INFILTRATION AND ADVANCE FOR AN OPEN-DITCH SURGE FLOW FURROW IRRIGATION SYSTEM

By

ROBERTO TESTEZLAF

Bachelor of Science in Agricultural Engineering
Universidade Estadual de Campinas
Campinas, Brazil
1979

Master of Engineering
Universidade Estadual de Campinas
Campinas, Brazil
1982

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 1985

INFILTRATION AND ADVANCE FOR AN OPEN-DITCH SURGE FLOW FURROW IRRIGATION SYSTEM

Thesis Approved:

James E. Garton
Thesis Adviser

Ronald L. Elliott

A. D. Barefoot

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to the Almighty God, the eternal being of love and kindness, without Whom I would not be here and have the most valid experience of my life.

I am very grateful to my wife, Vania, and my children, Alexandre, Vanessa, and Camila, who have shared the hardship with me, sacrificing themselves for the hope of a new and better life.

I am also thankful to my major adviser Dr. James E. Garton, one of the best men I have ever met in my life, for his guidance, friendship, and for everything he has done for me.

My thanks to the other committee members, Dr. Ron Elliott, for his helpful criticisms, and Dr. J. Stone and Prof. D. Barefoot, for their advisement in the course of this work.

The support and background given by the Agricultural Engineering Department through its staff and organization made the completion of this study possible.

The financial support of the CNPq - National Council of Research and Technology from Brazil is gratefully acknowledged.

To my parents, Jose and Ricardina, and my entire family, those whom I missed when I was here in Stillwater, my gratitude for their encouragement and prayers.

I give my deep appreciation to my friends, who directly or indirectly helped me throughout the duration of this work.

Table of Contents

Chapter Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Background

Irrigation increases the productivity of agricultural lands. Surface irrigation is the most widely used irrigation method in the world because of its small initial investment, low power requirements and potentially high application efficiency. According to the Irrigation Survey (Irrigation Journal, 1980), surface irrigation is used on approximately 16 million hectares of the 25 million irrigated hectares in the United States. The use of furrows to apply water to the crops is one of the most popular methods of surface irrigation.

The achievement of high application efficiency in furrow irrigation is a function of proper design and good management. Furrow irrigation efficiency can be improved by reducing runoff and deep percolation losses.

One of the latest techniques developed for furrow irrigation is called surge flow. It is defined as the application of water over the field surface using an intermittent flow regime. In other words, the water is applied over the furrows for a period of time and then shut off for another period of time. This procedure is repeated until the desired application of water is obtained.

Statement of the Problem

Initial studies with furrow irrigation show that surge flow has some advantages over the conventional method of applying water on a continuous basis. By reducing the soil intake rate, surge flow provides a faster advance rate for the wetted front. This effect helps to minimize the losses due to deep percolation. Additionally, the excessive runoff at the lower end of the field may be eliminated by controlling the on-off cycle and flow rate. Surge flow then results in small depths of water applied more uniformly and efficiently.

Since surge flow involves the concept of intermittent control of water, an increase in labor requirement can be expected, and the conventional irrigation system must be automated to achieve acceptance. Because open-channel conveyance systems play a significant role in surface irrigation in the United States, it is important that surge flow irrigation be adapted to make use of those channels. To date the emphasis in surge flow research has been with gated pipe.

Although surge flow has already been used extensively in some areas of the United States, it is important to emphasize that the physics of the phenomenon are not yet completely understood. Hence, more experiments and analyses with different soils and operating conditions should be conducted in order to develop reliable design criteria.

Objectives

The overall objective of this study is to determine through field experiments how surge flow affects the physical performance of furrow irrigation, and to evaluate an automated open-channel system for surge flow.

The specific supporting objectives are: (1) to evaluate the hydraulic performance of the automated open-channel system for surge flow; (2) to determine the effects of different cycle times on the advance rate for surge flow and compare with continuous irrigation; (3) To attempt to achieve a cutback irrigation using surge flow; and (4) to determine the intake characteristics for surge flow and continuous irrigation for three different types of soil.

Scope of Investigation

First, an automated open-channel system using an automated gate developed by Cudrak (1984) and an improved controller will be installed and tested at the Irrigation Research Station in Altus, Oklahoma.

Second, using this system advance rate data will be collected for three different cycle times of surge flow (20, 40 and 60 minutes), and also for continuous treatment. In addition, a cutback treatment will be evaluated.

The third part of this work consists of the measurement of infiltration parameters for three different types of soil and for the same treatments cited above. The furrow intake characteristics will be evaluated using a recirculating furrow infiltrometer, developed and tested to be used under field conditions.

The data collected in those experiments will be analysed statistically and used to evaluate the effects of surge flow on the water advance phase and the infiltration characteristics.

CHAPTER II

REVIEW OF THE LITERATURE

The review of the literature is divided in three parts: (1) Surge Flow Irrigation, (2) Infiltration, and (3) Water Advance Phase.

Surge Flow Irrigation

Surge flow is a new technique developed for the application of water by surface irrigation. It is defined as the application of water over the field surface using an intermittent flow regime.

Stringham and Keller (1979) introduced the concept of surge flow as an improved method of automating cutback furrow irrigation. They reported that cutback irrigation could be achieved by not only reducing the inflow rate when the water reaches the lower end of the furrow, but also by reducing the flow rate on a time basis through the use of cycling automatic valves developed by them.

Surge flow creates a series of on and off periods of constant or variable length. Bishop et al. (1981) defined cycle ratio as the ratio of the on-time to the cycle time. The cycle time is the sum of the on-time and the off-time.

Effects of Surge Flow on Furrow Irrigation

Allen (1980) and Poole (1981) presented studies done on the effects of surge flow on furrow irrigation. Both used the automatic system developed by Stringham and Keller (1979), with 180 meter long furrows on a slope of 1.5 percent and a Milville silt loam soil.

Allen (1980) conducted surge tests with cycle ratios of one-third, one half, and two-thirds for a cycle time of ten minutes. He also made continuous flow tests. He used different instantaneous furrow streams in order to achieve an equal quantity of water applied to each furrow over a given period of time. He noted that the surge flow effects were more pronounced during the first irrigation, when the furrow hydraulic and infiltration conditions are extreme. In this case, he found that the continuous flow treatment required almost an order of magnitude more time to complete the advance phase than the surge flow irrigated furrows. Although the advantages of surge flow were substantially reduced in the second irrigation, there was evidence of changes in the physical characteristics of furrow irrigation.

Poole (1981), trying to eliminate the effects of a variable and high instantaneous flow rate, utilized a constant value for the inflow rate for continuous and surge flow tests. He fixed the cycle ratio at one-half and tested cycle times of 2, 5, 10 and 20 minutes. Over the season he found that the average advance time for the continuous flow to reach the end of the furrow ranged from 270 to 3490 minutes, while for the 20 minutes cycled surge flow the range was 60 to 130 minutes. The reduction of both the advance time and its variation means that intermittent application of water not only reduced the intake rate on silt loam soils but also reduced the temporal and spatial variability of the intake.

Coolidge et al. (1982), using the same automatic furrow irrigation system in 100 meter furrows with a slope of one percent, analyzed furrow advance and runoff data. His objectives were to determine the importance of the on and off time in surge flow. The results indicated that surge flow treatments significantly accelerated furrow advance per unit of applied water and reduced the temporal and spatial variability among furrows in the field. He also concluded that the on-time significantly affected surge flow systems, but the off-time did not.

Walker et al. (1982) used a recirculating type infiltrometer to simulate furrow irrigation. They observed that cycled water application decreased the intake rate of the soils under study. In one of the tests, surge flow showed a reduction of 33 percent in the intake rate when compared with continuous application.

Podmore and Duke (1982) evaluated surge and continuous treatments under field conditions. They concluded that surge irrigation produced steady state infiltration rates which were half of those developed under continuous flow furrow irrigation. The irrigation efficiencies found for surge flow were equal to or slightly lower than those for continuous treatments.

Podmore et al. (1983) compared surge irrigation to continuous flow irrigation. They found that surge irrigation with cutback flow after the advance is completed gives higher application efficiency than either continuous flow or fully surged conditions.

Walker and Schlegel (1984) compared field performance for surge and continuous treatments on two fields having clay loam soil. For the first field it was found that surge did not show a great advantage over the conventional set, although the surge treatment had an application efficiency of 82 percent versus 71 percent for the continuous treatment. In the second field the surge treatment showed an application efficiency of 83 percent while the conventional set had an efficiency of only 34 percent.

Izuno et al. (1984) used blocked furrow infiltrometer test and field advance data to characterize the relationship between the surge infiltration phenomenon and the corresponding surge advance rates. They concluded that surge flow has the advantages of less time and water for advance, and a reduction in the advance time differences, both between irrigations and between compacted and uncompacted furrows.

Physical Factors which Affect Surge Flow

Surge flow increases the furrow advance velocity by reducing the infiltration rate of the soil. If less water is being infiltrated into the soil then more water is available to advance to the end of the furrow.

The decline of the intake rate caused by surge flow is related to a reduction of the hydraulic conductivity of the top layers of the soil. This decline is believed to be caused by the sum of the contribution of the following physical factors: (1) surface sealing, (2) entrapped air, and (3) swelling clay.

Surface Sealing. Walker (1984, p. I-8) concluded:

> " The effect of surging is probably associated with the accelerated development of a thin surface seal comprised of very fine soil particles created by soil movement. During the drainage period, the build up of negative pressure consolidates this thin seal, thereby reducing the permeability."

Although surface sealing caused by sediment movement is the most cited reason for surge flow effects, almost no literature can be found about the effect of this factor. However, the effect of sealing produced by rainfall has been studied extensively through the years. It seems valid to relate these two types of sealing, despite the existence of some differences such as the presence of the raindrop impact in the rainfall sealing.

McIntyre (1958) noted that the crust formed by a simulated rainfall consisted of two distinct parts: (a) a skin seal apparently formed by compaction due to raindrop impact, and (b) a " washed-in " region of decreased porosity. He compared those two different layers with the underlying cultivated soil. The underlying soil has a permeability approximately 200 times that of the washed-in region and 2000 times that of the skin seal. More evidence of significant decreases in surface conductivity due to surface sealing have been reported by Duley (1939), Hillel (1960), Schmidt et al. (1964), Edwards and Larson (1969) and Moore (1981).

Hillel (1960) found that, as saturation is approached during an infiltration event, the soil structure can begin to collapse and the platy particles may tend to assume a horizontal and a parallel orientation of greater density.

Tackett and Pearson (1965) compared the effect of simulated rainfall on structure, strength and permeability of the surface layer of soil materials of different textures. The results showed that an extremely dense crust from 1 to 3 mm thick underlaid by a more porous structure was formed under simulated rainfall. The underlying soil had a permeability approximately 5 times higher than the crust. Petrographic examination of the thin sections prepared from the crust showed that the surface was coated with a thin bond of very well oriented clay.

Moore (1981) cited that the surface seal formation is influenced by the texture of the soil; aggregate stability, which is closely affected by organic content; tillage practices; cropping history; method of cultivation; and rainfall intensity and duration. Instead of the rainfall factors surge application should have inflow rates and cycle on-time as major factors.

Trout and Kemper (1983), confirmed that the disintegration of aggregates on the furrow wetted perimeter and the hydraulic repacking of the soil particles can eliminate the large soil pores and form a surface seal which may reduce furrow intake.

Eisenhauer (1984) concluded that surface seals develop with overland flow and are probably caused by the destruction of aggregates at the soil surface by the dynamic forces of the flowing water. He also determined that the conductivity of layers beneath the surface seals decreases with time due to migration of finer material to deeper layers.

From the above cited studies, it appears that surge flow effects may be associated with structural change in the surface layers of the soil. Since this sealing process in surge flow is related to the presence of fine particles (clay or silt particles), it is expected that coarse or sandy soil with sufficiently low silt content will not give the same magnitude of response as found in a clay or loamy type soil. Walker et al. (1982) found that intermittent water applications created larger effects in sandy loam soils than either the silt loam or clay loam soils. This statement does not necessary invalidate the hypothesis of surface sealing, but may indicate that their soil had sufficient silt and clay to effect sealing.

Entrapped Air.Most of the models created until now to predict the infiltration process assume that the displaced soil air moves in the profile with negligible resistance and the air pressure remains constant through the soil profile. This assumption is justified by noting the small viscosity of the air relative to that of water and by theorizing that the air can escape through large pores that remain open during the infiltration process. However, there are cases in which this assumption is not valid because the air trapped by the water will cause an air pressure buildup in advance of the wetting front and it will reduce the infiltration rate. In this case entrapped air will decrease the conductivity and may have the same effects as a layer of lower conductivity such as the surface sealed layer.

Wilson and Luthin (1963) demonstrated the effect of air on infiltration under several conditions of obstruction to air flow. They reported that during infiltration into a homogeneous column the air pressure is greater than atmospheric pressure, with the greatest difference occurring in the initial phases of infiltration. They also concluded that, during infiltration into columns containing barriers that are impermeable to air flow, the air pressure increased continuously and approached a maximum final value, while the rate of infiltration decreased approaching zero as a limit.

Adrian and Franzini (1966) developed one of the first models assuming the presence of air movement in an infiltration process. The resulting equation predicted a decreased infiltration rate due to air entrapment, and if the infiltration process continued long enough, the pressure build-up in the soil would balance the hydraulic potential and infiltration would cease.

McWhorter (1976) analysed the effects of viscous resistance to air flow on the downward movement of water. He used a model based upon an equation, analogous to Darcy's law, which incorporated resistance to flow of both air and water. He indicated that there was a build up of air pressure by air compression below the wetting front, which tends to retard the infiltration process, and consequently decreased the intake rate. Further analyses showing the effects of air on the infiltration process have been developed by Jarrett and Fritton (1978). They proposed an infiltration model for infiltration under trapped air conditions. They found that in sand and in loam soil the average infiltration rates were lower when soil air was not free to escape from the soil at atmospheric pressure.

Morel-Seytoux and Vauclin (1983) developed a two phase model for infiltration considering movement of both water and air. They stated that the two phase approach is not only more characteristic of the physical process but also leads to simple approximate or exact solutions.

The literature shows at this point that entrapped air is at least a factor that should not be neglected when studying the infiltration process. During the on-time period for surge flow the upper layer of the soil may not reach total saturation due to the presence of entrapped air which can not escape. Therefore during the drainage period, it is possible that this air which is under some pressure will form a thin layer at some level below the surface. This layer then can behave as a layer of low conductivity when the next surge covers the furrow. This factor may act concomitant to the surface sealing process which would increase the effect on intake characteristics.

The only problem in this assumption is that the two phase scheme considers the movement of air and water in a homogeneous soil or in layers of homogeneous material. However, natural soils are seldom homogeneous and often permeated, especially in surface layers, by relatively large channels formed by roots, cracking and biological activity. But for the case of surge flow where the presence of a sealed surface is expected with consequent reduction of macropores, the entrapment of air is still a factor which may exist in the process.

Swelling Clay. Another factor that may reduce the macroporosity and the hydraulic conductivity is the soil swelling due to hydration of certain clays. Although the swelling effects should be present for both surge and continuous application, in surge flow swelling could help to assure the development of air entrapment by decreasing the soil porosity.

Automation of Surge Flow for Open Channels

Automated irrigation systems can reduce labor, energy and water inputs and maintain or increase farm irrigation efficiency. Since surge flow involves the concept of intermittent control of water, an increase in labor may be expected. Therefore, there is a need for the automation of surge applications to reduce this labor requirement.

Most of the research in automation of surge flow has been done in gated pipes with controlled valves. Since a large percent of the surface irrigation systems in the U.S. use an open-ditch for irrigation conveyance, efforts to develop an automated device for open-channels will be essential for the introduction of surge flow to those systems.

Garton (1964) presented procedures to design an automatic cutback furrow irrigation system. He presented a system consisting of a ditch divided into a series of level bays in which the water is distributed to individual furrows through short metallic tubes installed in the side of the ditch. Water was released downstream from one bay to the next by mechanically timed check gates. As the water was admitted to the next bay, the water level in the upper bay was lowered and flow from the upper bay outlets was reduced, reaching the cutback inflow rate.

Humpherys (1967) reported the development of some automatic irrigation structures for open-channels. He worked with both portable and semipermanent structures. A semiautomatic flexible check dam, consisting of a nylon-reinforced rubber dam supported in a metal frame, was designed to fit in the cross section of a level ditch. He also made modifications in the above design for unlined ditches. The model for lined ditches was tested in a furrow cutback system similar to the one developed by Garton (1964).

Several attempts have been made to design or modify drop-open and drop-close gate structures. Evans (1977) designed and tested both drop-open and drop-close gates for use in cutback irrigation systems. The field tests showed that both types of structures worked properly and successfully. He stated that many previously reported problems with gate designs had been overcome. Haise et al. (1980) reported on the performance of a wide variety of simple gates and release mechanisms.

Cudrak (1984) developed two types of automated gates, a drop gate and a rotating gate, for application in surge flow irrigation. Both gates were designed to fit in a trapezoidal lined channel. The rotating gate consisted of a double acting air cylinder to open and close the gate. The drop gate was automated using a windshield wiper motor winch in conjunction with lever type limit switches. The control unit for both gates utilized a multiple position electronic time clock and double acting relay to achieve the surging action. He concluded that the rotating gate was the one which performed better, and the control unit worked properly with the possibility of being adapted to other automated structures.

Infiltration

Infiltration is the entry of water into the soil through the soil surface. Knowledge of the infiltration characteristics of a soil is basic information required for designing and managing an efficient surface irrigation system.

Blair (1984, p. III-5) stated that the infiltration process is affected by the following physical factors:

a. Soil texture: sand, clay and silt content.
b. Soil structure: compaction, aeration, soil organic residue, biological activity, soil cracks, tillage.
c. Soil moisture content: surface and subsurface.
d. Irrigation hydraulics: wetted perimeter, furrow roughness and furrow shape.
e. Sediment movement: aggregate stability and sediment microstruture.
f. Chemical contents: salts, types of clays, organic products.

Most of the cited factors are interrelated and sometimes difficult to quantitatively define. The infiltration process is complex and difficult to accurately predict due to spatial and temporal variability commonly found in irrigated soils.

Infiltration Equations

Numerous equations have been proposed over the years to describe the infiltration process. Some of these equations have an entirely empirical approach, while others are theoretically derived. Philip (1957) gave a mathematical solution of the flow equation for vertical infiltration. His equation, which is a truncated form of the power series of his solution, is defined as:

$$Z = S\ t^{1/2} + A\ t \tag{1}$$

where Z = cumulative infiltration (L); t = intake opportunity time (T); and S and A are constants which are related to the soil physical characteristics.

The most commonly used empirical equation for irrigation design purposes is the Kostiakov equation:

$$Z = k\ t^{a} \tag{2}$$

where Z = cumulative infiltration (L), T = intake opportunity time (T), and k and a are empirical constants fitted to experimental data. The intake rate can be obtained by taking the derivative of this equation with respect to time, as follows:

$$I = a\ k\ t^{(a-1)} \tag{3}$$

where I = infiltration rate at time T (L/T).

The Kostiakov equation is simple and in most cases accurately describes infiltration during its early stages. However, as the process continues in time the accuracy of this equation becomes questionable since the infiltration rate approaches zero rather than a basic or steady-state intake rate.

Fangmeier and Ramsey (1978) used a water volume balance method on precision field furrows to determine the effect of the furrow geometry on infiltration functions and intake characteristics. They determined the intake rate using the inflow-outflow method for every 9.14 m (30 ft) station along 105 m (345 ft) precision furrows. They reported that the Kostiakov and Philip equations provided estimates of infiltration with comparable accuracy, but the constants of the Philip equation were more difficult to obtain. They also found that intake appeared to be dependent on the wetted perimeter.

For the purpose of this study the Kostiakov equation will be used to fit the experimental data, because of the simplicity of obtaining its parameters and since the infiltration test periods were limited to four hours.

Instrumentation

Several methods of infiltration measurement have been proposed in the past to determine the intake characteristics of a furrow. Basically, there are two types of field tests that can be done to evaluate the infiltration process: volume balance method and infiltrometers.

Volume balance methods use data gathered during an irrigation to estimate infiltration. Most of these methods require that data on advance times, furrow dimensions, and furrow inflow and outflow must be taken. Elliott and Eisenhauer (1983) presented a review of the volume balance methodology and described five different volume balance techniques in detail. This approach seems to be one of the most accurate methods for determining infiltration parameters, but can only be applied during irrigation events.

Infiltrometers are often used to evaluate infiltration characteristics. The three most common types of infiltrometers are: (1) cylinder or ring infiltrometer, (2) blocked furrow infiltrometer, and (3) recirculating blocked furrow infiltrometer.

The ring infiltrometer is the simplest type to use. It consists of two concentric rings, ranging from 8 to 16 inches in diameter, which are driven into the soil. This device measures primarily the vertical rate of water movement through the soil surface.

Bondurant (1957) developed a furrow infiltrometer which consisted of blocking a short section of the furrow by using two metal plates. The water level is kept constant in this section by a float valve arrangement. Water is supplied by a reservoir in which a water level recorder is used to obtain a continuous record of the water level variation.

Both the ring and blocked methods, which use static water, do not simulate the actual conditions caused by overland flow in which the soil surface is continually disturbed. Recirculating blocked furrow infiltrometers are similar to blocked furrow infiltrometers except that the water is kept flowing inside the test section. Malano (1982) and Tabago (1983) conducted field tests using recirculating type infiltrometers to evaluate the infiltration process under continuous and surge treatments. Although those tests required more equipment and effort to perform than ring and blocked furrow tests, the equipment provided reliable measurements of intake rate. Since the water is kept flowing during the test, the recirculating infiltrometer is the method which better duplicates the dynamic process of infiltration in furrow irrigation.

Water Advance Phase

Basset et al. (1980, p.451) defined the advance phase as:

> ".... the portion of the total irrigation time during which water advances in overland flow from the upper field boundary toward the lower field boundary."

Consequently, advance rate is the velocity of the water advance front over the field surface. Describing the advance phase is basic to defining the infiltration opportunity time, which is needed to evaluate the overall performance of a surface irrigation system.

The power function is the relationship most used to describe the advance of the water front in furrow irrigation. The general form of this equation is:

$$x = p\ t_x^{r} \tag{4}$$

where x = the advance distance (L), t_x is the time of advance to x (T), and p and r are empirical constants. This relationship was used by Fok and Bishop (1965) in developing expressions for the advance of water in surface irrigation.

The USDA Soil Conservation Service adopted another type of function to describe the advance phase:

$$t_x = (x/f) \exp(g x) \quad (5)$$

where f and g are empirical constants.

Since most of the research done in furrow irrigation utilizes the power function to describe advance phase, that relationship was used in this study.

CHAPTER III

EXPERIMENTAL EQUIPMENT AND PROCEDURES

Automated Open-Channel System for Surge Irrigation

Description and Operation of System

One of the objectives of this work was to evaluate an automated open-channel system used for surge flow. A trapezoidal open-ditch system located at the Irrigation Research Station at Altus, Oklahoma, was modified for surge flow irrigation. Originally, the system was designed and tested as an automated cutback system by Garton (1964).

The system consisted of a series of six level sections called bays. Water was applied to the furrows through short tubes installed in the side of the concrete ditch (Fig. 1). Each bay had 29 inlet tubes with the interior ends sawed at 45 degrees. The tubes were set at the same elevation in each bay and were 9.5 cm (0.31 ft) higher than those in the bay immediately downstream.

Irrigation proceeded downstream from the bays with highest elevation toward the bays with lowest elevation. At the start of an irrigation, a solid check dam was placed downstream of the second bay and the automated gate is installed between the first and second bay. The open-close

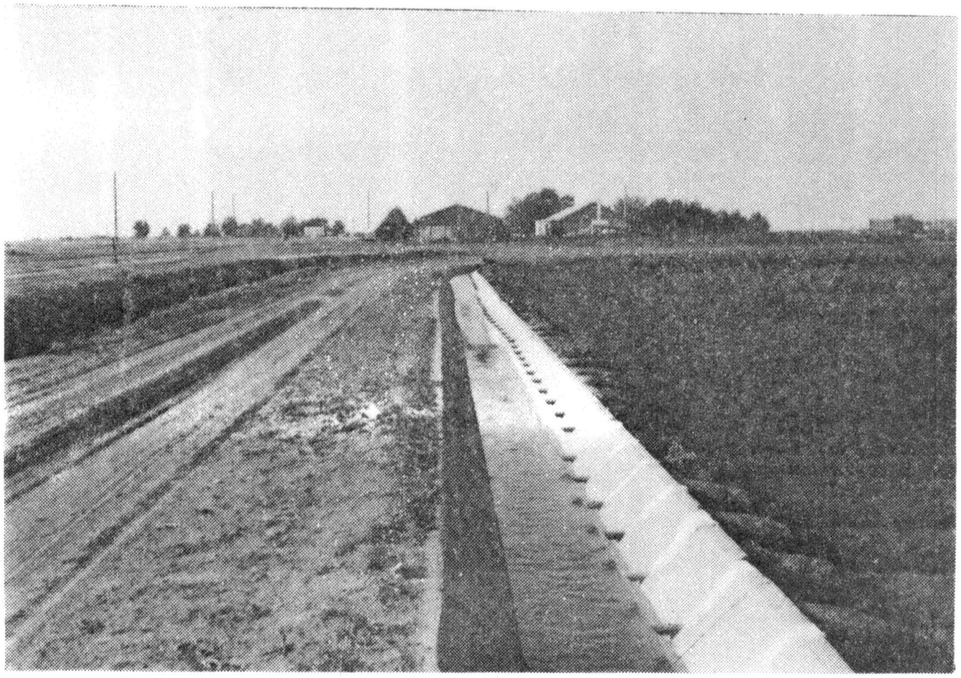

Figure 1. Open-Channel System with Level Bays and Installed Inlet Tubes

movement of the automated gate shifted water from one bay to another creating the surging effect. A control check dam was used upstream of the first bay in order to provide effective control of the upstream channel storage.

Figure 2 shows the two basic arrangements of the open channel system in operation. In Figure 2A, the automated gate is closed (Fig. 3) and bay 1 is delivering water to the furrows for the desired amount of time. In Figure 2B, the automated gate is open (Fig. 4), and bay 2 is now delivering water to the furrows, while in bay 1 the flow depth is below the outlet tubes, shutting off the flow.

The system has the following dimensions:

a. Bay length: 29.5 m (96.7 feet);
b. Number of tubes per bay: 29;
c. Distance between tubes: 1.02 m (40 inches);
d. Tube diameter: 38.1 mm (1.5 inches);
e. Tube length: 0.64 m (2.1 feet);
f. Channel bottom width: 0.30 m (1 feet);
g. Channel side slope: 1:1;
h. Height of the tube above channel bottom: 0.30 m (1 feet);
i. Drop between bays: 9.5 cm (0.31 feet).

Automated Rotating Gate

Cudrak (1984) developed and tested the automated rotating gate utilized in this work. He described its design and operating procedure in detail.

Basically, the automated gate is a typical half moon

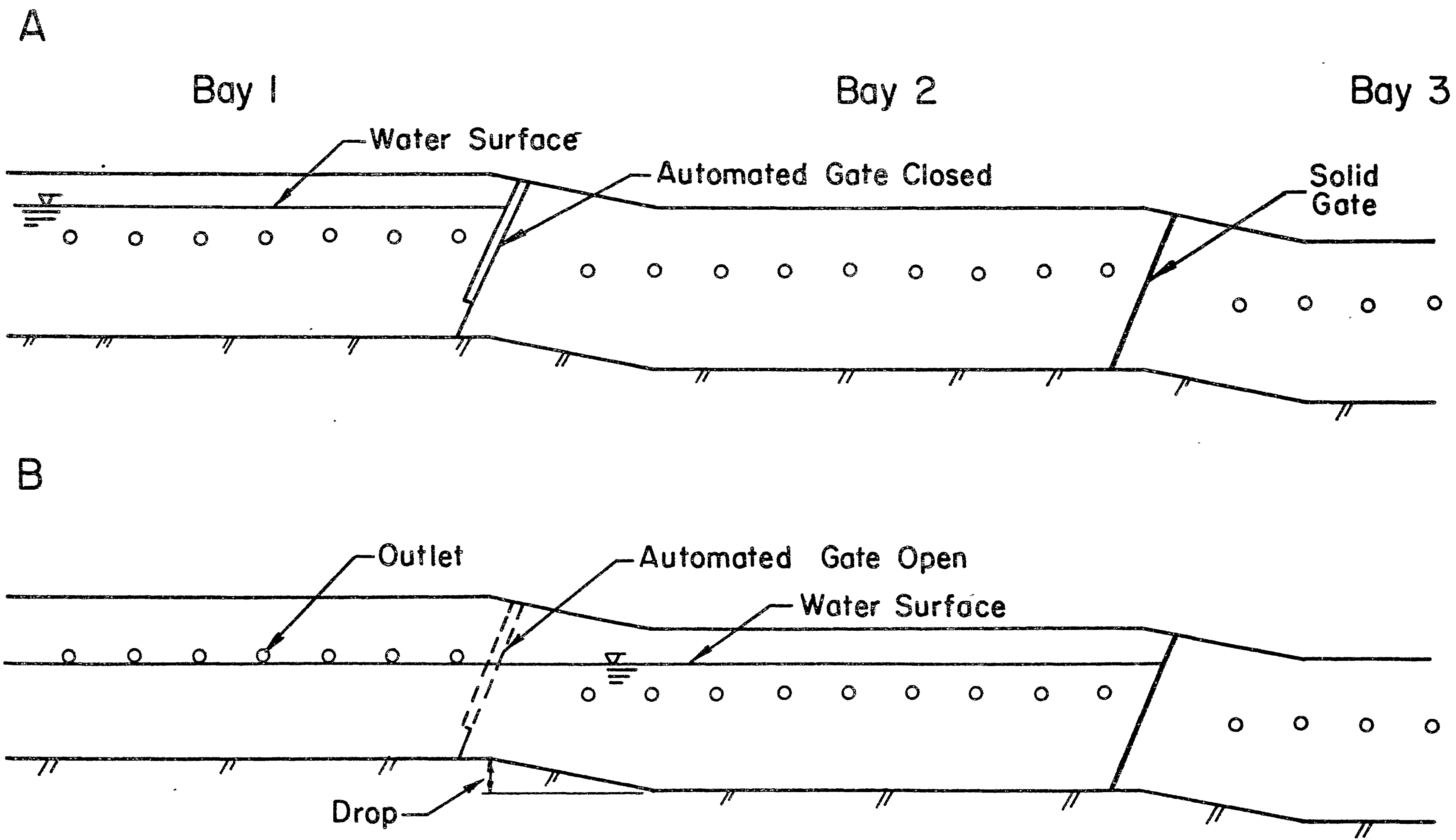

Figure 2. Schematic Diagram of the Two Basic Arrangements of the Open-Ditch System in Operation

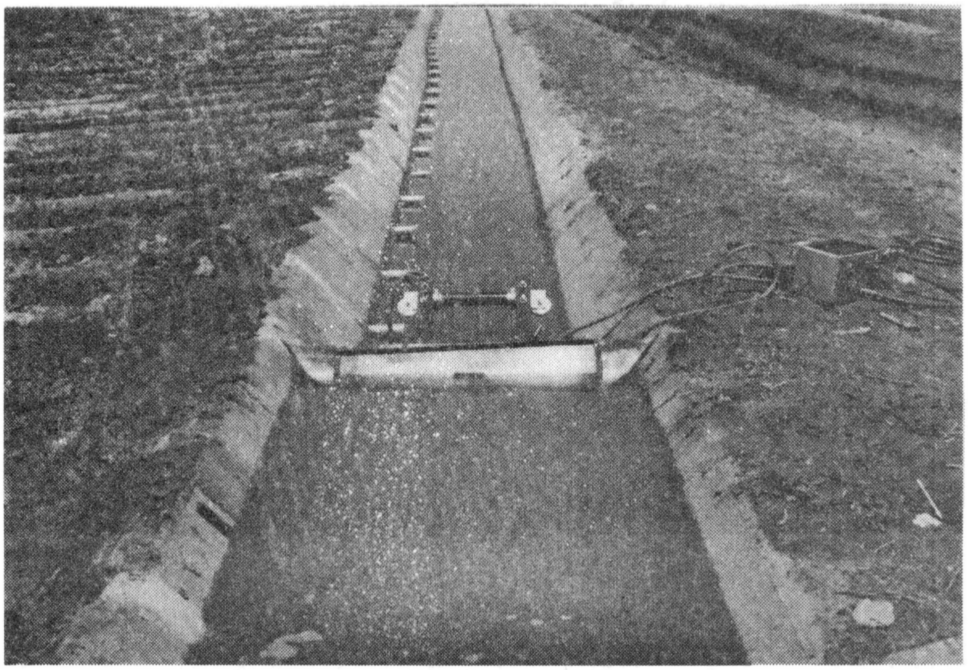

Figure 3. Automated Gate in Closed Position

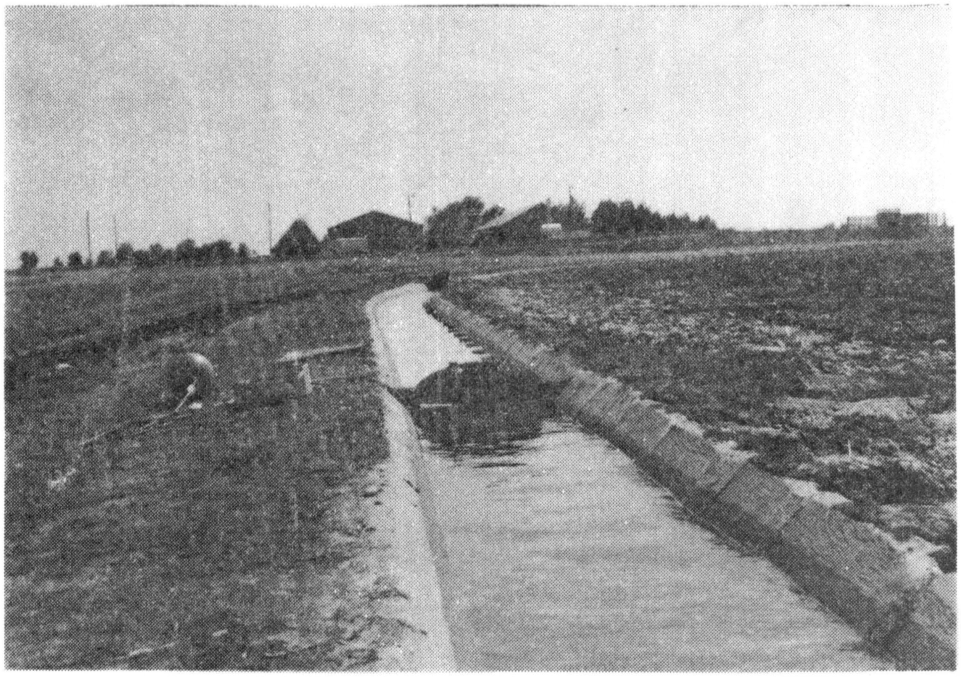

Figure 4. Automated Gate in Open Position

check dam with the movable portion mounted on a shaft. The other end of the shaft has a 15.2 cm (6 inches) diameter chain sprocket. The actuator is a double acting air cylinder (38.1 mm diameter) 25 cm (10 inches) long with plastic covered cables. The sprocket is rotated by a chain connected to the ends of the cables. The air needed to actuate the cylinders was supplied by an air tank which had a pressure gage to monitor the air pressure variation during the irrigation. Figure 5 shows a rear view of the gate in the closed position.

The movement of the gate was controlled by solenoid valves which were activated by a microprocessor control unit. The control unit used in this study was an improved model of the one utilized by Cudrak (1984). The improved unit allowed the setting of two different surge treatments with different numbers of surges and cycle times. In the initial pre-selected treatment, it allows up to 99 initial pulses with a pulse length of up to 999 minutes in one minute increment (two pulses per surge). For the sequent second treatment chosen, another set of switches allows up to an additional 99 pulses of up to 100 minutes each. A normal-reverse switch was also added to the old unit to allow the gate to switch from open to closed or vice versa without waiting until the end of a pulse, or to start an irrigation in either position. Figure 6 shows a top view of the microprocessor control unit.

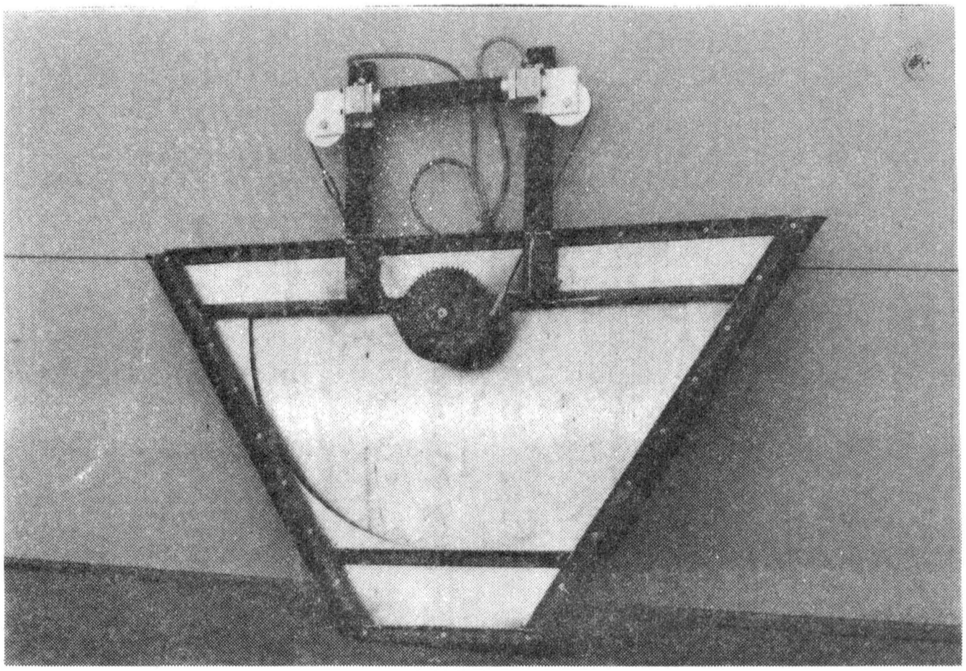

Figure 5. Rear View of the Automated Rotating Gate

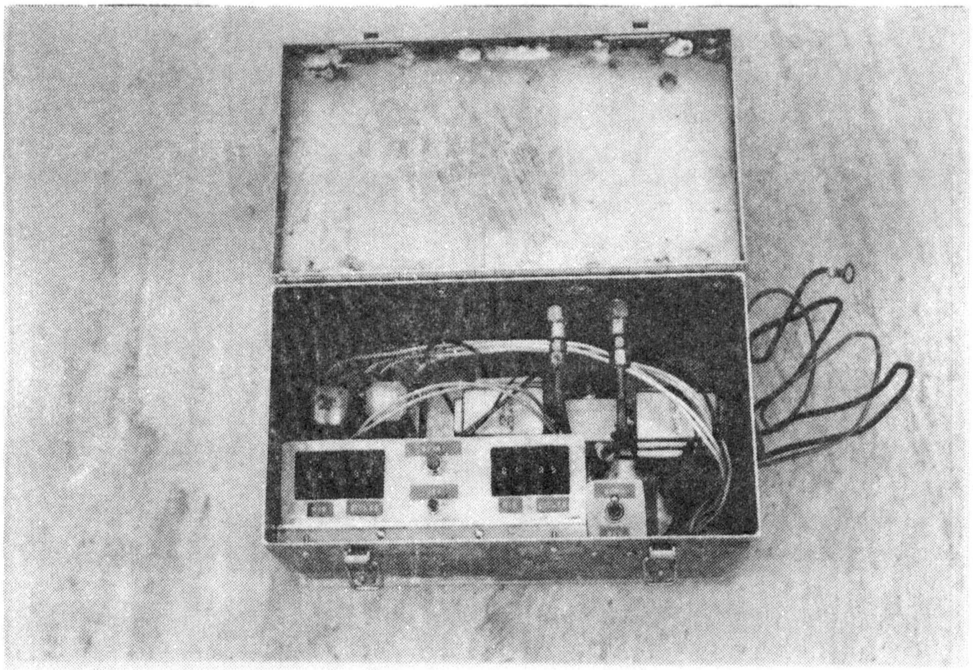

Figure 6. Top View of the Microprocessor Control Unit

Experimental Design

Using the described open-channel system, the performance of the automated gate was evaluated under different field conditions. The operating characteristics of the automated gate and the control unit were also evaluated in the laboratory.

A BASIC computer program was developed to evaluate the hydraulic performance of the discharging bay. Using the theory of spatially varied flow with decreasing discharge, the hydraulic head above each tube within the bay was estimated. The expected variation of the flow rate in the outlet tubes of the discharging bay is caused by the difference in the water surface elevation between tubes. This difference results from the gain in potential energy due to decreasing velocity and the loss in energy due to friction.

The method used in this computer program was to evaluate the flow depth at each outlet tube, using Bernoulli's energy equation and a step by step approach, starting from the last tube downstream. The expression used to calculate the flow depth of the next outlet was:

$$Y_{i+1} = Y_i - \frac{(V_{i+1}^2 - V_i^2)}{2\ g} + Hf \qquad (6)$$

where: Y = depth of flow (L); V = flow velocity (L/T); g = acceleration due to gravity (L/T^2); Hf = head loss (L) due to friction between two tubes; and (i) and (i+1) are subscripts identifying the outlet tubes, where (i+1) is the tube upstream of (i). In this case, the value of Y_1 was assumed equal to 39.9 cm (1.31 feet).

The head loss between two tubes was evaluated by using the Manning equation:

$$Hf = \frac{Q_{i+1}^{2} \quad n^{2} \quad L_t}{C \quad \overline{A}^2 \quad \overline{R}^{4/3}} \tag{7}$$

where: Q_{i+1} = discharge past the upstream outlet (L^3/T); n = Manning's friction coefficient; $\overline{A}$ = average area (L^2) for the section in study; $\overline{R}$ = average hydraulic radius (L) for the section; L_t = distance (L) between outlets ; and C = 2.208 for the equation in English units or C = 1 for SI units.

The discharge-head relationship for each outlet was developed from that presented by Garton (1964):

$$Q = 0.06193 \; (\; H \;)^{1/2} \tag{8}$$

where Q = flow through the outlet (cfs), and H = hydraulic head above the tube outlet (feet).

Advance Phase

Experimental Site

The test site was the Irrigation Research Station in Altus, Oklahoma, where the operating open-channel system was located. The field contained a soil classified as clay loam of the Tillman-Hollister complex, and was planted with cotton in both the 1983 and 1984 seasons. The furrows were 335 m (1,100 ft) long with 1 m (40 inches) spacing. The site has an overall average slope of 0.41 percent. Figure 7 (based on Table LXXXV in Appendix B.4) shows the relative elevation of a furrow in each of the bays used in the experiments.

Experimental Design

The advance phase tests were conducted in two years of study.

First Year (1983). A surge treatment with cycle time of 60 minutes and a cycle ratio of one-half (30 min on/ 30 min off) was compared with continuous treatment. The first year of the study had three irrigation tests (Jul/16, Aug/09, and Aug/25). In all of the irrigations, the surge treatment was evaluated in two bays of the system for different average inflow rates. On July/16 the inflow rates used were 34 L/min (9 gpm) and 57 L/min (15gpm), while on Aug/09 and Aug/25 they were 49 L/min (13 gpm) and 57 L/min (15 gpm). The continuous treatment was evaluated in just one bay for an average inflow rate of 57 L/min (15 gpm). The measurements were made in the last ten downstream furrows of each bay in the test. The variables measured in these experiments were the advance length, advance time, and the furrow inflow rate.

The advance length was evaluated by using an odometer, which is a device that counts the revolutions of a wheel

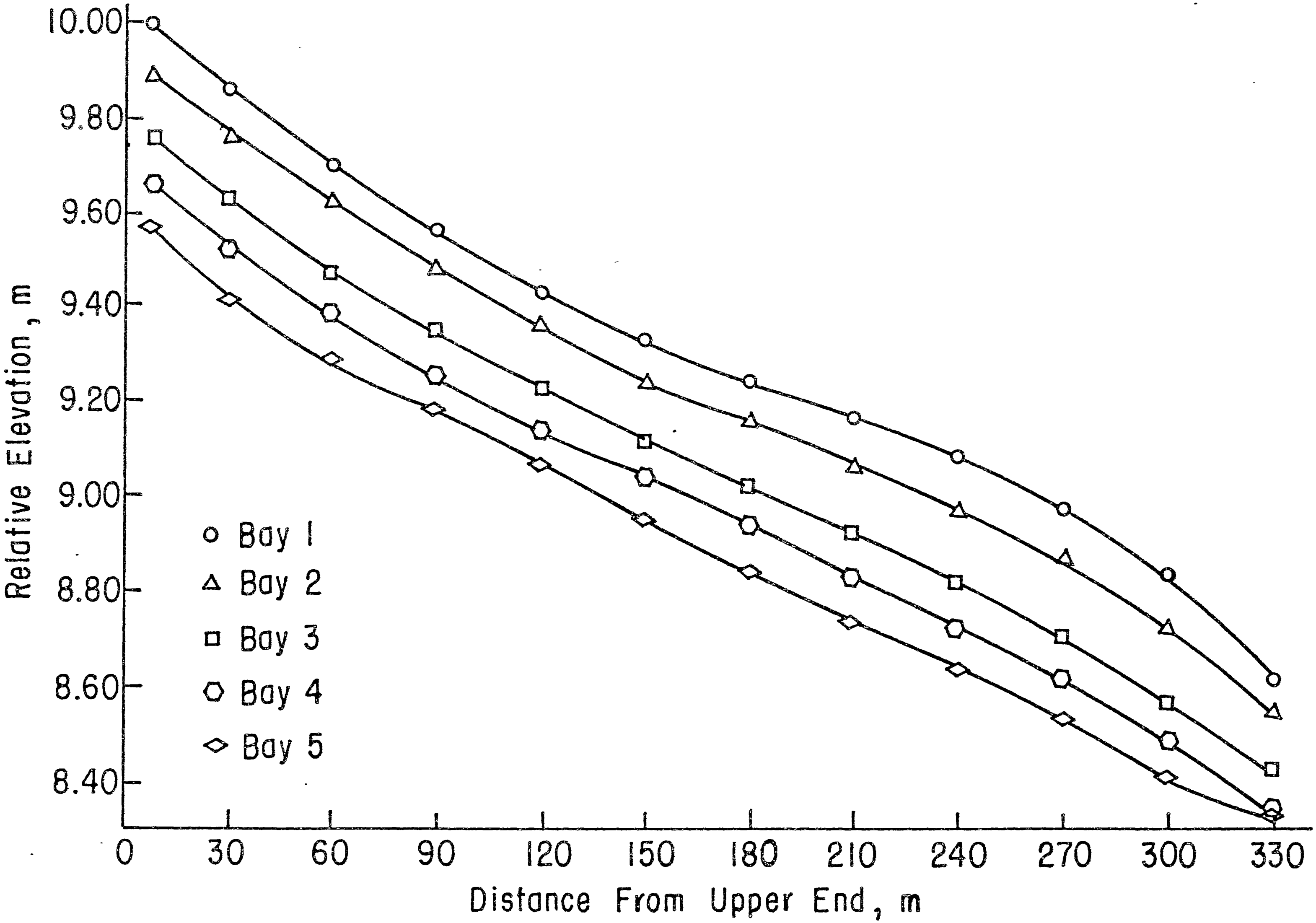

Figure 7. Average Profile of a Furrow in each Bay

rolled along the line to be measured (Fig. 8). The total length of the last downstream furrow in each bay was staked with flags 30.5 m (100 ft) apart. After each on-time for surge flow, or every 30 minutes for the continuous treatment, the total distance covered by the advancing water front was determined by noting the distance from the water front to the nearest flag.

To check the flow rate in each tube outlet during the operation of the system, a flow meter developed by Epperly et al. (1983) was used. This flow measuring device was designed based on the principle of orifice flow. A calibrated HS flume was also used to evaluate the flow rate. Both flow meter devices are shown in Fig. 9.

Second Year (1984). In the second year, the study was limited to two irrigation dates due to a shortage of water. In the first irrigation (Jul/17), two more surge treatments with cycle time of 40 minutes (20 min on/20 min off) and 20 minutes (10 min on/10 min off) were compared with continuous flow. Each surge treatment was evaluated in two bays of the system for both tractor wheel compacted furrows and non-wheel furrows. The continuous flow treatment was evaluated in one bay and for the same conditions of compaction. The data were collected in the last ten downstream furrows in each bay. The inflow rate used in all of the treatments was approximately 58.6 L/min (15.5 gpm).

In the second irrigation (Jul/30), two cutback irrigation treatments were used. It was noted in the former

Figure 8. Measurement of the Advance Distance using an Odometer

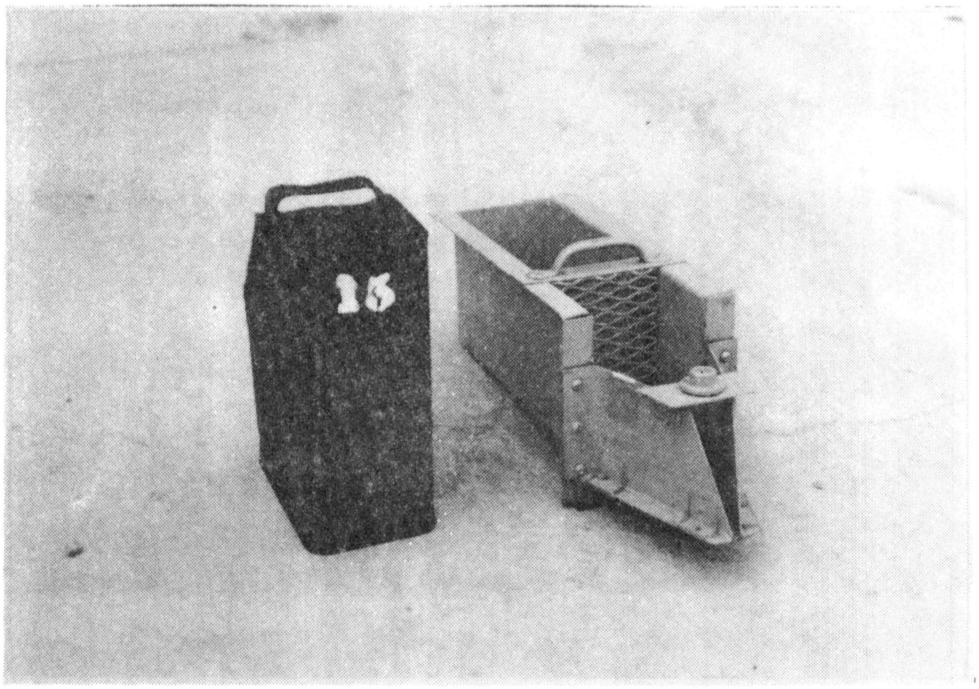

Figure 9. Orifice Meter (at left) and HS Flume (at right)

tests that a surged furrow with 30 minutes of on-time would reach the end of the furrow and create some runoff volume. Thus, a cutback surge with 30 minutes cycle time (15 min on/15 min off) was tried. The cutback was implemented in two different treatments. The first treatment, called SCB, was a combination of surges with different cycle times: two surges of 20 min, two surges of 40 min and two surges of 60 min. This combination was selected in order to create a linear advance of the water front through the field and to achieve a complete advance in most of the furrows in a bay. Then, a cutback surge with 30 min cycle time was applied. This treatment was evaluated in two bays of the system. With the second treatment, called CCB, the water was applied continuously for a period of time long enough for the water to reach the lower end of the field in most of the furrows. Then, the same cutback surge of 30 min cycle time was applied. Both treatments were evaluated for tractor wheel and non-wheel furrow conditions, and for an average inflow rate of 58.6 L/min (15.5 gpm).

In the second year of the study, the soil moisture content profile was evaluated using a neutron moisture meter (Fig. 10). One and one-half inch thin wall conduit was used as the access tube. These access tube were placed half way between the middle of the furrow and the middle of the crop rows, i. e., 25 cm (10 inches) from the middle of the furrow. Five tubes were installed in a non-wheel furrow of each bay of the system. The first tube was installed 15 m

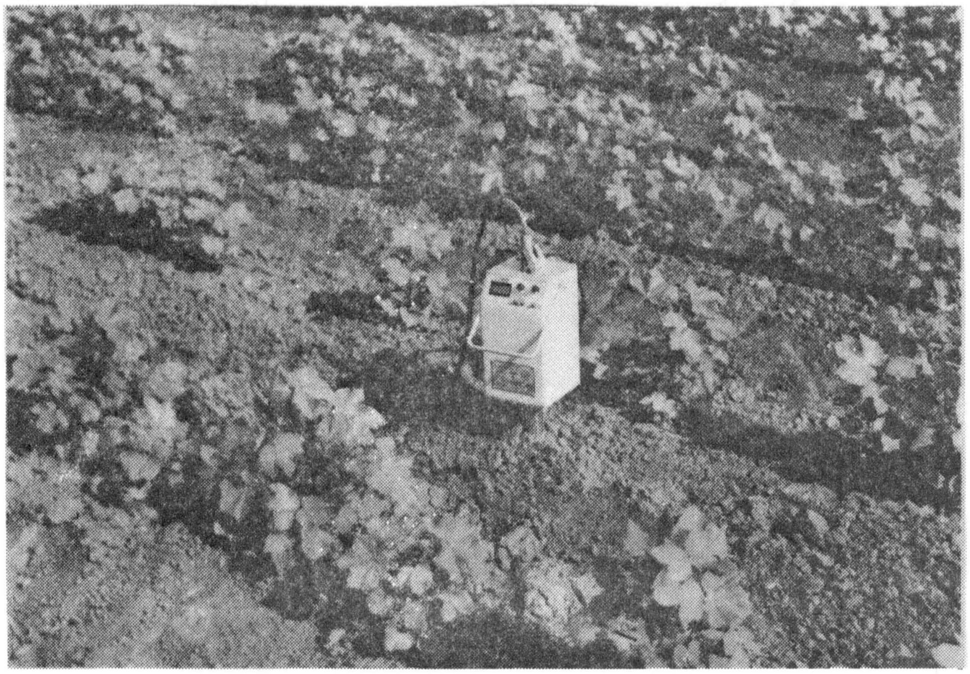

Figure 10. Neutron Moisture Meter Placed over Access Tube Installed in the Irrigated Area

(50 ft) from the upper end of the field and the others 69 m (225 ft) apart. Readings were taken before and 24 hours after each irrigation for 5 different depths (15, 30, 45, 60, and 75 cm).

Intake Characteristics

Recirculating Blocked Furrow Infiltrometer

In order to have a device which might simulate the actual flowing conditions in furrow irrigation, a recirculating furrow infiltrometer was designed, constructed and tested under field conditions. The device, depicted in Fig. 11, was composed of the following parts:

a. A 110 gallon reservoir
b. Two galvanized metal sumps (inflow and tailwater)
c. A 1/3 HP sump pump
d. A water level recorder
e. A portable gasoline powered electrical generator
f. 50 mm (2 inches) hoses and valves, fittings and electrical wires

The bottom of the reservoir was given a funnel shape in order to avoid excessive accumulation of sediments. Figure 12 shows the water supply reservoir installed in the field.

The inflow sump was provided with a calibrated orifice plate, as shown in Fig. 13. The equation used to design the orifice plate was:

$$Q = C A (2 g h)^{1/2} \qquad (9)$$

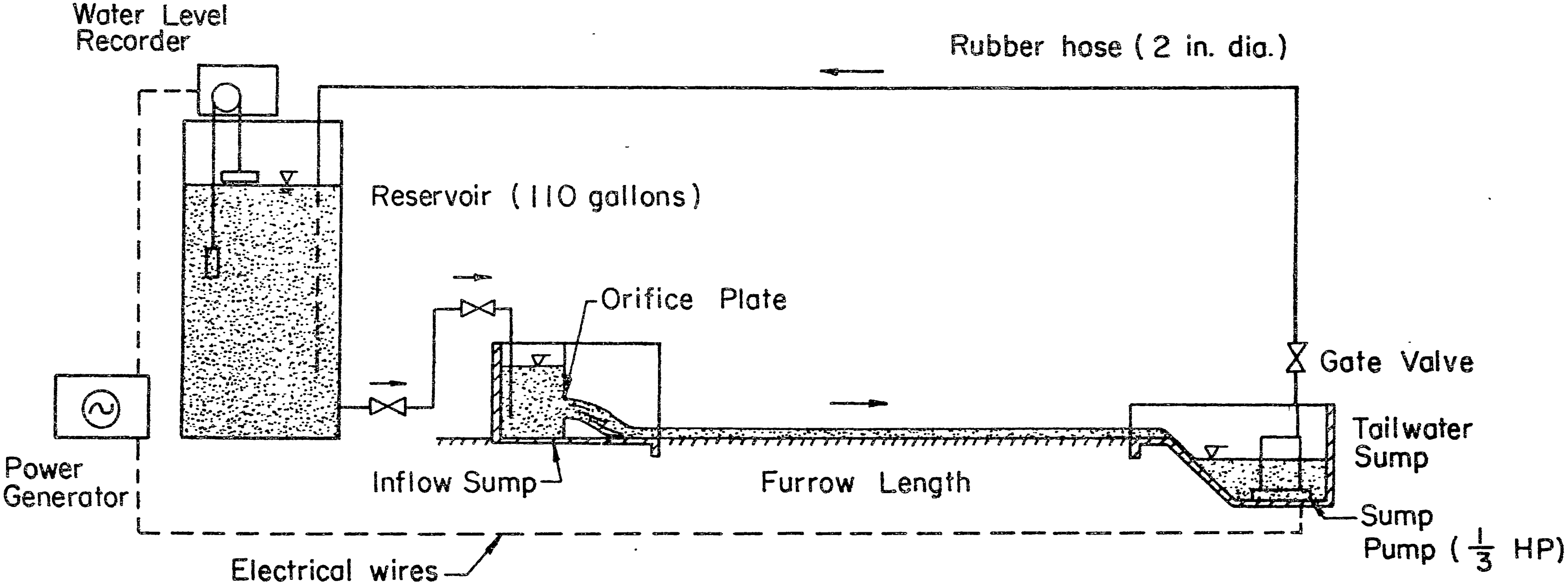

Figure 11. Schematic Diagram of the Recirculating Blocked Furrow Infiltrometer

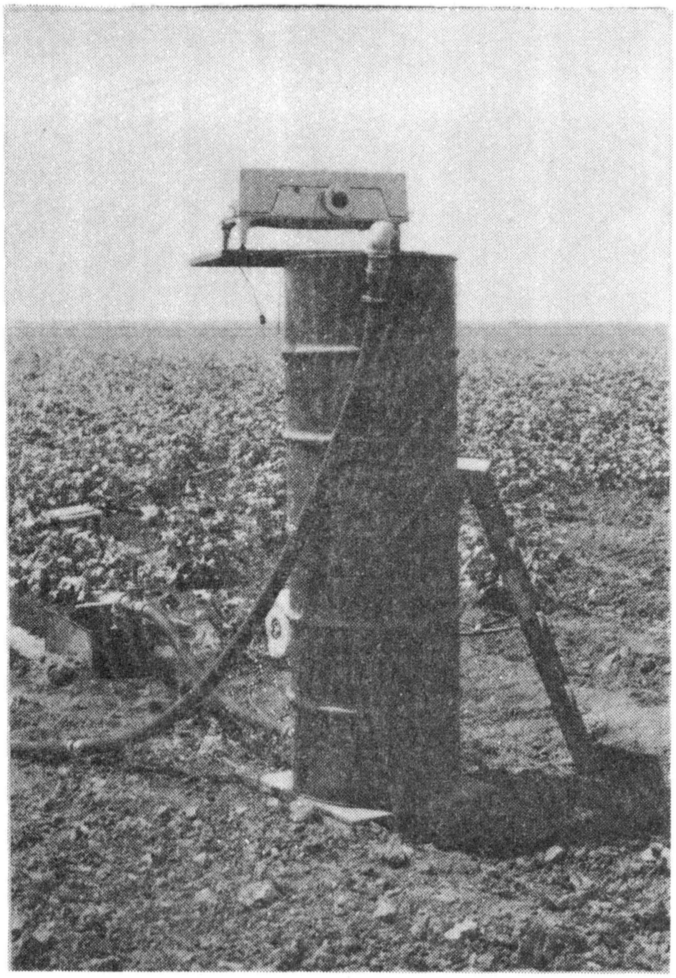

Figure 12. Water Supply Reservoir with the Inflow Sump Installed

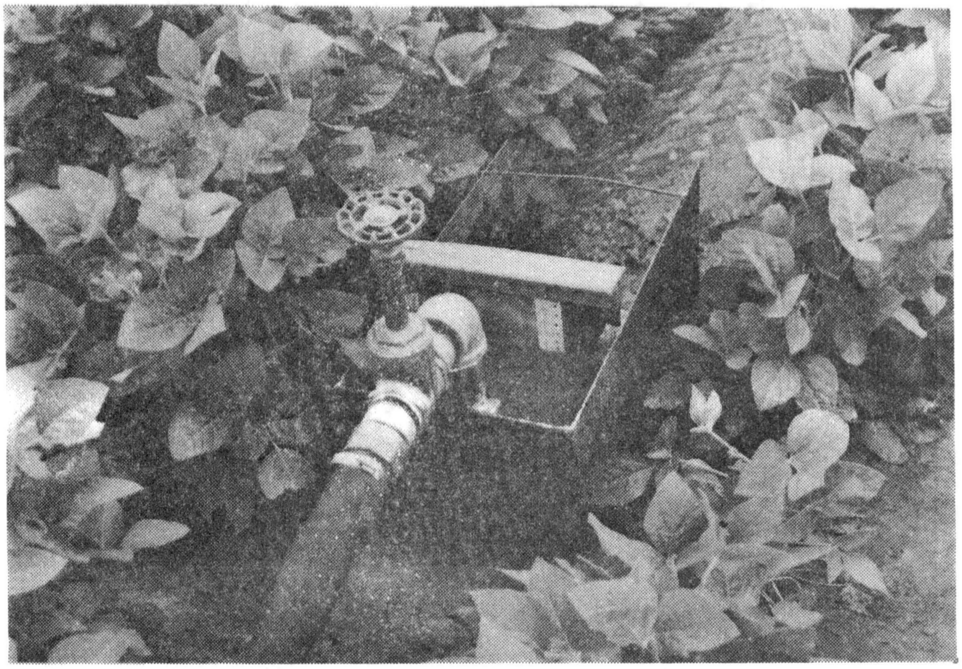

Figure 13. Inflow Sump in Field Operation

where Q = flow rate (L^3/T); A = cross sectional area of the orifice (L^2); g = acceleration due to gravity (L/T^2); h = hydraulic head measured from the water surface to the center of the orifice (L); and C = orifice constant which ranges from 0.61 to 0.65. The selected orifice diameter was 38.1 mm (1 1/2 inches), which gives appropriate hydraulic heads for the size of inflow sump and for the range of inflow rates in the study. With this orifice plate it was possible to measure the inflow to the test section.

The water level recorder speed was modified using a one RPM electrical motor. A gear ratio of 1:10 was used to give a chart speed of 90 cm/hr (0.6 inches/min), which provides sufficient resolution. A scale factor of 2:1 was chosen to relate the vertical scale of the chart and the depth of the water in the reservoir. Figure 14 shows the water level recorder placed over the reservoir.

The procedure used to operate the infiltrometer system in a field experiment consists of the following steps:

1. Installation of the two sumps at the desired distance apart;
2. Placement of the levelled reservoir and filling it with water;
3. Installation of the water level recorder with the desired adjustments in the float;
4. Placement of the sump pump (Fig. 15) in the tailwater sump;
5. Connection of the pipes and the electrical wires;

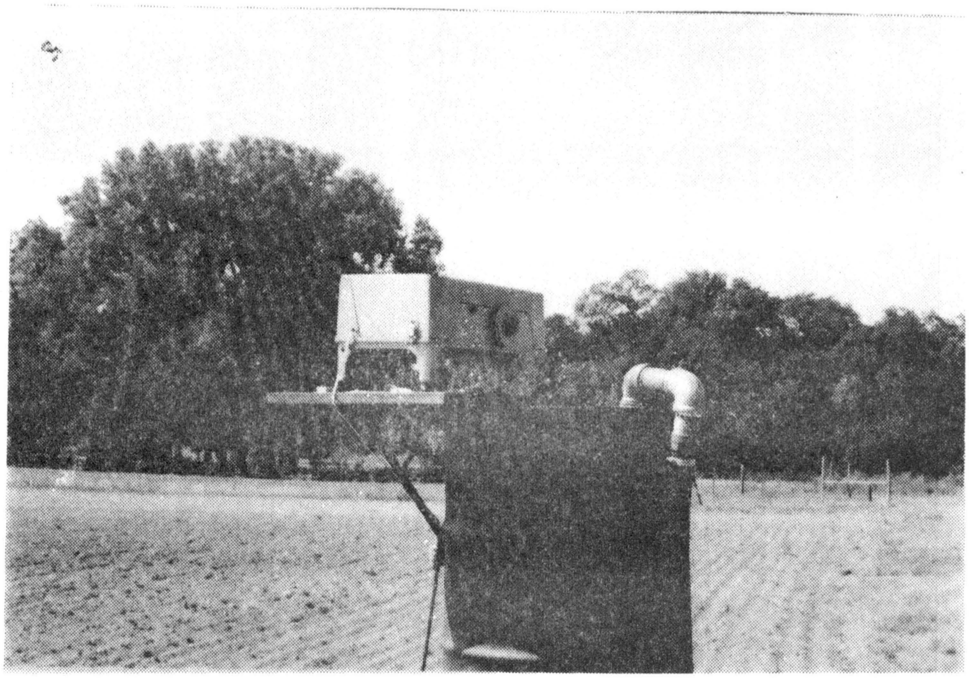

Figure 14. Water Level Recorder Installed over Reservoir

Figure 15. Tailwater Sump and Sump Pump in Place

6. Verification of the operation of the electrical system;
7. Diversion of water by gravity from the reservoir to the inflow sump, by opening full the first gate valve in the inflow line;
8. Calibration of the inflow rate by adjusting the second gate valve in the inflow line and checking the head at the orifice plate;
9. Operation of the sump pump as soon as the tailwater sump is filled to a desired level;
10. Running the test for the desired period of time.

Figure 16 shows the infiltrometer system being used in the field.

Experimental Site Description

The experiments were run at two research stations in Oklahoma: Perkins and Altus. Two sites with different soils, Teller loam and Carwile fine sandy loam, were chosen in Perkins, while in Altus one site with Tillman-Hollister clay loam soil was chosen.

Perkins: Site #1. This site contained a soil classified as a Teller loam. The field was planted with soybeans early in the season, and they were about 30 cm (12 inches) high by the time of the experiments (Aug/84). Since this field was usually irrigated by sprinkler, a new set of 20 m (65 ft) long furrows was made to run these tests. The average furrow slope was 1.13 percent. The tests were the

Figure 16. Blocked Furrow Infiltrometer in Field Operation

first irrigation for the field.

Perkins: Site #2. This set of tests was performed on a soil classified as Carwile fine sandy loam. The field was planted with wheat which was at the emergence stage by the time of the experiments (Oct/84). A new set of 15 m (50 ft) long furrows was made for this test. The average slope of the furrows was 0.60 percent. The tests were the first irrigation on this area.

Altus: Site #3. The soil in this site is classed as clay loam of the Tillman-Hollister complex. These soils are very difficult to manage due to the high clay content, but at the same time they are very productive, especially under irrigation. The field was planted to cotton, which was about 40 cm (16 inches) high at the time of the tests (Sept/84). The surface of the soil showed several cracks by the time of the experiments. The average slope for the furrows tested was 0.58 percent. The soil had been irrigated one time before the tests were run on this site.

Experimental Design

The surge treatments selected had cycle times of 20 min, 40 min and 60 min, with a cycle ratio of one-half. A continuous treatment was included as a control. The surge treatments hereafter will be called respectively T1, T2, and T3. The continuous treatment will be called TC. There were two repetitions of each treatment, conducted at different locations of the field. The inflow rate used in all of the locations of the field. The inflow rate used in all of the tests was 57 L/min (15 gpm).

Each test was conducted on a non-wheel furrow section, in order to minimize the effects of compaction produced by the farm machinery. The length of the test section was 3 m (10 feet) or 5 m (16.4 feet), depending on the intake characteristics of the soil. It was desirable to avoid the refilling of the reservoir during the test period.

Figure 17 shows a neutron moisture meter placed at the middle of the test length. This device was used to measure the soil moisture content at 5 different depths (15, 30, 45, 60, and 75 cm) before and after each test.

Through the drawdown graph produced by the water level recorder it was possible to evaluate the cumulative depth infiltrated for a chosen time interval. The intake flow rate $\dot{Q}_i$ (L^3/T) for a given length of furrow can be written as:

$$Q_i = A_i \; I = A_i \frac{dZ}{dt} \tag{10}$$

where, A_i = area of infiltration (L^2); and $I = dZ/dt$ = infiltration rate (L/T).

Since the intake flow rate over the length of the furrow is equal to the volumetric rate of drawdown of water in the reservoir, it is possible to write:

$$Q_i = S \frac{dh}{dt} \tag{11}$$

where, S = cross sectional area of the reservoir (L^2),

Figure 17. Neutron Moisture Meter at the Middle of the Infiltration Test Length

and dh/dt = rate of drawdown of the reservoir (L/T).

Equating equation (10) and (11):

$$A_i \frac{dZ}{dt} = S \frac{dh}{dt} \tag{12}$$

or

$$\frac{dZ}{dt} = \frac{S}{A_i} \frac{dh}{dt} \tag{13}$$

The cumulative infiltration of the water into the soil, Z, can be determined by integrating the above relationship over time:

$$Z = \frac{S}{A_i} h \tag{14}$$

Defining the infiltration area as:

$$A_i = W_p L_s \tag{15}$$

and the drawdown as:

$$h = \frac{R_d}{S_f} \tag{16}$$

where W_p = wetted perimeter (L); L_s = length of section tested (L); R_d = graph reading (L); and S_f = scale factor ($S_f = 2$), the cumulative infiltration can be determined by the following expression:

$$Z = \frac{R_d S}{2 W_p L_s} \tag{17}$$

The wetted perimeter was calculated assuming a rectangular furrow shape, which can be expressed by the equation:

$$W_p = T + 2 Y \tag{18}$$

where: T = top width (L); and Y = flow depth (L). Both variables were measured using a metal scale, and the value used for the calculation was an average of five different locations measured at different times during the test.

CHAPTER IV

RESULTS AND ANALYSIS

In order to provide a better understanding of the specific objectives of this study, this section was divided in three parts, namely: a) Surge Flow Irrigation System; b) Water Advance Phase; and c) Infiltration Characteristics.

Surge Flow Irrigation System

Open-Channel System

The open-channel system modified for surge flow irrigation was utilized through two seasons of study. The flow supply was 28.3 L/s (1 cfs), which had some slight variation during the irrigation events. Since the furrow inflow rate for each outlet tube is a function of the water elevation head above it, the relative elevation of each outlet in each bay was determined by surveying. The results are showed in Table I. In this table, the fractional maximum head deviation is equal to the maximum deviation from the average elevation divided by the available head in the bay, which is equal to 9.5 cm (0.31 ft).

Although it is difficult to maintain the construction standards that will assure a minimal degree of variation for the tube outlet elevations, the system used in this study showed a small variability among the elevations within a bay. Bay five showed a maximum flow deviation (from the average) of 13.7 percent, the highest among the bays.

TABLE I

AVERAGE RELATIVE ELEVATION FOR THE TUBE OUTLETS IN EACH BAY

Bay	Average Elevation (cm)	Std. Dev. (cm)	Maximum Dev. (cm)	Maximum Head Dev. (%)	Max. Flow Deviation (%)
1	156.8	0.9	1.8	19.3	9.6
2	165.8	0.4	1.2	12.8	6.4
3	174.9	0.5	1.2	12.8	6.4
4	184.6	0.4	1.2	12.8	6.4
5	194.0	0.6	2.6	27.4	13.7
6	203.6	0.5	1.8	19.3	9.6

A BASIC computer program was developed to predict the water surface profile for the discharging bay under conditions of decreasing spatially varied flow in a horizontal channel. The computer program and the printed output are found in Appendix A. The water surface profile determined through this procedure is shown in Fig. 18. The plot shows that the expected decline of the flow depth between the first upstream outlet and the last downstream outlet was 0.27 mm. This result means that in actual

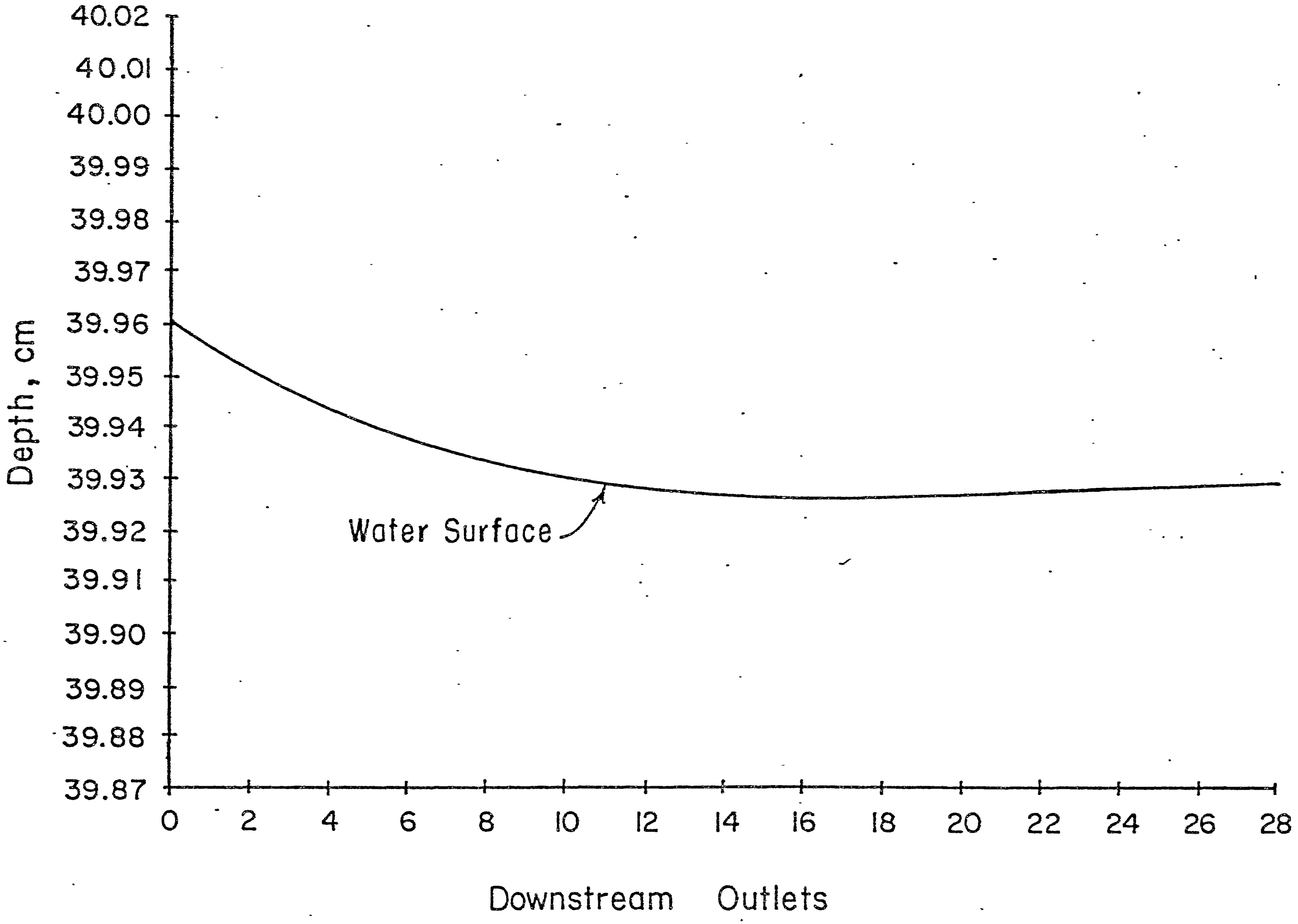

Figure 18. Water Surface Profile for the Discharging Bay as Determined by the Computer Program

practice the differences in the tube outlet elevation would cause much greater variation in the tube outflow rate than would the rise or decline of the water surface profiles.

In this system, it was not possible to have the same amount of water discharged from each bay during an irrigation event because the storage of the upstream bay is released to the downstream bay during the gate opening and the storage is not available to the upstream bay when the gate is closed. This storage condition created different outflow characteristics for each bay: one for the upstream bay where the discharge increases asymptotically to 0.93 L/s (15 gpm) due to the rise in the water head, and another for the downstream bay where the outflow reduces asymptotically to 0.93 L/s (15 gpm) due to the fall in the water head within the bay. Cudrak (1984) developed a mathematical procedure to analyze this phenomenon. He obtained a relationship of the bay discharge as a function of time. He found that for the rising head condition the bay would reach the steady flow in approximately 300 seconds, and for the falling head condition this time would be around 360 seconds. In this study, the time to reach the steady outflow for both situations was measured under field conditions. This measurement was done by using a stop watch and the flow meter developed by Epperly et al. (1983). The results, which are an average of five measurements for each condition in two bays, showed that the average time for the rising head condition to stabilize was 275 sec with a std. dev. of 22.3 sec, while the time for the falling head condition was 323 sec with a std. dev. of 24.9 sec.

Flow adjustment for this system can be accomplished by either adjusting the head of water above the outlet or by using rubber flow reducers. The maximum furrow stream available through this system is 1.0 L/s (17 gpm) which is limited by the maximum permissible height of the water above the tubes before the water discharges from the upstream bay. This height of 9.5 cm (0.31 feet) will correspond to the drop between bays.

In the design of these systems, accurate information on the prevailing slope in the direction of the ditch, the size of the ditch stream, furrow stream size, and desired bay length will be essential. The slope of the land in the direction of the ditch times the length of the bay is equal to the drop between bays. The operating head must be less than the drop between bays. The size of the outlet tube is determined by the desired furrow flow and the head available. The number of furrows is equal to the ditch flow divided by the furrow flow. The length of the bay is equal to the number of furrows in a bay times the furrow spacing. The total system should be an even number of bays because they operate in pairs. Figure 19 shows a design graph presented by Garton et al. (1963). It provides head-discharge curves for tubes 68.6 cm (2.25 feet) long for different diameters of galvanized pipes. This information can be used in the design of an open-channel surge flow system. For future designs, the use of tubes with a length

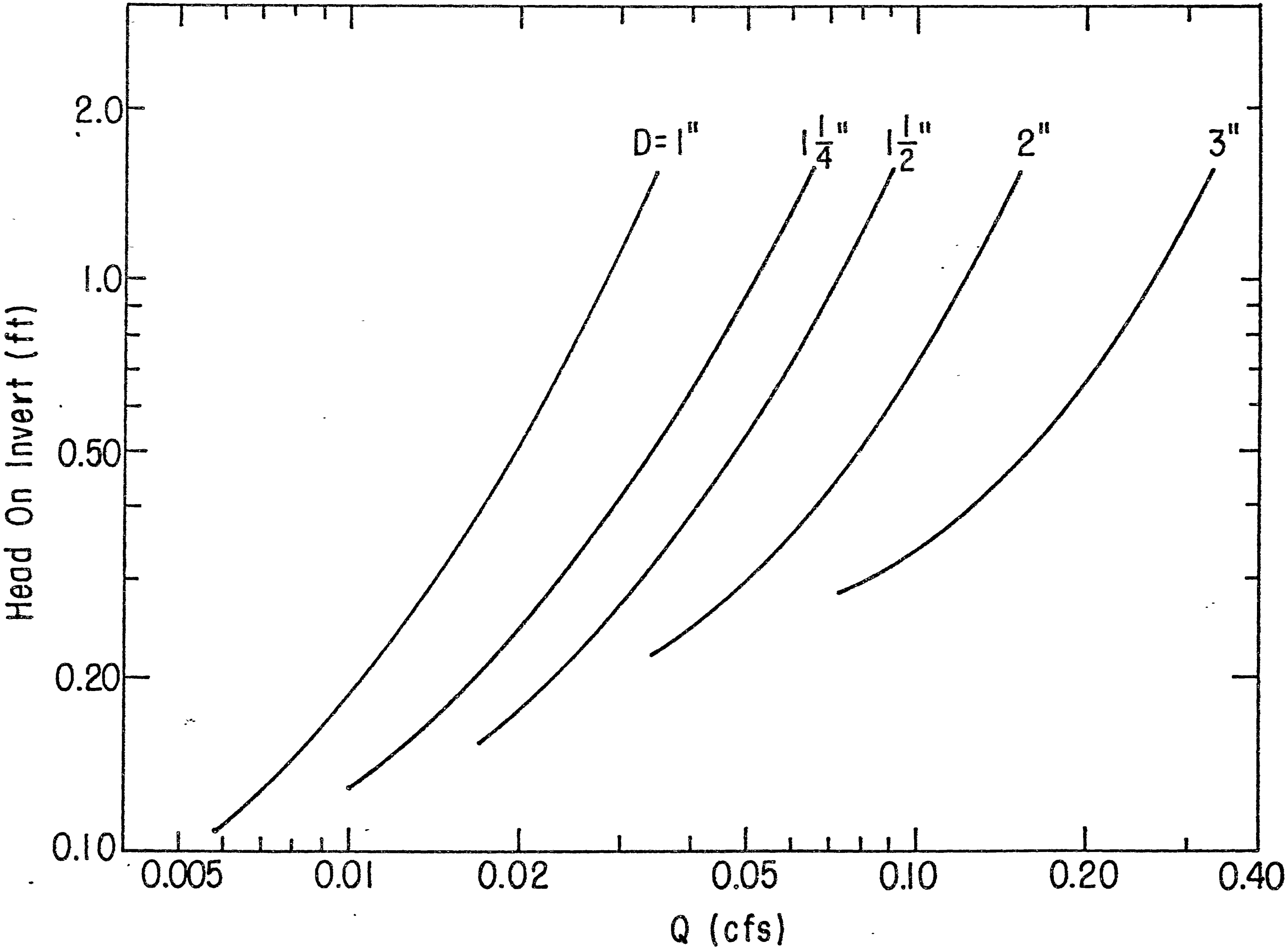

Figure 19. Relationship of Head to Discharge for Tubes 2.25 feet Long with Canopy Inlets (Garton et al., 1963)

of approximately 91 cm (3 feet) is recommended. This length will result in less erosion adjacent to the ditch. These longer tubes will require slightly more head than indicated on the graph.

A disadvantage found in this type of system is its rigid design. The tube spacing must be selected corresponding to the furrow spacing expected for the crops to be grown. Thus, if a new wider crop row spacing does not match with the tube spacing, some tubes would have to be blocked off and not used during the season. There would be some dry rows with more closely spaced furrows.

Automated Equipment

Automation for surge flow irrigation not only means savings in labor, but also provides an important technology for improving irrigation efficiency. This should promote the introduction of the surge technique to the open-channel type of surface irrigation system.

The rotating automated gate developed by Cudrak (1984) for surge flow irrigation provides a simple and inexpensive solution to the automation of surface irrigation systems. This automated gate using an improved control unit was tested in both laboratory and field conditions. The main objective of those tests was to check the durability and the reliability of the gate.

In the laboratory, the performance of the automated equipment was tested without any load or water pressure. The control unit was programmed for different cycle times and numbers of surges. In this condition, the minimum required pressure to open or close the gate was 69 KPa (10 psi). Tested for several cycles, the automated gate had a reliable performance, without showing any mechanism problem or electronic failures. Since the electronic circuit requires only a very small amount of current, a motorcycle battery was able to operate it for the entire day of tests without recharge.

Field tests consisted of evaluation of the performance of the automated equipment through two irrigation seasons. A pressure gage connected to the air supply line of the control valves showed that an average of 10.4 KPa (1.5 psi) was used during each operation of the air cylinder. The average minimum required pressure to operate the gate under load condition was 276 KPa (40 psi). Using an air tank with an initial pressure of 828 KPa (120 psi), it would be possible to have a total of 45 complete cycles before the refilling of the air tank.

The only minor problem which arose with the gate was that the drive chain came off from the sprocket once. But after the sprocket was put in alignment with the cylinder cables, the problem was solved permanently. The same battery was used in both seasons, and a recharge before the second season was sufficient to assure the operation of the control unit for the season.

Confirming the laboratory tests, the automated equipment showed a reliable performance under field conditions. The gate has a simple and durable mechanism, and no problems were experienced during the field operations. The new control unit performed well throughout all of the tests. The improvement made in the programming device allowed the gate to start in either the open or closed position. The evaluated system satisfied two basic requirements for an automatic system for surface irrigation: inexpensive equipment and simple design criteria.

Water Advance Phase

The water advance experiments were divided into two years of study. The data collected from all of the advance tests are found in Appendix B.1. Those tables include the average cumulative advance distance for the furrows under study, plus the standard deviation and the coefficient of variation. The data from each treatment were fitted with a power function using the least square technique, which was available through the Statistical Analysis System (SAS) from the OSU computer library. The analysis of variance tables for the regression lines are presented in Appendix B.2. The results show that the power function fitted very well for the advance data of all the experiments. The F-tests for regression were all significant and the coefficient of determination (R^2) ranged from 0.625 to 0.9908. Since there is strong statistical evidence that the fitted power function is adequate to describe the water advance, those equations were used to determine a new parameter, called the average total advance time. This parameter is defined as the time required for the water front to reach the end of the furrow, estimated by the fitted power function models. The utilization of this parameter was necessary because of the procedure used to monitor the advance phase in the experiments. The advance distance was measured at specified times, which makes the actual total advance time unknown in most of the evaluated furrows.

It is important to emphasize that, in addition to the variability caused by the differences among treatments, the temporal and spatial variability of the soil and furrow conditions affected the water advance rate and the infiltration characteristics in each experiment.

The soil moisture data taken after the irrigation were invalidated because the treatments under study were not able to apply the desired water depth for the crop and additional irrigation was necessary. Appendix B.3 shows the soil moisture data taken before each irrigation event for the second year of study.

First Year (1983)

The first year of study had three irrigation events: July/16, Aug/09, and Aug/25.

July/16. For this irrigation the surge treatment T3 (30 min on/ 30 min off) was tested at two different inflow rate, 34 L/min (9 gpm) in bay 1 and 57 L/min (15 gpm) in bay 2. The continuous treatment was evaluated for a inflow rate equal to 57 L/min (15 gpm) in bay 3. The inflow of 34 L/min

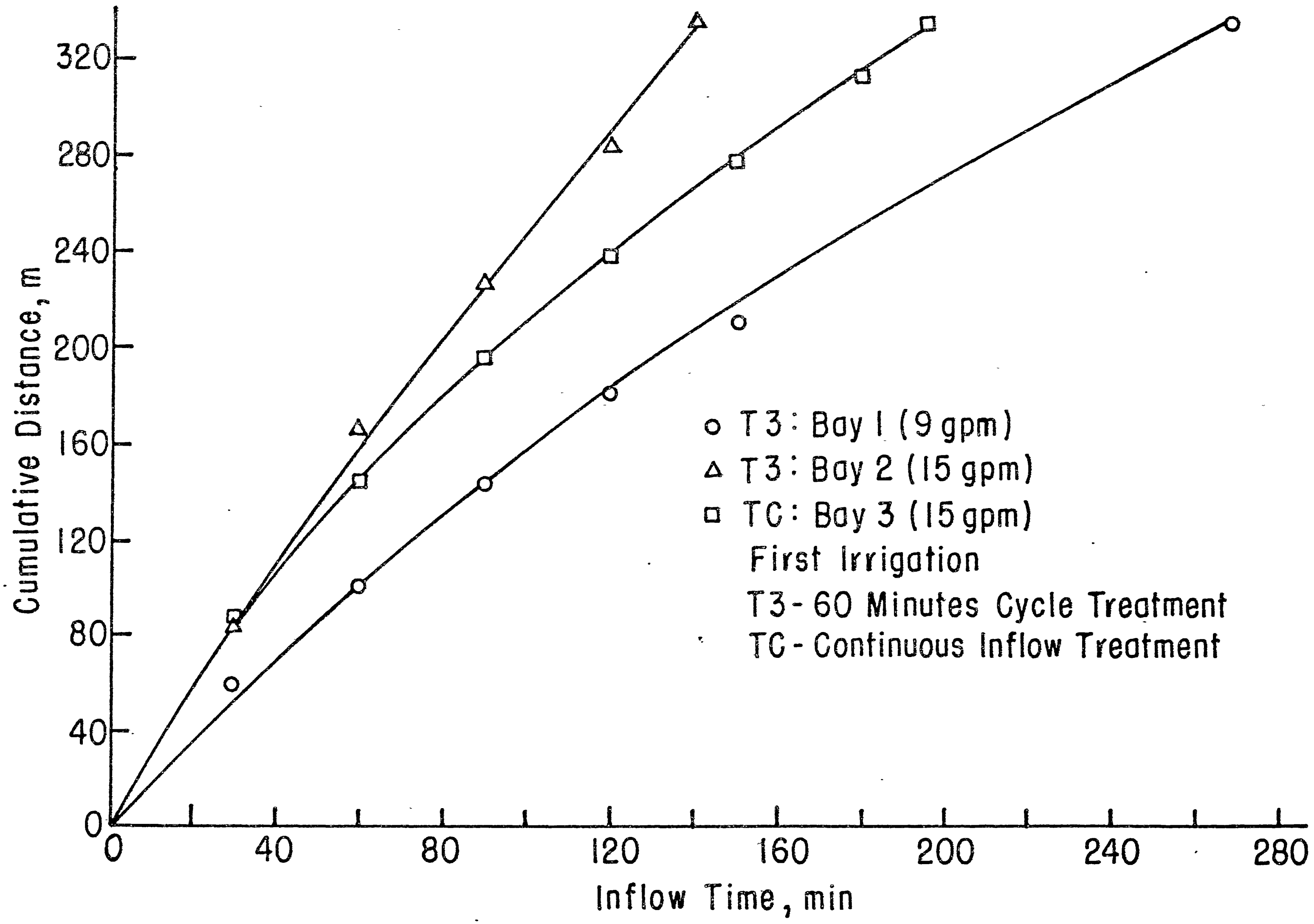

Figure 20. Cumulative Advance Curves for July/16 (1983)

was achieved by using rubber flow reducers inserted in the outlet tubes. Figure 20 shows the average curves produced by the three treatments on this date. The treatment T3 in bay 2 with an inflow rate of 57 L/min (15 gpm) showed an average total advance time of 140 min, while the treatment TC was equal to 196 min. The treatment T3 had an advance time 56 min less than treatment TC, which means a reduction of 28.6 percent from the continuous treatment. However, the treatment T3 in bay 1, with an average inflow rate of 34 L/min, appeared to be highly affected by the low inflow rate and showed an average total advance time of 269 min, which was an increase of 37.2 percent with respect to treatment TC.

<u>Aug/09</u>. The treatment T3 was evaluated in bays 1 and 2 for the respective inflow rates of 49 L/min (13 gpm) and 57 L/min (15 gpm). The treatment TC was evaluated in bay 3 for an inflow rate of 57 L/min (15 gpm). The results, shown in Figure 21, demonstrated a faster advance rate for the treatment T3 in bay 2 where the inflow rate is equal to that of the treatment TC. In the treatment T3 the average total time for the water to reach the end of the furrow was 132 min, while the treatment TC had an average total advance time of 148 min. Those numbers show a reduction of 16 min for the surge treatment which means 10.8 percent less than the treatment TC. The treatment T3 in bay 1 with the smaller inflow rate had an advance rate slower than the

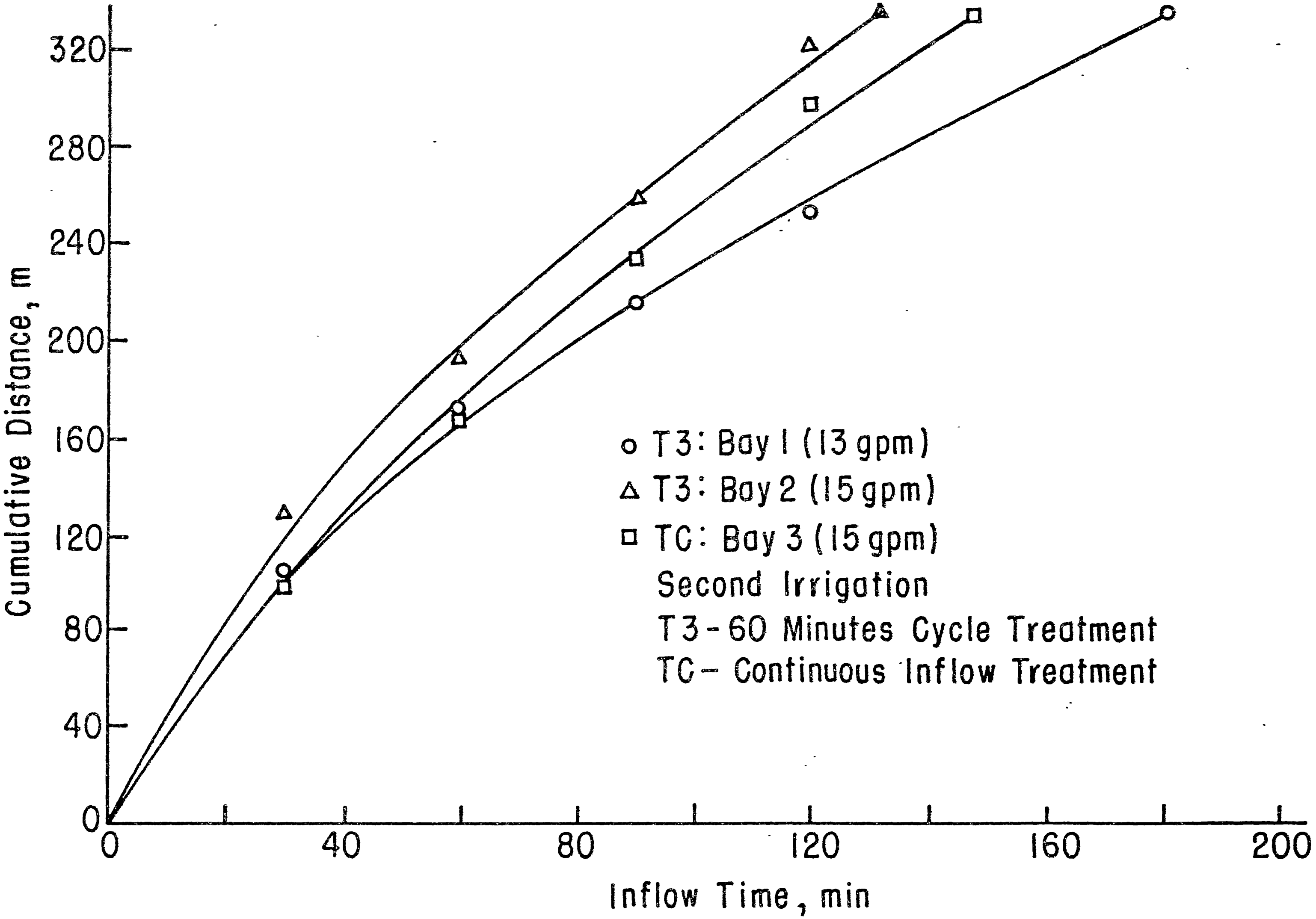

Figure 21. Cumulative Advance Curves for Aug/09 (1983).

continuous treatment. Compared to the first irrigation (July/16), the advance rates in this second event were higher for both surge and continuous treatment. This increase was expected because in the second irrigation the furrow shape was more defined and smoother, and the soil intake rate was reduced by a rainfall of 18 mm (0.71 inches) one day before the test.

Aug/25. The same treatments as the second irrigation were repeated in this third event. Figure 22 shows the average curves for all of the three treatments. The surge treatment T3 in bay 2 still had the highest advance rate. This treatment with an inflow rate of 57 L/min (15 gpm) showed an average total advance time of 173 min, while the value for treatment TC in bay 3 was 181 min. This gives a difference of 8 min between surge and continuous treatment, which means only a 4.4 percent reduction in advance time with respect to the continuous treatment. These experiments also showed that the advance rate for surge flow was affected by the inflow rate, because the surge treatment T3 at bay 1 with an average inflow rate of 49 L/min (13 gpm) had the slowest advance rate. At the time of the test the soil surface showed signs of cultivation and presented a surface condition different from the second irrigation.

The experiments in the first year of study showed that surge flow treatment did alter the intake characteristics of the soil, with the most pronounced effects during the first irrigation. The surge treatments seemed also to reduce the

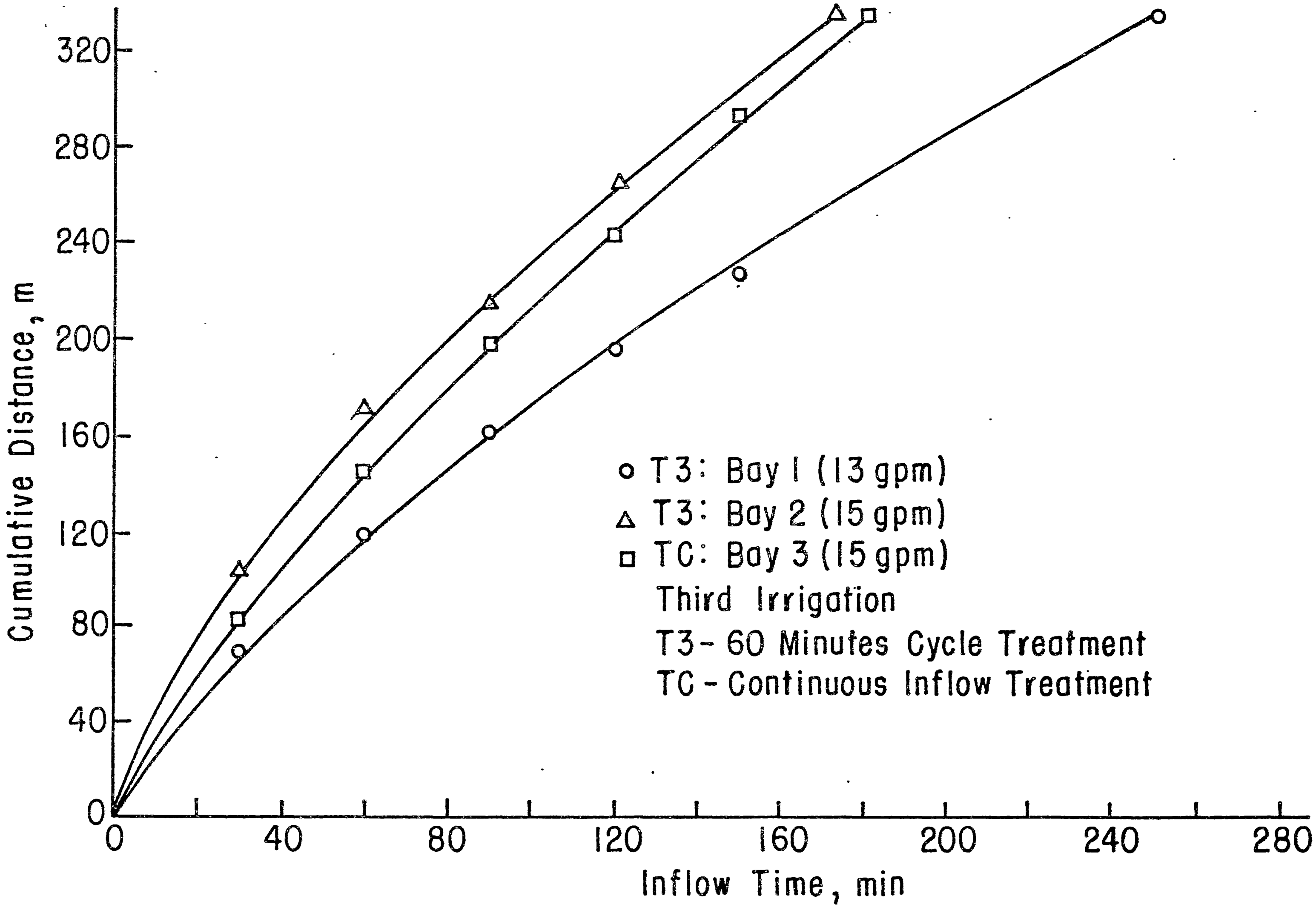

Figure 22. Cumulative Advance Curves for Aug/25 (1983)

variability caused by the differences among furrows, because the coefficients of variation for the cumulative advance distance were slightly smaller than those for the continuous treatment.

Second Year (1984)

Due to a shortage of water in the 1984 season, the study was limited to two irrigation tests, July/17 and July/30. Since the site was preirrigated before the first crop irrigation, it was not possible to evaluate the magnitude of the effects of surge flow under the condition of the first application of water to the field. All of the treatments in this season were evaluated for both tractor wheel compacted furrows and nonwheel compacted furrows.

July/17. The treatments evaluated in this irrigation event were: surge treatment T2 (20 min on/ 20 min off) in bay 1 and bay 2 with respective average inflow rates of 57 L/min (15 gpm) and 60 L/min (16 gpm); surge treatment T1 (10 min on/ 10 min off) in bay 3 and bay 4 with respective average inflow rates of 57 L/min and 60 L/min (16 gpm); and the continuous treatment TC in bay 5 with an average inflow rate of 60 L/min (16 gpm). Figure 23 shows the comparison between the average curves for the surge treatment T2 in bay 1 and bay 2, and the treatment TC in bay 5. Figures 24 and 25 reveal the respective curves of the same treatments for the conditions of nonwheel and wheel compacted furrows. For the nonwheel furrows surge

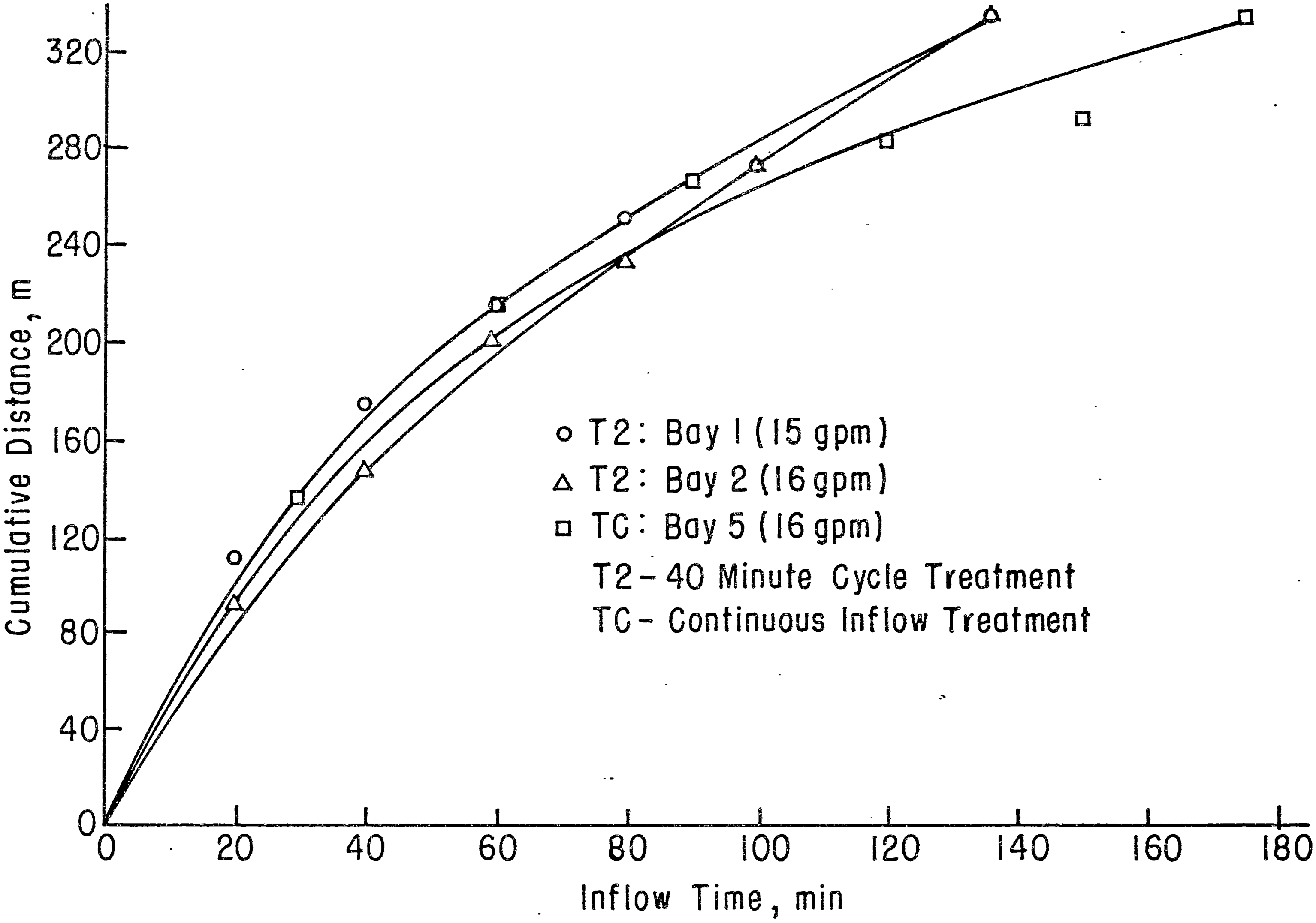

Figure 23. Average Cumulative Advance Curves for Treatments T2 and TC (July/17/1984)

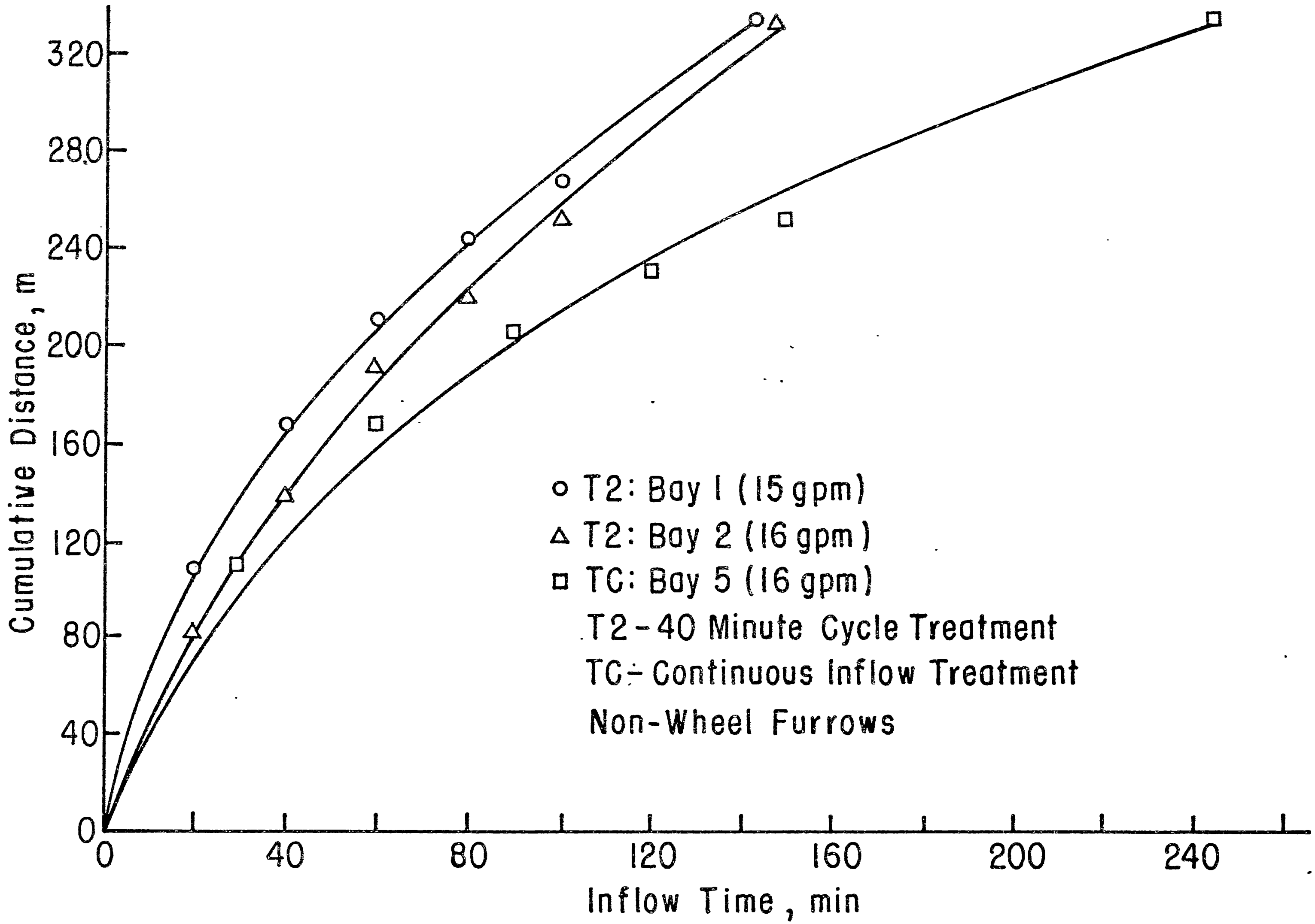

Figure 24. Cumulative Advance Curves for Treatments T2 and TC and Nonwheel Compacted Furrows (July/17/1984)

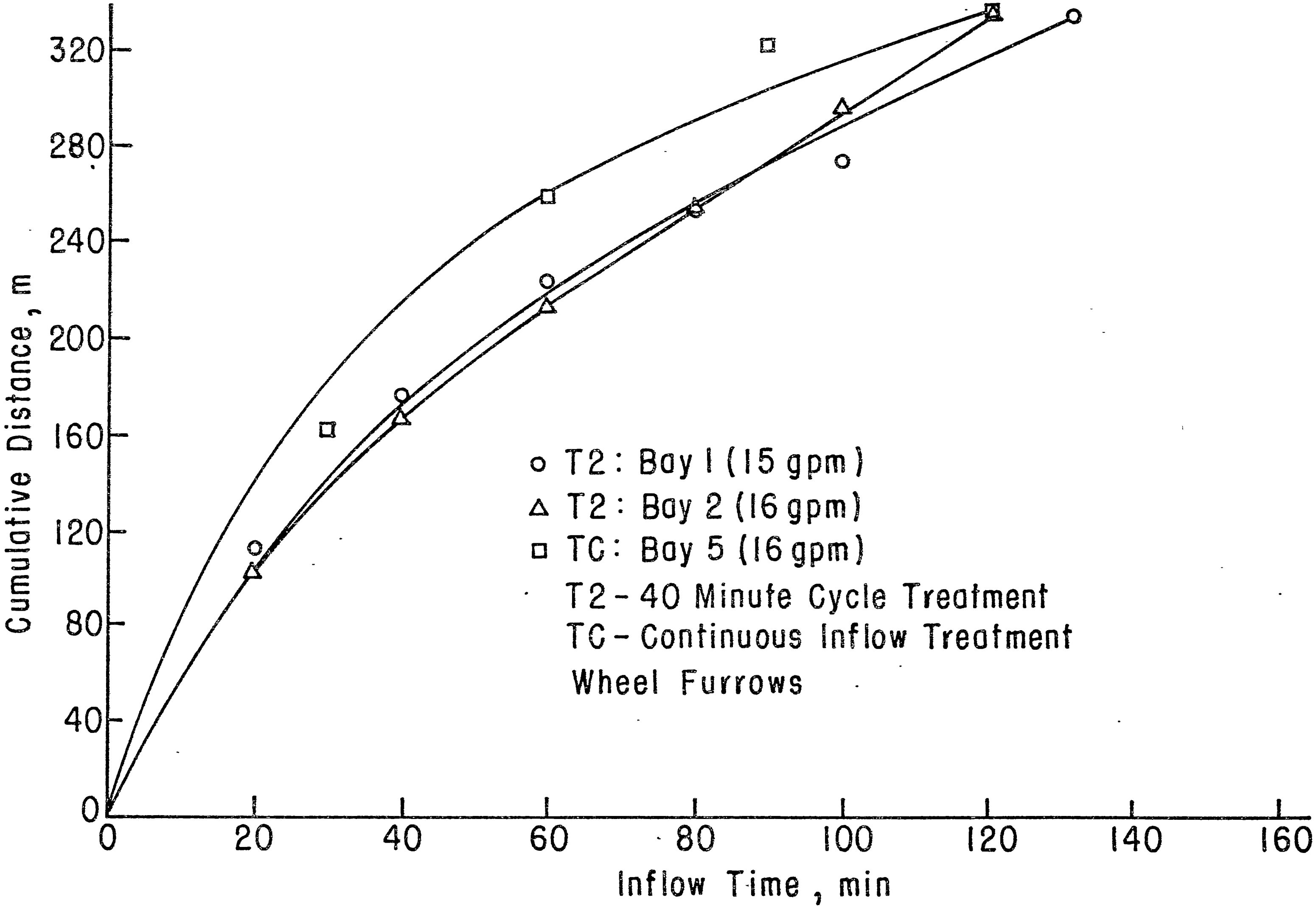

Figure 25. Cumulative Advance Curves for Treatments T2 and TC and Wheel Compacted Furrows (July/17/1984)

treatment T2 had an average total advance time of 143 min for bay 1 and 148 min for bay 2, while the treatment TC had an average total advance time of 245 min. The average difference between surge and continuous application was 100 min, which means a reduction in advance time of 40.8 percent with respect to the continuous treatment. For the wheel compacted furrow conditions, the continuous treatment had a faster advance rate with an average total advance time of 120 min, while surge treatment T2 in bay 1 and bay 2 had respectively 132 min and 121 min. The average difference between the two treatments was 6 min, which represents an increase of five percent with respect to the surge treatment. Analysing the average curves, shown in Figure 23, surge flow appeared not to give any advantages over the conventional continuous treatment. However, Tables LXXVI, LXXVII, and LXXX in Appendix B.3, which contain the soil moisture data for the three bays, show that bay 5, where the continuous treatment was run, had a higher soil moisture content at a depth of 15 cm (six inches) than bay 1 and bay 2. This condition means that bay 1 and bay 2 probably had a higher intake rate at the time of the irrigation, which caused a lower advance rate. Surge flow showed less variability in the average cumulative distance than continuous flow, with those treatments having coefficients of variation for the advance data smaller than those found for continuous application.

The average curves for surge treatment T1 in bay 3 and bay 4 and treatment TC in bay 5 are depicted in Figure 26.

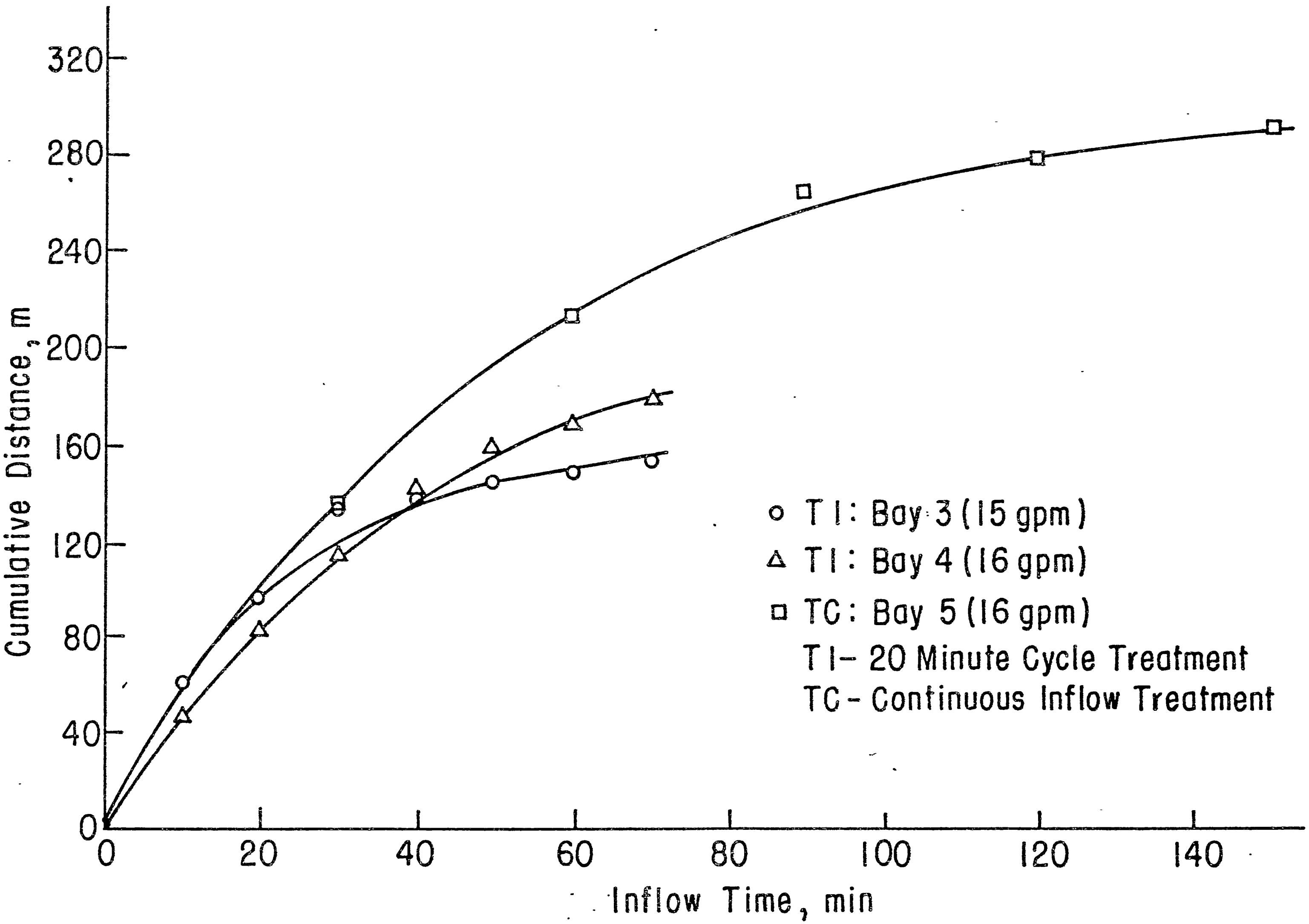

Figure 26. Average Cumulative Advance Curves for Treatments T1 and TC (July/17/1984)

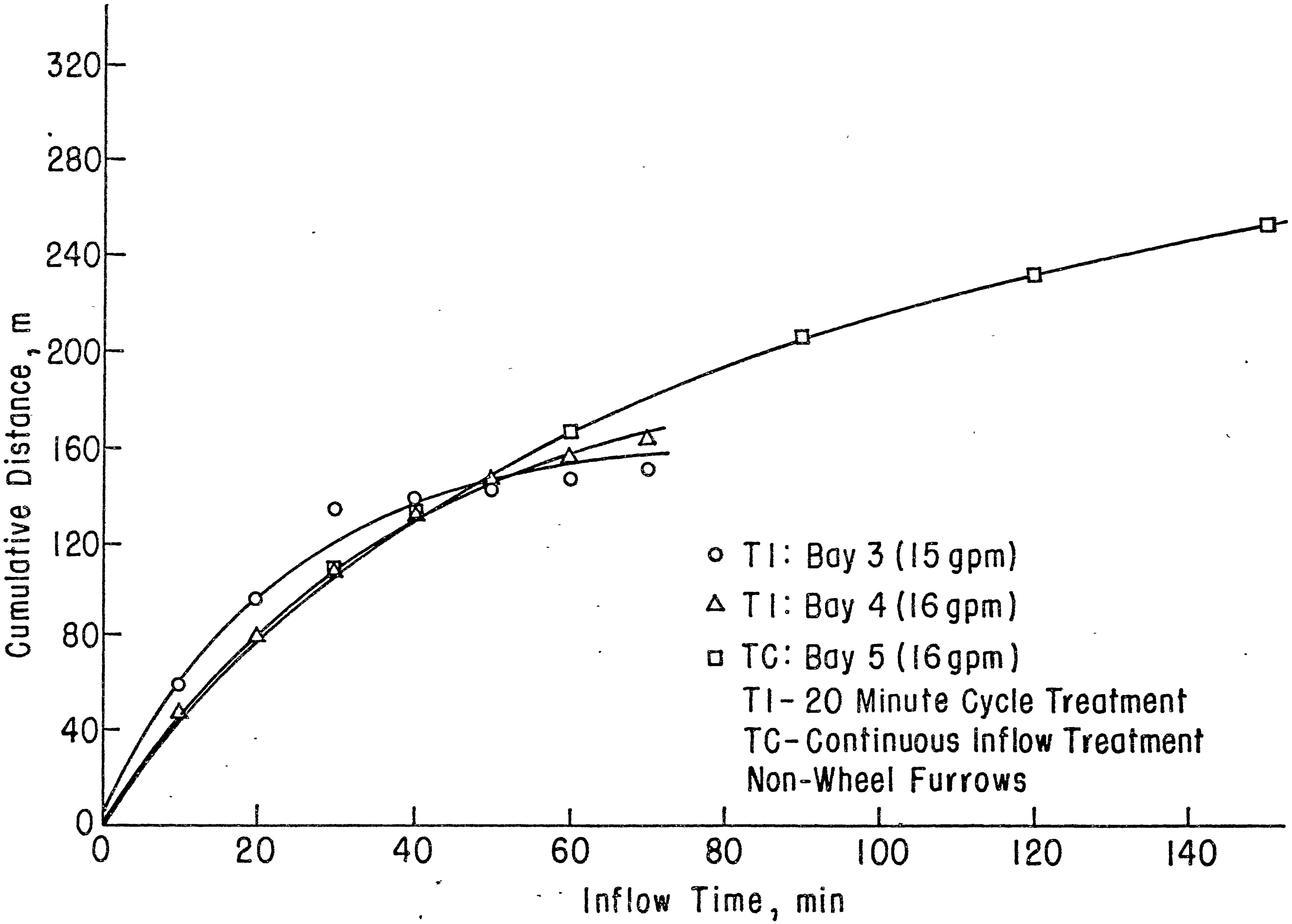

Figure 27. Cumulative Advance Curves for Treatments T1 and TC and Nonwheel Compacted Furrows (July/17/1984)

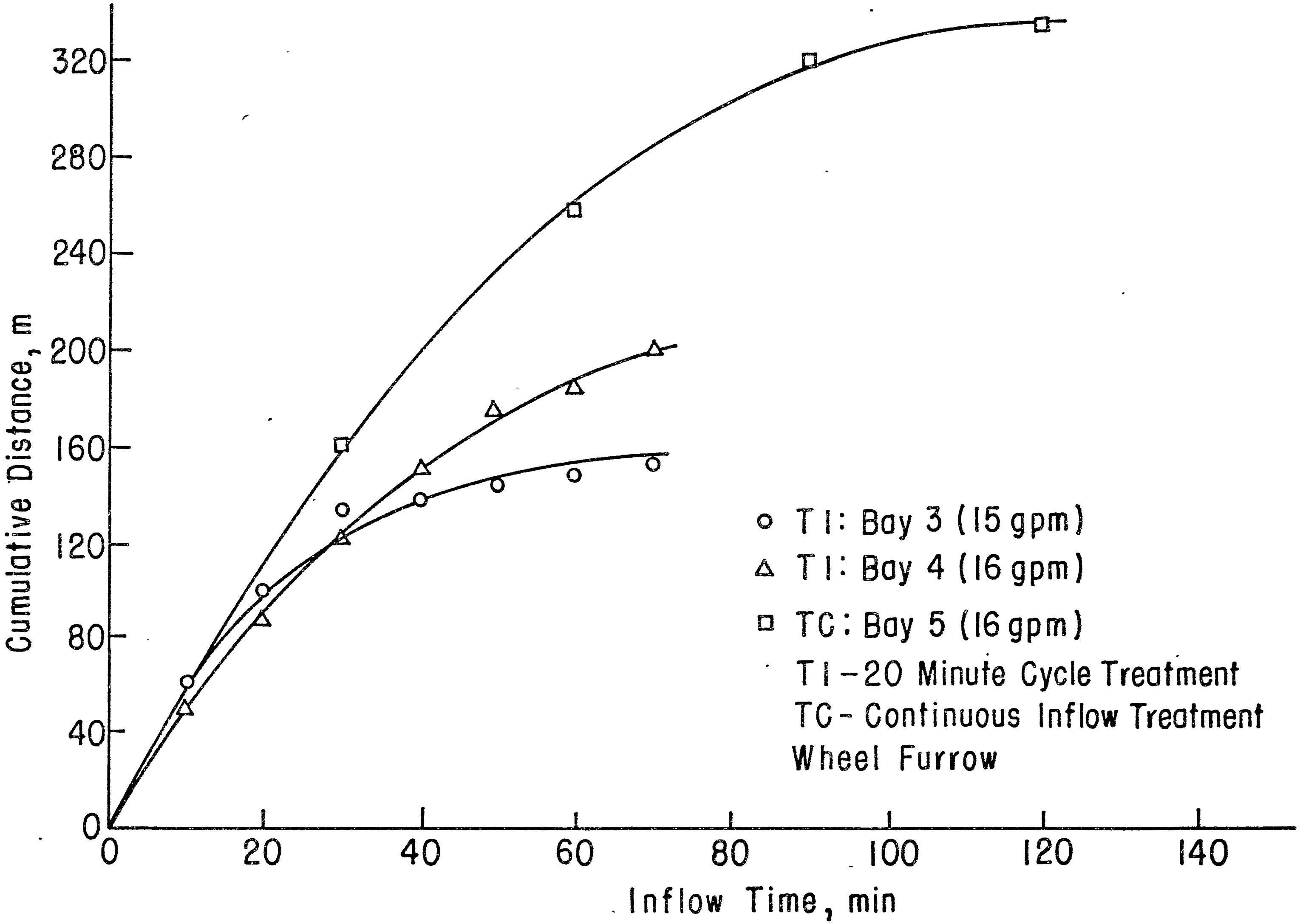

Figure 28. Cumulative Advance Curves for Treatments T1 and TC and Wheel Compacted Furrows (July/17/1984)

Figures 27 and 28 show the same treatments for the respective conditions of non-wheel and wheel compacted furrows. The surge treatment T1 (10 min on/ 10 min off) caused a different kind of behavior for the water advance phase in this type of soil. Due to the presence of big cracks in the furrow bed and the flat slope near the middle section of the furrows, the water advance front slowed down at this midpoint of the furrow, and moved at a lower advance rate. After 8 surges, the experiment for the treatment T1 was stopped. Although this surged cycle time did not work well for the soil condition at the time of the tests, this treatment still showed less variation in the advance distance than continuous application.

July/30. Two different cutback treatments were tried, surge cutback (called SCB) and continuous cutback (called CCB). The procedure used in both treatments was to make the furrow entirely wet, one by using a combination of surged conditions and the other by using the conventional continuous application, and then achieve cutback through a surge application with a cycle time of 30 min (15 min on/ 15 min off).

The treatment SCB consisted of two surges of 20 min cycle time, two surges of 40 min, and two surges of 60 min. The average curve for this experiment is depicted in Figure 29. The average total advance times for bay 1 and bay 2 were respectively 122 min and 162 min. This variation of 24.7 percent was not only caused by the differences among furrow

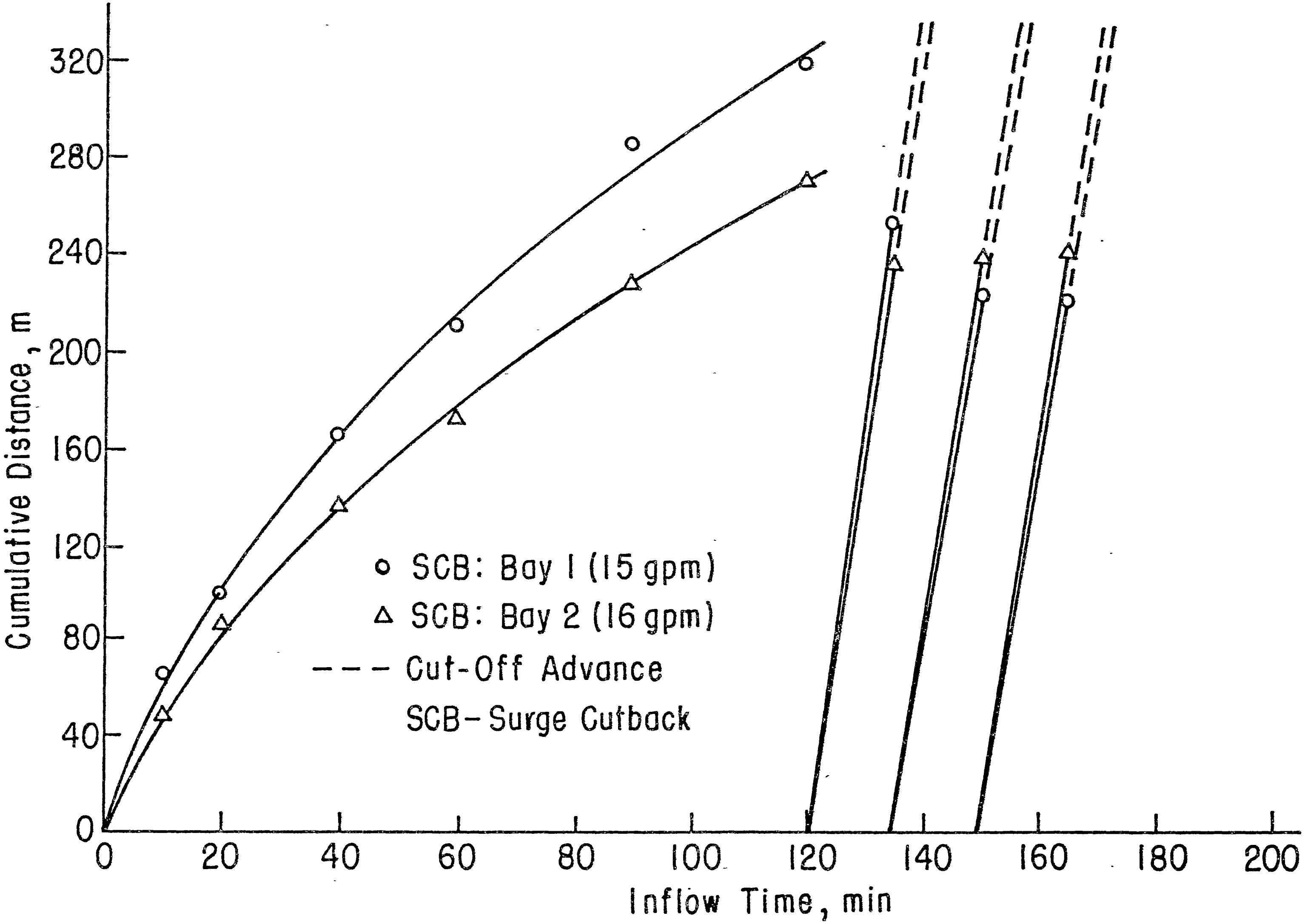

Figure 29. Average Cumulative Advance Curves for Treatment SCB (July/30/1984)

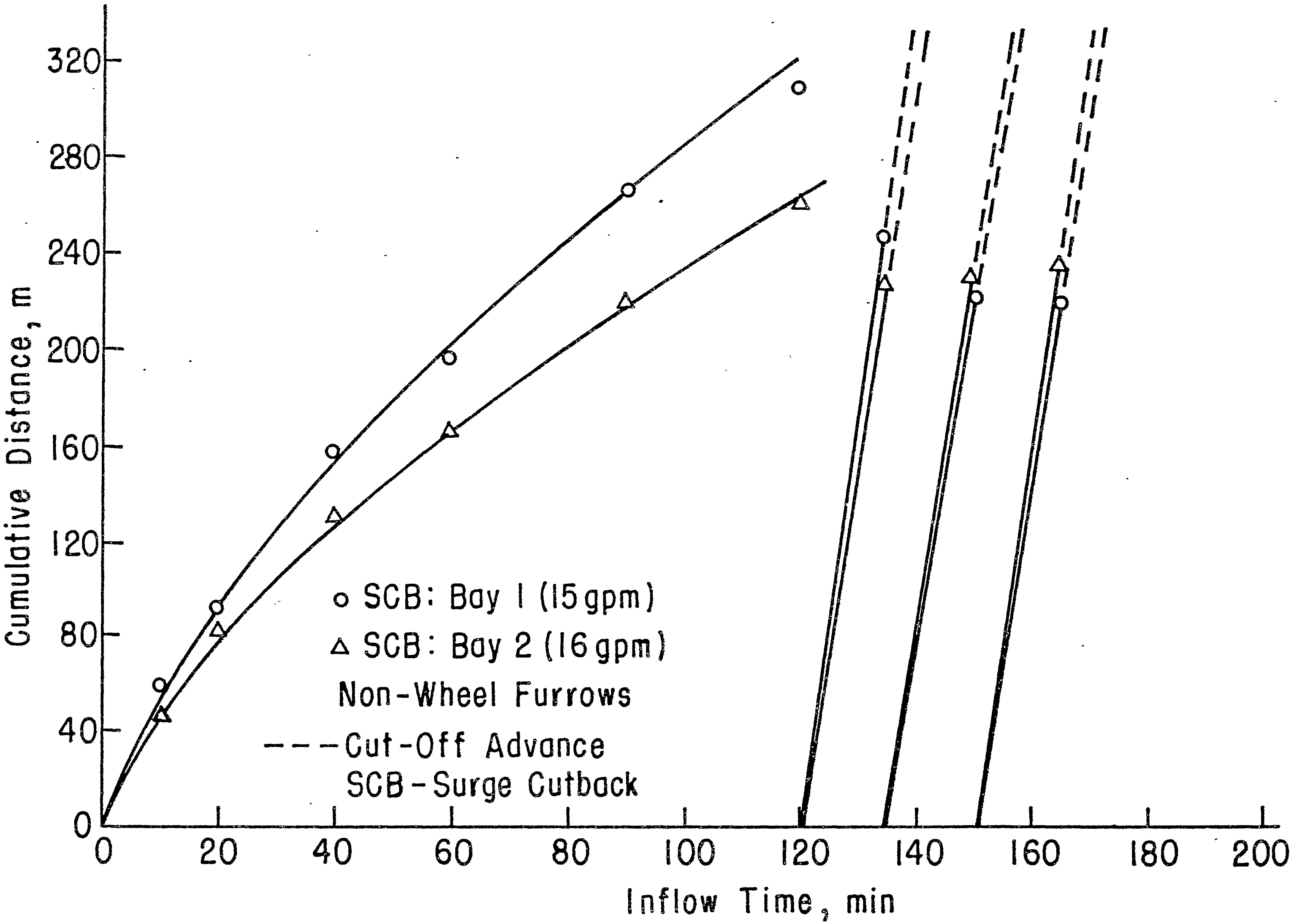

Figure 30. Cumulative Advance Curves for Treatment SCB and Nonwheel Compacted Furrows (July/30/1984)

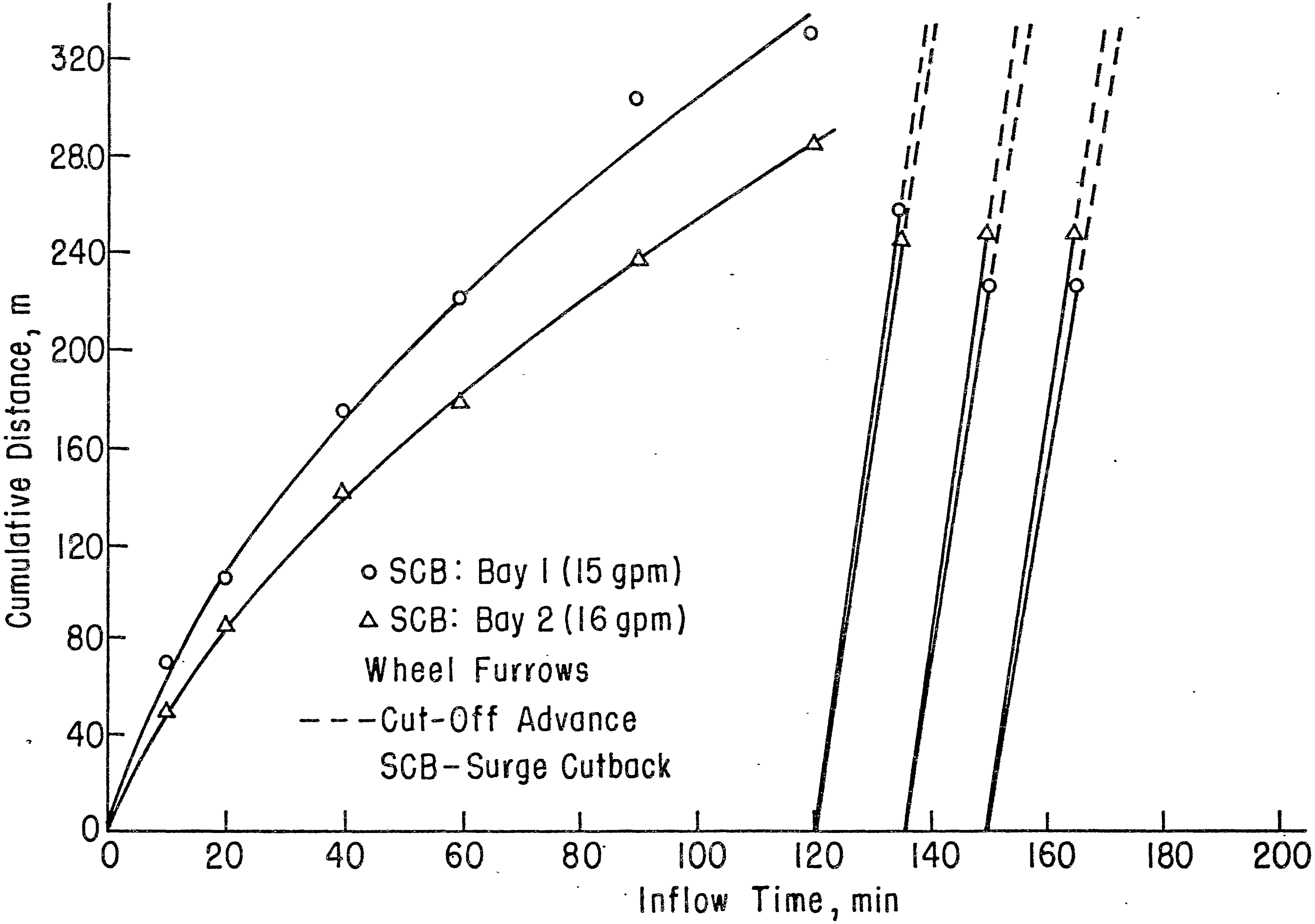

Figure 31. Cumulative Advance Curves for Treatments SCB and Wheel Compacted Furrows (July/30/1984)

and soil conditions, but also due to a difference in the duration of the off-period in each bay. Since the treatment was a surged combination with different cycle times, every time that a cycle time was changed in bay 1, bay 2 had an additional time in its off period.

For the SCB treatment, the cutback surge of 30 min cycle time had an average advance distance of 235 m (770 feet) for the two bays during the 15 min on-time, and during the off-time the stored volume of water in the furrows was able to reach the end of the furrows, with a minimal runoff volume. The distance covered by the water during the on-time corresponded to 70 percent of the total furrow length.

Figures 30 and 31 show curves for the same treatment curves for furrows under nonwheel and wheel compacted conditions, respectively. For the nonwheel compacted furrows the average distance travelled by the water in the 15 min on-time of the surge cutback was 229 m (751 feet), while for the wheel compacted furrow the distance was 240 m (789 feet).

The average curves for the treatment CCB, which was run in bays 3 and 4 are depicted in Figure 32. The average total advance time for bays 3 and 4 was respectively 120 min and 234 min. Although the treatment applied in both bays was the same, the result shows a reduction in the advance time of 48.7 percent in bay 3 with respect to bay 4. There seem to be two basic reasons for this variability. First, bay 4

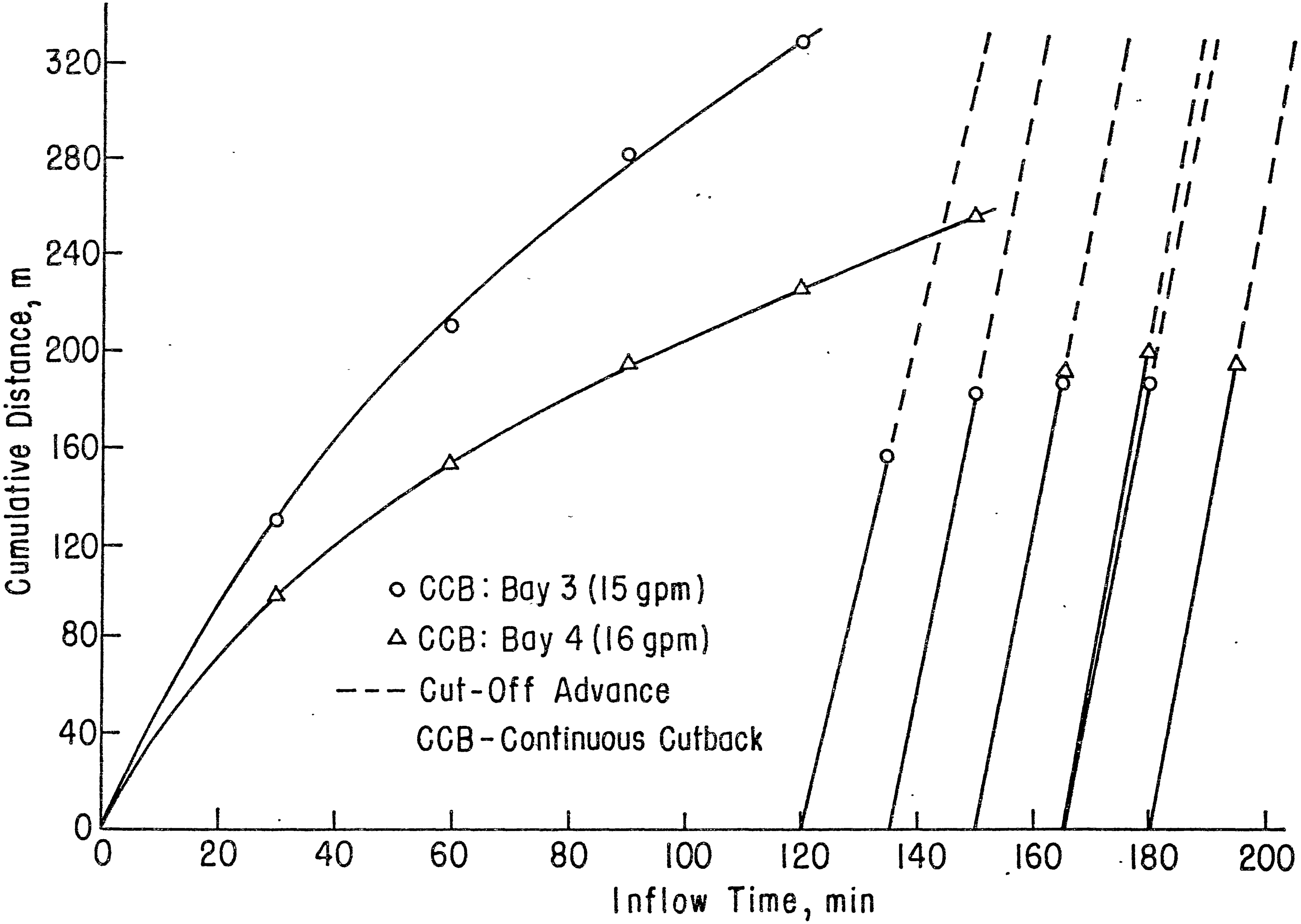

Figure 32. Average Cumulative Advance Curves for Treatment CCB (July/30/1984)

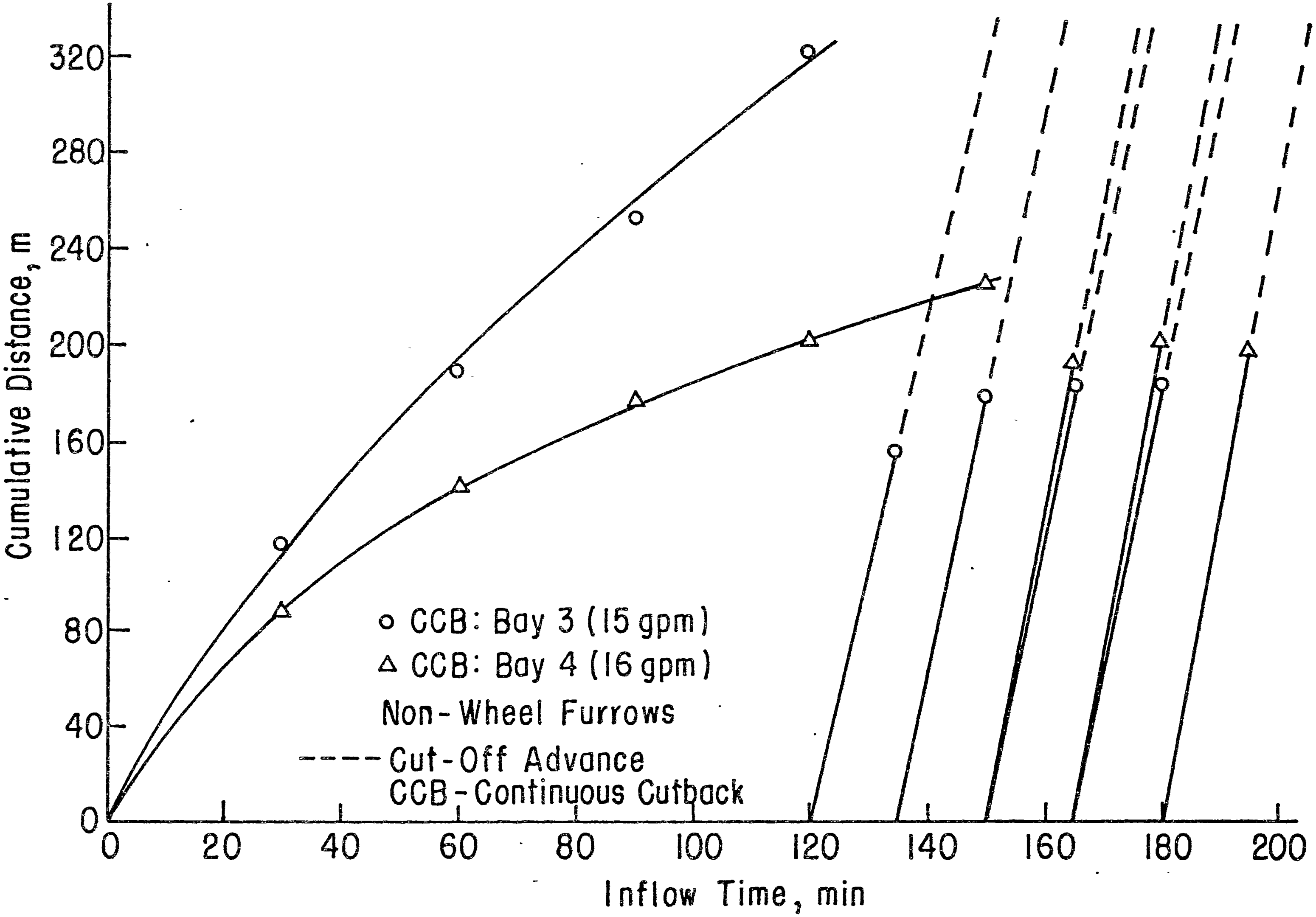

Figure 33. Cumulative Advance Curves for Treatment CCB and Nonwheel Compacted Furrows (July/30/1984)

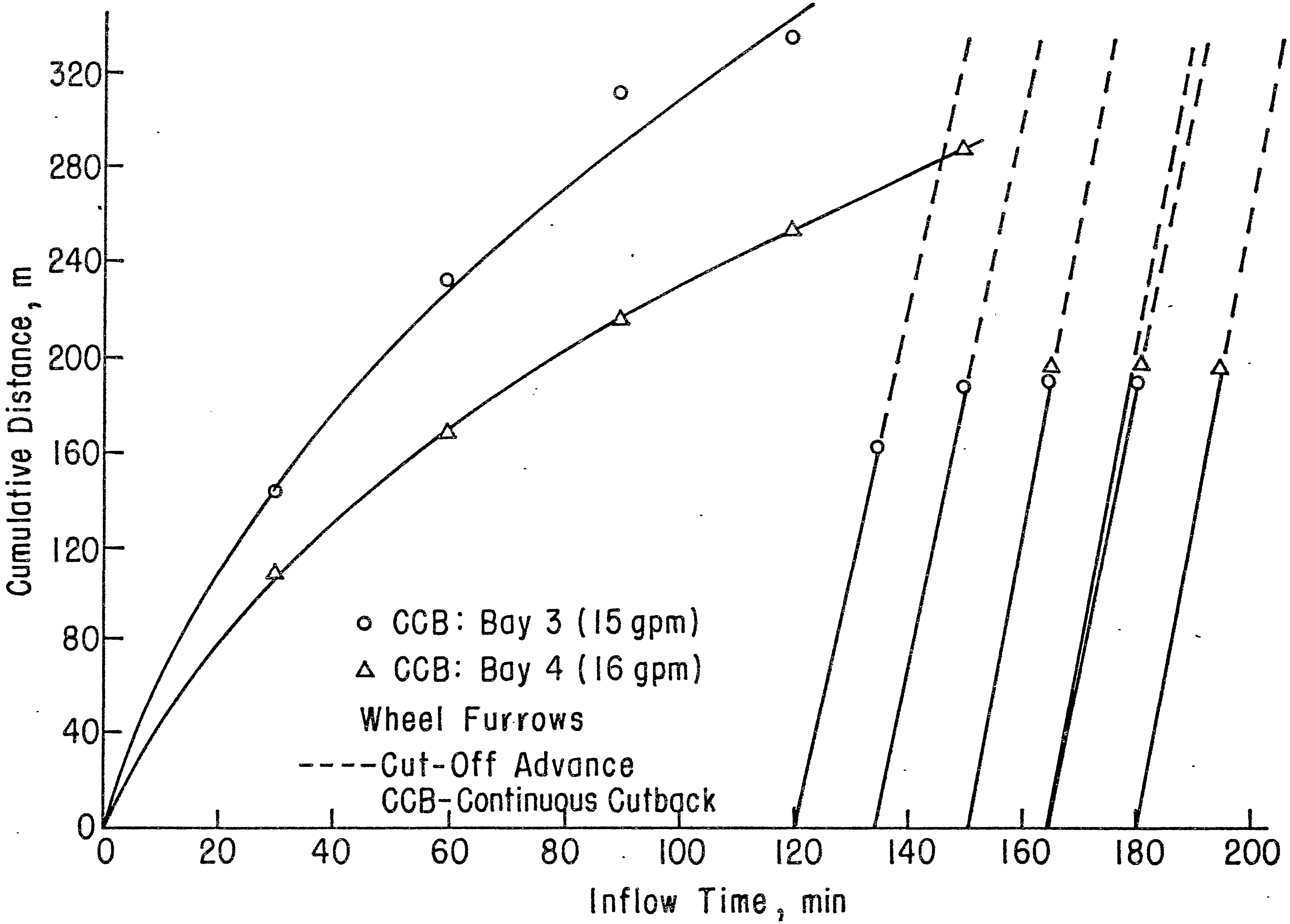

Figure 34. Cumulative Advance Curves for Treatments CCB and Wheel Compacted Furrows (July/30/1984)

had a lower soil moisture content at 15 cm (six inches) depth, as shown in Table LXXXIII and LXXXIV in Appendix B.3, which would reduce the advance rate for this bay. Second, the procedure used for this treatment caused bay 3 to have an off-time after the continuous application equal to the total advance time for bay 4, after which the surge cutback was applied.

For this treatment, the average distance travelled by the water during the 15 min on-time of the surge cutback application was 188 m (617 feet), which corresponded to 56 percent of the total furrow length. The stored volume of water available in the furrows was able to reach the end of the field with practically no runoff volume. Figures 33 and 34 show the average curves for the same treatment for non-wheel and wheel compacted furrows, respectively. For the nonwheel compacted furrows the average distance travelled by the water in the 15 min on-time of the surge cutback was 186 m (611 feet), while for the wheel compacted furrows it was 190 m (623 feet).

The most important result from both cutback treatments was that for the furrow length and inflow rate in the study, the surge cutback of 30 min cycle time was able to irrigate the entire length of the furrow with a minimum runoff volume.

Infiltration Characteristics

The infiltration experiments were conducted at three sites with different soil types. All of the tests were run with an average inflow rate of 57 L/min (15 gpm). The experiments evaluated at each site were the surge treatments T1, T2, T3, and the continuous treatment TC. There were two repetitions of each treatment, conducted at different locations in the field. The data collected in those tests are found in Appendix C.1. For each test the tables present the depth infiltrated (mm) for constant time intervals, and the intake rate (mm/hr) at the middle point of the time interval. The analysis was based on the average of the intake rate for the two repetitions of each treatment in each experimental area. The average data are presented in Table CX through Table CXXI in Appendix C.1.

The Kostiakov equation was fitted to the data for the continuous treatment, using the least square scheme which was available through computer software (Plotrax) from the Agricultural Engineering Department Computer System. The analysis of variance tables for the regression lines are shown in Appendix C.2. The Kostiakov equation fitted the intake rate data very well for the TC treatment at all of the three sites. The coefficient of determination ranged from 0.936 to 0.968 with the F-test for the regression being highly significant for all of the fitted models.

The surge treatments in each experiment were assumed to be composed of a series of individual curves from each surge, instead of being a single curve for the entire irrigation. Since the Kostiakov equation did not well represent the actual physical behavior for the surge treatments, the regression procedure was not used for those treatments. The analysis approach was to plot the average intake rate data for each surge treatment on the same graph with the fitted line for the continuous flow treatment. The time basis used was the opportunity time, which was defined as the elapsed time for the period of application of water without including the off-time.

The soil moisture profile for each infiltration test is shown in Appendix C.4. Those tables show a considerable soil moisture content variability among the tests, although the experiments were performed in small experimental areas (less than 400 m^2) and in a period of time of two weeks.

The characteristic intake curve for the surge tests showed an unexpected "jump" between surges. For all of the surge treatments the initial intake rate for the next surge was always higher than the final intake rate for the last surge, even higher than the intake rate presented by the continuous curve at the same opportunity time. The magnitude of this "jump" seems to vary among sites and within treatments, and to reduce in size as the experiment continues in time. This jump effect did not show up in the preliminary tests for the furrow infiltrometer when a plastic cover was used over the tested length. One possible cause for this effect is the increase of the effective test length from surge to surge. It would mean that the actual test length was not the one measured at the site, but a larger length changed during the infiltration experiment. A seepage face at the tailwater sump could cause this, although most of the experiments did not show excessive seepage volume below the sump after finishing the test. Another possibility is to credit this jump effect to surge flow application. However, to date not enough literature is available to check the validity of this assumption.

For each treatment at each treatment site, the basic intake rate and the opportunity time taken to reach it are shown in Table II. This table also shows the percent of reduction found for the basic intake rate for each surge treatment with respect to the continuous treatment. The basic intake rate was considered to be the lowest intake rate measured for each treatment, which seemed to remain constant for the rest of the experiment. In some surge experiments, where this value was not well defined, the last intake rate of the test was assumed to be the basic intake rate.

Perkins: Site #1

This experimental area contained a soil classed as a Teller loam. The length of the test section at this site was 5 m (16.4 feet) with an average top width of 24 cm (9.5 inches) and an average flow depth of 1.9 cm (0.75 inches). The curves of the average intake rate for the treatments at this site are shown in Figures 35 through 37. All of the surge treatments showed an average basic intake rate lower than the treatment TC. The treatment T3 reached the lowest basic intake rate of 8 mm/hr (0.32 inch/hr) in 117 min, while the treatment TC took 132 min to reach a basic intake rate of 15 mm/hr (0.58 inch/hour). The treatment T1 was

TABLE II

BASIC INTAKE RATE AND CORRESPONDENT OPPORTUNITY TIME FOR EACH INFILTRATION TREATMENT

Soil Type	Treat	Aver. Basic Int. Rate (mm/hr)	Opportunity Time (min)	Reduction from TC (%)
Loam	TC	15	132	---
	T1	9	78	40.0
	T2	10	117	33.3
	T3	8	117	46.7
Fine Sandy	TC	25	172	---
	T1	8	98	68.0
	T2	10	117	60.0
	T3	10	117	60.0
Clay Loam	TC	22	105	---
	T1	13	98	40.9
	T2	15	97	31.8
	T3	14	147	36.4

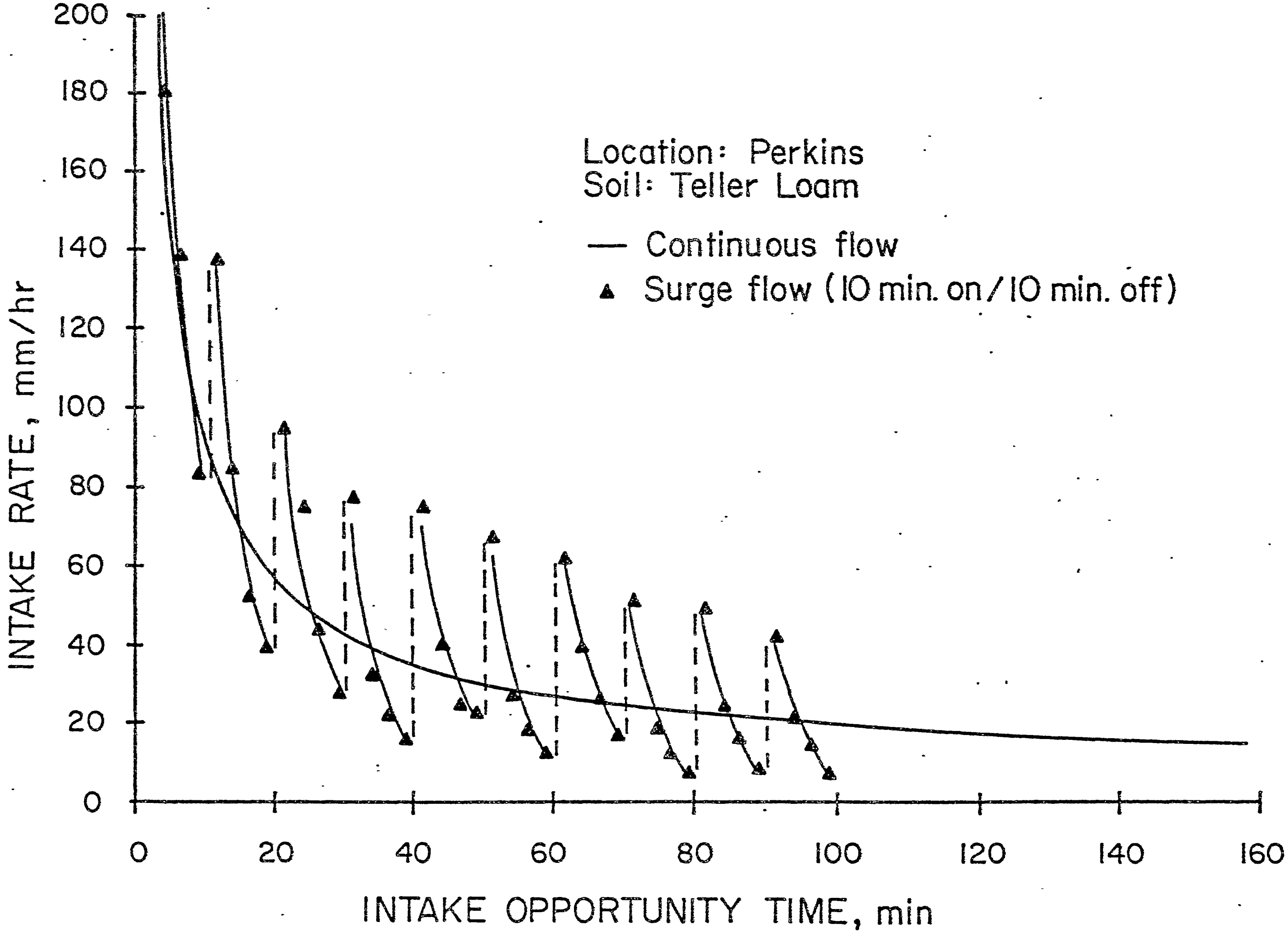

Figure 35. Average Intake Rate Curves for Perkins: Site #1 Treatments T1 and TC

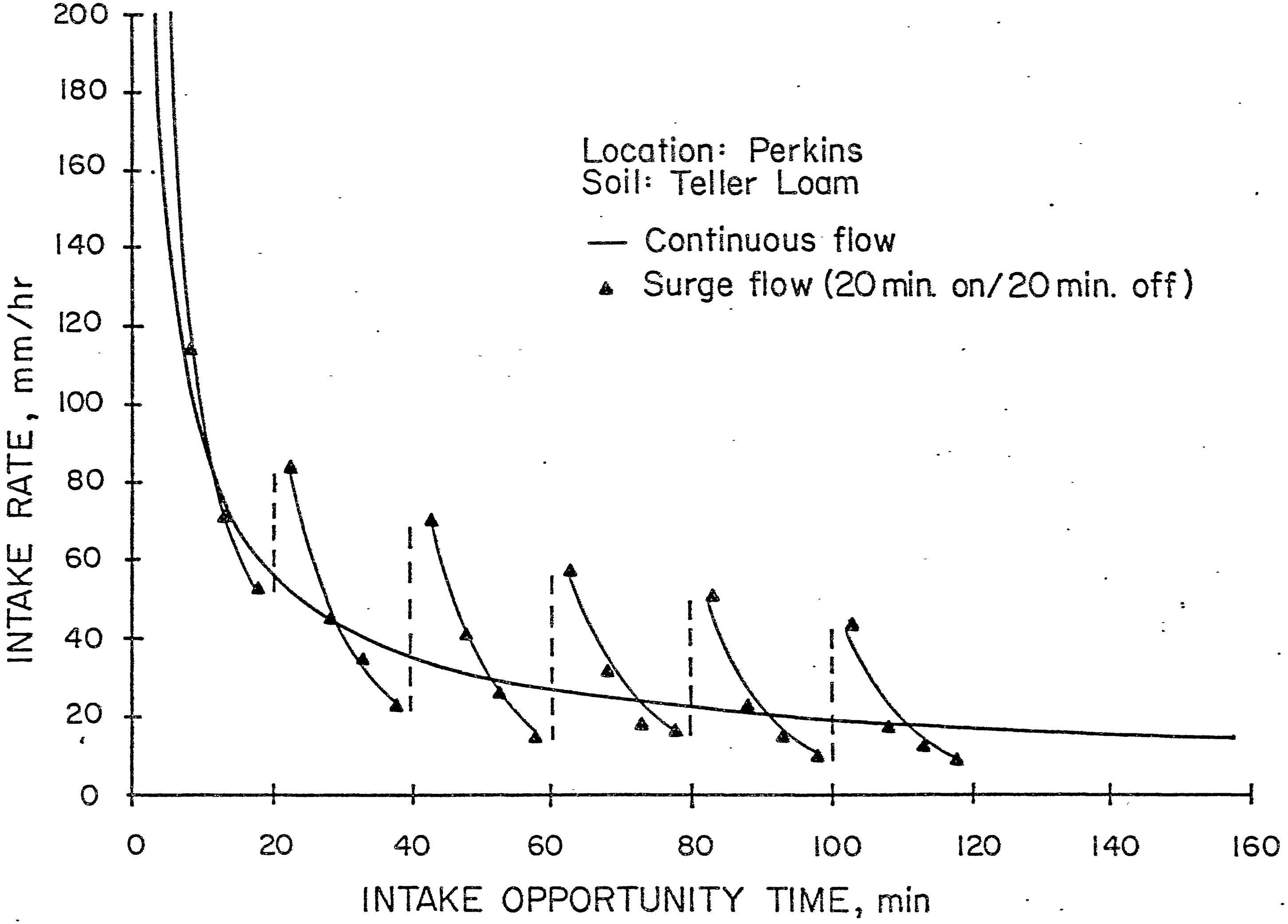

Figure 36. Average Intake Rate Curves for Perkins: Site #1 Treatments T2 and TC.

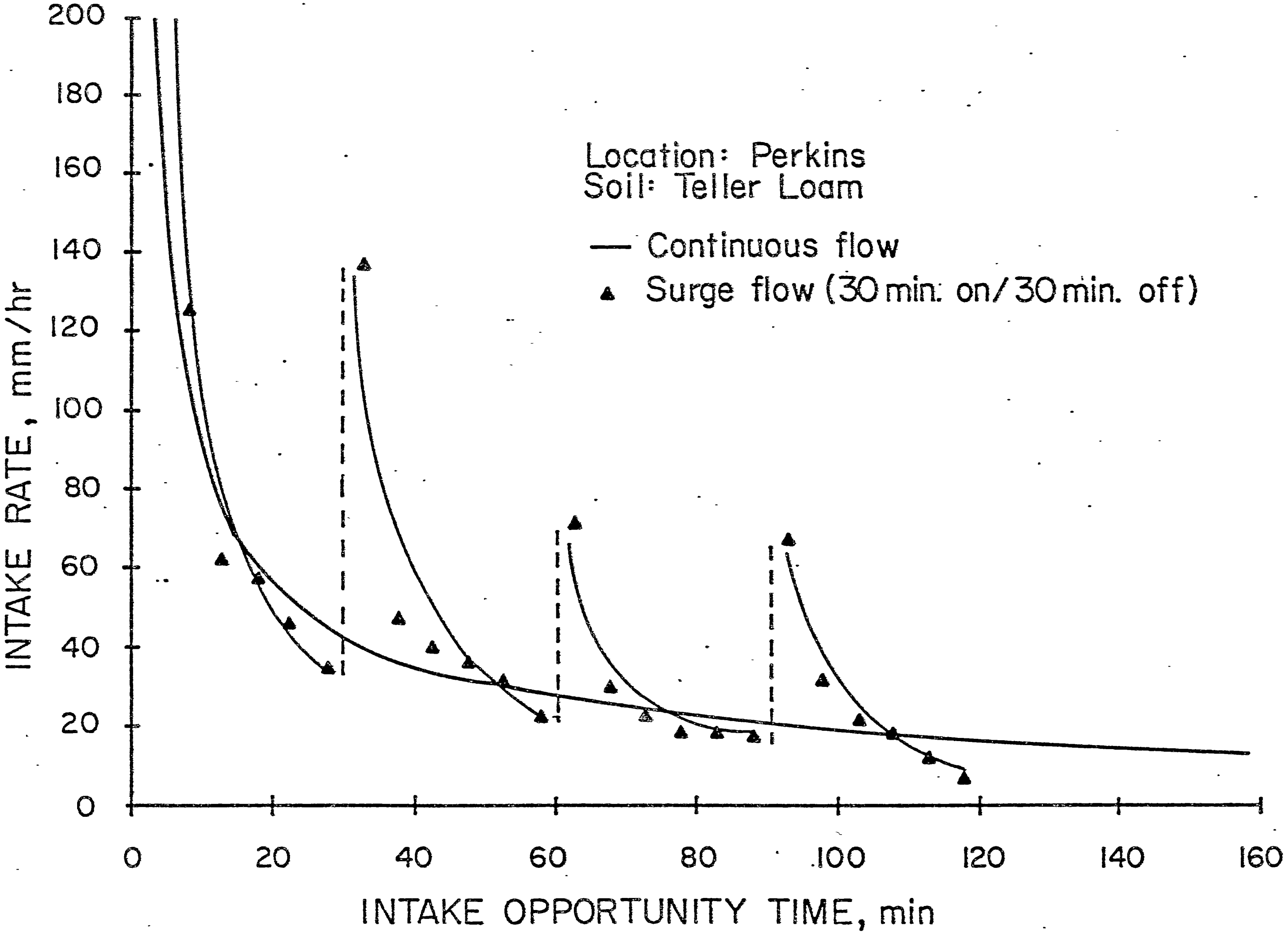

Figure 37. Average Intake Rate Curves for Perkins: Site #1 Treatments T3 and TC.

able to reach the basic intake rate in just 78 min of opportunity time, which means a reduction of 40.9 percent from the opportunity time taken by the continuous treatment. Table CXXV in Appendix C.3 shows an analysis of variance for the basic intake rates of all of the treatments for this type of soil. The AOV table gives an F-value of 6.64, which provides evidence of differences among treatments at the 4.94 percent level. The Duncan's Multiple Range Test was performed to check which of the treatments had a significant difference. This test showed that the continuous treatment was the only significantly different treatment at the five percent level. Taking into consideration the statistical analysis, the average basic intake rate for the surge treatments was 9 mm/hr (0.35 inch/hr) which corresponds to a reduction of 40 percent with respect to the basic intake rate for the continuous treatment.

The surge treatments showed the "jump" effect, with the treatment T3 giving the highest average jump magnitude.

Perkins: Site #2

This set of experiments was conducted on soil classified as Carwile fine sandy loam. The length of the test section was 3 m (9.84 feet) with an average top width of 20.3 cm (8 inches) and an average flow depth of 2.5 cm (one inch). The curves of the average intake rate for each treatment are shown in Figures 38 through 40. When compared with treatment TC, all of the surge treatments had a lower average basic intake rate. While the treatment TC took 172 minutes to reach a basic intake rate of 25 mm/hr (0.99 inch/hr), the surge treatment T1 took 98 minutes to reach a basic intake rate of 8 mm/hr (0.30 inch/hr). These numbers mean a reduction of 43 percent in opportunity time, and a reduction of 68 percent in basic intake rate. Table CXXVI in Appendix C.3 shows an analysis of variance for the basic intake rates of all of the treatments for this experimental area. The AOV table gives an F-value of 41.1, which provides strong evidence of differences among treatments at the 0.18 percent level. The Duncan's Test showed that the continuous treatment was the only significantly different treatment at the five percent level. Taking into consideration the statistical analysis, the average basic intake rate for the surge treatments was 9 mm/hr (0.36 inch/hr) which corresponds to a reduction of 64 percent with respect to the basic intake rate for the continuous treatment. The comparison of the three surge treatments with the continuous treatment indicated that the surge treatments had lower values for the initial intake rate at the beginning of the test. This behavior was explained by the difference in the soil moisture content found in the different runs at this site (Appendix C.4), which highly affected the intake process of the soil.

The surge treatments also showed the "jump" effect and the treatment T1 had the highest average jump magnitude. Among the three soil types in this study, this site had the highest erosion occurrence, showing a large amount of

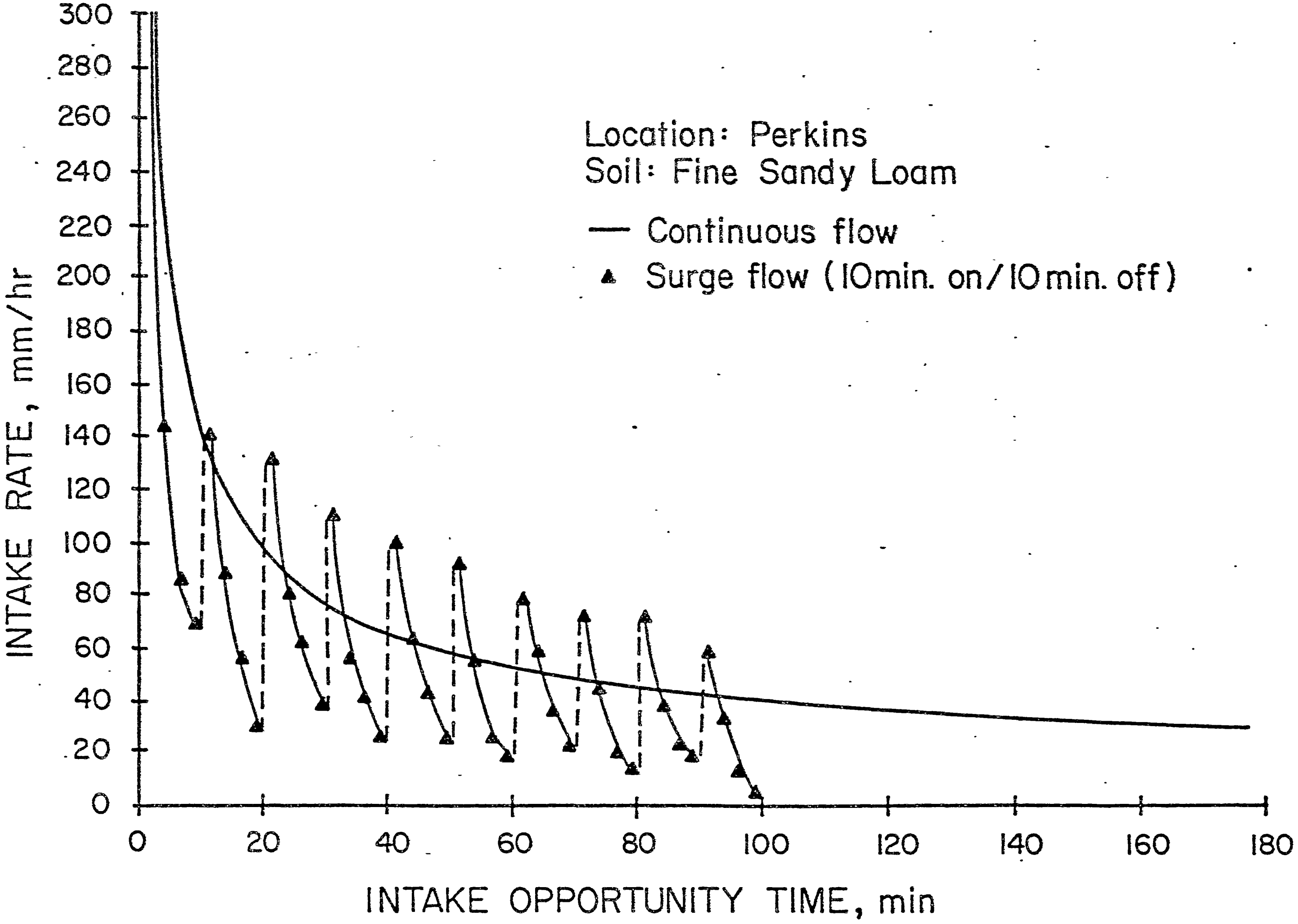

Figure 38. Average Intake Rate Curves for Perkins: Site #2 Treatments T1 and TC.

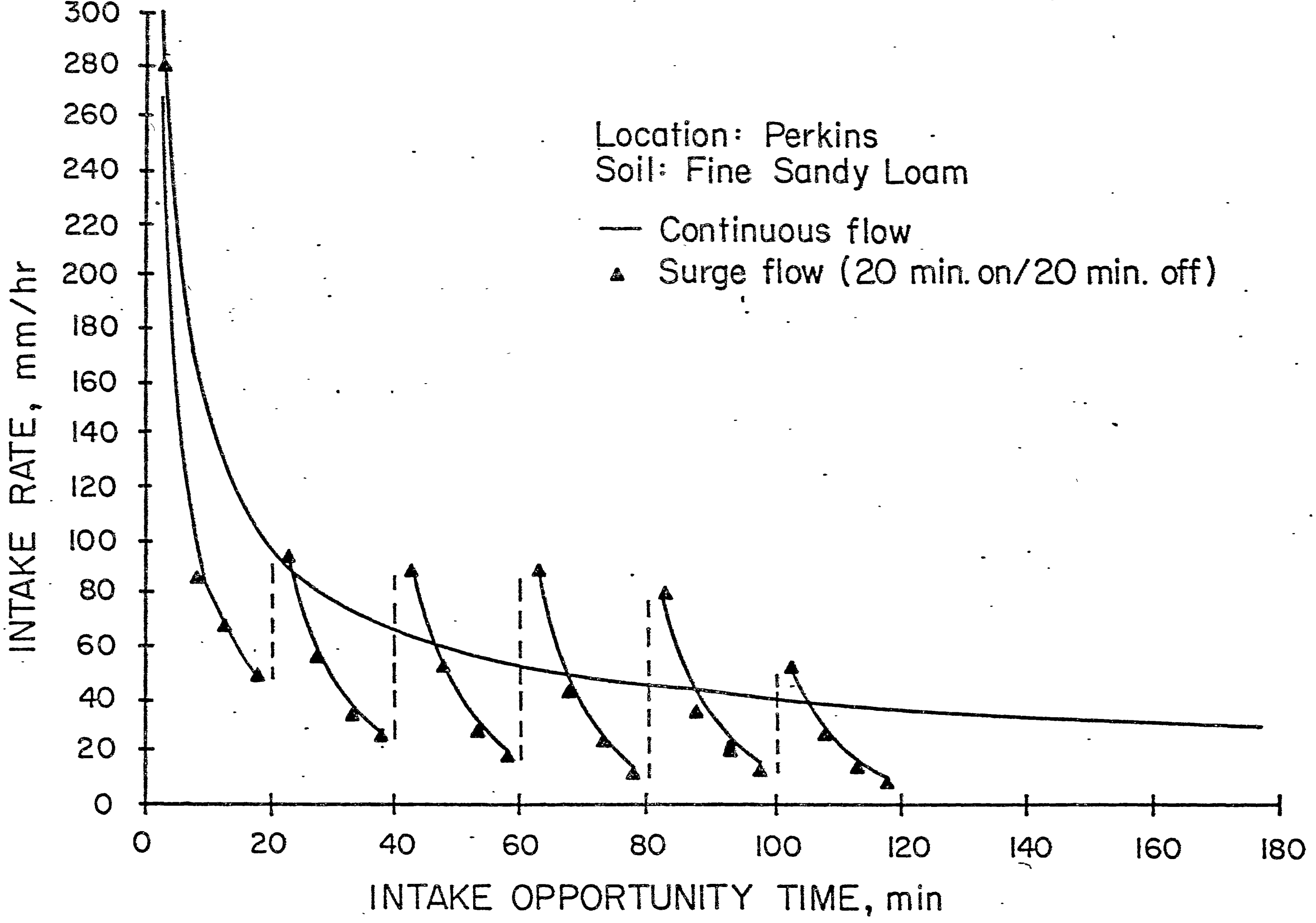

Figure 39. Average Intake Rate Curves for Perkins: Site #2 Treatments T2 and TC.

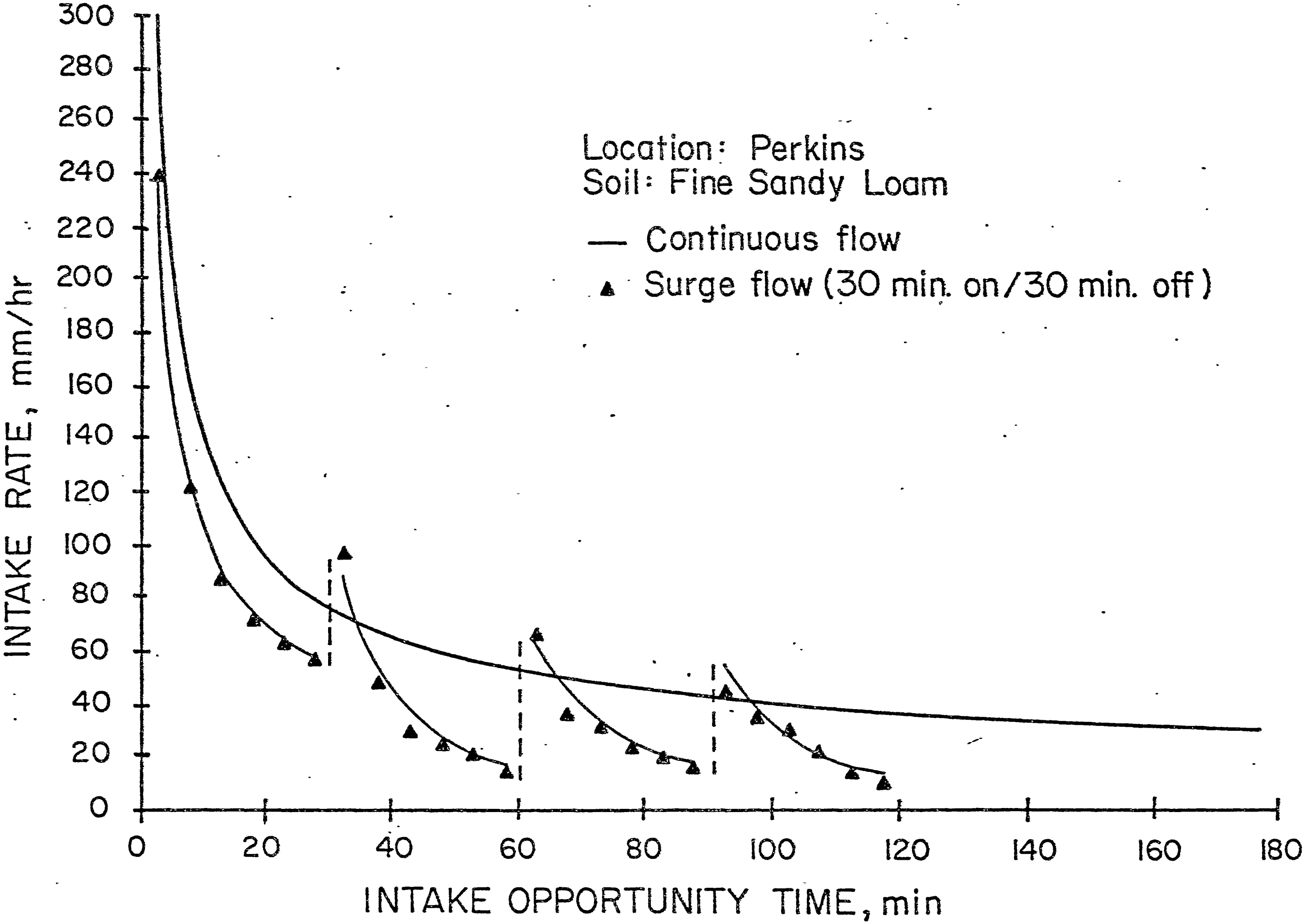

Figure 40. Average Intake Rate Curves for Perkins: Site #2
Treatments T3 and TC.

sediment in both sumps during the tests. This soil also formed a superficial washed crust, which could work as an impermeable layer for the water intake.

Altus: Site #3

The soil at this site is classed as a clay loam of the Tillman-Hollister Complex. The length of this test section was 5 m (16.4 feet) with an average top width of 20.3 cm (eight inches) and an average flow depth of 25.4 cm (one inch). The curves of the average intake rate for the treatments at this site are shown in Figures 41 through 43. All of the surge treatments had an average basic intake rate lower than the continuous treatment. The treatment T1 reached the lowest basic intake rate of 13 mm/hr (0.51 inch/hr) in 98 min, while the treatment TC took 105 min to reach a basic intake rate of 22 mm/hr (0.86 inch/hr). Table CXXVI in Appendix C.3 shows the analysis of variance of the basic intake rate for all of the treatments in this experimental site. The analysis shows an F-value of 7.32, which provides evidence of real difference among treatments at the 4.22 percent level of significance. The Duncan's Test showed the continuous treatment was the only significantly different treatment, while there was no significant difference among the average basic intake rate for the surge treatments. Therefore, it is possible to say that the average intake rate for the surge treatments was 14 mm/hr (0.54 inch/hr), which means an average reduction

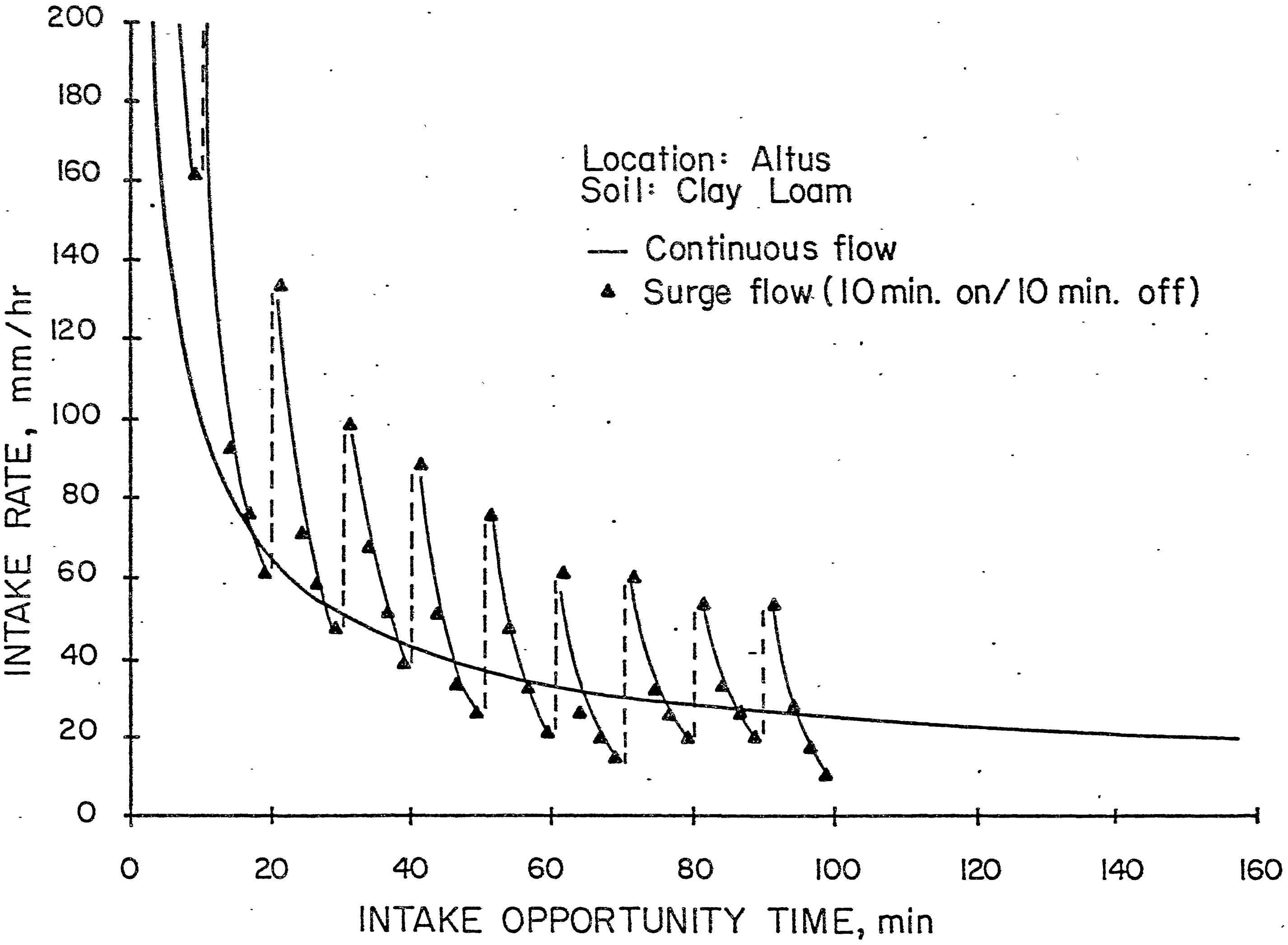

Figure 41. Average Intake Rate Curves for Altus: Site #3 Treatments T1 and TC

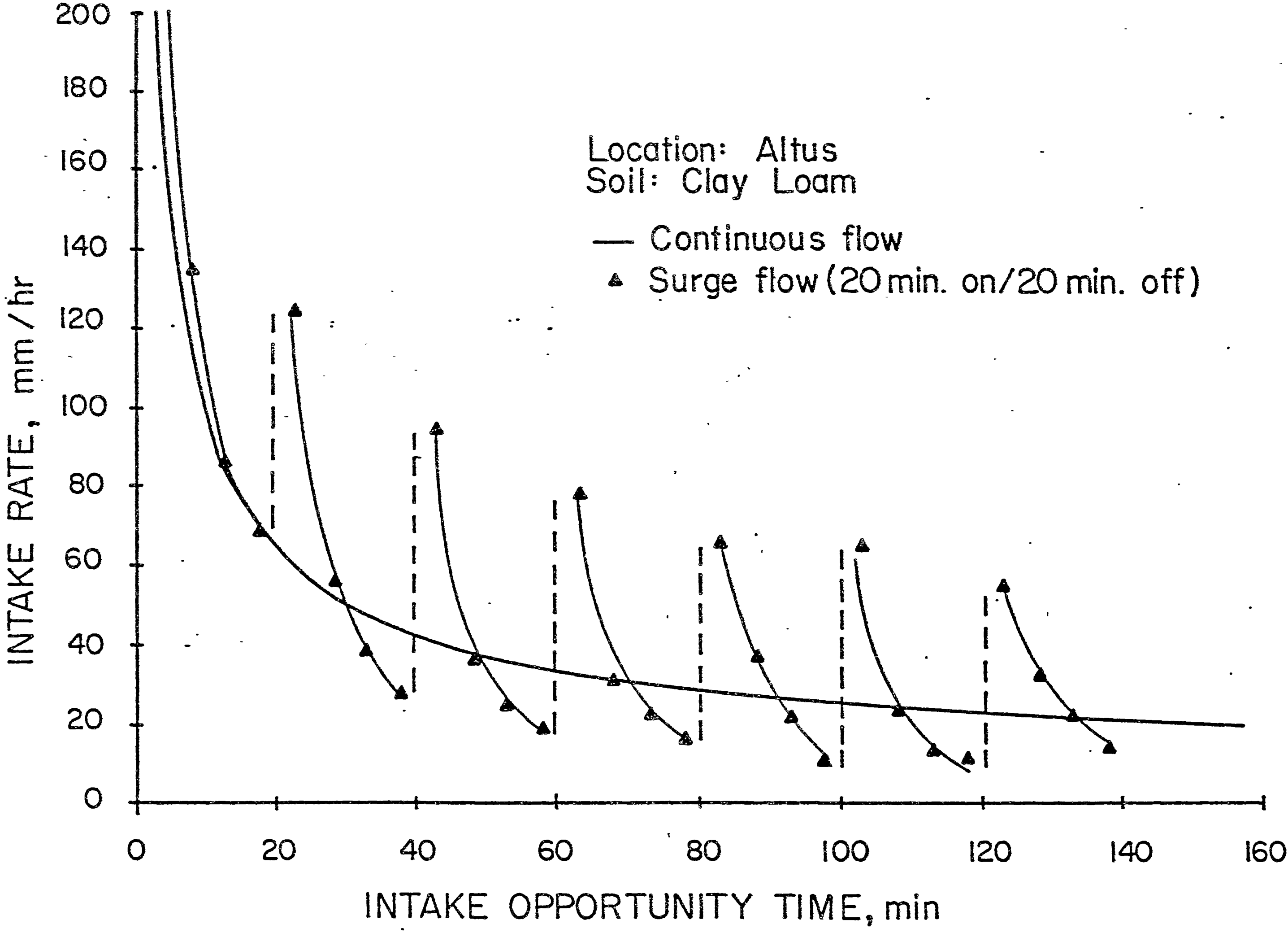

Figure 42. Average Intake Rate Curves for Altus: Site #3
Treatments T2 and TC

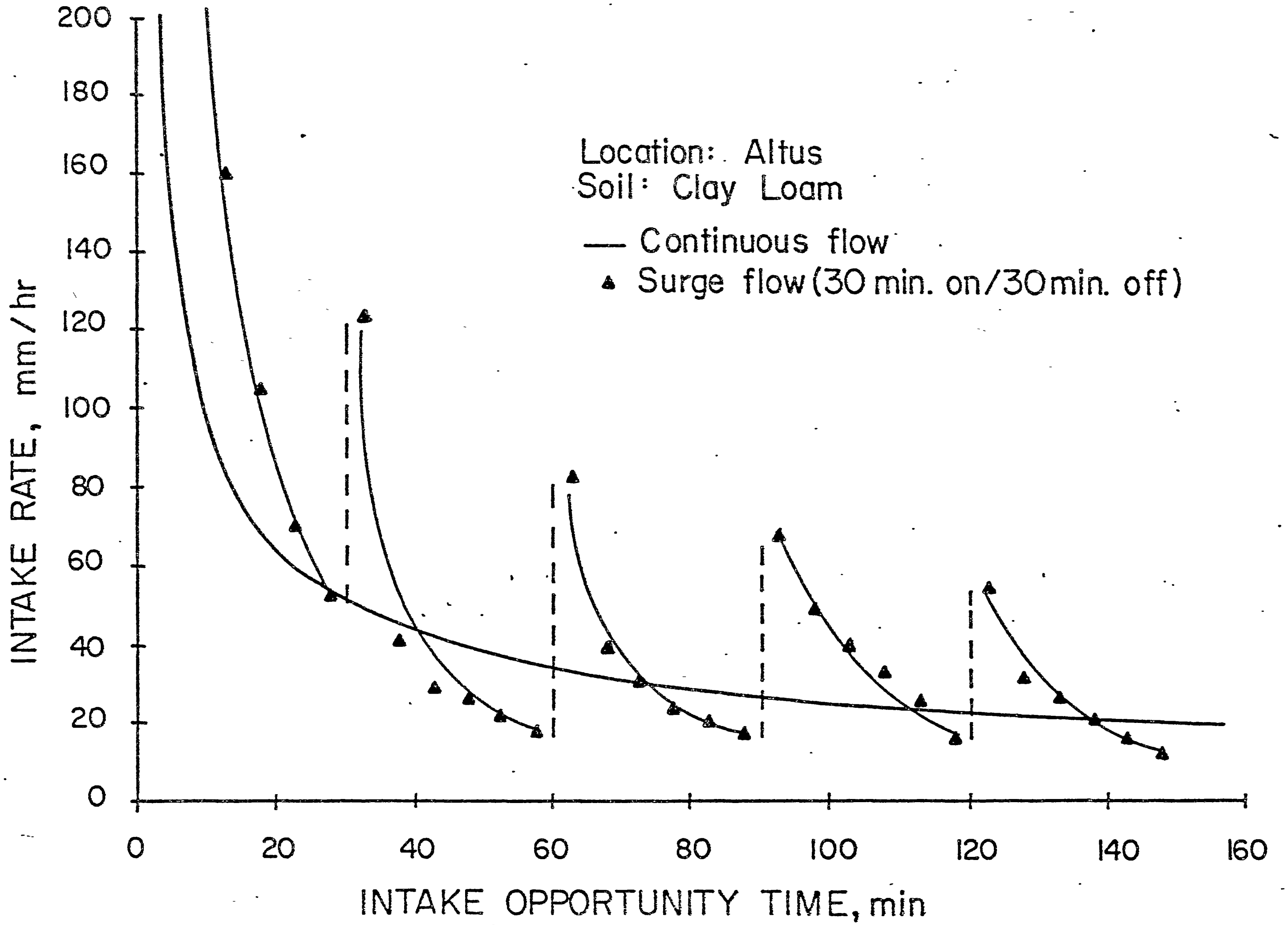

Figure 43. Average Intake Rate Curves for Altus: Site #3 Treatments T3 and TC

of 36.4 percent with respect to the treatment TC.

The "jump" effect was also present in this set of tests, with the surge treatment T3 giving the highest average jump magnitude. The basic intake rate found for continuous and surge treatments in this site was higher than the common values found in the literature for a clay loam soil. This appeared to be the result of a hot and dry season, which caused big cracks to form at the soil surface. These soil conditions also produced high intake rates at the beginning of the experiments.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The overall purposes of this study were to develop reliable information about the adaptability of the surge flow technique to an open channel furrow irrigation system, and to contribute to the understanding of how surge flow changes the advance and the infiltration characteristics of surface irrigation. To meet the stated objectives this study was divided in three sections: (1) Open-Channel Surge Flow Furrow Irrigation System; (2) Water Advance Phase; and (3) Infiltration Characteristics.

Open-Channel Surge Flow Furrow Irrigation System

An automated open channel system using an automated gate developed by Cudrak (1984) and an improved controller was installed at the Irrigation Research Station at Altus, Oklahoma.

A hydraulic analysis was performed in order to know which factors would have major effects on the variation of the tube outlet flow rates. It was found that in practice the differences in the tube elevation would cause much greater variation in the tube flow rate than would the rise or decline of the water surface profile.

Through the evaluation of the hydraulic performance of the open-channel system, it was possible to develop information which can lead to an appropriate design of surge flow open-channel systems. The performance of the automated equipment used in the system was evaluated under field conditions through two irrigation seasons. The operating characteristics of this equipment were also evaluated in the laboratory. In both cases, the automated gate performed reliably, being a durable mechanism without any major problems.

Water Advance Phase

The advance phase is an important aspect of surface irrigation and should be analyzed in surge flow. The water advance study experiments were performed at the Irrigation Research Station at Altus, Oklahoma, and were divided into two years of study. The field contained a soil classified as a clay loam of the Tillman-Hollister complex.

In the first year of study (1983) the surge treatment T3 with a cycle time of 60 minutes and a cycle ratio of one-half (30 min on/ 30 min off) was compared with a continuous treatment in three irrigation events (July/16, Aug/09, and Aug/25). In all of the irrigations, the surge treatment was evaluated in two bays of the system for different average inflow rates. On July/16 the inflow rates used were 34 L/min (9 gpm) and 57 L/min (15 gpm), while on Aug/09 and Aug/25 the flow rates used were 49 L/min (13 gpm) and 57 L/min (15 gpm). The continuous treatment was tested in just one bay for an average inflow rate of 57 L/min (15 gpm). From those experiments, it was found that the surge treatment with an average inflow rate of 57 L/min (15 gpm) showed an advance rate higher than the continuous treatment. This effect was more pronounced in the first irrigation event, when the surge application had an average reduction of 28.6 percent in the total advance time with respect to the continuous treatment. The same surge treatment with lower inflow rates showed an advance rate slower than the continuous treatment. Those experiments showed also that the intermittent application of water reduced the variation in the advance distance caused by differing furrow conditions.

In the 1984 season, the study was limited to two irrigation dates, July/17 and July/30. All of the treatments in this season were evaluated for both wheel and nonwheel compacted furrows. On July/17 the treatments evaluated were: surge treatment T2 (20 min on/20 min off) in bay 1 and bay 2 with respective average inflow rates of 57 L/min (15 gpm) and 60 L/min (16 gpm); surge treatment T1 (10 min on/10min off) in bay 3 and bay 4 with respective average inflow rates of 57 L/min (15 gpm) and 60 L/min (16 gpm); and the continuous treatment TC in bay 5 with an average inflow rate of 57 L/min (15 gpm). The surge treatments T2 and T1 did not show any advantage in advance rate over the treatment TC, under the prevailing soil conditions at the time of the tests. The furrow compaction condition was one of the major source of variability in these experiments. While for nonwheel the surge treatment T2 showed a reduction in the total advance time of 40.8 percent with respect to the continuous treatment, for the wheel compacted furrows the continuous treatment showed a faster advance rate with a reduction of five percent in total advance time over the surge treatment. Although overall the surge treatments on this date did not give an advance faster than the continuous treatment, they still showed less variability in advance distance for both compaction conditions.

The experiments on July/30 evaluated two different cutback treatments. The most significant result on this date was that for the furrow length and inflow rate in the study, the surge cutback of 30 min cycle time (15 min on/15 min off), after the furrow was entirely wet, created a furrow stream able to cover an average of 60 percent of the furrow length during the on-time period and finish the advance during the off-time using the storage volume of water left in the furrow. This procedure created a minimum runoff volume, having the effect of a cutback irrigation.

Infiltration Characteristics

A series of infiltration experiments using a recirculating furrow infiltrometer was conducted at two research stations in Oklahoma, Perkins and Altus. Two sites with different soils, Teller Loam (site #1) and Carwile fine sandy loam soil (site #2), were chosen at Perkins, while at Altus one site with Tillman-Hollister clay loam soil (site #3) was chosen. The surge treatments selected had cycle times of 20 min (T1), 40 min (T2), and 60 min (T3), with a cycle ratio of one-half. A continuous treatment (TC) was included as a control. All of the tests were run with an average inflow rate of 57 L/min (15 gpm).

For site #1, the average basic intake rate reached by the surge treatments was 9 mm/hr (0.35 inch/hr), which corresponds to a reduction of 40 percent with respect to the continuous treatment. The surge treatment T3 reached the lowest basic intake rate of 8 mm/hr (0.32 inch/hr) in 117 min, while the treatment TC took 132 min to reach a basic intake rate of 15 mm/hr (0.58 inch/hr).

The average basic intake rate for the surge treatments at site #2 was 9 mm/hr (0.36 inch/hr), which means a reduction of 63 percent with respect to the treatment TC. While the continuous treatment took 172 min to reach a basic intake rate of 25 mm/hr (0.99 inch/hr), the treatment T1 took 99 minutes to reach a basic intake rate of 8 mm/hr (0.30 inch/hr), the lowest at this site.

At site #3, the average basic intake rate for the surge treatments was 14 mm/hr (0.54 inch/hr), which means a reduction of 37 percent with respect to the treatment TC. The surge treatment T1 reached the lowest basic intake rate of 13 mm/hr (0.51 inch/hr) in 98 min, while the treatment TC took 105 min to reach a basic intake rate of 22 mm/hr

(0.86 inch/hr).

The surge treatments affected the intake characteristics of the soils in this study, by reducing the intake rate at all of the three sites. Site #2 with a soil classed as a Carwile fine sandy loam showed the most pronounced effect, with the surge treatments showing an average reduction in the basic intake rate of 63 percent with respect to the continuous treatment.

Conclusions

The results of the research study reported herein allow one to draw the following conclusions:

1. The full automation of an open-channel irrigation system using the surge flow technique was achieved, with the system having the potential to reduce labor and increase the irrigation application efficiency;

2. Basic and simple design criteria were established for adapting surge flow to open-channel systems;

3. The automated equipment performed very well for the conditions tested, showing a reliable and durable mechanism, and having the flexibility to control both time and quantity of water application;

4. The surge treatment with a cycle time of 60 min and a cycle ratio of one-half (30 min on/ 30 min off) showed the highest advance rate when compared with the continuous application of water;

5. The effects of surge flow were more pronounced during the first water application to newly made furrows and

were also more pronounced in nonwheel compacted furrows;

6. Reduced inflow rate or decreased cycle time may lead to increased advance time;

7. Surge irrigation reduced the differences in rate of advance between furrows with different levels of compaction;

8. A surge flow cutback was obtained by using after initial wetting a short cycle time of 30 min (15 min on/15 min off), which made the average flow into the furrow slightly larger than the basic intake rate of the soil;

9. The amount of water applied and the surface runoff can be reduced when surge cutback is used in furrow irrigation;

10. Surge flow altered the basic intake rate of the furrows, showing values lower than those produced under continuous flow conditions;

11. Larger reductions of the basic intake rate were found in the fine sandy loam soil than in either the loam or clay loam soils under surged application of water;

12. The reduction in surge infiltration rates should result in smaller volumes of water being required for advance when surge flow irrigation is compared to continuous application.

Recommendations

Six years after the appearance of surge flow as an optional technique for surface irrigation, it still does not have well developed design criteria. The most difficult problem is to develop a reliable mathematical model which predicts the infiltration process for surge flow application under field conditions. Therefore, a great deal of research is still necessary to determine the variables which affect the intake characteristics of different soils under intermittent application of water and how to relate them to the furrow advance phase. More research has to be done also to evaluate the effects of surge flow on advance, uniformity and efficiency for different operating conditions and a wide variety of soils.

Although the flowing furrow infiltrometer used in this study performed satisfactorily, it still needs further improvements with the objective to increase the practicality and reliability of the measurements. Modifications of the shape of the sumps would help to avoid seepage and erosion around them.

LITERATURE CITED

1. Adrian, D.D. and J.B. Franzini. 1966. Impedance to Infiltration by Pressure Build-Up Ahead of the Wetting Front. J. Geophys. Res. 71(24):5857-5862.

2. Allen, N. L. 1980. Advance Rates in Furrow Irrigation to Cycled Flow. Unpub. M.S. thesis. Utah State University, Logan, Utah.

3. Basset, D. L., D. D. Fangmeier, and T. Strelkoff. 1980. Hydraulics of Surface Irrigation. Chapter 12. In Design and Operation of Farm Irrigation Systems, M. E. Jensen (editor). 1st Edition. ASAE. St. Joseph, Michigan.

4. Bishop, A. A., W. R. Walker, N. L. Allen, and G. J. Poole. 1981. Furrow Advance Rates Under Surge Flow Systems. Journal of the Irrigation and Drainage Division, ASCE. 107(IR3):257-264.

5. Blair, A. W. 1984. Infiltration and Surge Flow. Proc. of Surge Flow Irrigation Conference. Texas Agricultural Extension Service. Midland, Texas. pp. III1-III12.

6. Bondurant, J. A. 1957. Developing Furrow Infiltrometer. Agricultural Engineering Journal, ASAE. 38(8):602-604.

7. Coolidge, P. S., W. R. Walker, and A. A. Bishop. 1982. Advance and Runoff-Surge Flow Furrow Irrigation. Journal of the Irrigation and Drainage Division, ASCE. 108(IR1):35-41.

8. Cudrak, A. J. 1984. Automation of Open-Channel Surge Flow Irrigation. Unpub. M. S. thesis. Oklahoma State University, Stillwater, Oklahoma.

9. Duley, F.L. 1939. Surface Factors Affecting the Rate of Intake of Water by Soils. Soil Sci. Am. Proc. 4:60-64.

10. Edwards, W. M. and W. E. Larson. 1969. Infiltration of Water into Soils as Influenced by Surface Seal Development. Trans. ASAE 12(4):463-465.

11. Eisenhauer, D. E. 1984. Surface Sealing and Infiltration with Surface Irrigation. Unp. Ph.D. Dissertation. Colorado State University, Fort Collins, Colorado.

12. Elliott, R. L. and D. E. Eisenhauer. 1983. Volume Balance Techniques for Measuring Infiltration in Surface Irrigation. Paper No. 83-2520. Presented at ASAE Winter Meeting. Chicago, Illinois.

13. Epperly, D. R., R. L. Elliott and J. E. Garton. 1983. An Improved Furrow Flow Meter for Gated Pipe. Mimeo. Agricultural Engineering Department, Oklahoma State university. Stillwater, Oklahoma.

14. Evans, R. G. 1977. Improved Semi-Automatic Gates for Cut-Back Surface Irrigation Systems. Trans. ASAE 20(1):105-108.

15. Fangmeier, D. D. and M. K. Ramsey. 1978. Intake Characteristics of Irrigation Furrows. Trans. ASAE 21SW(Special Edition):696-700, 705.

16. Fok, Y. S. and A. A. Bishop. 1965. Analysis of Water Advance in Surface Irrigation. Journal of the Irrigation and Drainage Division, ASCE. 91(IR1): 99-116.

17. Garton, J. E., R. P. Beasley, and A. D. Barefoot. 1963. Automation of Cut-Back Furrow Irrigation. Paper No. 63-719. Presented at ASAE Winter Meeting. Chicago, Illinois.

18. Garton, J. E. 1964. Automation of Cut-Back Furrow Irrigation. Unpub. Ph.D. Dissertation. University of Missouri, Columbia, Missouri.

19. Haise, H. R., E. G. Kruse, M. L. Payne, and H. R. Duke. 1980. Automation of Surface Irrigation: 15 Years of USDA Research and Development at Fort Collins, Colorado. USDA Production Research Report No. 179.

20. Hillel, D. 1960. Crust formation in Loessial Soils. Trans. VIIth Intern. Soil Sci. Congr. Madison, WI. pp. 330-337.

21. Humpherys, A. S. 1967. Automating Surface Irrigation. Agricultural Engineering, ASAE. 48(6):338-340.

22. Humpherys, A. S. 1971. Automatic Furrow Irrigation Systems. Trans. ASAE 14(3):466-470.

23. Irrigation Journal. 1980. Irrigation Survey. Irrigation Journal. 30(6):72A-72H.

24. Izuno, F. T., T. H. Podmore and H. R. Duke. 1984. Infiltration under Surge Irrigation. Paper No. 84-2088. Presented at ASAE Summer Meeting. Knoxville, Tennessee.

25. James, L. G. and C. L. Larson. 1976. Modeling Infiltration and Redistribution of Soil Water during Intermittent Application. Trans. ASAE 19(3):482-488.

26. Jarrett, A.R. and D.D. Fritton. 1978. Effect of Entrapped Soil Air on Infiltration. Trans. ASAE 21(5): 901-906.

27. Malano, H. M. 1982. Comparison of the Infiltration Process Under Continuous and Surge Flow. Unpub. M. S. thesis. Utah State University, Logan, Utah.

28. McIntyre, D. S. 1958. Permeability Measurements of Soil Crusts Formed by Raindrop Impact. Soil Sci. 85(4):185-189.

29. McWhorter, D. B. 1976. Vertical Flow of Air and Water with a Flux Boundary Condition. Trans. ASAE 19(2): 259-261,265.

30. Moore, I. D. 1981. Effect of Surface Sealing on Infiltration. Trans. ASAE, 24(6):1546-1552.

31. Morel-Seytoux, H. J. and N. Vauclin. 1983. Superiority of Two-Phase Formulation for Infiltration. Proc. of the National Conference on Advances in Infiltration. ASAE. Chicago, Illinois. pp. 34-47.

32. Philip, J. R. 1957. The Theory of infiltration: 4. Sorptivity and Algebraic Infiltration Equations. Soil Science. 84:257-264.

33. Podmore, T. H., and H. R. Duke. 1982. Field Evaluation of Surge Irrigation. Paper No. 82-2102. Presented at ASAE Summer Meeting, Madison, Wiscosin.

34. Podmore, T.H., H. R. Duke, and F. T. Izuno. 1983. Implementation of Surge Irrigation. Paper No. 83-2018. Presented at ASAE Summer Meeting, Bozeman, Montana.

35. Poole, G. J. 1981. Infiltration and Advance Under Surge Flow in Furrow Irrigation. Unpub. M.S. thesis. Utah State University, Logan, Utah.

36. Schmidt, B. L., W. D. Shrader and W. C. Moldenhauer. 1964. Relative Erodibility of Three Loess Derived Soils in Southwestern Iowa. Soil Sci. Soc. Amer. Proc. 28:570-574.

37. Stringham, G. E. and J. Keller. 1979. Surge Flow for Automatic Irrigation. Proceedings 1979 Irrigation and Drainage Division Specialty Conference. ASCE. Albuquerque, New Mexico. pp. 132-142.

38. Sweeten, J. M. Jr., J. E. Garton, and A. L. Mink. 1969. Hydraulic Roughness of an Irrigation Channel with Decreasing Spatially Varied Flow. Trans. ASAE, 12(4):466-470.

39. Tabago, J. L. 1983. Adaptation and Evaluation of Surge Irrigation under Philippine Conditions. Unpub. Ph.D. Dissertation. Oklahoma State Universersity, Stillwater, Oklahoma.

40. Tackett, J. L. and R. W. Pearson. 1965. Some Characteristics of Soil Crusts Formed by Simulated Rainfall. Soil Science. 99(6):407-413.

41. Trout, T. J. and W. D. Kemper. 1983. Factors which Affect Furrow Intake Rates. Proc. of National Conference on Advances in Infiltration. ASAE. Chicago, Illinois. pp. 302-312.

42. Walker, W. R. 1984. Surge Flow in the West. Proc. of Surge Flow Irrigation Conference. Texas Agricultural Extension Service. Midland, Texas. pp. I1-I30.

43. Walker, W. R., H. Malano and J. A. Replogle. 1982. Reduction in Infiltration Rates due to Intermittent Wetting. Paper No. 82-2029. Presented at ASAE Summer Meeting. Madison, Wisconsin.

44. Walker, J. and N. R. Schlegel. 1984. Field Testing of Surge Irrigation System. Proc. of Surge Irrigation Conference. Texas Agricultural Extension Service. Midland, Texas. pp. IV1-IV11.

45. Walker, W. R. and L. S. Willardson. 1983. Infiltration Measurements for Simulating Furrow Irrigation. Proc. of the National Conference on Advances in Infiltration. ASAE. Chicago, Illinois. pp. 241-248.

46. Wilson, L. G. and J. N. Luthin. 1963 . Effect of Air Flow Ahead of the Wetting Front on Infiltration. Soil Science. 96(2):136-143.

47. Zur, B. 1976. The Pulsed Irrigation Principle for Controlled Soil Wetting. Soil Science. 122(5): 282-291.

48. Zur, B. and D. Savaldi. 1977. Infiltration under a Pulsed Water Application: 1 The Nature of the Flow System. Soil Science. 124(3):127-134.

APPENDIXES

APPENDIX A

BASIC COMPUTER PROGRAM FOR DETERMINATION OF WATER SURFACE PROFILE

```
10 REM
20 REM      BASIC PROGRAM TO ESTIMATE THE WATER PROFILE IN SPATIALLY VARIED
30 REM                     FLOW WITH DECREASING DISCHARGE
40 REM
50 DIM DEPTH(200),AREA(200),WETP(200),HYDR(200),VEL(200),AVGAREA(200)
60 DIM AVGHYDR(200),HEAD(200),Q(200),SF(200),HF(200),DEPTHC(200)
70 DIM VELREC(200),WATSUF(200),DV(200),DHF(200)
80 REM
90 REM                   INPUT OF THE CHANNEL DIMENSIONS
100 REM
110 REM  B = BOTTOM OF CHANNEL ( feet )
120 REM  Z = SIDE SLOPE OF CHANNEL
130 REM  Y = DEPTH OF FLOW AT THE FIST TUBE OUTLET ( feet )
140 REM  D = DISTANCE FROM THE BOTTOM OF CHANNEL TO THE OUTLET ( feet )
150 REM  L = DISTANCE BETWEEN OUTLETS ( feet )
160 REM  MN = ROUGHNESS COEFFICIENT FOR MANNING'S EQUATION
170 REM  N = NUMBER OF OUTLETS PER BAY
180 REM
190 READ B,Z,Y,D,L,MN,N
200 DATA 1,1,1.31,1,3.33,0.03,29
210 REM
220 REM      ESTIMATION OF THE VARIABLES FOR THE FIRST OUTLET DOWNSTREAM
230 REM
240 DEPTH(0)=Y
250 AREA(0)=(B+Z*Y)*Y
260 WETP(0)=B+(2*Y*SQR(1+Z^2))
270 HYDR(0)=AREA(0)/WETP(0)
280 VEL(0)=0
290 HEAD(0)=DEPTH(0)-D
300 Q(I)=0
310 REM
320 REM      ESTIMATION OF THE VARIABLES FOR EACH OUTLET UPSTREAM
330 REM
340 FOR I=1 TO N-1
350 DEPTH(I)=DEPTH(I-1)                      ' FLOW DEPTH '
360 AREA(I)=(B+Z*DEPTH(I))*DEPTH(I)          ' FLOW AREA  '
370 WETP(I)=B+(2*DEPTH(I)*SQR(1+Z^2))        ' WETTED PERIMETER '
380 HYDR(I)=AREA(I)/WETP(I)                  ' HYDRAULIC RADIUS '
390 AVGAREA(I)=(AREA(I)+AREA(I-1))/2         ' AVERAGE AREA '
400 AVGHYDR(I)=(HYDR(I)+HYDR(I-1))/2         ' AVERAGE HYDRAULIC RADIUS '
410 HEAD(I)=DEPTH(I)-D                       ' HEAD ABOVE OUTLET '
420 Q(I)=.06193*SQR(HEAD(I))                 ' DISCHARGE THROUGH THE OUTLET'
430 QT=Q(I-1)+Q(I)                           ' TOTAL DISCHARGE AT THE SECTION '
440 VEL(I)=QT/AVGAREA(I)
450 SF(I)=((VEL(I)^2)*(MN^2))/(2.208*(AVGHYDR(I)^1.3333))
460 HF(I)=SF(I)*L                            ' SECTION HEAD LOSS IN FEET '
470 DEPTHC(I)=DEPTH(I-1)+((VEL(I-1)^2-VEL(I)^2)/64.4)+HF(I)
480 IF ABS(DEPTHC(I)-DEPTH(I))<=.001 THEN GOTO 510
490 DEPTH(I-1)=DEPTHC(I)
500 GOTO 350
510 DEPTH(I)=DEPTHC(I)
520 VELREC(I)=VEL(I)^2/64.4                   ' VELOCITY RECOVERY TERM '
530 DV(I)=DEPTH(0)-VELREC(I)
540 HFT=HF(I-1)+HF(I)                         ' HEAD LOSS TERM '
550 DHF(I)=DEPTH(0)+HFT
560 HEAD(I)=DEPTH(I)-D
570 WATSUF(I)=HFT-VELREC(I)                   ' WATER SURFACE PROFILE '
580 Q(I)=QT
590 HF(I)=HFT
600 NEXT I
610 LPRINT:LPRINT:
620 LPRINT"                                    TABLE III
630 LPRINT:
640 LPRINT"                  WATER SURFACE PROFILE FOR THE DISCHARGING BAY"
650 LPRINT:
660 LPRINT "           __________________________________________________________
____"
670 LPRINT:
680 LPRINT "           Outlet Head Loss  Vel Recovery  Wat Surface  Actual     Actua
l"
690 LPRINT "            Tube    Profile      Profile     Variation   Depth       Head
 "
700 LPRINT "                     (cm)         (cm)         (cm)      (cm)        (cm)
"
710 LPRINT "           __________________________________________________________
____"
720 LPRINT:
730 REM
740 REM    OUTPUT OF THE VARIABLES ESTIMATED FOR EACH OUTLET IN SI UNITS
750 REM
760 FOR I=0  TO  N-1
770 DHF(I)=DHF(I)*30.48
780 DV(I)=DV(I)*30.48
790 WATSUF(I)=WATSUF(I)*30.48
800 DEPTH(I)=DEPTH(I)*30.48
810 HEAD(I)=HEAD(I)*30.48
820 LPRINT TAB(8) USING " ## ";I,
830 LPRINT USING "  ##.######  ";HF(I),VELREC(I),WATSUF(I),
840 LPRINT USING " ##.###### ";DEPTH(I),HEAD(I)
850 NEXT I
860 LPRINT "           __________________________________________________________
____"
```

TABLE III

WATER SURFACE PROFILE FOR THE DISCHARGING BAY

Outlet Tube	Head Loss Profile (cm)	Vel Recovery Profile (cm)	Wat Surface Variation (cm)	Actual Depth (cm)	Actual Head (cm)
0	0.000000	0.000000	0.000000	39.928800	9.448798
1	0.000000	0.000002	-0.000052	39.928750	9.448748
2	0.000002	0.000008	-0.000197	39.928600	9.448602
3	0.000004	0.000018	-0.000418	39.928380	9.448381
4	0.000010	0.000032	-0.000693	39.928110	9.448104
5	0.000017	0.000050	-0.001004	39.927800	9.447795
6	0.000029	0.000073	-0.001332	39.927470	9.447468
7	0.000044	0.000099	-0.001657	39.927140	9.447142
8	0.000065	0.000129	-0.001959	39.926840	9.446836
9	0.000090	0.000163	-0.002220	39.926580	9.446574
10	0.000122	0.000202	-0.002420	39.926370	9.446371
11	0.000161	0.000244	-0.002540	39.926250	9.446251
12	0.000206	0.000290	-0.002560	39.926230	9.446232
13	0.000260	0.000341	-0.002460	39.926330	9.446331
14	0.000322	0.000395	-0.002223	39.926570	9.446568
15	0.000394	0.000454	-0.001827	39.926970	9.446963
16	0.000475	0.000516	-0.001255	39.927540	9.447538
17	0.000567	0.000583	-0.000486	39.928310	9.448307
18	0.000670	0.000653	0.000499	39.929290	9.449292
19	0.000784	0.000728	0.001720	39.930510	9.450509
20	0.000911	0.000806	0.003195	39.931990	9.451984
21	0.001051	0.000889	0.004943	39.933730	9.453732
22	0.001205	0.000975	0.006986	39.935780	9.455774
23	0.001372	0.001066	0.009340	39.938130	9.458129
24	0.001555	0.001161	0.012027	39.940820	9.460818
25	0.001753	0.001259	0.015064	39.943860	9.463856
26	0.001968	0.001362	0.018472	39.947260	9.467263
27	0.002199	0.001468	0.022269	39.951060	9.471061
28	0.002447	0.001579	0.026475	39.955270	9.475264

APPENDIX B

WATER ADVANCE EXPERIMENTAL DATA

APPENDIX B.1

AVERAGE CUMULATIVE DISTANCE DATA

TABLE IV

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T3 (30 min on/30 min off) FOR BAY ONE

DATE:Jul/16/83 (first irrigation)
Q = 34 L/min (9 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
6	30	60.55	8.23	13.59
6	60	99.97	13.24	13.24
6	90	142.14	14.15	9.95
6	120	181.49	12.40	6.83
6	150	210.57	18.28	8.68

TABLE V

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T3 (30 min on/30 min off) FOR BAY TWO

DATE:Jul/16/83 (first irrigation)
Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
6	30	82.40	2.77	3.36
6	60	166.22	3.28	1.97
6	90	224.43	11.97	5.33
6	120	284.99	22.88	8.03

TABLE VI

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT TC (Continuous) FOR BAY THREE
DATE:Jul/16/83 (first irrigation)
Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
7	30	89.74	10.31	11.49
7	60	144.30	24.87	17.24
7	90	195.33	11.08	5.67
7	120	237.37	15.48	6.52
7	150	278.37	19.21	6.90
7	180	314.03	13.99	4.45

TABLE VII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T3 (30 min on/30 min off) FOR BAY ONE
DATE:Aug/09/83 (second irrigation)
Q = 49 L/min (13 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
8	30	103.10	14.54	14.11
8	60	170.69	17.08	10.01
8	90	215.15	24.89	11.57
8	120	251.88	27.82	11.05

TABLE VIII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT
T3 (30 min on/30 min off) FOR BAY TWO
DATE:Aug/09/83 (second irrigation)
Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
8	30	127.60	6.58	5.16
8	60	190.23	10.69	5.62
8	90	259.46	29.12	11.22
8	120	323.47	13.50	4.17

TABLE IX

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT
TC (Continuous) FOR BAY THREE
DATE:Aug/09/83 (second irrigation)
Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
8	30	98.07	11.18	11.40
8	60	168.63	18.47	10.96
8	90	234.39	24.09	10.28
8	120	297.68	32.82	11.03

TABLE X

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T3 (30 min on/30 min off) FOR BAY ONE
DATE:Aug/25/83 (third irrigation)
Q = 49 L/min (13 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
8	30	69.95	3.18	4.55
8	60	118.91	3.93	3.30
8	90	160.59	5.93	3.69
8	120	194.92	7.13	3.66
8	150	226.89	12.29	5.14

TABLE XI

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T3 (30 min on/30 min off) FOR BAY TWO
DATE:Aug/25/83 (third irrigation)
Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
10	30	105.13	4.98	4.74
10	60	169.26	6.19	3.61
10	90	214.15	10.27	4.80
10	120	265.30	10.93	4.12

TABLE XII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT
TC (Continuous) FOR BAY THREE
DATE:Aug/25/83 (third irrigation)
Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
9	30	83.42	4.61	5.52
9	60	143.60	6.83	4.76
9	90	197.61	7.68	3.88
9	120	241.77	9.91	4.10
9	150	292.74	17.32	5.92

TABLE XIII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT
T2 (20 min on/20 min off) FOR BAY ONE
DATE:Jul/17/84 - Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
8	20	110.54	8.65	7.83
8	40	173.44	11.86	6.84
8	60	217.59	15.55	7.15
8	80	249.78	15.91	6.37
8	100	271.70	16.06	5.91

TABLE XIV

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T2 (20 min on/20 min off) FOR BAY ONE AND NON-WHEEL FURROWS DATE:Jul/17/84 Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
3	20	108.52	1.29	1.19
3	40	168.82	9.18	5.44
3	60	209.57	13.07	6.23
3	80	243.45	16.41	6.74
3	100	267.61	18.60	6.95

TABLE XV

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T2 (20 min on/20 min off) FOR BAY ONE AND WHEEL FURROWS DATE:Jul/17/84 Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
5	20	111.75	11.20	10.02
5	40	176.22	13.36	7.58
5	60	222.41	16.14	7.26
5	80	253.58	16.13	6.36
5	100	274.16	16.07	5.86

TABLE XVI

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT
T2 (20 min on/20 min off) FOR BAY TWO
DATE:Jul/17/84 - Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
7	20	91.05	10.92	11.99
7	40	149.22	15.83	10.61
7	60	198.73	15.70	7.90
7	80	233.39	21.25	9.11
7	100	271.23	27.58	10.17

TABLE XVII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT
T2 (20 min on/20 min off) FOR BAY TWO
AND NON-WHEEL FURROWS DATE:Jul/17/84
Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Averaged Distance (m)	Standard Dev. (m)	Coef. Var. (%)
4	20	83.52	7.05	8.44
4	40	137.24	6.13	4.47
4	60	190.42	14.65	7.70
4	80	219.46	14.03	6.39
4	100	250.77	12.43	4.96

TABLE XVIII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T2 (20 min on/20 min off) FOR BAY TWO AND WHEEL FURROWS DATE:Jul/17/84 Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
3	20	101.09	4.27	4.22
3	40	165.20	5.04	3.05
3	60	209.80	9.76	4.65
3	80	251.97	12.40	4.92
3	100	298.50	9.87	3.31

TABLE XIX

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT
T1 (10 min on/10 min off) FOR BAY THREE
DATE:Jul/17/84 - Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
9	10	60.66	5.07	8.35
9	20	97.47	5.35	5.49
9	30	133.30	10.47	7.85
9	40	137.77	7.98	5.79
9	50	143.73	6.12	4.26
9	60	148.03	3.90	2.63
9	70	152.57	5.11	3.35

TABLE XX

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T1 (10 min on/10 min off) FOR BAY THREE AND NON-WHEEL FURROWS DATE:Jul/17/84
Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
4	10	58.83	5.39	9.16
4	20	95.33	6.89	7.22
4	30	133.43	14.30	10.71
4	30	137.92	10.61	7.69
4	50	142.34	8.23	5.78
4	60	147.07	4.94	3.36
4	70	151.41	3.63	2.40

TABLE XXI

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T1 (10 min on/10 min off) FOR BAY THREE AND WHEEL FURROWS DATE:Jul/17/84 Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
5	10	62.12	4.85	7.81
5	20	99.18	3.66	3.69
5	30	133.20	8.12	6.09
5	40	137.65	6.55	4.76
5	50	144.84	4.55	3.14
5	60	148.80	3.22	2.16
5	70	153.50	6.33	4.12

TABLE XXII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T1 (10 min on/10 min off) FOR BAY FOUR DATE:Jul/17/84 - Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
9	10	47.04	3.84	8.16
9	20	83.41	8.20	9.83
9	30	113.72	11.54	10.15
9	40	139.72	15.05	10.76
9	50	158.43	21.53	13.59
9	60	168.01	19.07	11.35
9	70	179.02	19.20	10.73

TABLE XXIII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T1 (10 min on/10 min off) FOR BAY FOUR AND NON-WHEEL FURROWS DATE:Jul/17/84 Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
5	10	46.39	4.53	9.76
5	20	79.98	7.63	9.55
5	30	108.27	10.69	9.87
5	40	130.94	11.82	9.03
5	50	145.15	15.87	10.94
5	60	154.41	11.68	7.56
5	70	164.65	9.84	5.98

TABLE XXIV

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT T1 (10 min on/10 min off) FOR BAY FOUR AND WHEEL FURROWS DATE:Jul/17/84 Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
4	10	47.85	3.23	6.74
4	20	87.71	7.57	8.64
4	30	120.55	9.54	7.92
4	40	150.95	11.02	7.30
4	50	175.03	15.45	8.83
4	60	185.01	9.71	5.25
4	70	196.98	8.94	4.54

TABLE XXV

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT TC (Continuous) FOR BAY FIVE DATE:Jul/17/84
Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
10	30	135.70	28.83	21.25
10	60	213.27	50.61	23.73
10	90	264.75	65.54	24.76
10	120	283.37	58.01	20.47
10	150	294.22	48.62	16.53

TABLE XXVI

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT TC (Continuous) FOR BAY FIVE AND NON-WHEEL FURROWS DATE:Jul/17/84
Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
5	30	109.61	9.31	8.54
5	60	167.95	16.13	9.61
5	90	207.02	22.66	10.94
5	120	231.47	28.93	12.50
5	150	253.17	33.25	13.13

TABLE XXVII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT TC (Continuous) FOR BAY FIVE AND WHEEL FURROWS DATE:Jul/17/84
Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
5	30	161.79	9.03	5.58
5	60	258.59	19.16	7.41
5	90	322.49	28.63	8.88
5	120	335.28	0.0	0.0
5	150	335.28	0.0	0.0

TABLE XXVIII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT SCB (Surge Cutback) FOR BAY ONE DATE:Jul/30/84
Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
9	10	66.14	12.17	18.40
9	20	99.67	15.71	15.76
9	40	166.32	20.31	12.21
9	60	209.36	24.32	11.61
9	90	286.61	32.58	11.37
9	120	321.53	17.57	5.46
9	135	252.48	12.75	5.05
9	150	222.84	8.58	3.85
9	165	221.83	9.76	4.40

TABLE XXIX

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT SCB (Surge Cutback) FOR BAY ONE AND NON-WHEEL FURROWS DATE:Jul/30/84
Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
4	10	60.20	4.43	7.37
4	20	90.98	7.54	8.29
4	40	156.36	11.87	7.59
4	60	195.45	13.16	6.73
4	90	266.17	23.15	8.70
4	120	309.22	18.91	6.12
4	135	247.27	2.60	1.05
4	150	220.98	1.24	0.56
4	165	218.69	1.97	0.90

TABLE XXX

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT SCB (Surge Cutback) FOR BAY ONE AND WHEEL FURROWS DATE:Jul/30/84

Q = 57 L/min (15 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
5	10	70.90	14.76	20.82
5	20	106.62	17.75	16.65
5	40	174.29	23.26	13.34
5	60	220.49	26.54	12.04
5	90	302.97	31.12	10.27
5	120	331.38	8.72	2.63
5	135	256.64	16.47	6.42
5	150	224.33	11.82	5.27
5	165	224.33	13.04	5.81

TABLE XXXI

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT SCB (Surge Cutback) FOR BAY TWO DATE:Jul/30/84 Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
10	10	49.16	7.48	15.22
10	20	84.61	12.25	14.48
10	40	135.18	24.94	18.45
10	60	171.27	20.97	12.24
10	90	227.35	43.39	19.08
10	120	269.96	38.45	14.24
10	135	234.97	14.91	6.35
10	150	236.43	15.72	6.65
10	165	240.43	11.84	4.92

TABLE XXXII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT SCB (Surge Cutback) FOR BAY TWO AND NON-WHEEL FURROWS DATE:Jul/30/84

Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
5	10	46.94	8.36	17.81
5	20	83.52	16.15	19.34
5	40	129.42	21.47	16.59
5	60	164.65	10.95	6.65
5	90	218.30	30.35	13.90
5	120	258.11	43.88	17.00
5	135	225.86	15.89	7.03
5	150	226.41	16.23	7.17
5	165	234.21	12.92	5.52

TABLE XXXIII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT SCB (Surge Cutback) FOR BAY TWO AND WHEEL FURROWS DATE:Jul/30/84
Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
5	10	51.39	6.61	12.87
5	20	85.71	8.60	10.03
5	40	140.94	29.25	20.75
5	60	177.88	27.57	15.50
5	90	236.40	55.77	23.59
5	120	281.82	32.39	11.49
5	135	244.08	6.35	2.60
5	150	246.46	6.38	2.59
5	165	246.64	7.18	2.91

TABLE XXXIV

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT CCB (Continuous Cutback) FOR BAY THREE DATE:Jul/30/84 Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
10	30	128.72	17.96	13.96
10	60	210.46	28.15	13.37
10	90	282.92	39.28	13.88
10	120	329.18	19.28	5.86
10	135	158.04	15.39	9.74
10	150	182.42	11.72	6.43
10	165	186.45	14.91	6.35
10	180	185.45	9.83	5.27

TABLE XXXV

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT CCB (Continuous Cutback) FOR BAY THREE AND NON-WHEEL FURROWS DATE:Jul/30/84

Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
5	30	115.95	7.81	6.74
5	60	189.71	12.21	6.44
5	90	253.41	17.67	6.97
5	120	323.09	27.26	8.44
5	135	155.27	14.36	9.25
5	150	177.52	5.93	3.34
5	165	182.88	3.73	2.04
5	180	182.03	4.27	2.35

TABLE XXXVI

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT CCB (Continuous Cutback) FOR BAY THREE AND WHEEL FURROWS DATE:Jul/30/84
Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
5	30	141.49	16.04	11.34
5	60	231.22	23.59	10.20
5	90	312.42	31.36	10.04
5	120	335.28	0.0	0.0
5	135	160.81	17.54	10.90
5	150	187.33	14.62	7.80
5	165	190.01	13.10	6.90
5	180	189.89	11.64	6.13

TABLE XXXVII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT CCB
(Continuous Cutback) FOR BAY FOUR DATE:Jul/30/84
Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
10	30	98.30	15.81	16.09
10	60	153.50	23.36	15.22
10	90	195.01	28.07	14.39
10	120	226.28	36.86	16.29
10	150	256.61	43.56	16.98
10	165	192.18	8.78	4.57
10	180	199.77	8.48	4.25
10	195	194.83	7.91	4.06
10	210	203.09	8.64	4.25

TABLE XXXVIII

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT CCB (Continuous Cutback) FOR BAY FOUR AND NON-WHEEL FURROWS DATE:Jul/30/84

Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
5	30	87.90	4.55	5.18
5	60	138.99	10.92	7.86
5	90	176.11	16.41	9.32
5	120	200.92	19.60	9.76
5	150	223.48	24.76	11.08
5	165	192.02	12.71	6.62
5	180	200.44	10.56	5.27
5	195	195.44	11.39	5.83
5	210	203.18	10.48	5.16

TABLE XXXIX

AVERAGE CUMULATIVE ADVANCE DISTANCE OF TREATMENT CCB (Continuous Cutback) FOR BAY FOUR AND WHEEL FURROWS DATE:Jul/30/84

Q = 60 L/min (16 gpm)

Number of Obs.	Opportunity Time (min)	Average Distance (m)	Standard Dev. (m)	Coef. Var. (%)
5	30	108.69	16.49	15.17
5	60	168.01	24.12	14.36
5	90	213.91	24.71	11.55
5	120	251.64	32.62	12.96
5	150	289.74	30.21	10.43
5	165	192.33	3.48	1.81
5	180	199.09	7.03	3.53
5	195	194.22	3.16	1.63
5	210	202.99	7.62	3.76

APPENDIX B.2

ANALYSIS OF VARIANCE TABLES FOR THE FITTED ADVANCE POWER FUNCTIONS

TABLE XL

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T3 - BAY ONE DATE: JUL/16/83

Q = 34 L/min (9 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.142568	1.142568	557.226	0.0001
Error	28	0.057413	0.002050		
Cor. Total	29	1.199981			

Root MSE	0.045282	R-SQUARE	0.9522
Dep MEAN	2.101263	ADJ R-SQ	0.9504
C.V.	2.154989		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	0.604786	0.063932	9.460	0.0001
Log(time)	1	0.790550	0.033490	23.606	0.0001

EQUATION : $X = 4.0252 * t^{0.79055}$

TABLE XLI

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T3 - BAY TWO DATE: JUL/16/83
Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.974689	0.974689	1375.742	0.0001
Error	22	0.015587	0.000708		
Cor. Total	23	0.990275			

Root MSE	0.026617	R-SQUARE	0.9843
Dep MEAN	2.235132	ADJ R-SQ	0.9835
C.V.	1.190862		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	0.611055	0.044122	13.849	0.0001
Log(time)	1	0.891286	0.024030	37.091	0.0001

EQUATION : $X = 4.0837 * t^{0.891286}$

TABLE XLII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT TC - BAY THREE DATE: JUL/16/83 Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.451563	1.451563	802.052	0.0001
Error	40	0.072393	0.001809		
Cor. Total	23	1.523955			

Root MSE	0.042542	R-SQUARE	0.9525
Dep MEAN	2.235132	ADJ R-SQ	0.9513
C.V.	1.861923		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	0.902552	0.049248	18.327	0.0001
Log(time)	1	0.7077652	0.024987	28.320	0.0001

EQUATION : $X = 7.9901 * t^{0.707765}$

TABLE XLIII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T3 - BAY ONE DATE: AUG/09/83 Q = 49 L/min (13 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.689061	0.689061	281.309	0.0001
Error	30	0.073484	0.002449		
Cor. Total	31	0.762546			

Root MSE	0.049492	R-SQUARE	0.9036
Dep MEAN	2.242296	ADJ R-SQ	0.9004
C.V.	2.207211		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	1.059709	0.071049	14.915	0.0001
Log(time)	1	0.648998	0.038695	16.772	0.0001

EQUATION : $X = 11.4738 * t^{0.648998}$

TABLE XLIV

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T3 - BAY TWO DATE: AUG/09/83
Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.731036	0.731036	731.268	0.0001
Error	30	0.029990	0.000999		
Cor. Total	31	0.761026			

Root MSE	0.031618	R-SQUARE	0.9606
Dep MEAN	2.326328	ADJ R-SQ	0.9593
C.V.	1.359127		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>:T:
Intercept	1	1.108254	0.045389	24.417	0.0001
Log(time)	1	0.668473	0.024720	27.042	0.0001

EQUATION : $X = 12.8308 * t^{0.668473}$

TABLE XLV

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT TC - BAY THREE DATE: AUG/09/83 Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.047960	1.047960	490.060	0.0001
Error	30	0.064153	0.002138		
Cor. Total	31	1.112113			

Root MSE	0.046243	R-SQUARE	0.9423
Dep MEAN	2.263249	ADJ R-SQ	0.9404
C.V.	2.043219		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>|T|
Intercept	1	0.804850	0.066385	12.124	0.0001
Log(time)	1	0.800363	0.036154	22.137	0.0001

EQUATION : $X = 6.3804 * t^{0.800363}$

TABLE XLVI

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T3 - BAY ONE DATE: AUG/25/83 Q = 49 L/min (13 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.307930	1.307930	3888.682	0.0001
Error	38	0.012781	0.000336		
Cor. Total	39	1.320711			

Root MSE	0.018340	R-SQUARE	0.9903
Dep MEAN	2.153944	ADJ R-SQ	0.9901
C.V.	0.851445		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	0.767342	0.022424	34.220	0.0001
Log(time)	1	0.732506	0.011747	62.359	0.0001

EQUATION : $X = 5.8525 * t^{0.732506}$

TABLE XLVII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T3 - BAY TWO DATE: AUG/25/83
Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.891867	0.891867	2436.416	0.0001
Error	38	0.013910	0.000366		
Cor. Total	39	0.905778			

Root MSE	0.019133	R-SQUARE	0.9846
Dep MEAN	2.250809	ADJ R-SQ	0.9842
C.V.	0.850033		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	1.047438	0.024566	42.637	0.0001
Log(time)	1	0.660404	0.013379	49.360	0.0001

EQUATION : $X = 11.1542 * t^{0.660404}$

TABLE XLVIII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT TC - BAY THREE DATE: AUG/25/83 Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.646897	1.646897	4015.376	0.0001
Error	43	0.017636	0.000410		
Cor. Total	44	1.664534			

Root MSE	0.020252	R-SQUARE	0.9894
Dep MEAN	2.244476	ADJ R-SQ	0.9892
C.V.	0.902389		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>¦T¦
Intercept	1	0.777522	0.023346	33.304	0.0001
Log(time)	1	0.774954	0.012230	63.367	0.0001

EQUATION : $X = 5.9913 * t^{0.774954}$

TABLE XLIX

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T2 - BAY ONE DATE: JUL/17/84 Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.779137	0.779137	812.460	0.0001
Error	38	0.036441	0.000959		
Cor. Total	39	0.815578			

Root MSE	0.030967	R-SQUARE	0.9553
Dep MEAN	2.289514	ADJ R-SQ	0.9541
C.V.	1.352579		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	1.318865	0.034404	38.335	0.0001
Log(time)	1	0.565361	0.019835	28.504	0.0001

EQUATION : $X = 20.8384 * t^{0.565361}$

TABLE L

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T2-BAY ONE AND NON-WHEEL FURROWS

DATE: JUL/17/84 Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.289637	0.289637	487.166	0.0001
Error	13	0.007729	0.000595		
Cor. Total	14	0.297366			

Root MSE	0.024383	R-SQUARE	0.9740
Dep MEAN	2.279150	ADJ R-SQ	0.9720
C.V.	1.069832		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	1.312729	0.044236	29.676	0.0001
Log(time)	1	0.562898	0.025503	22.072	0.0001

EQUATION : $X = 20.5461 * t^{0.562898}$

TABLE LI

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T2 - BAY ONE AND WHEEL FURROWS
DATE: JUL/17/84 Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.489509	0.489509	430.937	0.0001
Error	23	0.026126	0.001136		
Cor. Total	24	0.515635			

Root MSE	0.033703	R-SQUARE	0.9493
Dep MEAN	2.295731	ADJ R-SQ	0.9471
C.V.	1.468088		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>|T|
Intercept	1	1.322546	0.047362	27.924	0.0001
Log(time)	1	0.566838	0.027306	20.759	0.0001

EQUATION : $X = 21.0158 * t^{0.566838}$

TABLE LII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T2 - BAY TWO DATE: JUL/17/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.984095	0.984095	547.494	0.0001
Error	33	0.059316	0.001797		
Cor. Total	34	1.043411			

Root MSE	0.042396	R-SQUARE	0.9432
Dep MEAN	2.244664	ADJ R-SQ	0.9414
C.V.	1.888763		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>:T:
Intercept	1	1.078473	0.050353	21.418	0.0001
Log(time)	1	0.679255	0.029030	23.399	0.0001

EQUATION : $X = 11.9804 * t^{0.679255}$

TABLE LIII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T2-BAY TWO AND NON-WHEEL FURROWS DATE: JUL/17/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.583031	0.583031	714.860	0.0001
Error	18	0.014681	0.000816		
Cor. Total	19	0.597711			

Root MSE	0.028558	R-SQUARE	0.9754
Dep MEAN	2.215221	ADJ R-SQ	0.9741
C.V.	1.289194		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	1.027769	0.044869	22.906	0.0001
Log(time)	1	0.691639	0.025868	26.737	0.0001

EQUATION : $X = 10.6603 * t^{0.691639}$

TABLE LIV

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T2 - BAY TWO AND WHEEL FURROWS DATE: JUL/17/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.401500	0.401500	1394.187	0.0001
Error	13	0.003744	0.000288		
Cor. Total	14	0.405244			

Root MSE	0.016970	R-SQUARE	0.9908
Dep MEAN	2.283922	ADJ R-SQ	0.9901
C.V.	0.743021		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>:T:
Intercept	1	1.146079	0.030787	37.226	0.0001
Log(time)	1	0.662744	0.017749	37.339	0.0001

EQUATION : $X = 13.9984 * t^{0.662744}$

TABLE LV

# ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T1 - BAY THREE DATE: JUL/17/84
Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.051877	1.051877	489.613	0.0001
Error	61	0.131051	0.002148		
Cor. Total	62	1.182929			

Root MSE	0.046351	R-SQUARE	0.8892
Dep MEAN	2.077516	ADJ R-SQ	0.8874
C.V.	2.231062		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	1.360034	0.032947	41.279	0.0001
Log(time)	1	0.469274	0.021208	22.127	0.0001

EQUATION : $X = 22.9105 * t^{0.469274}$

TABLE LVI

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T1-BAY THREE AND NON-WHEEL FURROWS
DATE: JUL/17/84 Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.493592	0.493592	187.385	0.0001
Error	26	0.068487	0.002634		
Cor. Total	27	0.562079			

Root MSE	0.051324	R-SQUARE	0.8782
Dep MEAN	2.072687	ADJ R-SQ	0.8735
C.V.	2.476183		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>|T|
Intercept	1	1.335455	0.054723	24.404	0.0001
Log(time)	1	0.482192	0.035225	13.689	0.0001

EQUATION : $X = 21.6499 * t^{0.482192}$

TABLE LVII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T1 - BAY THREE AND WHEEL FURROWS

DATE: JUL/17/84 Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.558923	0.558923	303.604	0.0001
Error	33	0.060752	0.001841		
Cor. Total	34	0.619675			

Root MSE	0.042906	R-SQUARE	0.9020
Dep MEAN	2.081379	ADJ R-SQ	0.8990
C.V.	2.061442		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>|T|
Intercept	1	1.379697	0.040918	33.718	0.0001
Log(time)	1	0.458940	0.026339	17.424	0.0001

EQUATION : $X = 23.9716 * t^{0.458940}$

TABLE LVIII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T1 - BAY FOUR DATE: JUL/17/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	2.298589	2.298589	894.436	0.0001
Error	61	0.156762	0.002570		
Cor. Total	62	2.455352			

Root MSE	0.050694	R-SQUARE	0.9362
Dep MEAN	2.065369	ADJ R-SQ	0.9351
C.V.	2.454473		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>:T:
Intercept	1	1.004751	0.036034	27.883	0.0001
Log(time)	1	0.693705	0.023195	29.907	0.0001

EQUATION : $X = 10.1100 * t^{0.693705}$

TABLE LIX

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T1-BAY FOUR AND NON-WHEEL FURROWS DATE: JUL/17/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.145987	1.145987	623.817	0.0001
Error	33	0.060623	0.001837		
Cor. Total	34	1.206610			

Root MSE	0.042861	R-SQUARE 0.9498
Dep MEAN	2.039747	ADJ R-SQ 0.9482
C.V.	2.101285	

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>:T:
Intercept	1	1.035004	0.040875	25.321	0.0001
Log(time)	1	0.657159	0.026311	24.976	0.0001

EQUATION : $X = 10.8394 * t^{0.657159}$

TABLE LX

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT T1 - BAY FOUR AND WHEEL FURROWS DATE: JUL/17/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.160577	1.160577	827.537	0.0001
Error	26	0.036464	0.001402		
Cor. Total	27	1.197041			

Root MSE	0.037449	R-SQUARE	0.9695
Dep MEAN	2.097398	ADJ R-SQ	0.9684
C.V.	1.785511		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>|T|
Intercept	1	0.966934	0.039930	24.216	0.0001
Log(time)	1	0.739388	0.025703	28.767	0.0001

EQUATION : $X = 9.2669 * t^{0.739388}$

TABLE LXI

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT TC - BAY FIVE DATE: JUL/17/84
Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.748098	0.748098	79.986	0.0001
Error	48	0.448936	0.009353		
Cor. Total	49	1.197034			

Root MSE	0.096710	R-SQUARE	0.6250
Dep MEAN	2.351576	ADJ R-SQ	0.6171
C.V.	4.112565		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	1.413617	0.105764	13.366	0.0001
Log(time)	1	0.495499	0.055403	8.943	0.0001

EQUATION : $X = 25.9189 * t^{0.495499}$

TABLE LXII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT TC-BAY FIVE AND NON-WHEEL FURROWS DATE: JUL/17/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.410787	0.410787	176.676	0.0001
Error	23	0.053477	0.002325		
Cor. Total	24	0.464264			

Root MSE	0.048219	R-SQUARE	0.8848
Dep MEAN	2.267559	ADJ R-SQ	0.8798
C.V.	2.126476		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>|T|
Intercept	1	1.284617	0.074576	17.226	0.0001
Log(time)	1	0.519263	0.039066	13.292	0.0001

EQUATION : $X = 19.2583 * t^{0.519263}$

TABLE LXIII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT TC - BAY FIVE AND WHEEL FURROWS
DATE: JUL/17/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.339031	0.339031	191.125	0.0001
Error	26	0.040799	0.001774		
Cor. Total	27	0.379830			

Root MSE	0.042117	R-SQUARE	0.8926
Dep MEAN	2.435593	ADJ R-SQ	0.8879
C.V.	1.729245		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>:T:
Intercept	1	1.542617	0.065139	23.682	0.0001
Log(time)	1	0.471735	0.034122	13.825	0.0001

EQUATION : $X = 34.8833 * t^{0.471735}$

TABLE LXIV

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT SCB - BAY ONE DATE: JUL/30/84 Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	3.254213	3.254213	1127.623	0.0001
Error	52	0.150067	0.002886		
Cor. Total	53	3.404281			

Root MSE	0.053721	R-SQUARE	0.9559
Dep MEAN	2.217776	ADJ R-SQ	0.9551
C.V.	2.422275		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>|T|
Intercept	1	1.151705	0.032578	35.352	0.0001
Log(time)	1	0.658430	0.019608	33.580	0.0001

EQUATION : $X = 14.1809 * t^{0.658430}$

Obs.: The data points for cut-off advance were not used in the regression procedure.

TABLE LXV

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT SCB-BAY ONE AND NON-WHEEL FURROWS
DATE: JUL/30/84 Q = 57 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.507555	1.507555	1528.125	0.0001
Error	22	0.021704	0.000987		
Cor. Total	23	1.529259			

Root MSE	0.031409	R-SQUARE	0.9858
Dep MEAN	2.188955	ADJ R-SQ	0.9852
C.V.	1.434895		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	1.100550	0.028571	38.519	0.0001
Log(time)	1	0.672224	0.017196	39.091	0.0001

EQUATION : $X = 12.6052 * t^{0.672224}$

Obs.: The data points for cut-off advance were not used in the regression procedure.

TABLE LXVI

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT SCB - BAY ONE AND WHEEL FURROWS

DATE: JUL/30/84 Q = 57 L/min (15 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.747801	1.747801	535.796	0.0001
Error	28	0.091338	0.003262		
Cor. Total	29	1.839139			

Root MSE	0.057114	R-SQUARE	0.9503
Dep MEAN	2.240832	ADJ R-SQ	0.9486
C.V.	2.548807		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>:T:
Intercept	1	1.192630	0.046469	25.665	0.0001
Log(time)	1	0.647394	0.027968	23.147	0.0001

EQUATION : $X = 15.5822 * t^{0.647394}$

Obs.: The data points for cut-off advance were not used in the regression procedure.

TABLE LXVII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT SCB - BAY TWO DATE: JUL/30/84

Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	3.852306	3.852306	985.626	0.0001
Error	58	0.226692	0.003908		
Cor. Total	59	4.078998			

Root MSE	0.062518	R-SQUARE	0.9444
Dep MEAN	2.124198	ADJ R-SQ	0.9435
C.V.	2.943129		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	1.023813	0.035967	28.465	0.0001
Log(time)	1	0.679623	0.021648	31.395	0.0001

EQUATION : $X = 10.5636 * t^{0.679623}$

Obs.: The data points for cut-off advance were not used in the regression procedure.

TABLE LXVIII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT SCB-BAY TWO AND NON-WHEEL FURROWS

DATE: JUL/30/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.919902	1.919902	505.640	0.0001
Error	28	0.106315	0.003797		
Cor. Total	29	2.0262179			

Root MSE	0.061620	R-SQUARE	0.9475
Dep MEAN	2.108135	ADJ R-SQ	0.9457
C.V.	2.922944		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>¦T¦
Intercept	1	1.009537	0.050135	20.137	0.0001
Log(time)	1	0.678519	0.030175	22.486	0.0001

EQUATION : $X = 10.2220 * t^{0.678519}$

Obs.: The data points for cut-off advance were not used in the regression procedure.

TABLE LXIX

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT SCB - BAY TWO AND WHEEL FURROWS DATE: JUL/30/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.932414	1.932414	515.874	0.0001
Error	28	0.104885	0.003746		
Cor. Total	29	2.037300			

Root MSE	0.061204	R-SQUARE	0.9485
Dep MEAN	2.140261	ADJ R-SQ	0.9467
C.V.	2.859640		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	1.038089	0.049796	20.847	0.0001
Log(time)	1	0.680727	0.029971	22.713	0.0001

EQUATION : $X = 10.9166 * t^{0.680727}$

Obs.: The data points for cut-off advance were not used in the regression procedure.

TABLE LXX

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT CCB - BAY THREE DATE: JUL/30/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.976824	0.976824	363.728	0.0001
Error	38	0.102052	0.002686		
Cor. Total	39	1.078876			

Root MSE	0.051823	R-SQUARE	0.9054
Dep MEAN	2.347576	ADJ R-SQ	0.9029
C.V.	2.207496		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>|T|
Intercept	1	1.088194	0.066541	16.354	0.0001
Log(time)	1	0.691142	0.036239	19.072	0.0001

EQUATION : $X = 12.2516 * t^{0.691142}$

Obs.: The data points for cut-off advance were not used in the regression procedure.

TABLE LXXI

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT CCB-BAY THREE AND NON-WHEEL FURROWS

DATE: JUL/30/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.547748	0.547748	570.470	0.0001
Error	18	0.017283	0.000960		
Cor. Total	19	0.565031			

Root MSE	0.030987	R-SQUARE	0.9694
Dep MEAN	2.312931	ADJ R-SQ	0.9677
C.V.	1.339711		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	0.979242	0.056267	17.403	0.0001
Log(time)	1	0.731922	0.030644	23.885	0.0001

EQUATION : $X = 9.5333 * t^{0.731922}$

Obs.: The data points for cut-off advance were not used in the regression procedure.

TABLE LXXII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT CCB - BAY THREE AND WHEEL FURROWS DATE: JUL/30/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.432476	0.432476	233.361	0.0001
Error	18	0.033359	0.001853		
Cor. Total	19	0.465835			

Root MSE	0.043049	R-SQUARE	0.9284
Dep MEAN	2.382221	ADJ R-SQ	0.9244
C.V.	1.807112		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	1.197146	0.078172	15.314	0.0001
Log(time)	1	0.650363	0.042574	15.276	0.0001

EQUATION : $X = 15.7451 * t^{0.650363}$

Obs.: The data points for cut-off advance were not used in the regression procedure.

TABLE LXXIII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT CCB - BAY FOUR DATE: JUL/30/84

Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.075630	1.075630	261.622	0.0001
Error	48	0.197619	0.004117		
Cor. Total	49	1.273249			

Root MSE	0.064164	R-SQUARE	0.8448
Dep MEAN	2.241914	ADJ R-SQ	0.8416
C.V.	2.862034		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>|T|
Intercept	1	1.117215	0.070171	15.921	0.0001
Log(time)	1	0.594149	0.036758	16.164	0.0001

EQUATION : $X = 13.0983 * t^{0.594149}$

Obs.: The data points for cut-off advance were not used in the regression procedure.

TABLE LXXIV

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT CCB-BAY FOUR AND NON-WHEEL FURROWS
DATE: JUL/30/84 Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.511618	0.511618	362.169	0.0001
Error	23	0.032491	0.001413		
Cor. Total	24	0.544109			

Root MSE	0.037585	R-SQUARE	0.9403
Dep MEAN	2.195653	ADJ R-SQ	0.9377
C.V.	1.711802		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>¦T¦
Intercept	1	1.098689	0.058130	18.901	0.0001
Log(time)	1	0.579498	0.030451	19.031	0.0001

EQUATION : $X = 12.5513 * t^{0.579498}$

Obs.: The data points for cut-off advance were not used in the regression procedure.

TABLE LXXV

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR TREATMENT CCB - BAY FOUR AND WHEEL FURROWS

DATE: JUL/30/84   Q = 60 L/min (16 gpm)

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.564666	0.564666	225.977	0.0001
Error	23	0.057472	0.002499		
Cor. Total	24	0.622138			

Root MSE	0.049988	R-SQUARE	0.9076
Dep MEAN	2.288174	ADJ R-SQ	0.9036
C.V.	2.184612		

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob>!T!
Intercept	1	1.135742	0.077312	14.690	0.0001
Log(time)	1	0.608800	0.040499	15.033	0.0001

EQUATION : $X = 13.6692 * t^{0.60880}$

Obs.: The data points for cut-off advance were not used in the regression procedure.

APPENDIX B.3

SOIL MOISTURE PROFILE DATA FOR THE WATER ADVANCE EXPERIMENTS

TABLE LXXVI

SOIL MOISTURE PROFILE OF BAY ONE FOR TREATMENT T2
DATE: 07/17/84 - BEFORE IRRIGATION

Station (m)	Soil Moisture Content (cm^3/cm^3) Depth (cm) 15	30	45	60	75
00+15	0.239	0.317	0.328	0.310	0.320
00+84	0.177	0.309	0.328	0.314	0.318
01+53	0.250	0.325	0.330	0.335	0.331
02+22	0.274	0.326	0.321	0.322	0.322
02+91	0.227	0.345	0.326	0.330	0.325

TABLE LXXVII

SOIL MOISTURE PROFILE OF BAY TWO FOR TREATMENT T2
DATE: 07/17/84 - BEFORE IRRIGATION

Station (m)	Soil Moisture Content (cm^3/cm^3) Depth (cm) 15	30	45	60	75
00+15	0.197	0.307	0.309	0.301	0.303
00+84	0.197	0.292	0.326	0.329	0.317
01+53	0.182	0.266	0.303	0.299	0.285
02+22	0.266	0.328	0.323	0.323	0.326
02+91	0.228	0.330	0.326	0.335	0.321

TABLE LXXVIII

SOIL MOISTURE PROFILE OF BAY THREE FOR TREATMENT T1
DATE: 07/17/84 - BEFORE IRRIGATION

Station (m)	Soil Moisture Content (cm^3/cm^3) Depth (cm) 15	30	45	60	75
00+15	0.223	0.310	0.316	0.318	0.313
00+84	0.218	0.321	0.314	0.324	0.308
01+53	0.227	0.319	0.321	0.319	0.318
02+22	0.258	0.312	0.328	0.333	0.348
02+91	0.246	0.325	0.327	0.308	0.310

TABLE LXXIX

SOIL MOISTURE PROFILE OF BAY FOUR FOR TREATMENT T1
DATE: 07/17/84 - BEFORE IRRIGATION

Station (m)	Soil Moisture Content (cm^3/cm^3) Depth (cm) 15	30	45	60	75
00+15	0.220	0.291	0.322	0.310	0.322
00+84	0.215	0.316	0.345	0.339	0.339
01+53	0.235	0.332	0.328	0.323	0.322
02+22	0.229	0.336	0.335	0.328	0.337
02+91	0.271	0.321	0.321	0.334	0.329

TABLE LXXX

SOIL MOISTURE PROFILE OF BAY FIVE FOR TREATMENT TC
DATE: 07/17/84 - BEFORE IRRIGATION

Station (m)	Soil Moisture Content (cm^3/cm^3)				
	Depth (cm)				
	15	30	45	60	75
00+15	0.299	0.335	0.331	0.324	0.325
00+84	0.280	0.341	0.333	0.331	0.334
01+53	0.278	0.340	0.338	0.335	0.334
02+22	0.297	0.346	0.338	0.332	0.337
02+91	0.300	0.328	0.322	0.328	0.324

TABLE LXXXI

SOIL MOISTURE PROFILE OF BAY ONE FOR TREATMENT SCB
DATE: 07/30/84 - BEFORE IRRIGATION

Station (m)	Soil Moisture Content (cm^3/cm^3)				
	Depth (cm)				
	15	30	45	60	75
00+15	0.259	0.311	0.333	0.331	0.332
00+84	0.187	0.253	0.326	0.316	0.337
01+53	0.254	0.284	0.326	0.344	0.345
02+22	0.283	0.342	0.321	0.335	0.328
02+91	0.250	0.320	0.322	0.317	0.316

TABLE LXXXII

SOIL MOISTURE PROFILE OF BAY TWO FOR TREATMENT SCB
DATE: 07/30/84 - BEFORE IRRIGATION

Station (m)	Soil Moisture Content (cm^3/cm^3) Depth (cm) 15	30	45	60	75
00+15	0.225	0.304	0.340	0.324	0.339
00+84	0.236	0.286	0.317	0.321	0.307
01+53	0.180	0.230	0.283	0.313	0.315
02+22	0.199	0.245	0.279	0.326	0.326
02+91	0.180	0.242	0.297	0.297	0.300

TABLE LXXXIII

SOIL MOISTURE PROFILE OF BAY THREE FOR TREATMENT CCB
DATE: 07/30/84 - BEFORE IRRIGATION

Station (m)	Soil Moisture Content (cm^3/cm^3) Depth (cm) 15	30	45	60	75
00+15	0.259	0.318	0.337	0.346	0.338
00+84	0.222	0.284	0.329	0.329	0.335
01+53	0.273	0.323	0.341	0.346	0.338
02+22	0.248	0.297	0.316	0.307	0.304
02+91	0.258	0.333	0.329	0.320	0.321

TABLE LXXXIV

SOIL MOISTURE PROFILE OF BAY THREE FOR TREATMENT CCB
DATE: 07/30/84 - BEFORE IRRIGATION

Station (m)	Soil Moisture Content (cm^3/cm^3) Depth (cm) 15	30	45	60	75
00+15	0.241	0.308	0.317	0.329	0.341
00+84	0.215	0.297	0.329	0.333	0.335
01+53	0.221	0.269	0.309	0.320	0.328
02+22	0.152	0.277	0.305	0.325	0.334
02+91	0.208	0.227	0.301	0.313	0.317

APPENDIX B.4

AVERAGE SURFACE SLOPE FOR WATER ADVANCE EXPERIMENTAL SITE

TABLE LXXXV

AVERAGE PROFILE OF A FURROW IN EACH BAY OF THE ADVANCE EXPERIMENTAL SITE

Station (m)	Relative Elevation (m)				
	Bay				
	1	2	3	4	5
00+08	10.00	9.88	9.77	9.66	9.58
00+30	9.86	9.77	9.63	9.52	9.42
00+60	9.70	9.62	9.47	9.38	9.29
00+90	9.56	9.48	9.35	9.26	9.18
01+20	9.44	9.36	9.23	9.14	9.06
01+50	9.33	9.24	9.12	9.04	8.95
01+80	9.25	9.16	9.02	8.94	8.84
02+10	9.17	9.06	8.93	8.83	8.74
02+40	9.09	8.97	8.82	8.72	8.64
02+70	8.98	8.87	8.71	8.62	8.64
03+00	8.84	8.73	8.57	8.49	8.41
03+30	8.62	8.54	8.42	8.33	8.32
Avg. Slope	0.0042	0.0042	0.0042	0.0041	0.0039
Std. Dev.	0.0014	0.0011	0.0008	0.0007	0.0006
C.V. (%)	20.9	21.3	20.6	20.8	21.8

APPENDIX C

INFILTRATION EXPERIMENTAL DATA

APPENDIX C.1

EXPERIMENTAL INFILTRATION DATA
AND AVERAGE INTAKE TABLES

TABLE LXXXVI

INFILTRATION TEST FOR CONTINUOUS TREATMENT

SOIL: TELLER LOAM SITE: PERKINS
TEST N.: 2 DATE: 08/03/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	10.30	25.11	2.50	301.27
10.00	3.10	7.56	7.50	90.67
15.00	2.10	5.12	12.50	61.42
20.00	1.80	4.39	17.50	52.65
25.00	1.40	3.41	22.50	40.95
30.00	1.30	3.17	27.50	38.02
35.00	1.20	2.92	32.50	35.10
40.00	1.30	3.17	37.50	38.02
45.00	1.30	3.17	42.50	38.02
50.00	1.20	2.92	47.50	35.10
55.00	1.10	2.68	52.50	32.17
60.00	1.10	2.68	57.50	32.17
65.00	1.00	2.44	62.50	29.25
70.00	0.90	2.19	67.50	26.32
75.00	0.90	2.19	72.50	26.32
80.00	0.80	1.95	77.50	23.40
85.00	0.75	1.83	82.50	21.94
90.00	0.70	1.71	87.50	20.47
95.00	0.70	1.71	92.50	20.47
100.00	0.65	1.58	97.50	19.01
105.00	0.60	1.46	102.50	17.55
110.00	0.60	1.46	107.50	17.55
115.00	0.50	1.22	112.50	14.62
120.00	0.50	1.22	117.50	14.62
125.00	0.60	1.46	122.50	17.55
130.00	0.50	1.22	127.50	14.62
135.00	0.50	1.22	132.50	14.62
140.00	0.55	1.34	137.50	16.09
145.00	0.50	1.22	142.50	14.62
150.00	0.55	1.34	147.50	16.09
155.00	0.50	1.22	152.50	14.62
160.00	0.50	1.22	157.50	14.62

TABLE LXXXVII

INFILTRATION TEST FOR CONTINUOUS TREATMENT
SOIL: TELLER LOAM SITE: PERKINS
TEST N.: 9 DATE: 08/09/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	13.15	32.05	2.50	384.63
10.00	3.20	7.80	7.50	93.60
15.00	2.40	5.85	12.50	70.20
20.00	1.90	4.63	17.50	55.57
25.00	1.60	3.90	22.50	46.80
30.00	1.20	2.92	27.50	35.10
35.00	1.10	2.68	32.50	32.17
40.00	1.10	2.68	37.50	32.17
45.00	1.00	2.44	42.50	29.25
50.00	1.00	2.44	47.50	29.25
55.00	0.85	2.07	52.50	24.86
60.00	0.85	2.07	57.50	24.86
65.00	0.85	2.07	62.50	24.86
70.00	0.80	1.95	67.50	23.40
75.00	0.80	1.95	72.50	23.40
80.00	0.70	1.71	77.50	20.47
85.00	0.70	1.71	82.50	20.47
90.00	0.65	1.58	87.50	19.01
95.00	0.60	1.46	92.50	17.55
100.00	0.50	1.22	97.50	14.62
105.00	0.60	1.46	102.50	17.55
110.00	0.50	1.22	107.50	14.62
115.00	0.45	1.10	112.50	13.16
120.00	0.60	1.46	117.50	17.55
125.00	0.60	1.46	122.50	17.55
130.00	0.55	1.34	127.50	16.09
135.00	0.50	1.22	132.50	14.62
140.00	0.55	1.34	137.50	16.09
145.00	0.50	1.22	142.50	14.62
150.00	0.55	1.34	147.50	16.09
155.00	0.50	1.22	152.50	14.62
160.00	0.50	1.22	157.50	14.62

TABLE LXXXVIII

INFILTRATION TEST FOR SURGE TREATMENT 1 (10 ON/10 OFF)
SOIL: TELLER LOAM SITE: PERKINS
TEST N.: 6 DATE: 08/07/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
2.50	12.90	31.44	1.25	754.64
5.00	3.30	8.04	3.75	193.05
7.50	2.70	6.58	6.25	157.95
10.00	1.50	3.66	8.75	87.75
12.50	1.80	4.39	11.25	105.30
15.00	1.35	3.29	13.75	78.97
17.50	1.00	2.44	16.25	58.50
20.00	0.85	2.07	18.75	49.72
22.50	1.60	3.90	21.25	93.60
25.00	1.40	3.41	23.75	81.90
27.50	0.60	1.46	26.25	35.10
30.00	0.30	0.73	28.75	17.55
32.50	1.50	3.66	31.25	87.75
35.00	0.65	1.58	33.75	38.02
37.50	0.40	0.97	36.25	23.40
40.00	0.30	0.73	38.75	17.55
42.50	1.45	3.53	41.25	84.82
45.00	0.65	1.58	43.75	38.02
47.50	0.40	0.97	46.25	23.40
50.00	0.35	0.85	48.75	20.47
52.50	1.30	3.17	51.25	76.05
55.00	0.40	0.97	53.75	23.40
57.50	0.25	0.61	56.25	14.62
60.00	0.15	0.37	58.75	8.77
62.50	1.20	2.92	61.25	70.20
65.00	0.85	2.07	63.75	49.72
67.50	0.55	1.34	66.25	32.17
70.00	0.35	0.85	68.75	20.47
72.50	1.00	2.44	71.25	58.50
75.00	0.40	0.97	73.75	23.40
77.50	0.20	0.49	76.25	11.70
80.00	0.15	0.37	78.75	8.77
82.50	0.90	2.19	81.25	52.65
85.00	0.30	0.73	83.75	17.55
87.50	0.20	0.49	86.25	11.70
90.00	0.15	0.37	88.75	8.77
92.50	0.90	2.19	91.25	52.65
95.00	0.35	0.85	93.75	20.47
97.50	0.25	0.61	96.25	14.62
100.00	0.15	0.37	98.75	8.77

TABLE LXXXIX

INFILTRATION TEST FOR SURGE TREATMENT 1 (10 ON/10 OFF)

SOIL: TELLER LOAM SITE: PERKINS
TEST N.: 8 DATE: 08/10/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
2.50	6.80	16.57	1.25	397.80
5.00	2.90	7.07	3.75	169.65
7.50	2.10	5.12	6.25	122.85
10.00	1.40	3.41	8.75	81.90
12.50	2.95	7.19	11.25	172.57
15.00	1.60	3.90	13.75	93.60
17.50	0.85	2.07	16.25	49.72
20.00	0.55	1.34	18.75	32.17
22.50	1.70	4.14	21.25	99.45
25.00	1.20	2.92	23.75	70.20
27.50	0.95	2.32	26.25	55.57
30.00	0.70	1.71	28.75	40.95
32.50	1.20	2.92	31.25	70.20
35.00	0.50	1.22	33.75	29.25
37.50	0.40	0.97	36.25	23.40
40.00	0.30	0.73	38.75	17.55
42.50	1.15	2.80	41.25	67.27
45.00	0.75	1.83	43.75	43.87
47.50	0.50	1.22	46.25	29.25
50.00	0.45	1.10	48.75	26.32
52.50	1.05	2.56	51.25	61.42
55.00	0.60	1.46	53.75	35.10
57.50	0.45	1.10	56.25	26.32
60.00	0.30	0.73	58.75	17.55
62.50	1.00	2.44	61.25	58.50
65.00	0.55	1.34	63.75	32.17
67.50	0.40	0.97	66.25	23.40
70.00	0.30	0.73	68.75	17.55
72.50	0.80	1.95	71.25	46.80
75.00	0.30	0.73	73.75	17.55
77.50	0.25	0.61	76.25	14.62
80.00	0.15	0.37	78.75	8.77
82.50	0.80	1.95	81.25	46.80
85.00	0.60	1.46	83.75	35.10
87.50	0.40	0.97	86.25	23.40
90.00	0.20	0.49	88.75	11.70
92.50	0.60	1.46	91.25	35.10
95.00	0.40	0.97	93.75	23.40
97.50	0.30	0.73	96.25	17.55
100.00	0.15	0.37	98.75	8.77

TABLE XC

INFILTRATION TEST FOR SURGE TREATMENT 2 (20 ON/20 OFF)

SOIL: TELLER LOAM SITE: PERKINS
TEST N.: 4 DATE: 08/06/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	17.40	42.41	2.50	508.95
10.00	3.40	8.29	7.50	99.45
15.00	2.20	5.36	12.50	64.35
20.00	1.80	4.39	17.50	52.65
25.00	3.10	7.56	22.50	90.67
30.00	1.45	3.53	27.50	42.41
35.00	1.10	2.68	32.50	32.17
40.00	0.80	1.95	37.50	23.40
45.00	2.80	6.82	42.50	81.90
50.00	1.40	3.41	47.50	40.95
55.00	0.75	1.83	52.50	21.94
60.00	0.40	0.97	57.50	11.70
65.00	1.95	4.75	62.50	57.04
70.00	1.00	2.44	67.50	29.25
75.00	0.65	1.58	72.50	19.01
80.00	0.60	1.46	77.50	17.55
85.00	1.90	4.63	82.50	55.57
90.00	0.95	2.32	87.50	27.79
95.00	0.65	1.58	92.50	19.01
100.00	0.40	0.97	97.50	11.70
105.00	1.60	3.90	102.50	46.80
110.00	0.60	1.46	107.50	17.55
115.00	0.40	0.97	112.50	11.70
120.00	0.35	0.85	117.50	10.24

TABLE XCI

INFILTRATION TEST FOR SURGE TREATMENT 2 (20 ON/20 OFF)
SOIL: TELLER LOAM SITE: PERKINS
TEST N.: 5 DATE: 08/07/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	18.40	44.85	2.50	538.19
10.00	4.50	10.97	7.50	131.62
15.00	2.80	6.82	12.50	81.90
20.00	1.85	4.51	17.50	54.11
25.00	2.70	6.58	22.50	78.97
30.00	1.70	4.14	27.50	49.72
35.00	1.35	3.29	32.50	39.49
40.00	0.80	1.95	37.50	23.40
45.00	2.05	5.00	42.50	59.96
50.00	1.50	3.66	47.50	43.87
55.00	1.10	2.68	52.50	32.17
60.00	0.70	1.71	57.50	20.47
65.00	2.10	5.12	62.50	61.42
70.00	1.20	2.92	67.50	35.10
75.00	0.75	1.83	72.50	21.94
80.00	0.60	1.46	77.50	17.55
85.00	1.70	4.14	82.50	49.72
90.00	0.65	1.58	87.50	19.01
95.00	0.45	1.10	92.50	13.16
100.00	0.35	0.85	97.50	10.24
105.00	1.50	3.66	102.50	43.87
110.00	0.70	1.71	107.50	20.47
115.00	0.50	1.22	112.50	14.62
120.00	0.30	0.73	117.50	8.77

TABLE XCII

INFILTRATION TEST FOR SURGE TREATMENT 3 (30 ON/30 OFF)
SOIL: TELLER LOAM SITE: PERKINS
TEST N.: 2 DATE: 08/03/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	18.90	46.07	2.50	552.82
10.00	4.10	9.99	7.50	119.92
15.00	2.00	4.87	12.50	58.50
20.00	1.90	4.63	17.50	55.57
25.00	1.75	4.27	22.50	51.19
30.00	1.40	3.41	27.50	40.95
35.00	4.20	10.24	32.50	122.85
40.00	1.60	3.90	37.50	46.80
45.00	1.35	3.29	42.50	39.49
50.00	1.20	2.92	47.50	35.10
55.00	1.05	2.56	52.50	30.71
60.00	0.70	1.71	57.50	20.47
65.00	2.20	5.36	62.50	64.35
70.00	0.90	2.19	67.50	26.32
75.00	0.80	1.95	72.50	23.40
80.00	0.65	1.58	77.50	19.01
85.00	0.70	1.71	82.50	20.47
90.00	0.65	1.58	87.50	19.01
95.00	2.40	5.85	92.50	70.20
100.00	0.90	2.19	97.50	26.32
105.00	0.70	1.71	102.50	20.47
110.00	0.55	1.34	107.50	16.09
115.00	0.35	0.85	112.50	10.24
120.00	0.20	0.49	117.50	5.85

TABLE XCIII

INFILTRATION TEST FOR SURGE TREATMENT 3 (30 ON/30 OFF)
SOIL: TELLER LOAM SITE: PERKINS
TEST N.: 3 DATE: 08/04/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	20.90	50.94	2.50	611.32
10.00	4.50	10.97	7.50	131.62
15.00	2.40	5.85	12.50	70.20
20.00	2.10	5.12	17.50	61.42
25.00	1.50	3.66	22.50	43.87
30.00	1.05	2.56	27.50	30.71
35.00	5.30	12.92	32.50	155.02
40.00	1.75	4.27	37.50	51.19
45.00	1.50	3.66	42.50	43.87
50.00	1.40	3.41	47.50	40.95
55.00	1.20	2.92	52.50	35.10
60.00	0.90	2.19	57.50	26.32
65.00	2.80	6.82	62.50	81.90
70.00	1.20	2.92	67.50	35.10
75.00	0.80	1.95	72.50	23.40
80.00	0.75	1.83	77.50	21.94
85.00	0.70	1.71	82.50	20.47
90.00	0.60	1.46	87.50	17.55
95.00	2.30	5.61	92.50	67.27
100.00	1.45	3.53	97.50	42.41
105.00	0.90	2.19	102.50	26.32
110.00	0.80	1.95	107.50	23.40
115.00	0.55	1.34	112.50	16.09
120.00	0.35	0.85	117.50	10.24

TABLE XCIV

INFILTRATION TEST FOR CONTINUOUS TREATMENT
SOIL: FINE SANDY LOAM SITE: PERKINS
TEST N.: 1 DATE: 09/19/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	6.25	26.17	2.50	314.08
10.00	3.20	13.40	7.50	160.81
15.00	2.40	10.05	12.50	120.61
20.00	2.20	9.21	17.50	110.56
25.00	2.05	8.58	22.50	103.02
30.00	1.90	7.96	27.50	95.48
35.00	1.85	7.75	32.50	92.97
40.00	1.80	7.54	37.50	90.46
45.00	1.70	7.12	42.50	85.43
50.00	1.65	6.91	47.50	82.92
55.00	1.65	6.91	52.50	82.92
60.00	1.60	6.70	57.50	80.40
65.00	1.55	6.49	62.50	77.89
70.00	1.50	6.28	67.50	75.38
75.00	1.50	6.28	72.50	75.38
80.00	1.40	5.86	77.50	70.35
85.00	1.35	5.65	82.50	67.84
90.00	1.30	5.44	87.50	65.33
95.00	1.10	4.61	92.50	55.28
100.00	1.05	4.40	97.50	52.77
105.00	1.00	4.19	102.50	50.25
110.00	1.00	4.19	107.50	50.25
115.00	0.95	3.98	112.50	47.74
120.00	0.90	3.77	117.50	45.23
125.00	0.85	3.56	122.50	42.71
130.00	0.80	3.35	127.50	40.20
135.00	0.70	2.93	132.50	35.18
140.00	0.70	2.93	137.50	35.18
145.00	0.65	2.72	142.50	32.66
150.00	0.60	2.51	147.50	30.15
155.00	0.55	2.30	152.50	27.64
160.00	0.55	2.30	157.50	27.64
165.00	0.50	2.09	162.50	25.13
170.00	0.55	2.30	167.50	27.64
175.00	0.50	2.09	172.50	25.13
180.00	0.50	2.09	177.50	25.13

TABLE XCV

INFILTRATION TEST FOR CONTINUOUS TREATMENT
SOIL: FINE SANDY LOAM SITE: PERKINS
TEST N.: 8 DATE: 10/07/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	5.00	20.94	2.50	251.26
10.00	2.85	11.94	7.50	143.22
15.00	1.90	7.96	12.50	95.48
20.00	1.70	7.12	17.50	85.43
25.00	1.20	5.03	22.50	60.30
30.00	1.15	4.82	27.50	57.79
35.00	1.10	4.61	32.50	55.28
40.00	1.05	4.40	37.50	52.77
45.00	0.90	3.77	42.50	45.23
50.00	0.85	3.56	47.50	42.71
55.00	0.80	3.35	52.50	40.20
60.00	0.75	3.14	57.50	37.69
65.00	0.75	3.14	62.50	37.69
70.00	0.70	2.93	67.50	35.18
75.00	0.60	2.51	72.50	30.15
80.00	0.60	2.51	77.50	30.15
85.00	0.55	2.30	82.50	27.64
90.00	0.55	2.30	87.50	27.64
95.00	0.55	2.30	92.50	27.64
100.00	0.50	2.09	97.50	25.13
105.00	0.45	1.88	102.50	22.61
110.00	0.50	2.09	107.50	25.13
115.00	0.50	2.09	112.50	25.13
120.00	0.55	2.30	117.50	27.64
125.00	0.50	2.09	122.50	25.13
130.00	0.55	2.30	127.50	27.64
135.00	0.50	2.09	132.50	25.13
140.00	0.50	2.09	137.50	25.13
145.00	0.50	2.09	142.50	25.13
150.00	0.50	2.09	147.50	25.13
155.00	0.50	2.09	152.50	25.13
160.00	0.50	2.09	157.50	25.13
165.00	0.50	2.09	162.50	25.13
170.00	0.50	2.09	167.50	25.13
175.00	0.50	2.09	172.50	25.13
180.00	0.50	2.09	177.50	25.13

TABLE XCVI

INFILTRATION TEST FOR SURGE TREATMENT 1 (10 ON/10 OFF)
SOIL: FINE SANDY LOAM   SITE: PERKINS
TEST N.: 5   DATE: 10/03/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
2.50	4.55	19.05	1.25	457.30
5.00	2.10	8.79	3.75	211.06
7.50	1.20	5.03	6.25	120.61
10.00	1.00	4.19	8.75	100.51
12.50	1.50	6.28	11.25	150.76
15.00	1.10	4.61	13.75	110.56
17.50	0.70	2.93	16.25	70.35
20.00	0.35	1.47	18.75	35.18
22.50	1.40	5.86	21.25	140.71
25.00	1.00	4.19	23.75	100.51
27.50	0.70	2.93	26.25	70.35
30.00	0.35	1.47	28.75	35.18
32.50	1.30	5.44	31.25	130.66
35.00	0.50	2.09	33.75	50.25
37.50	0.45	1.88	36.25	45.23
40.00	0.40	1.68	38.75	40.20
42.50	1.20	5.03	41.25	120.61
45.00	0.70	2.93	43.75	70.35
47.50	0.60	2.51	46.25	60.30
50.00	0.40	1.68	48.75	40.20
52.50	0.95	3.98	51.25	95.48
55.00	0.80	3.35	53.75	80.40
57.50	0.40	1.68	56.25	40.20
60.00	0.30	1.26	58.75	30.15
62.50	0.90	3.77	61.25	90.46
65.00	0.70	2.93	63.75	70.35
67.50	0.50	2.09	66.25	50.25
70.00	0.30	1.26	68.75	30.15
72.50	0.80	3.35	71.25	80.40
75.00	0.60	2.51	73.75	60.30
77.50	0.30	1.26	76.25	30.15
80.00	0.25	1.05	78.75	25.13
82.50	0.85	3.56	81.25	85.43
85.00	0.50	2.09	83.75	50.25
87.50	0.30	1.26	86.25	30.15
90.00	0.25	1.05	88.75	25.13
92.50	0.80	3.35	91.25	80.40
95.00	0.50	2.09	93.75	50.25
97.50	0.15	0.63	96.25	15.08
100.00	0.10	0.42	98.75	10.05

TABLE XCVII

INFILTRATION TEST FOR SURGE TREATMENT 1 (10 ON/10 OFF)
SOIL: FINE SANDY LOAM SITE: PERKINS
TEST N.: 7 DATE: 10/07/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
2.50	3.90	16.33	1.25	391.97
5.00	0.80	3.35	3.75	80.40
7.50	0.55	2.30	6.25	55.28
10.00	0.40	1.68	8.75	40.20
12.50	1.35	5.65	11.25	135.68
15.00	0.70	2.93	13.75	70.35
17.50	0.45	1.88	16.25	45.23
20.00	0.30	1.26	18.75	30.15
22.50	1.25	5.23	21.25	125.63
25.00	0.65	2.72	23.75	65.33
27.50	0.55	2.30	26.25	55.28
30.00	0.45	1.88	28.75	45.23
32.50	0.95	3.98	31.25	95.48
35.00	0.65	2.72	33.75	65.33
37.50	0.40	1.68	36.25	40.20
40.00	0.15	0.63	38.75	15.08
42.50	0.80	3.35	41.25	80.40
45.00	0.60	2.51	43.75	60.30
47.50	0.30	1.26	46.25	30.15
50.00	0.15	0.63	48.75	15.08
52.50	0.90	3.77	51.25	90.46
55.00	0.35	1.47	53.75	35.18
57.50	0.15	0.63	56.25	15.08
60.00	0.10	0.42	58.75	10.05
62.50	0.70	2.93	61.25	70.35
65.00	0.50	2.09	63.75	50.25
67.50	0.25	1.05	66.25	25.13
70.00	0.20	0.84	68.75	20.10
72.50	0.65	2.72	71.25	65.33
75.00	0.35	1.47	73.75	35.18
77.50	0.15	0.63	76.25	15.08
80.00	0.05	0.21	78.75	5.03
82.50	0.60	2.51	81.25	60.30
85.00	0.30	1.26	83.75	30.15
87.50	0.20	0.84	86.25	20.10
90.00	0.15	0.63	88.75	15.08
92.50	0.40	1.68	91.25	40.20
95.00	0.20	0.84	93.75	20.10
97.50	0.15	0.63	96.25	15.08
100.00	0.05	0.21	98.75	5.03

TABLE XCVIII

INFILTRATION TEST FOR SURGE TREATMENT 2 (20 ON/20 OFF)
SOIL: FINE SANDY LOAM SITE: PERKINS
TEST N.: 3 DATE: 09/23/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	5.05	21.15	2.50	253.78
10.00	1.70	7.12	7.50	85.43
15.00	1.05	4.40	12.50	52.77
20.00	0.80	3.35	17.50	40.20
25.00	1.80	7.54	22.50	90.46
30.00	1.05	4.40	27.50	52.77
35.00	0.75	3.14	32.50	37.69
40.00	0.60	2.51	37.50	30.15
45.00	1.75	7.33	42.50	87.94
50.00	1.20	5.03	47.50	60.30
55.00	0.65	2.72	52.50	32.66
60.00	0.50	2.09	57.50	25.13
65.00	1.70	7.12	62.50	85.43
70.00	1.00	4.19	67.50	50.25
75.00	0.75	3.14	72.50	37.69
80.00	0.30	1.26	77.50	15.08
85.00	1.40	5.86	82.50	70.35
90.00	0.90	3.77	87.50	45.23
95.00	0.55	2.30	92.50	27.64
100.00	0.35	1.47	97.50	17.59
105.00	1.10	4.61	102.50	55.28
110.00	0.50	2.09	107.50	25.13
115.00	0.30	1.26	112.50	15.08
120.00	0.20	0.84	117.50	10.05

TABLE XCIX

INFILTRATION TEST FOR SURGE TREATMENT 2 (20 ON/20 OFF)
SOIL: FINE SANDY LOAM SITE: PERKINS
TEST N.: 6 DATE: 10/05/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	6.15	25.75	2.50	309.05
10.00	1.80	7.54	7.50	90.46
15.00	1.70	7.12	12.50	85.43
20.00	1.20	5.03	17.50	60.30
25.00	2.00	8.38	22.50	100.51
30.00	1.25	5.23	27.50	62.82
35.00	0.65	2.72	32.50	32.66
40.00	0.50	2.09	37.50	25.13
45.00	1.80	7.54	42.50	90.46
50.00	1.00	4.19	47.50	50.25
55.00	0.55	2.30	52.50	27.64
60.00	0.30	1.26	57.50	15.08
65.00	1.90	7.96	62.50	95.48
70.00	0.80	3.35	67.50	40.20
75.00	0.30	1.26	72.50	15.08
80.00	0.25	1.05	77.50	12.56
85.00	1.85	7.75	82.50	92.97
90.00	0.60	2.51	87.50	30.15
95.00	0.35	1.47	92.50	17.59
100.00	0.25	1.05	97.50	12.56
105.00	1.10	4.61	102.50	55.28
110.00	0.60	2.51	107.50	30.15
115.00	0.30	1.26	112.50	15.08
120.00	0.20	0.84	117.50	10.05

TABLE C

INFILTRATION TEST FOR SURGE TREATMENT 3 (30 ON/30 OFF)
SOIL: FINE SANDY LOAM SITE: PERKINS
TEST N.: 4 DATE: 10/02/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	4.55	19.05	2.50	228.65
10.00	2.20	9.21	7.50	110.56
15.00	1.40	5.86	12.50	70.35
20.00	1.10	4.61	17.50	55.28
25.00	1.05	4.40	22.50	52.77
30.00	0.90	3.77	27.50	45.23
35.00	1.30	5.44	32.50	65.33
40.00	0.75	3.14	37.50	37.69
45.00	0.50	2.09	42.50	25.13
50.00	0.45	1.88	47.50	22.61
55.00	0.35	1.47	52.50	17.59
60.00	0.25	1.05	57.50	12.56
65.00	1.10	4.61	62.50	55.28
70.00	0.60	2.51	67.50	30.15
75.00	0.50	2.09	72.50	25.13
80.00	0.45	1.88	77.50	22.61
85.00	0.40	1.68	82.50	20.10
90.00	0.35	1.47	87.50	17.59
95.00	1.00	4.19	92.50	50.25
100.00	0.75	3.14	97.50	37.69
105.00	0.60	2.51	102.50	30.15
110.00	0.45	1.88	107.50	22.61
115.00	0.30	1.26	112.50	15.08
120.00	0.20	0.84	117.50	10.05

TABLE CI

INFILTRATION TEST FOR SURGE TREATMENT 3 (30 ON/30 OFF)
SOIL: FINE SANDY LOAM SITE: PERKINS
TEST N.: 2 DATE: 09/21/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	5.10	21.36	2.50	256.29
10.00	2.70	11.31	7.50	135.68
15.00	2.10	8.79	12.50	105.53
20.00	1.80	7.54	17.50	90.46
25.00	1.55	6.49	22.50	77.89
30.00	1.40	5.86	27.50	70.35
35.00	2.55	10.68	32.50	128.14
40.00	1.20	5.03	37.50	60.30
45.00	0.80	3.35	42.50	40.20
50.00	0.60	2.51	47.50	30.15
55.00	0.55	2.30	52.50	27.64
60.00	0.35	1.47	57.50	17.59
65.00	1.60	6.70	62.50	80.40
70.00	0.90	3.77	67.50	45.23
75.00	0.80	3.35	72.50	40.20
80.00	0.50	2.09	77.50	25.13
85.00	0.40	1.68	82.50	20.10
90.00	0.30	1.26	87.50	15.08
95.00	0.90	3.77	92.50	45.23
100.00	0.70	2.93	97.50	35.18
105.00	0.65	2.72	102.50	32.66
110.00	0.50	2.09	107.50	25.13
115.00	0.30	1.26	112.50	15.08
120.00	0.20	0.84	117.50	10.05

TABLE CII

INFILTRATION TEST FOR CONTINUOUS TREATMENT
SOIL: CLAY LOAM SITE: ALTUS
TEST N.: 1 DATE: 08/16/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	8.60	23.06	2.50	276.70
10.00	2.20	5.90	7.50	70.78
15.00	1.80	4.83	12.50	57.91
20.00	1.60	4.29	17.50	51.48
25.00	1.55	4.16	22.50	49.87
30.00	1.55	4.16	27.50	49.87
35.00	1.50	4.02	32.50	48.26
40.00	1.30	3.49	37.50	41.83
45.00	1.10	2.95	42.50	35.39
50.00	1.05	2.82	47.50	33.78
55.00	1.00	2.68	52.50	32.17
60.00	1.00	2.68	57.50	32.17
65.00	1.00	2.68	62.50	32.17
70.00	0.80	2.14	67.50	25.74
75.00	0.80	2.14	72.50	25.74
80.00	0.80	2.14	77.50	25.74
85.00	0.75	2.01	82.50	24.13
90.00	0.80	2.14	87.50	25.74
95.00	0.70	1.88	92.50	22.52
100.00	0.75	2.01	97.50	24.13
105.00	0.70	1.88	102.50	22.52
110.00	0.70	1.88	107.50	22.52
115.00	0.65	1.74	112.50	20.91
120.00	0.65	1.74	117.50	20.91
125.00	0.70	1.88	122.50	22.52
130.00	0.70	1.88	127.50	22.52
135.00	0.70	1.88	132.50	22.52
140.00	0.70	1.88	137.50	22.52
145.00	0.70	1.88	142.50	22.52
150.00	0.70	1.88	147.50	22.52
155.00	0.65	1.74	152.50	20.91
160.00	0.65	1.74	157.50	20.91

TABLE CIII

INFILTRATION TEST FOR CONTINUOUS TREATMENT

SOIL: CLAY LOAM SITE: ALTUS
TEST N.: 5 DATE: 08/25/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	15.70	42.10	2.50	505.14
10.00	4.10	10.99	7.50	131.92
15.00	2.60	6.97	12.50	83.65
20.00	1.80	4.83	17.50	57.91
25.00	1.70	4.56	22.50	54.70
30.00	1.65	4.42	27.50	53.09
35.00	1.60	4.29	32.50	51.48
40.00	1.30	3.49	37.50	41.83
45.00	1.20	3.22	42.50	38.61
50.00	1.15	3.08	47.50	37.00
55.00	0.95	2.55	52.50	30.57
60.00	0.90	2.41	57.50	28.96
65.00	0.85	2.28	62.50	27.35
70.00	0.80	2.14	67.50	25.74
75.00	0.75	2.01	72.50	24.13
80.00	0.75	2.01	77.50	24.13
85.00	0.80	2.14	82.50	25.74
90.00	0.75	2.01	87.50	24.13
95.00	0.75	2.01	92.50	24.13
100.00	0.75	2.01	97.50	24.13
105.00	0.70	1.88	102.50	22.52
110.00	0.70	1.88	107.50	22.52
115.00	0.70	1.88	112.50	22.52
120.00	0.70	1.88	117.50	22.52
125.00	0.75	2.01	122.50	24.13
130.00	0.75	2.01	127.50	24.13
135.00	0.70	1.88	132.50	22.52
140.00	0.70	1.88	137.50	22.52
145.00	0.70	1.88	142.50	22.52
150.00	0.70	1.88	147.50	22.52
155.00	0.70	1.88	152.50	22.52
160.00	0.70	1.88	157.50	22.52

TABLE CIV

INFILTRATION TEST FOR SURGE TREATMENT 1 (10 ON/10 OFF)
SOIL: CLAY LOAM SITE: ALTUS
TEST N.: 4 DATE: 08/25/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
2.50	17.20	46.12	1.25	1106.81
5.00	7.40	19.84	3.75	476.19
7.50	2.95	7.91	6.25	189.83
10.00	2.50	6.70	8.75	160.87
12.50	2.80	7.51	11.25	180.18
15.00	1.20	3.22	13.75	77.22
17.50	1.00	2.68	16.25	64.35
20.00	0.85	2.28	18.75	54.70
22.50	2.40	6.43	21.25	154.44
25.00	1.15	3.08	23.75	74.00
27.50	1.00	2.68	26.25	64.35
30.00	0.80	2.14	28.75	51.48
32.50	1.40	3.75	31.25	90.09
35.00	1.15	3.08	33.75	74.00
37.50	0.95	2.55	36.25	61.13
40.00	0.80	2.14	38.75	51.48
42.50	1.20	3.22	41.25	77.22
45.00	0.85	2.28	43.75	54.70
47.50	0.60	1.61	46.25	38.61
50.00	0.50	1.34	48.75	32.17
52.50	1.10	2.95	51.25	70.78
55.00	0.80	2.14	53.75	51.48
57.50	0.60	1.61	56.25	38.61
60.00	0.40	1.07	58.75	25.74
62.50	1.00	2.68	61.25	64.35
65.00	0.45	1.21	63.75	28.96
67.50	0.35	0.94	66.25	22.52
70.00	0.30	0.80	68.75	19.30
72.50	1.00	2.68	71.25	64.35
75.00	0.50	1.34	73.75	32.17
77.50	0.40	1.07	76.25	25.74
80.00	0.35	0.94	78.75	22.52
82.50	0.90	2.41	81.25	57.91
85.00	0.45	1.21	83.75	28.96
87.50	0.35	0.94	86.25	22.52
90.00	0.30	0.80	88.75	19.30
92.50	0.90	2.41	91.25	57.91
95.00	0.45	1.21	93.75	28.96
97.50	0.30	0.80	96.25	19.30
100.00	0.20	0.54	98.75	12.87

TABLE CV

INFILTRATION TEST FOR SURGE TREATMENT 1 (10 ON/10 OFF)
SOIL: CLAY LOAM SITE: ALTUS
TEST N.: 8 DATE: 09/02/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
2.50	15.50	41.56	1.25	997.42
5.00	9.80	26.28	3.75	630.62
7.50	4.50	12.07	6.25	289.57
10.00	2.55	6.84	8.75	164.09
12.50	4.40	11.80	11.25	283.14
15.00	1.70	4.56	13.75	109.39
17.50	1.40	3.75	16.25	90.09
20.00	1.10	2.95	18.75	70.78
22.50	1.80	4.83	21.25	115.83
25.00	1.10	2.95	23.75	70.78
27.50	0.85	2.28	26.25	54.70
30.00	0.70	1.88	28.75	45.04
32.50	1.70	4.56	31.25	109.39
35.00	1.00	2.68	33.75	64.35
37.50	0.70	1.88	36.25	45.04
40.00	0.45	1.21	38.75	28.96
42.50	1.60	4.29	41.25	102.96
45.00	0.80	2.14	43.75	51.48
47.50	0.50	1.34	46.25	32.17
50.00	0.35	0.94	48.75	22.52
52.50	1.30	3.49	51.25	83.65
55.00	0.70	1.88	53.75	45.04
57.50	0.45	1.21	56.25	28.96
60.00	0.30	0.80	58.75	19.30
62.50	0.95	2.55	61.25	61.13
65.00	0.40	1.07	63.75	25.74
67.50	0.30	0.80	66.25	19.30
70.00	0.20	0.54	68.75	12.87
72.50	0.90	2.41	71.25	57.91
75.00	0.50	1.34	73.75	32.17
77.50	0.45	1.21	76.25	28.96
80.00	0.30	0.80	78.75	19.30
82.50	0.80	2.14	81.25	51.48
85.00	0.60	1.61	83.75	38.61
87.50	0.50	1.34	86.25	32.17
90.00	0.35	0.94	88.75	22.52
92.50	0.80	2.14	91.25	51.48
95.00	0.50	1.34	93.75	32.17
97.50	0.30	0.80	96.25	19.30
100.00	0.20	0.54	98.75	12.87

TABLE CVI

INFILTRATION TEST FOR SURGE TREATMENT 2 (20 ON/20 OFF)
SOIL: CLAY LOAM SITE: ALTUS
TEST N.: 3 DATE: 08/24/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	21.80	58.45	2.50	701.41
10.00	3.90	10.46	7.50	125.48
15.00	2.90	7.78	12.50	93.31
20.00	2.30	6.17	17.50	74.00
25.00	4.85	13.00	22.50	156.05
30.00	1.80	4.83	27.50	57.91
35.00	1.30	3.49	32.50	41.83
40.00	1.05	2.82	37.50	33.78
45.00	3.35	8.98	42.50	107.79
50.00	1.20	3.22	47.50	38.61
55.00	1.00	2.68	52.50	32.17
60.00	0.75	2.01	57.50	24.13
65.00	2.85	7.64	62.50	91.70
70.00	1.00	2.68	67.50	32.17
75.00	0.90	2.41	72.50	28.96
80.00	0.60	1.61	77.50	19.30
85.00	2.10	5.63	82.50	67.57
90.00	1.40	3.75	87.50	45.04
95.00	0.90	2.41	92.50	28.96
100.00	0.40	1.07	97.50	12.87
105.00	2.00	5.36	102.50	64.35
110.00	0.95	2.55	107.50	30.57
115.00	0.60	1.61	112.50	19.30
120.00	0.50	1.34	117.50	16.09
125.00	1.60	4.29	122.50	51.48
130.00	1.10	2.95	127.50	35.39
135.00	0.85	2.28	132.50	27.35
140.00	0.50	1.34	137.50	16.09

TABLE CVII

INFILTRATION TEST FOR SURGE TREATMENT 2 (20 ON/20 OFF)

SOIL: CLAY LOAM SITE: ALTUS
TEST N.: 7 DATE: 09/01/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	26.00	69.71	2.50	836.54
10.00	4.60	12.33	7.50	148.00
15.00	2.55	6.84	12.50	82.05
20.00	2.10	5.63	17.50	67.57
25.00	3.00	8.04	22.50	96.52
30.00	1.75	4.69	27.50	56.31
35.00	1.20	3.22	32.50	38.61
40.00	0.70	1.88	37.50	22.52
45.00	2.60	6.97	42.50	83.65
50.00	1.15	3.08	47.50	37.00
55.00	0.65	1.74	52.50	20.91
60.00	0.50	1.34	57.50	16.09
65.00	2.15	5.76	62.50	69.18
70.00	1.00	2.68	67.50	32.17
75.00	0.55	1.47	72.50	17.70
80.00	0.45	1.21	77.50	14.48
85.00	2.10	5.63	82.50	67.57
90.00	1.00	2.68	87.50	32.17
95.00	0.60	1.61	92.50	19.30
100.00	0.40	1.07	97.50	12.87
105.00	2.10	5.63	102.50	67.57
110.00	0.60	1.61	107.50	19.30
115.00	0.35	0.94	112.50	11.26
120.00	0.30	0.80	117.50	9.65
125.00	1.90	5.09	122.50	61.13
130.00	0.90	2.41	127.50	28.96
135.00	0.55	1.47	132.50	17.70
140.00	0.40	1.07	137.50	12.87

TABLE CVIII

INFILTRATION TEST FOR SURGE TREATMENT 3 (30 ON/30 OFF)
SOIL: CLAY LOAM SITE: ALTUS
TEST N.: 2 DATE: 08/17/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	25.80	69.18	2.50	830.11
10.00	4.30	11.53	7.50	138.35
15.00	3.30	8.85	12.50	106.18
20.00	1.40	3.75	17.50	45.04
25.00	1.05	2.82	22.50	33.78
30.00	0.85	2.28	27.50	27.35
35.00	1.80	4.83	32.50	57.91
40.00	0.95	2.55	37.50	30.57
45.00	0.70	1.88	42.50	22.52
50.00	0.65	1.74	47.50	20.91
55.00	0.50	1.34	52.50	16.09
60.00	0.50	1.34	57.50	16.09
65.00	1.50	4.02	62.50	48.26
70.00	1.05	2.82	67.50	33.78
75.00	0.75	2.01	72.50	24.13
80.00	0.60	1.61	77.50	19.30
85.00	0.50	1.34	82.50	16.09
90.00	0.45	1.21	87.50	14.48
95.00	1.40	3.75	92.50	45.04
100.00	1.20	3.22	97.50	38.61
105.00	0.90	2.41	102.50	28.96
110.00	0.85	2.28	107.50	27.35
115.00	0.70	1.88	112.50	22.52
120.00	0.50	1.34	117.50	16.09
125.00	1.20	3.22	122.50	38.61
130.00	1.00	2.68	127.50	32.17
135.00	0.90	2.41	132.50	28.96
140.00	0.70	1.88	137.50	22.52
145.00	0.60	1.61	142.50	19.30
150.00	0.50	1.34	147.50	16.09

TABLE CIX

INFILTRATION TEST FOR SURGE TREATMENT 3 (30 ON/30 OFF)

SOIL: CLAY LOAM SITE: ALTUS
TEST N.: 6 DATE: 09/01/84

Elapsed Time (Min)	Recorder Readings (Inches)	Depth Infiltrated (mm)	Interval Mid Point (min)	Intake Rate (mm/hr)
5.00	54.30	145.59	2.50	1747.09
10.00	10.40	27.88	7.50	334.62
15.00	6.70	17.96	12.50	215.57
20.00	5.20	13.94	17.50	167.31
25.00	3.40	9.12	22.50	109.39
30.00	2.50	6.70	27.50	80.44
35.00	6.00	16.09	32.50	193.05
40.00	1.70	4.56	37.50	54.70
45.00	1.15	3.08	42.50	37.00
50.00	1.05	2.82	47.50	33.78
55.00	0.90	2.41	52.50	28.96
60.00	0.70	1.88	57.50	22.52
65.00	3.70	9.92	62.50	119.05
70.00	1.40	3.75	67.50	45.04
75.00	1.20	3.22	72.50	38.61
80.00	0.95	2.55	77.50	30.57
85.00	0.85	2.28	82.50	27.35
90.00	0.75	2.01	87.50	24.13
95.00	2.90	7.78	92.50	93.31
100.00	1.90	5.09	97.50	61.13
105.00	1.70	4.56	102.50	54.70
110.00	1.25	3.35	107.50	40.22
115.00	0.90	2.41	112.50	28.96
120.00	0.60	1.61	117.50	19.30
125.00	2.30	6.17	122.50	74.00
130.00	1.00	2.68	127.50	32.17
135.00	0.80	2.14	132.50	25.74
140.00	0.70	1.88	137.50	22.52
145.00	0.50	1.34	142.50	16.09
150.00	0.35	0.94	147.50	11.26

TABLE CX

AVERAGE CURVE FOR CONTINUOUS TREATMENT
SOIL: TELLER LOAM SITE: PERKINS

Interval Mid Point (Min)	Intake Rate Repl. 1 (mm/hr)	Intake Rate Repl. 2 (mm/hr)	Average Intake (mm/hr)
2.50	301.27	384.63	342.95
7.50	90.67	93.60	92.14
12.50	61.42	70.20	65.81
17.50	52.65	55.57	54.11
22.50	40.95	46.80	43.87
27.50	38.02	35.10	36.56
32.50	35.10	32.17	33.64
37.50	38.02	32.17	35.10
42.50	38.02	29.25	33.64
47.50	35.10	29.25	32.17
52.50	32.17	24.86	28.52
57.50	32.17	24.86	28.52
62.50	29.25	24.86	27.06
67.50	26.32	23.40	24.86
72.50	26.32	23.40	24.86
77.50	23.40	20.47	21.94
82.50	21.94	20.47	21.21
87.50	20.47	19.01	19.74
92.50	20.47	17.55	19.01
97.50	19.01	14.62	16.82
102.50	17.55	17.55	17.55
107.50	17.55	14.62	16.09
112.50	14.62	13.16	13.89
117.50	14.62	17.55	16.09
122.50	17.55	17.55	17.55
127.50	14.62	16.09	15.36
132.50	14.62	14.62	14.62
137.50	16.09	16.09	16.09
142.50	14.62	14.62	14.62
147.50	16.09	16.09	16.09
152.50	14.62	14.62	14.62
157.50	14.62	14.62	14.62

TABLE CXI

AVERAGE CURVE FOR SURGE TREATMENT 1 (10 ON/10 OFF)
SOIL: TELLER LOAM SITE: PERKINS

Interval Mid Point (Min)	Intake Rate Repl.1 (mm/hr)	Intake Rate Repl. 2 (mm/hr)	Average Intake (mm/hr)
1.25	754.64	397.80	576.22
3.75	193.05	169.65	181.35
6.25	157.95	122.85	140.40
8.75	87.75	81.90	84.82
11.25	105.30	172.57	138.94
13.75	78.97	93.60	86.29
16.25	58.50	49.72	54.11
18.75	49.72	32.17	40.95
21.25	93.60	99.45	96.52
23.75	81.90	70.20	76.05
26.25	35.10	55.57	45.34
28.75	17.55	40.95	29.25
31.25	87.75	70.20	78.97
33.75	38.02	29.25	33.64
36.25	23.40	23.40	23.40
38.75	17.55	17.55	17.55
41.25	84.82	67.27	76.05
43.75	38.02	43.87	40.95
46.25	23.40	29.25	26.32
48.75	20.47	26.32	23.40
51.25	76.05	61.42	68.74
53.75	23.40	35.10	29.25
56.25	14.62	26.32	20.47
58.75	8.77	17.55	13.16
61.25	70.20	58.50	64.35
63.75	49.72	32.17	40.95
66.25	32.17	23.40	27.79
68.75	20.47	17.55	19.01
71.25	58.50	46.80	52.65
73.75	23.40	17.55	20.47
76.25	11.70	14.62	13.16
78.75	8.77	8.77	8.77
81.25	52.65	46.80	49.72
83.75	17.55	35.10	26.32
86.25	11.70	23.40	17.55
88.75	8.77	11.70	10.24
91.25	52.65	35.10	43.87
93.75	20.47	23.40	21.94
96.25	14.62	17.55	16.09
98.75	8.77	8.77	8.77

TABLE CXII

AVERAGE CURVE FOR SURGE TREATMENT 2 (20 ON/20 OFF)
SOIL: TELLER LOAM SITE: PERKINS

Interval Mid Point (Min)	Intake Rate Repl.1 (mm/hr)	Intake Rate Repl. 2 (mm/hr)	Average Intake (mm/hr)
2.50	508.95	538.19	523.57
7.50	99.45	131.62	115.54
12.50	64.35	81.90	73.12
17.50	52.65	54.11	53.38
22.50	90.67	78.97	84.82
27.50	42.41	49.72	46.07
32.50	32.17	39.49	35.83
37.50	23.40	23.40	23.40
42.50	81.90	59.96	70.93
47.50	40.95	43.87	42.41
52.50	21.94	32.17	27.06
57.50	11.70	20.47	16.09
62.50	57.04	61.42	59.23
67.50	29.25	35.10	32.17
72.50	19.01	21.94	20.47
77.50	17.55	17.55	17.55
82.50	55.57	49.72	52.65
87.50	27.79	19.01	23.40
92.50	19.01	13.16	16.09
97.50	11.70	10.24	10.97
102.50	46.80	43.87	45.34
107.50	17.55	20.47	19.01
112.50	11.70	14.62	13.16
117.50	10.24	8.77	9.51

TABLE CXIII

AVERAGE CURVE FOR SURGE TREATMENT 3 (30 ON/30 OFF)
SOIL: TELLER LOAM SITE: PERKINS

Interval Mid Point (Min)	Intake Rate Repl. 1 (mm/hr)	Intake Rate Repl. 2 (mm/hr)	Average Intake (mm/hr)
2.50	552.82	611.32	582.07
7.50	119.92	131.62	125.77
12.50	58.50	70.20	64.35
17.50	55.57	61.42	58.50
22.50	51.19	43.87	47.53
27.50	40.95	30.71	35.83
32.50	122.85	155.02	138.94
37.50	46.80	51.19	48.99
42.50	39.49	43.87	41.68
47.50	35.10	40.95	38.02
52.50	30.71	35.10	32.91
57.50	20.47	26.32	23.40
62.50	64.35	81.90	73.12
67.50	26.32	35.10	30.71
72.50	23.40	23.40	23.40
77.50	19.01	21.94	20.47
82.50	20.47	20.47	20.47
87.50	19.01	17.55	18.28
92.50	70.20	67.27	68.74
97.50	26.32	42.41	34.37
102.50	20.47	26.32	23.40
107.50	16.09	23.40	19.74
112.50	10.24	16.09	13.16
117.50	5.85	10.24	8.04

TABLE CXIV

AVERAGE CURVE FOR CONTINUOUS TREATMENT
SOIL: FINE SANDY LOAM SITE: PERKINS

Interval Mid Point (Min)	Intake Rate Repl.1 (mm/hr)	Intake Rate Repl. 2 (mm/hr)	Average Intake (mm/hr)
2.50	251.26	314.08	282.67
7.50	143.22	160.81	152.01
12.50	95.48	120.61	108.04
17.50	85.43	110.56	97.99
22.50	60.30	103.02	81.66
27.50	57.79	95.48	76.64
32.50	55.28	92.97	74.12
37.50	52.77	90.46	71.61
42.50	45.23	85.43	65.33
47.50	42.71	82.92	62.82
52.50	40.20	82.92	61.56
57.50	37.69	80.40	59.05
62.50	37.69	77.89	57.79
67.50	35.18	75.38	55.28
72.50	30.15	75.38	52.77
77.50	30.15	70.35	50.25
82.50	27.64	67.84	47.74
87.50	27.64	65.33	46.48
92.50	27.64	55.28	41.46
97.50	25.13	52.77	38.95
102.50	22.61	50.25	36.43
107.50	25.13	50.25	37.69
112.50	25.13	47.74	36.43
117.50	27.64	45.23	36.43
122.50	25.13	42.71	33.92
127.50	27.64	40.20	33.92
132.50	25.13	35.18	30.15
137.50	25.13	35.18	30.15
142.50	25.13	32.66	28.90
147.50	25.13	30.15	27.64
152.50	25.13	27.64	26.38
157.50	25.13	27.64	26.38
162.50	25.13	25.13	25.13
167.50	25.13	27.64	26.38
172.50	25.13	25.13	25.13
177.50	25.13	25.13	25.13

TABLE CXV

AVERAGE CURVE FOR SURGE TREATMENT 1 (10 ON/10 OFF)
SOIL: FINE SANDY LOAM SITE: PERKINS

Interval Mid Point (Min)	Intake Rate Repl. 1 (mm/hr)	Intake Rate Repl. 2 (mm/hr)	Average Intake (mm/hr)
1.25	457.30	391.97	424.64
3.75	211.06	80.40	145.73
6.25	120.61	55.28	87.94
8.75	100.51	40.20	70.35
11.25	150.76	135.68	143.22
13.75	110.56	70.35	90.46
16.25	70.35	45.23	57.79
18.75	35.18	30.15	32.66
21.25	140.71	125.63	133.17
23.75	100.51	65.33	82.92
26.25	70.35	55.28	62.82
28.75	35.18	45.23	40.20
31.25	130.66	95.48	113.07
33.75	50.25	65.33	57.79
36.25	45.23	40.20	42.71
38.75	40.20	15.08	27.64
41.25	120.61	80.40	100.51
43.75	70.35	60.30	65.33
46.25	60.30	30.15	45.23
48.75	40.20	15.08	27.64
51.25	95.48	90.46	92.97
53.75	80.40	35.18	57.79
56.25	40.20	15.08	27.64
58.75	30.15	10.05	20.10
61.25	90.46	70.35	80.40
63.75	70.35	50.25	60.30
66.25	50.25	25.13	37.69
68.75	30.15	20.10	25.13
71.25	80.40	65.33	72.87
73.75	60.30	35.18	47.74
76.25	30.15	15.08	22.61
78.75	25.13	5.03	15.08
81.25	85.43	60.30	72.87
83.75	50.25	30.15	40.20
86.25	30.15	20.10	25.13
88.75	25.13	15.08	20.10
91.25	80.40	40.20	60.30
93.75	50.25	20.10	35.18
96.25	15.08	15.08	15.08
98.75	10.05	5.03	7.54

TABLE CXVI

AVERAGE CURVE FOR SURGE TREATMENT 2 (20 ON/20 OFF) SOIL: FINE SANDY LOAM SITE: PERKINS

Interval Mid Point (Min)	Intake Rate Repl.1 (mm/hr)	Intake Rate Repl. 2 (mm/hr)	Average Intake (mm/hr)
2.50	253.78	309.05	281.42
7.50	85.43	90.46	87.94
12.50	52.77	85.43	69.10
17.50	40.20	60.30	50.25
22.50	90.46	100.51	95.48
27.50	52.77	62.82	57.79
32.50	37.69	32.66	35.18
37.50	30.15	25.13	27.64
42.50	87.94	90.46	89.20
47.50	60.30	50.25	55.28
52.50	32.66	27.64	30.15
57.50	25.13	15.08	20.10
62.50	85.43	95.48	90.46
67.50	50.25	40.20	45.23
72.50	37.69	15.08	26.38
77.50	15.08	12.56	13.82
82.50	70.35	92.97	81.66
87.50	45.23	30.15	37.69
92.50	27.64	17.59	22.61
97.50	17.59	12.56	15.08
102.50	55.28	55.28	55.28
107.50	25.13	30.15	27.64
112.50	15.08	15.08	15.08
117.50	10.05	10.05	10.05

TABLE CXVII

AVERAGE CURVE FOR SURGE TREATMENT 3 (30 ON/30 OFF)
SOIL: FINE SANDY LOAM   SITE: PERKINS

Interval Mid Point (Min)	Intake Rate Repl. 1 (mm/hr)	Intake Rate Repl. 2 (mm/hr)	Average Intake (mm/hr)
2.50	228.65	256.29	242.47
7.50	110.56	135.68	123.12
12.50	70.35	105.53	87.94
17.50	55.28	90.46	72.87
22.50	52.77	77.89	65.33
27.50	45.23	70.35	57.79
32.50	65.33	128.14	96.74
37.50	37.69	60.30	49.00
42.50	25.13	40.20	32.66
47.50	22.61	30.15	26.38
52.50	17.59	27.64	22.61
57.50	12.56	17.59	15.08
62.50	55.28	80.40	67.84
67.50	30.15	45.23	37.69
72.50	25.13	40.20	32.66
77.50	22.61	25.13	23.87
82.50	20.10	20.10	20.10
87.50	17.59	15.08	16.33
92.50	50.25	45.23	47.74
97.50	37.69	35.18	36.43
102.50	30.15	32.66	31.41
107.50	22.61	25.13	23.87
112.50	15.08	15.08	15.08
117.50	10.05	10.05	10.05

TABLE CXVIII

AVERAGE CURVE FOR CONTINUOUS TREATMENT
SOIL: CLAY LOAM SITE: ALTUS

Interval Mid Point (Min)	Intake Rate Repl.1 (mm/hr)	Intake Rate Repl. 2 (mm/hr)	Average Intake (mm/hr)
2.50	276.70	505.14	390.92
7.50	70.78	131.92	101.35
12.50	57.91	83.65	70.78
17.50	51.48	57.91	54.70
22.50	49.87	54.70	52.28
27.50	49.87	53.09	51.48
32.50	48.26	51.48	49.87
37.50	41.83	41.83	41.83
42.50	35.39	38.61	37.00
47.50	33.78	37.00	35.39
52.50	32.17	30.57	31.37
57.50	32.17	28.96	30.57
62.50	32.17	27.35	29.76
67.50	25.74	25.74	25.74
72.50	25.74	24.13	24.94
77.50	25.74	24.13	24.94
82.50	24.13	25.74	24.94
87.50	25.74	24.13	24.94
92.50	22.52	24.13	23.33
97.50	24.13	24.13	24.13
102.50	22.52	22.52	22.52
107.50	22.52	22.52	22.52
112.50	20.91	22.52	21.72
117.50	20.91	22.52	21.72
122.50	22.52	24.13	23.33
127.50	22.52	24.13	23.33
132.50	22.52	22.52	22.52
137.50	22.52	22.52	22.52
142.50	22.52	22.52	22.52
147.50	22.52	22.52	22.52
152.50	20.91	22.52	21.72
157.50	20.91	22.52	21.72

TABLE CXIX

AVERAGE CURVE FOR SURGE TREATMENT 1 (10 ON/10 OFF)
SOIL: CLAY LOAM SITE: ALTUS

Interval Mid Point (Min)	Intake Rate Repl.1 (mm/hr)	Intake Rate Repl. 2 (mm/hr)	Average Intake (mm/hr)
1.25	1106.81	997.42	1052.11
3.75	476.19	630.62	553.40
6.25	189.83	289.57	239.70
8.75	160.87	164.09	162.48
11.25	180.18	283.14	231.66
13.75	77.22	109.39	93.31
16.25	64.35	90.09	77.22
18.75	54.70	70.78	62.74
21.25	154.44	115.83	135.13
23.75	74.00	70.78	72.39
26.25	64.35	54.70	59.52
28.75	51.48	45.04	48.26
31.25	90.09	109.39	99.74
33.75	74.00	64.35	69.18
36.25	61.13	45.04	53.09
38.75	51.48	28.96	40.22
41.25	77.22	102.96	90.09
43.75	54.70	51.48	53.09
46.25	38.61	32.17	35.39
48.75	32.17	22.52	27.35
51.25	70.78	83.65	77.22
53.75	51.48	45.04	48.26
56.25	38.61	28.96	33.78
58.75	25.74	19.30	22.52
61.25	64.35	61.13	62.74
63.75	28.96	25.74	27.35
66.25	22.52	19.30	20.91
68.75	19.30	12.87	16.09
71.25	64.35	57.91	61.13
73.75	32.17	32.17	32.17
76.25	25.74	28.96	27.35
78.75	22.52	19.30	20.91
81.25	57.91	51.48	54.70
83.75	28.96	38.61	33.78
86.25	22.52	32.17	27.35
88.75	19.30	22.52	20.91
91.25	57.91	51.48	54.70
93.75	28.96	32.17	30.57
96.25	19.30	19.30	19.30
98.75	12.87	12.87	12.87

TABLE CXX

AVERAGE CURVE FOR SURGE TREATMENT 2 (20 ON/20 OFF)
SOIL: CLAY LOAM SITE: ALTUS

Interval Mid Point (Min)	Intake Rate Repl.1 (mm/hr)	Intake Rate Repl. 2 (mm/hr)	Average Intake (mm/hr)
2.50	701.41	836.54	768.98
7.50	125.48	148.00	136.74
12.50	93.31	82.05	87.68
17.50	74.00	67.57	70.78
22.50	156.05	96.52	126.29
27.50	57.91	56.31	57.11
32.50	41.83	38.61	40.22
37.50	33.78	22.52	28.15
42.50	107.79	83.65	95.72
47.50	38.61	37.00	37.81
52.50	32.17	20.91	26.54
57.50	24.13	16.09	20.11
62.50	91.70	69.18	80.44
67.50	32.17	32.17	32.17
72.50	28.96	17.70	23.33
77.50	19.30	14.48	16.89
82.50	67.57	67.57	67.57
87.50	45.04	32.17	38.61
92.50	28.96	19.30	24.13
97.50	12.87	12.87	12.87
102.50	64.35	67.57	65.96
107.50	30.57	19.30	24.94
112.50	19.30	11.26	15.28
117.50	16.09	9.65	12.87
122.50	51.48	61.13	56.31
127.50	35.39	28.96	32.17
132.50	27.35	17.70	22.52
137.50	16.09	12.87	14.48

TABLE CXXI

AVERAGE CURVE FOR SURGE TREATMENT 3 (30 ON/30 OFF)
SOIL: CLAY LOAM SITE: ALTUS

Interval Mid Point (Min)	Intake Rate Repl. 1 (mm/hr)	Intake Rate Repl. 2 (mm/hr)	Average Intake (mm/hr)
2.50	830.11	1747.09	1288.60
7.50	138.35	334.62	236.48
12.50	106.18	215.57	160.87
17.50	45.04	167.31	106.18
22.50	33.78	109.39	71.59
27.50	27.35	80.44	53.89
32.50	57.91	193.05	125.48
37.50	30.57	54.70	42.63
42.50	22.52	37.00	29.76
47.50	20.91	33.78	27.35
52.50	16.09	28.96	22.52
57.50	16.09	22.52	19.30
62.50	48.26	119.05	83.65
67.50	33.78	45.04	39.41
72.50	24.13	38.61	31.37
77.50	19.30	30.57	24.94
82.50	16.09	27.35	21.72
87.50	14.48	24.13	19.30
92.50	45.04	93.31	69.18
97.50	38.61	61.13	49.87
102.50	28.96	54.70	41.83
107.50	27.35	40.22	33.78
112.50	22.52	28.96	25.74
117.50	16.09	19.30	17.70
122.50	38.61	74.00	56.31
127.50	32.17	32.17	32.17
132.50	28.96	25.74	27.35
137.50	22.52	22.52	22.52
142.50	19.30	16.09	17.70
147.50	16.09	11.26	13.67

APPENDIX C.2

ANALYSIS OF VARIANCE OF THE REGRESSION LINES FOR CONTINUOUS TREATMENT

TABLE CXXII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR CONTINUOUS TREATMENT SITE: PERKINS #1 SOIL: TELLER LOAM

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	13.56188	13.56188	941.6901	0.0001
Error	30	0.432049	0.001402		
Cor. Total	59	13.99393			

R-SQUARE	0.969126
ADJ R-SQ	0.968097

EQUATION : $I = 429.5065 * t^{-0.686573}$

TABLE CXXIII

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR CONTINUOUS TREATMENT SITE: PERKINS #2 SOIL: FINE SANDY LOAM

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	10.44404	10.44404	1169.21	0.0001
Error	34	0.303707	0.008933		
Cor. Total	35	10.74775			

R-SQUARE	0.971742
ADJ R-SQ	0.970911

EQUATION : $I = 514.8716 * t^{-0.565237}$

TABLE CXXIV

ANALYSIS OF VARIANCE TABLE OF THE REGRESSION LINE FOR CONTINUOUS TREATMENT SITE: ALTUS #3 SOIL: CLAY LOAM

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	10.57639	10.57639	445.7391	0.0001
Error	30	0.711833	0.023728		
Cor. Total	31	11.28822			

R-SQUARE 0.9369402
ADJ R-SQ 0.9348382

EQUATION : $X = 389.1461 * t^{-0.6063113}$

APPENDIX C.3

ANALYSIS OF VARIANCE TABLE AND DUNCAN'S TEST FOR BASIC INTAKE RATE COMPARISON

TABLE CXXV

ANALYSIS OF VARIANCE TABLE FOR THE COMPARISON OF BASIC INTAKE RATE SITE: PERKINS #1

Class Level Information

Class	Levels	Values
Trt	4	TC T1 T2 T3

Number of Observations per Site: 8

AOV

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	3	53.40690	17.80230	6.64	0.0494
Error	4	10.71650	2.679125		
Cor. Total	7	64.12340			

Mean	10.2350	Root MSE	1.636803
R-SQUARE	0.832877	C.V.	15.99220

Source	DF	Anova SS	F Value	Pr > F
Trt	3	53.40960	6.64	0.0494

Duncan's Multiple Range Test for Variable: Basic Intake Mean

Alpha = 0.05 DF = 4 MSE= 2.67913

Means with the Same Letter are not Significant Different.

Grouping	Mean	N	Trt
A	14.620	2	TC
B	9.505	2	T2
B	8.770	2	T1
B	8.045	2	T3

TABLE CXXVI

ANALYSIS OF VARIANCE TABLE FOR THE COMPARISON OF BASIC INTAKE RATE SITE: PERKINS #2

Class Level Information

Class	Levels	Values
Trt	4	TC T1 T2 T3

Number of Observations per Site: 8

AOV

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	3	388.41055	129.47018	41.10	0.0018
Error	4	12.60020	3.150050		
Cor. Total	7	401.0108			

Mean	13.1925	Root MSE	1.774838
R-SQUARE	0.96858	C.V.	13.45340

Source	DF	Anova SS	F Value	Pr > F
Trt	3	388.41055	41.10	0.0018

Duncan's Multiple Range Test for Variable: Basic Intake Mean

Alpha = 0.05 DF = 4 MSE= 3.15005

Means with the Same Letter are not Significant Different.

Grouping	Mean	N	Trt
A	25.130	2	TC
B	10.050	2	T2
B	10.050	2	T3
B	7.540	2	T1

TABLE CXXVII

ANALYSIS OF VARIANCE TABLE FOR THE COMPARISON OF BASIC INTAKE RATE SITE: ALTUS #3

Class Level Information

Class	Levels	Values
Trt	4	TC T1 T2 T3

Number of Observations per Site: 8

AOV

Sources of Variation	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	3	99.55450	33.184333	7.32	0.0422
Error	4	18.14470	4.536175		
Cor. Total	7	117.6992			

Mean	15.6850	Root MSE	2.129829
R-SQUARE	0.84584	C.V.	13.45340

Source	DF	Anova SS	F Value	Pr > F
Trt	3	99.55450	7.32	0.0422

Duncan's Multiple Range Test for Variable: Basic Intake Mean

Alpha = 0.05 DF = 4 MSE= 4.53618

Means with the Same Letter are not Significant Different.

Grouping	Mean	N	Trt
A	21.715	2	TC
B	14.480	2	T2
B	13.675	2	T3
B	12.870	2	T1

APPENDIX C.4

SOIL MOISTURE PROFILE DATA FOR INFILTRATION TESTS

TABLE CXXVIII

SOIL MOISTURE PROFILE FOR THE INFILTRATION TESTS
SITE: PERKINS #1 SOIL: TELLER LOAM

Treat	Rep	Time	Soil Moisture Content (cm^3/cm^3)				
			Depth (cm)				
			15	30	45	60	75
T1	1	Pre	0.091	0.095	0.130	0.152	0.189
		Post	0.173	0.103	0.130	0.159	0.196
	2	Pre	0.153	0.142	0.166	0.175	0.208
		Post	0.228	0.145	0.167	0.177	0.219
T2	1	Pre	0.096	0.088	0.104	0.135	0.185
		Post	0.157	0.099	0.107	0.136	0.188
	2	Pre	0.107	0.102	0.118	0.144	0.158
		Post	0.167	0.109	0.126	0.146	0.159
T3	1	Pre	0.126	0.101	0.113	0.152	0.198
		Post	0.157	0.101	0.113	0.163	0.195
	2	Pre	0.094	0.154	0.181	0.184	0.167
		Post	0.180	0.164	0.182	0.170	0.161
TC	1	Pre	0.131	0.166	0.174	0.159	0.162
		Post	0.170	0.167	0.171	0.161	0.164
	2	Pre	0.138	0.121	0.127	0.175	0.210
		Post	0.200	0.133	0.133	0.170	0.218

TABLE CXXIX
SOIL MOISTURE PROFILE FOR THE INFILTRATION TESTS
SITE: PERKINS #2 SOIL: FINE SANDY LOAM

Treat	Rep	Time	Soil Moisture Content (cm^3/cm^3)				
			Depth (cm)				
			15	30	45	60	75
T1	1	Pre	0.099	0.057	0.056	0.054	0.064
		Post	0.110	0.067	0.057	0.061	0.064
	2	Pre	0.106	0.066	0.079	0.092	0.091
		Post	0.112	0.072	0.084	0.088	0.086
T2	1	Pre	0.096	0.057	0.056	0.074	0.094
		Post	0.108	0.065	0.059	0.075	0.098
	2	Pre	0.093	0.061	0.059	0.052	0.054
		Post	0.102	0.065	0.059	0.051	0.057
T3	1	Pre	0.091	0.058	0.050	0.071	0.123
		Post	0.100	0.059	0.048	0.067	0.115
	2	Pre	0.102	0.058	0.054	0.067	0.060
		Post	0.123	0.062	0.052	0.069	0.061
TC	1	Pre	0.089	0.059	0.052	0.067	0.120
		Post	0.161	0.096	0.056	0.068	0.118
	2	Pre	0.110	0.068	0.070	0.077	0.064
		Post	0.124	0.068	0.076	0.074	0.071

TABLE CXXX
SOIL MOISTURE PROFILE FOR THE INFILTRATION TESTS
SITE: ALTUS #3 SOIL: CLAY LOAM

Treat	Rep	Time	Soil Moisture Content (cm^3/cm^3) Depth (cm) 15	30	45	60	75
T1	1	Pre	0.302	0.297	0.321	0.318	0.315
		Post	0.315	0.291	0.321	0.318	0.325
	2	Pre	0.261	0.281	0.298	0.299	0.308
		Post	0.290	0.303	0.305	0.312	0.321
T2	1	Pre	0.315	0.307	0.309	0.316	0.319
		Post	0.320	0.304	0.311	0.315	0.320
	2	Pre	0.288	0.263	0.270	0.296	0.312
		Post	0.294	0.252	0.260	0.293	0.300
T3	1	Pre	0.345	0.337	0.323	0.316	0.315
		Post	0.361	0.320	0.315	0.315	0.314
	2	Pre	0.243	0.235	0.257	0.306	0.320
		Post	0.284	0.265	0.268	0.298	0.319
TC	1	Pre	0.269	0.302	0.313	0.312	0.318
		Post	0.332	0.312	0.327	0.324	0.330
	2	Pre	0.272	0.283	0.299	0.329	0.323
		Post	0.292	0.257	0.292	0.310	0.309

VITA

ROBERTO TESTEZLAF

Candidate for the Degree of

Doctor in Philosophy

Thesis: INFILTRATION AND ADVANCE FOR AN OPEN-DITCH SURGE FLOW FURROW IRRIGATION SYSTEM.

Major Field: Agricultural Engineering

Bibliographical:

Personal Data: Born in Moji Guacu, Sao Paulo, Brazil, March 24, 1956, the son of Jose Testezlaf and Ricardina O. Testezlaf. Married to Vania C. Borim Testezlaf on July 22, 1978.

Education: Graduated high school from the EEPSG "Luis Martini," Moji Guacu, Sao Paulo, Brazil in Dec., 1973; received Bachelor of Science degree in Agricultural Engineering from the Universidade Estadual de Campinas, Campinas, Brazil, in Dec., 1979; received Master of Engineering degree from the Universidade Estadual de Campinas, Campinas, Brazil, in June, 1982; completed the requirements for Doctor of Philosophy degree at Oklahoma State University in July, 1985.

Professional Experience: High school teacher in Physics, Fundacao Educacional Guacuana, Aug., 1978 to July, 1980; high school teacher in Basic Concepts of Agricultural Science, EEPSG Luis Martini, March, 1979 to Feb., 1980; Instructor and Assistant Professor, Department of Agricultural Engineering, Universidade Estadual de Campinas, Jan., 1980 to present.