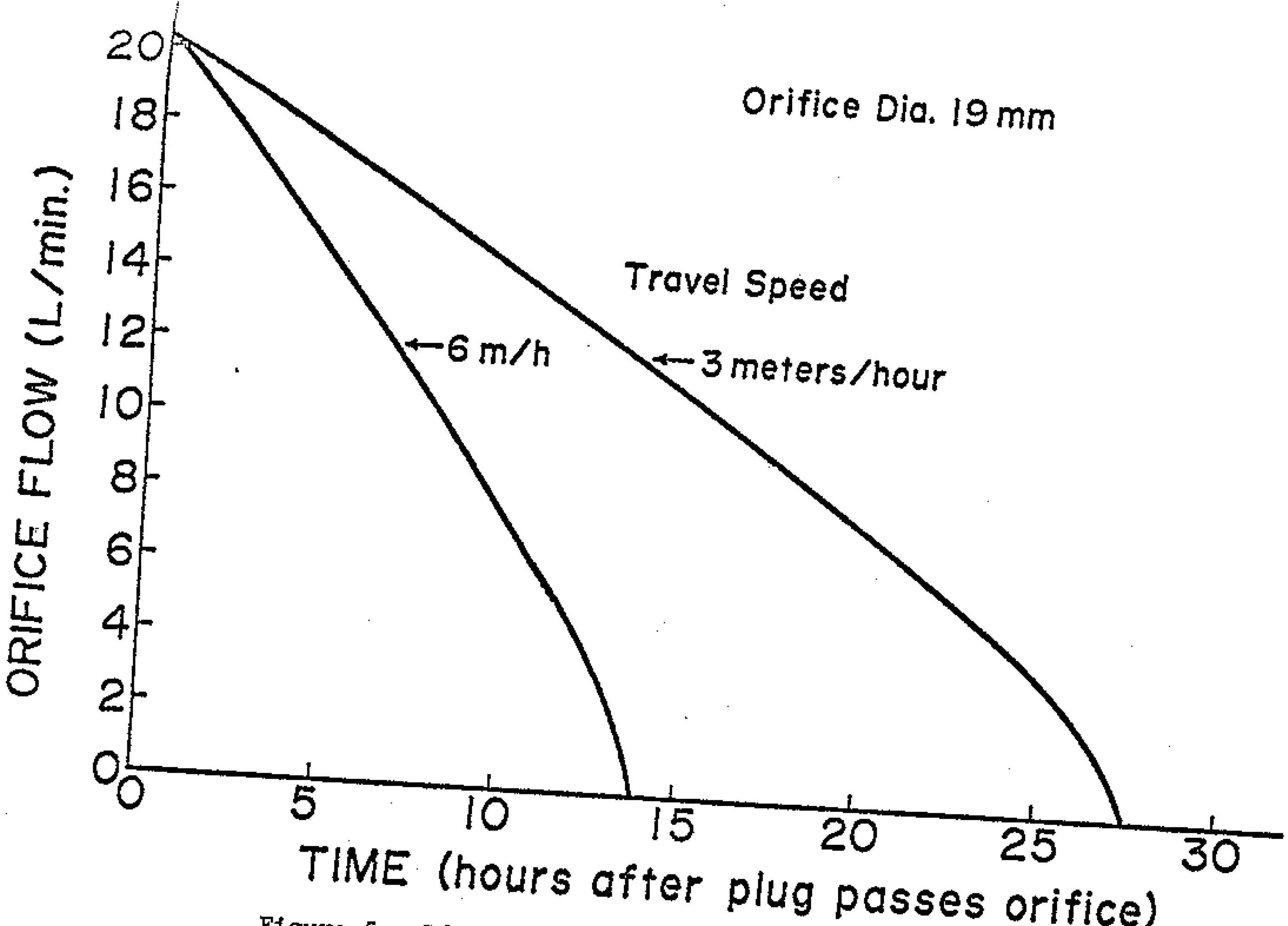

Figure 5. Effect of Plug Speed on Orifice Flow Rates and Times

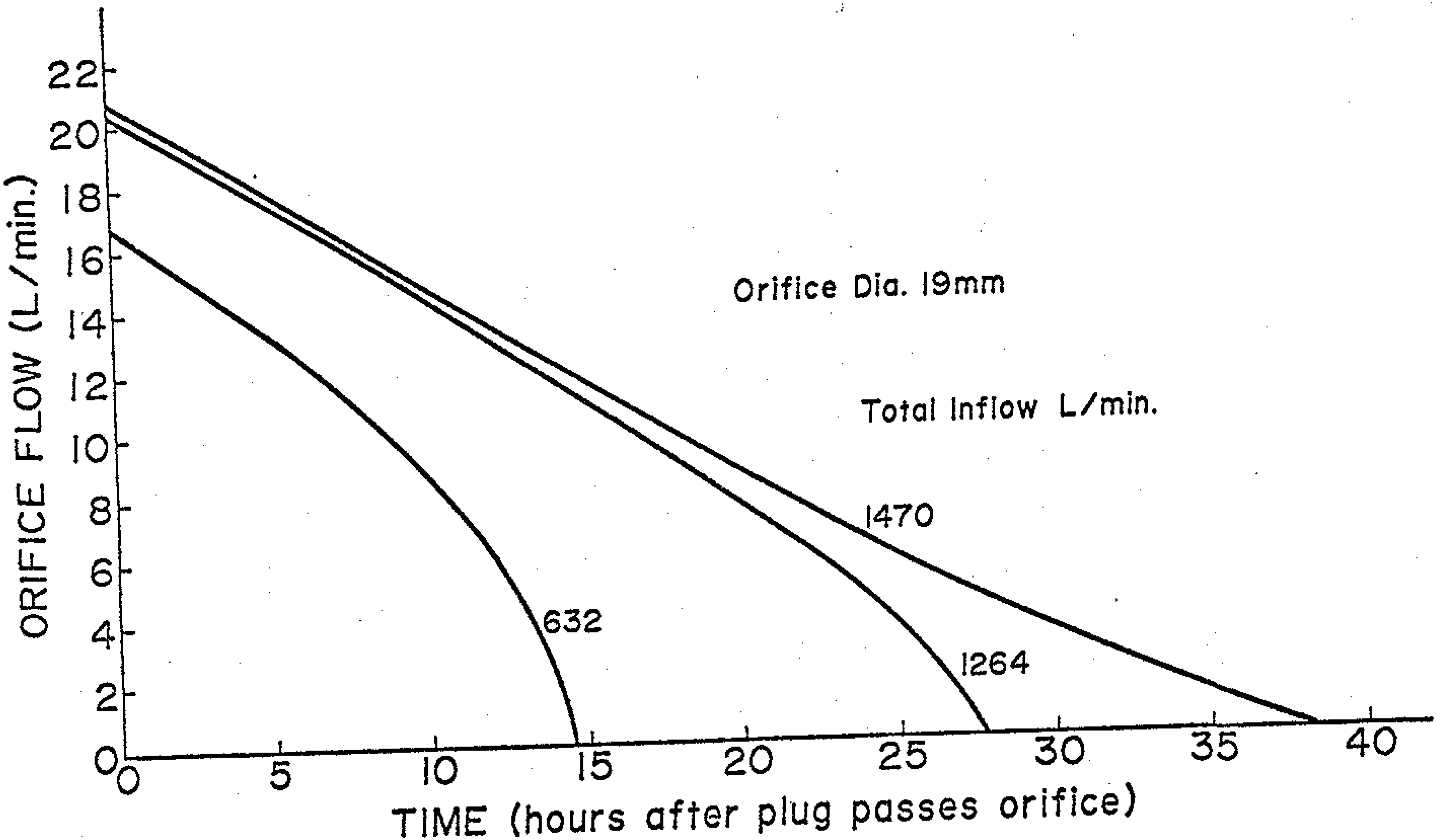

Figure 6. Effect of Total Inflow on Orifice Flow Rates and Times

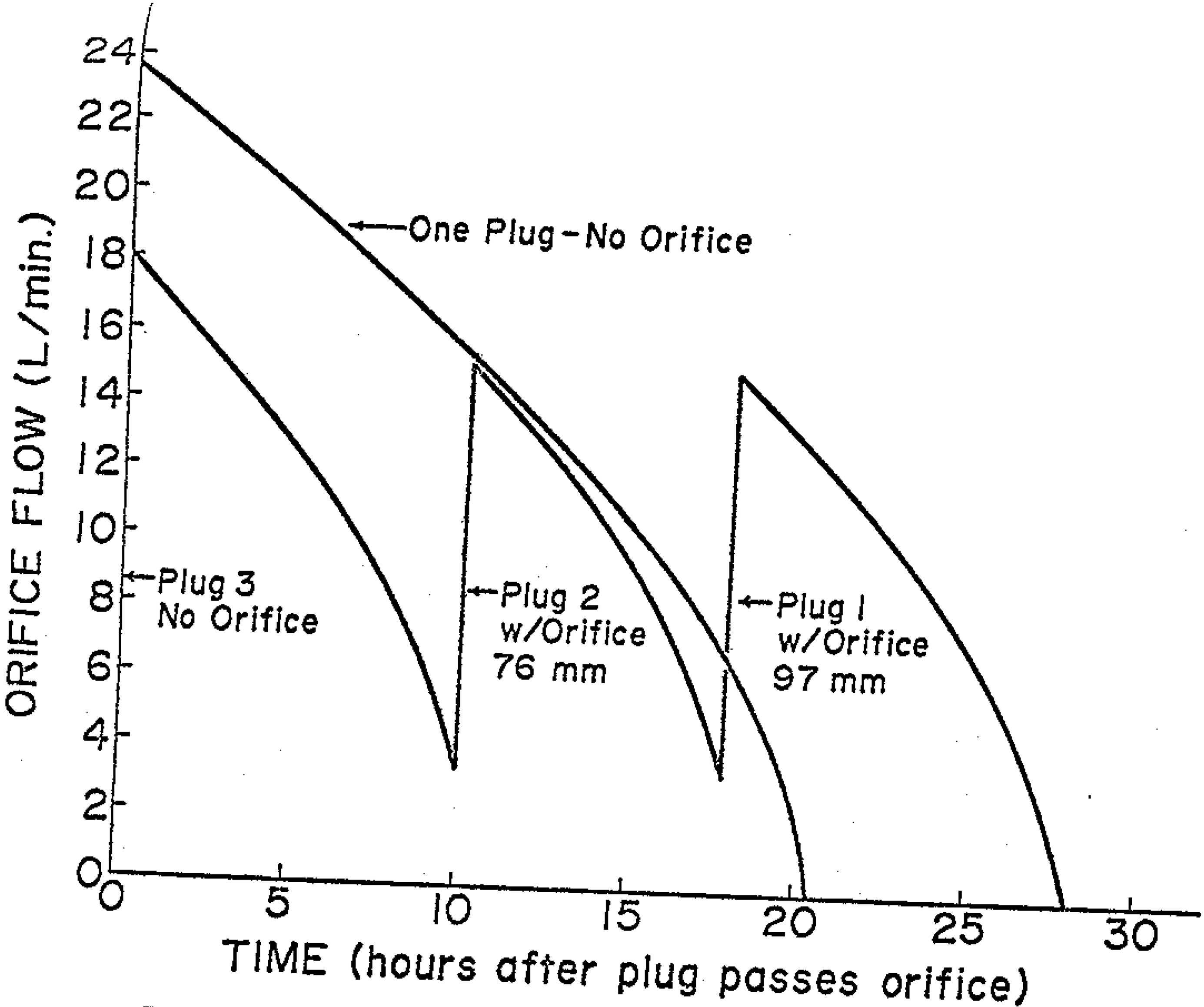

Figure 7. Effects (on a steep slope) of Multiple Plugs with Orifices Allowing Water to Pass Through All But the Last Plug

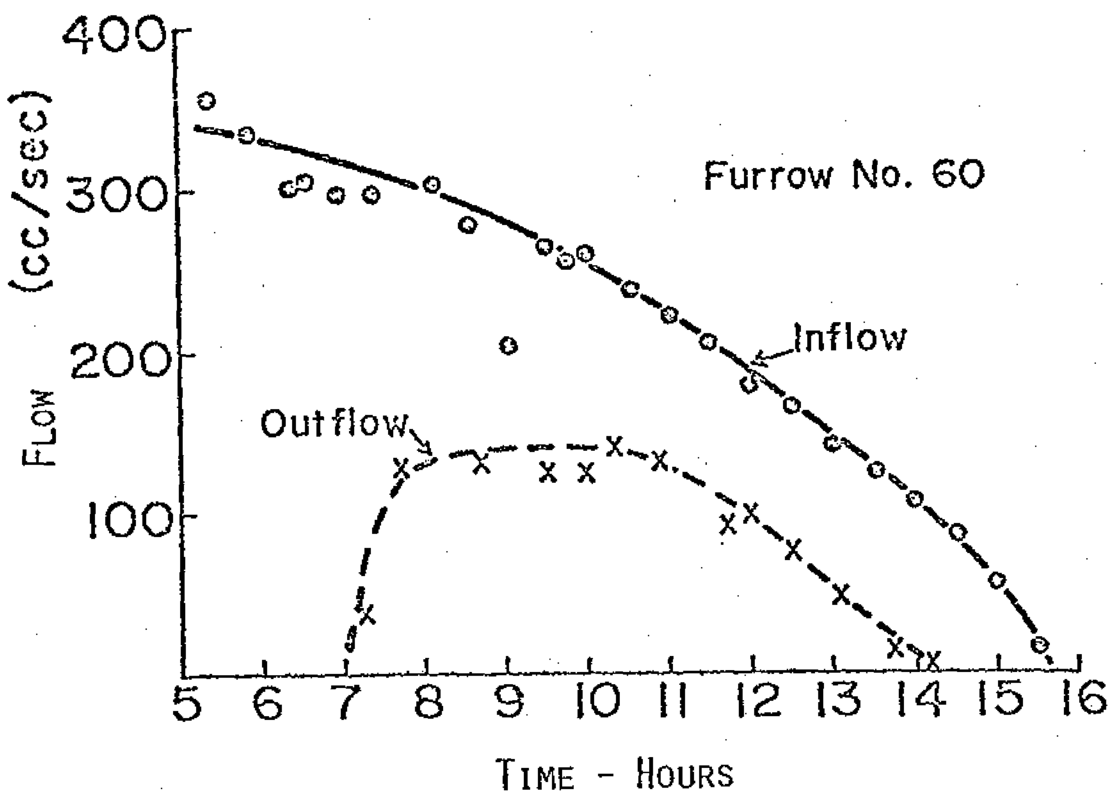

Figure 8. Comparison Between Measured Values of Inflow and Runoff

The slope of the cabelgation pipe lines has varied between 0.2 and 3.0 ft/100 ft on the first installations. The pipe line must be installed on a very constant slope to achieve the most uniform discharge from the outlets. The constant slope can be increased or decreased at widely spaced points along the line, but the slope must be constant between these points of change. When the slope increases, the outlets are made smaller, and when it decreases, the outlets are made larger to give a uniform application. The precise grading requirements for laying the pipe has been the main time-consuming operation for installing the system. This may well become a laser controlled operation on commercial installations.

On steeply sloped systems, there is a greater build-up of low pressure in the pipe. This requires reducing the outlet size and also requires the use of "socks" or tubes to catch the water jetting from the pipe and conduct it gently into the furrow to eliminate erosion.

One installation was troubled with breakage of the cable. This was a system with a long cable and steep pipe slopes. A new source for 500-lb test cable was located, and the reel will be redesigned slightly to accommodate the storage of this cable which is somewhat larger in diameter.

Evaluation of these systems will continue during the 1982 season to improve our knowledge of the application efficiency of each system, the maintenance requirements, and any further operational options that may need to be developed.

Cost of Systems

The total cost of the systems installed to date has ranged between $130 to $150/acre. These costs have been for systems on medium textured soils with irrigation runs in the range of 1000 to 1300 feet long. Costs will be higher on soils with high intake rates since the runs must be reduced to achieve efficient applications. Design costs and profit requirements may further increase the per acre costs of commercially installed systems.

Summary

A new automatic gravity irrigation technique has been developed in response to rising energy costs and the lack of skilled irrigators. The concept is basically simple, but requires design adjustments for specific sites and careful installation to make a system most effective and efficient. During the 1981 season, solutions were developed for nine common water management and control problems. Future research will be directed toward further improvement of the application efficiency of the present system and toward making the concept even more adaptable.

References

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Table 1
Problems Solved by 1981 Research on Cablegation

Problem	Solution
1. Coarse sediment accumulates in cablegation pipe.	Underslung orifices which draw their water from the bottom of the pipe.
2. Slope increases along cablegation line so pressure on plug becomes excessive.	Pipe diameter reduced and transition box and compound plug designed in which large plug stops at transition and smaller plug proceeds.
3. Pressure in pipe causes jetting of water and consequent soil erosion.	Energy dissipating orifices designed, installed and evaluated.
4. High infiltration rate of soils and farmers' desire for reasonable cultivation runs are incompatible.	Designed cablegation system adapted to bordered irrigation with risers in borders.
5. Trash in water plugs some orifices preventing uniform and adequate irrigation.	Designed, constructed and evaluated turbulent fountain type trash and weed screens.
6. Rows change in length and orientation to cablegation pipe which causes irrigation supply to furrows different than desired when simple reel is used at one speed.	Equations developed to construct compound reels of size to provide desired amounts of water to rows.
7. Water supplied to furrows from top and bottom ends of pipe is different from that in middle.	Bypass system designed and constructed which allows irrigation on end section to be essentially the same as in middle.
8. Changes in infiltration rates during cropping season require changes in supply rates to furrows.	Variable flow, energy dissipating orifices designed and evaluated by farmers.
9. Farmer not always available when water needs to be transferred from one cablegation field to another cablegation field.	Designed a transfer box structure with perforated pipe & additional plug & reel assemblies which automatically & gradually transfers flow from one cablegation field to another. This is also another solution to problem #7.