# EVALUATION OF IRRIGATION SYSTEMS IN THE SNAKE RIVER FAN, JEFFERSON COUNTY, IDAHO

A Thesis

Presented in Partial Fulfillment of the Requirement for the

DEGREE OF MASTER OF SCIENCE

Major in Agricultural Engineering

in the

UNIVERSITY OF IDAHO GRADUATE SCHOOL

by

GUILLERMO D. GALINATO

May 1974

AUTHORIZATION TO PROCEED WITH THE FINAL DRAFT:

This thesis of Guillermo Dionisio Galinato for the Master of Science degree with major in Agricultural Engineering and titled "Evaluation of Irrigation Systems in the Snake River Fan, Jefferson County, Idaho" was reviewed in rough draft form by each committee member as indicated by the signatures and dates given below and permission was granted to prepare the final copy incorporating suggestions of the Committee; permission was also given to schedule the final examination upon submission of two final copies to the Graduate School Office:

Major Professor D. W. Fitzsimmons Date 5/8/74

Committee Members [signature] Date 5/8/74

John R. Busch Date 5/8/74

FINAL EXAMINATION: By majority vote of the candidate's Committee at the final examination held on date of 5/23/74 Committee approval and acceptance was granted.

Major Professor D. W. Fitzsimmons Date 5/23/74

GRADUATE COUNCIL FINAL APPROVAL AND ACCEPTANCE:

Graduate School Dean ________________ Date ________

## ACKNOWLEDGMENT

The author wishes to acknowledge his appreciation to Professor John R. Busch of the Agricultural Engineering Department for his constant guidance, technical assistance and constructive criticisms during the course of this investigation.

Thanks are due to Dr. Delbert W. Fitzsimmons, Head of the Agricultural Engineering Department, who served as his major professor and for administering the project and assistantship which made the author's education possible.

Gratitude is expressed to Professor Charles E. Brockway of the Civil Engineering Department for his suggestions and review of this thesis.

Thanks are also due to the following: Agricultural County Agent, Jefferson County, Idaho; Soil Conservation Service, Rigby, Idaho, and; to the farmers in Jefferson County who unselfishly allowed the author to conduct studies on their farms.

Finally, special thanks go the author's wife, LETTIE JACINTO GALINATO, for her moral support and encouragement throughout this study.

# TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

# LIST OF FIGURES

LIST OF FIGURES (Continued)

# LIST OF TABLES

# SELECTED SYMBOLS

| Symbols | Description |
|---|---|
| $A_s$ | apparent specific gravity of the soil |
| a,b | empirical coefficients of the advance function |
| D | intake depth at any time |
| d | average depth of water stored during irrigation |
| $d_f$ | amount of water stored |
| $d_s$ | depth of soil |
| $E_a$ | water application efficiency |
| $E_s$ | water storage efficiency |
| $E_d$ | water distribution efficiency |
| $E_u$ | consumptive-use efficiency |
| $E_i$ | overall irrigation efficiency for the farm |
| I | intake rate of soil |
| K | intake rate at unit time |
| k | ratio of average velocity of advance to the average velocity of flow |
| L | length of irrigation run |
| n | Manning's coefficient of roughness |
| $P_{w1}$ | soil moisture before irrigation |
| $P_{w2}$ | soil moisture after irrigation |
| Q | volume rate of flow |
| r | correlation coefficient |
| $R_e$ | volume of effective precipitation |

# SELECTED SYMBOLS

| Symbols | Description |
|---|---|
| $S$ | slope of the field |
| $T$ | time that the water is on the surface of the soil |
| $t$ | time for the advancing streamfront to reach a given point |
| $W_l$ | volume of water necessary for leaching |
| $W_{et}$ | volume of water lost to evapotranspiration |
| $W_f$ | volume of water delivered to the field |
| $W_i$ | volume of water that is diverted, stored or pumped specifically for irrigation |
| $W_s$ | depth of water stored in the root zone |
| $W_n$ | water needed in root zone prior to irrigation |
| $y$ | average numerical deviation in depth of water stored from the average depth stored during irrigation |
| $x$ | advance distance |

# ABSTRACT

A study was conducted to evaluate the present irrigation systems in the Snake River Fan, Jefferson County, Idaho. The study was made during the 1973 irrigation season.

Representative fields were selected for measuring water application efficiencies; and, within these fields, specific furrows and border strips were chosen for description and analysis in order to evaluate the performance of the existing irrigation systems.

Results of water application efficiency tests show an average efficiency of 24 percent for border irrigation, and 51 percent for furrow irrigation. Since there was no surface runoff, 76 percent of the water applied was lost to deep percolation from the border-irrigated fields and 49 percent was lost from furrow-irrigated fields.

The average labor input for the area was 0.31 hour per acre per irrigation for border irrigation and 0.45 hour per acre per irrigation for furrow irrigation. The labor input did not appear to have a significant effect on water application efficiencies in the study area.

The dominant factors that caused low water application efficiencies were long durations of irrigation for high intake rate soils and long irrigation runs.

# CHAPTER I

# INTRODUCTION

Surface irrigation has been practiced in this country for many years. More than 45 million acres are irrigated in the United States and irrigation accounts for 83 percent of the water consumptively used (28). In southern Idaho alone more than 3 million acres of land are irrigated.

When water is plentiful and low in cost, it is taken for granted and very few people are concerned about its use (32). As a consequence, there is a tendency for the farmer to run water carelessly over his land and hence, to over-irrigate. Efficient use of water is as important in areas of plentiful supply as it is in areas where water resources are limited.

Excessive irrigation wastes not only water but also leaches water soluble nutrients through the root zone beyond plant reach. Also, excess application of irrigation water often results in drainage problems and high water tables.

For instance, in the Upper Snake River area of south-eastern Idaho, water is diverted in an amount far above the consumptive use requirements of crops growing in the area. A recent study showed a water table rise of more than 40 feet during the 1972 irrigation season and damage to rural and urban land from the high water table was reported in excess of $25,000 per year (5).

Irrigation entails considerable waste of water if the system is not properly designed, operated and managed. The United States Bureau of Reclamation reported farm irrigation efficiencies as low as 31 to 52 percent with an average of 42 percent in conventional surface irrigation systems where irrigators followed normal irrigation practices (36). On the other hand, water application efficiencies as high as 80 to 95 percent on border irrigation (34) and 72 percent on furrow irrigation have been attained on properly designed and managed systems (25).

Many presently used irrigation systems use excessive water with low water application efficiencies resulting. This fact suggests that improved design, operation and management of the systems are needed.

## Purpose of the Study

The objective of this study was to evaluate the present irrigation systems in the Snake River Fan, Jefferson County, Idaho.

The specific objectives were:

1. To observe and describe the present irrigation systems and practices in the area.

2. To determine the water application efficiencies under the present irrigation practices.

3. To compare the efficiencies of water application for the different methods of irrigation.

4. To observe the amount of labor required in using border and furrow irrigation and determine its effect on water application efficiency.

5. To study some hydraulic characteristics of surface irrigation in the area.

6. To study the operational performance of selected systems to determine adjustments in operations, practices and design features which will insure higher irrigation efficiency in the study area.

# CHAPTER II

## IRRIGATION CONCEPT

Irrigation is the application of water to the soil to supplement deficient rainfall to provide moisture for plant growth. There are several methods by which irrigation water can be applied to a field. The most common are: border, furrow and sprinkler irrigation. Each has characteristics that are more desirable for certain locations.

Irrigation systems when properly designed, operated and managed, will not only save water and labor but will also prevent the damage of land, reduce production costs, and hence, increase income. The irrigation water, however, must be applied at the right time and in the right amount to produce high crop yields without undue losses to evaporation, deep percolation and surface runoff.

In order to understand the concept of irrigation, two terms must be defined, namely: field capacity and permanent wilting point. Field capacity is the moisture content of the soil when gravitational water has been removed. Permanent wilting point is the soil moisture content when plants permanently wilt. A plant will wilt when it is no longer able to extract sufficient moisture from the soil and is considered permanently wilted when it will not recover after being placed in a saturated atmosphere. The difference in moisture content of the soil between field capacity and the permanent wilting point is considered the total available moisture. This represents the moisture which can be stored in the soil for subsequent use by plants. For most crops, the optimum moisture zone appears to be between the field capacity and some level above the wilting point (7).

Research on wheat, for instance, showed that higher yields resulted when low to medium water levels were maintained during the early growing period than when higher moisture levels were maintained (1). In this study, irrigation water was applied when 20 to 40 percent of the available moisture was depleted. On row crops, like potatoes, research has indicated that soil moisture must be replenished when the available moisture is 50 percent depleted (11). This means that when the soil holds about 1.5 inches of available water per foot of depth and 3 feet is assumed as the rooting depth, the amount of water stored in that zone is 4.5 inches. When 2.3 inches of soil moisture is depleted irrigation water should be applied.

In all methods of irrigation where water is applied to the surface of the soil water infiltrates into the soil surface and is stored for later use by plants. The rate at which water enters the soil is an important parameter in irrigation system design and use. This is called the intake rate of soil. The intake rate when plotted against time on logarithmic paper is a straight line. The infiltration-time curve is then represented by the equation:

$$I = KT^n \qquad (1)$$

where I = intake rate of the soil, inches per hour

T = time that water is on surface of the soil, minutes

K = intake rate at unit time

n = slope of the curve when plotted on logarithmic paper

The intake depth at any time is represented by the area under the intake rate curve and can be computed by integration. This area, by integration is

$$D = \frac{K\ T^{n+1}}{60(n+1)} \qquad (2)$$

The factor 60 is introduced in the equation so that the infiltration rate can be expressed in inches per hour. The values K and n can be determined by plotting the curve on logarithmic paper.

For furrow irrigation, Criddle and others (9) introduced the concept that the stream front should reach the end of the furrow within approximately one-fourth of the total time needed to bring the root zone to field capacity at the lower end of the field. If one-fourth of the total time is required for the water to advance across the field, the opportunity time for the soil to absorb water will be about 25 percent greater at the upper end than at the lower end of the field. However, since the infiltration rate of the soil is not constant and decreases at a rate which is generally inversely proportional to the square root of the elapsed time, the amount of water absorbed during this extra time will be less than 25 percent of the total. Typical furrow intake characteristic curves are shown in Figure 1 where the average intake rate is, $I = 3.21T^{-0.5}$. If the square root relationship is true, 12 percent more water will be absorbed at the upper end of the field than at the lower end. The average deep percolation loss for the full length would be in the magnitude of 5 percent.

The advance, recession, infiltration and runoff relationships in surface irrigation are graphically presented in Figures 2 and 3.

A typical advance-recession curve is shown in Figure 2. The advance distance is plotted as the abcissa and the time as the ordinate. Similarly, the recession time is plotted versus the distance. When these are plotted on the same graph, the vertical distance between the recession and advance curves represents the intake opportunity time. This is the time that water stands at any point down the length of the irrigation run. If the time required to apply a certain depth of water to the soil at a point is more than the intake opportunity time, deep percolation will occur at

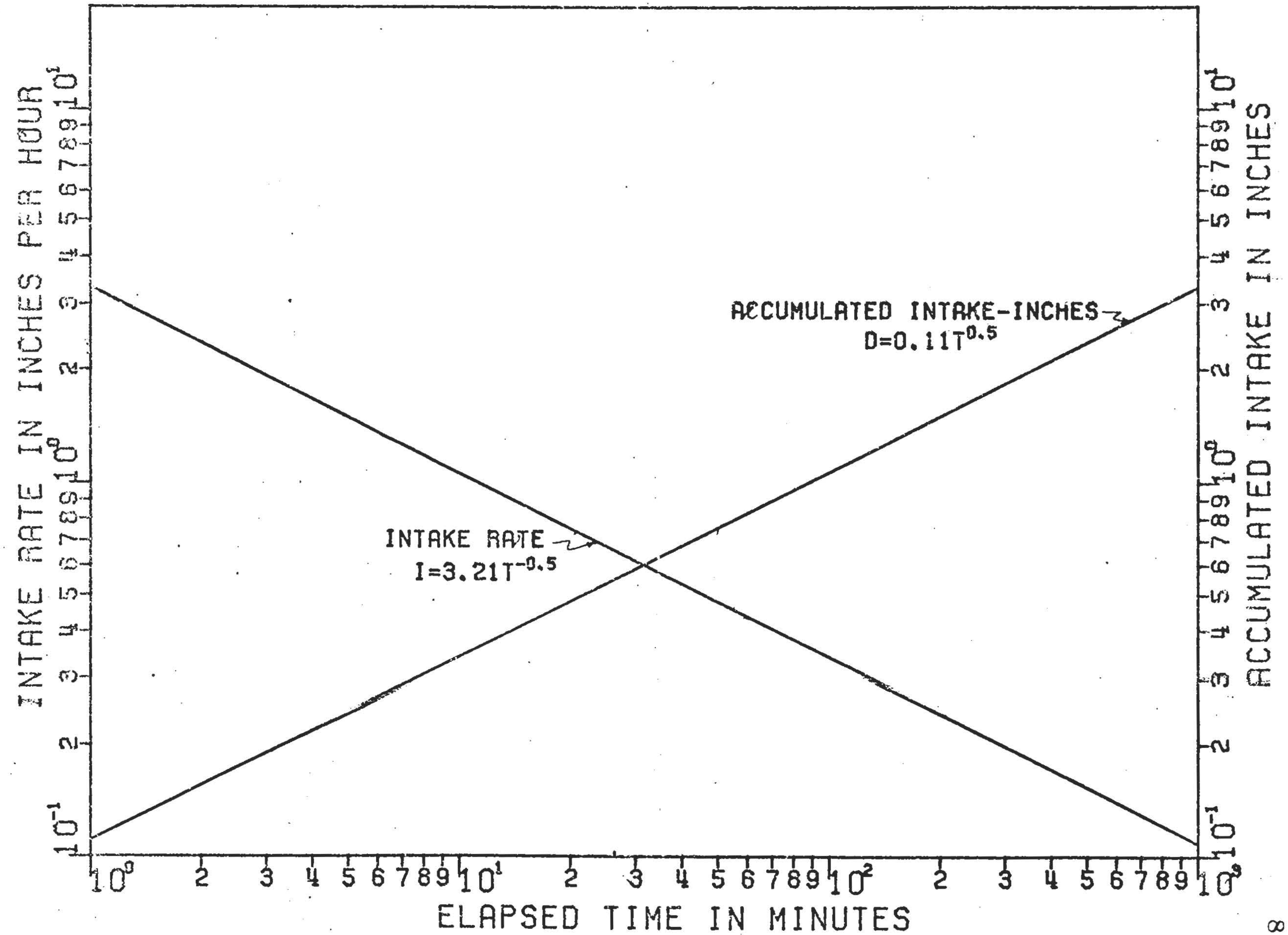



Figure 1. Typical furrow intake characteristic curves.

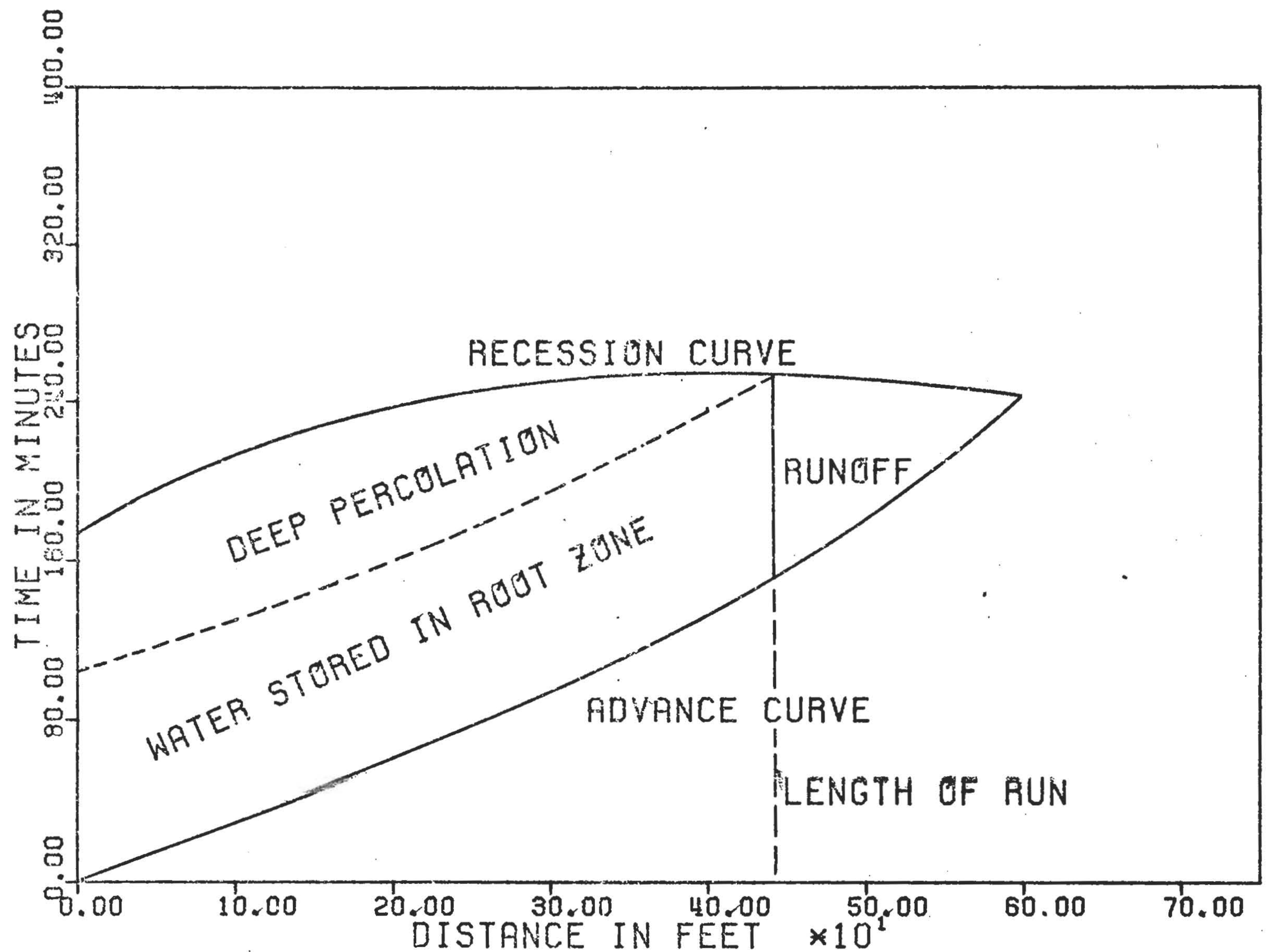



Figure 2. Typical advance -recession curve.

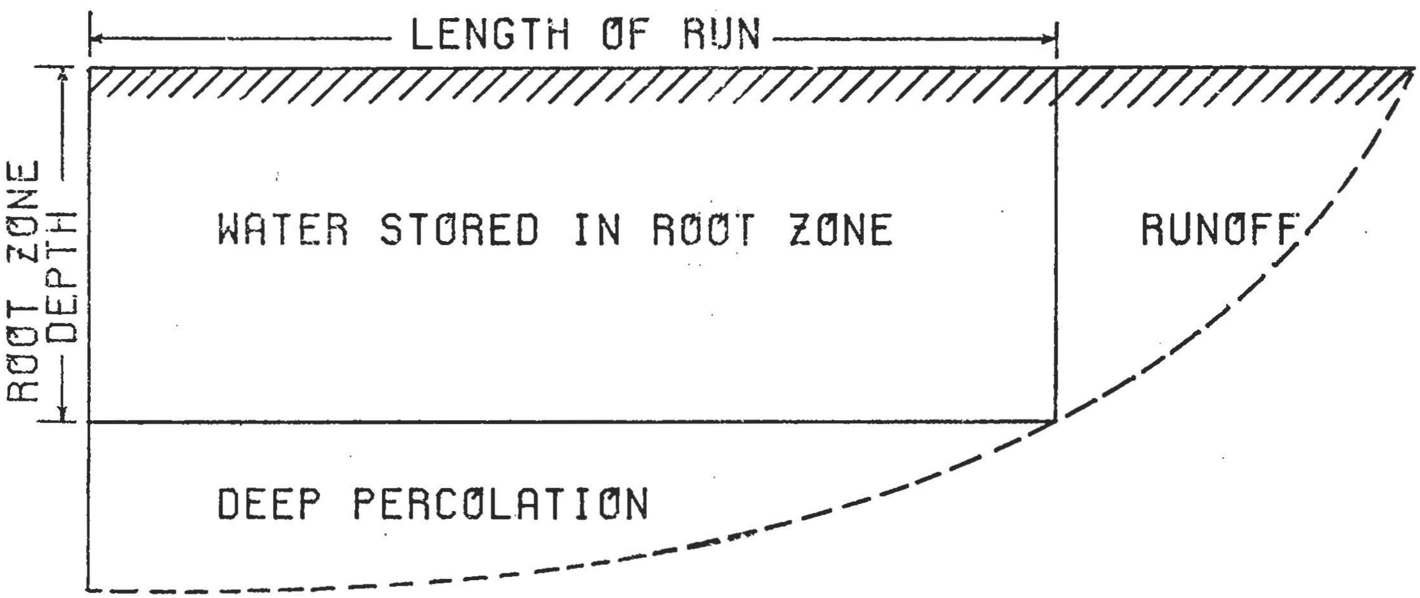



Figure 3. Typical distribution of onflow water.

that point. When it is less, the moisture deficit is not completely replenished.

The theoretical distribution of onflow water for an irrigation run is shown in Figure 3. Using the infiltration opportunity time and the intake characteristics of the soil, the depth of water applied can be calculated for any point. The resulting water distribution profile can be used to evaluate the adequacy of irrigation and relative amounts of percolation and runoff.

# CHAPTER III

# REVIEW OF LITERATURE

There has been a considerable amount of research done on border and furrow irrigation. Numerous articles have been published on how to evaluate the water use on a field, farm or project. Different opinions have been raised as to what method is best to evaluate an irrigation system.

Researchers have used different approaches to evaluate existing irrigation systems depending upon their research needs and objectives. The water application efficiency concept, however, has been widely used.

## Approach in Evaluating Efficiency

Israelsen (22) developed the concept of water application efficiency to measure and focus attention on the efficiency with which water is delivered to the farm and stored within the root zone.

In algebraic terms:

$$E_a = \frac{100 W_s}{W_f} \tag{3}$$

where $E_a$ = water application efficiency, percent

$W_s$ = water stored in the root zone during irrigation, inches

$W_f$ = water delivered to the farm, inches

Israelsen (21) further stated that measuring water application efficiency consists of three important phases:

1. Provide appropriate water measurement structures for the farm, such as weirs, flumes, orifices or other reliable structures.
2. Provide a reasonably constant flow during the period of delivery to the field.
3. Provide for the measurement of the amount of water stored in the root zone during each irrigation.

Measurement of the volume of water stored in the soil during irrigation may be difficult and costly. The gravimetric method of obtaining soil samples and weighing them before and after oven drying is a simple yet effective method of determining changes in moisture content. Representative measurements of the apparent specific gravity of the soil are necessary to convert moisture contents from percent weight to percent volume.

Moreover, two assumptions must be introduced, namely; 1) the depth of soil in which the soil moisture may be considered as stored and available to crops, and 2) the time after irrigation when further downward flow of water may be considered negligible (21).

Hansen (19) recognized that application efficiency alone does not adequately describe the operation of an irrigation system. Application efficiency may be high where crop response is poor. He proposed some concepts for evaluating the adequacy of irrigation, namely water storage and water distribution efficiencies.

Storage efficiency is a measure of how completely the needed water has been stored in the root zone during the irrigation. Water storage efficiency becomes important whenever insufficient water is stored in the root zone. This condition may occur because of scarcity of water or because of excessive time required to secure adequate penetration. Storage efficiency is written as follows:

$$E_s = 100 \frac{W_s}{W_n} \qquad (4)$$

where $E_s$ = water storage efficiency, percent

$W_s$ = water stored in the root zone during irrigation, inches

$W_n$ = water needed in the root zone prior to irrigation, inches

Hansen (19) stated that water distribution efficiency is used to evaluate the extent to which water is uniformly distributed. Uniform distribution of irrigation water throughout the field is desirable. Drought areas will appear in a field which is not irrigated uniformly. In equation form

$$E_d = 100 \left(1 - \frac{y}{d}\right) \qquad (5)$$

where $E_d$ = water distribution efficiency, percent

$y$ = average numerical deviation in depth of water stored from depth stored during irrigation

$d$ = average depth of water stored during irrigation

Meriam (29) defined distribution efficiency as the percent ratio of the minimum depth of water infiltered into the ground to the average depth infiltered. The depth of water infiltered refers to the depth of water stored at any point in the farm.

Another concept that Hansen (19) introduced was the consumptive use efficiency. Not all water stored in the soil is used by the crop. Evaporation occurs from exposed ground surface, such as in a row crop field with wide furrow spacing. Significant downward movement of moisture beyond the root zone also occurs. The loss of water by deep percolation and surface evaporation following an irrigation can be evaluated by determining the consumptive-use efficiency. The equation is:

$$E_u = 100 \frac{W_u}{W_d} \qquad (6)$$

where $E_u$ = consumptive-use efficiency, percent

$W_u$ = normal consumptive use of water

$W_d$ = net amount of water depleted from the root zone

Efficiency parameters described by Hall (17) are also useful in the complete evaluation of farm irrigation systems. For purposes of evaluation, the following are the most valuable parameters.

<u>Operational efficiency</u> is a ratio of the actual system application efficiency to the ideal system application

efficiency. It is a measure of how well the system is operated.

Season application efficiency is a ratio of the useful water applied during the entire irrigation season to the total volume delivered. If any part of the field suffers yield reduction because of over-irrigating or under-irrigating, the amount of useful water applied is reduced by the amount of the excess or deficiency.

Economic irrigation efficiency is a ratio of the total production under actual conditions to the expected production with ideal conditions. Hall stated that poor design and operation cost more in lost production than in wasted water. An irrigated farm is an enterprise for profit not for water conservation. Therefore, any investment to improve systems must be justified by dollar return due to increased production.

Hall suggested that for purposes of design, the following are the most valuable:

System application efficiency is the application efficiency of a system at satisfactory output. Satisfactory output is defined as the output obtained when 95 percent or some other percentage of the field has received adequate irrigation. This term is useful when it is not economically justifiable to achieve adequate irrigation of an entire field.

Ideal system efficiency is the highest application efficiency a system can attain as it is designed. This parameter is useful for comparing systems because it does not include operational deficiencies.

Coefficient of uniformity is equivalent to Hansen's water distribution efficiency.

Jensen (24) stated that the quantity of water that is essential and effectively used to control salts must be recognized as a beneficial and necessary use of water in order to evaluate the efficiency of irrigation systems. He defined irrigation efficiency as the ratio of the volume of irrigation transpired by plants and evaporated from the soil and plant surfaces, plus that necessary to regulate the salt concentration in the soil solution, and that used by the plant in building plant tissue, to the total volume of water diverted, stored, or pumped for irrigation. This definition takes into account all losses of water that occur after the water in a natural stream or aquifer is controlled or removed specifically for irrigation purposes. Expressed analytically, the irrigation efficiency under steady state conditions, or for long periods of time, becomes

$$E_i = 100 \frac{W_{et} + W_1 - R_e + W_s}{W_i} \qquad (7)$$

where $E_i$ = overall irrigation efficiency for the farm, project or basin as specified, percent

$W_{et}$ = the volume of water lost to evapotranspiration

$W_l$ = the volume of water necessary for leaching on a steady state basis

$R_e$ = volume of effective precipitation

$W_s$ = volume change in stored soil water

$W_i$ = volume of water that is diverted, stored or pumped specifically for irrigation

## Infiltration and Water Advance

The Soil Conservation Service (9) has presented methods and procedures for measuring furrow intake rates. The instantaneous intake rate and accumulated intake are represented by equations 1 and 2, respectively. The basic intake rate is the rate when the elapsed time is equal to about -600n.

A furrow infiltrometer was developed by Bondurant (3) to directly measure the intake rate at any section of a furrow. A cross section of the furrow is isolated by two plates. A constant water level in the supply reservoir is measured at frequent intervals. This infiltrometer simulates the infiltration conditions that occur in a furrow during irrigation. It provides a means of measuring furrow infiltration rates when field measurement during an irrigation trial is not feasible.

The advance of a stream front in surface irrigation is dependent on several factors: 1) intake characteristics of the soil, 2) roughness of the soil surface, 3) retardance due to vegetation, 4) slope of the field, 5) size of irrigation stream, 6) size and slope of furrow channel, and 7) fluid characteristics of irrigation water. The interaction of these variables results in non-uniform, unsteady, open channel flow over the porous bed (12, 14, 22).

Hall (18) developed a numerical method for predicting advance in a border. Later, the method was modified by Davis (12). The method assumed the following: 1) the flow is constant, 2) the intake is some function of time, 3) the depth approaches the normal depth at the head of the furrow and can be obtained by Manning's equation for open channel flow, 4) infiltration characteristics are uniform throughout the length of run, and 5) slope, roughness and shape of the flow channel are uniform throughout the length of run. The incremental distance is calculated for each successive equal time period using the volume balance principle.

Christiansen and others (8) derived an equation relating time of advance to the intake characteristics of the soil. It is a volume balance method but assumes a constant rate and thus a triangular subsurface distribution pattern. They did not consider the effect of slope and roughness on depth of surface storage, but rather they assumed an average constant flow depth which was adjusted by trial and error to fit field measurements. They also developed a nomograph to obtain a correction factor for the average depth of infiltration.

## Design Methods

Israelsen and Hansen (22) discussed several variables which are associated with the hydraulics of surface irrigation. These are: 1) rate of application, 2) rate at which water infiltrates into the soil, 3) rate of advance of the wetting front, 4) surface roughness of the soil and vegetation, 5) shape of flow channel, 6) slope of the soil surface, 7) erosion hazard, and 8) fluid characteristics of irrigation water.

An equation for flow in border irrigation was developed by Monson (30) based on Manning's equation. He related the time needed to infiltrate the required depth of water into the soil to the time for the water to advance across the field. A constant k was introduced which was the ratio of the average velocity of advance to the average velocity of flow as determined by Manning's equation. The resulting equation is

$$Q = \left[\frac{L\ I}{360kD}\right]^{5/2} \left[\frac{n}{1.49}\right]^{3/2} \frac{W}{S^{3/4}} \qquad (8)$$

where Q = size of stream to apply the desired depth of irrigation, cubic feet per second

L = length of run, feet

I = infiltration rate, inches per hour

k = ratio of average velocity of advance to the average velocity of flow

D = depth of irrigation, inches

n = coefficient of roughness

W = width of the border, feet

S = slope of the border

Shockley and others (33) developed a "quasi-rational" approach to surface irrigation design. Using the net volume required and an assumed efficiency, they calculated the total volume of inflow required. The time of application was the time necessary to produce the desired infiltration opportunity at the head of the border. Allowance was made for the time lag after the stream was cut off before enough water drained away and recession actually started. A disadvantage of this method is that the attainable efficiency must be known before the size of the irrigation stream can be estimated.

Shockley (33) also reported some design limitations for maximum and minimum flow depths and maximum non-erosive streams. The maximum flow depths should not overtop the border dikes. He suggested six inches as the maximum advisable depth. Also, the stream should be large enough to spread evenly over the border. The minimum flow depends on slope, length of border and surface irregularities. For an adequately smoothed border, Shockley suggested the following flow:

$$Q_{min} = 0.0004\ L\ S^{0.5} \tag{9}$$

where $Q_{min}$ = minimum allowable unit stream, cubic feet per second per foot.

$L$ = length of the border, feet

$S$ = slope of the border

The irrigation stream should not cause erosion. For non-sod-forming crops like alfalfa and small grains under most conditions:

$$Q_{max} = 0.06(100S)^{-0.75} \tag{10}$$

where $Q_{max}$ = maximum non-erosive stream per foot of width

For sod-forming crops, streams twice as large are considered permisible.

Phelan and Criddle (31) reported the maximum non-erosive furrow stream to be:

$$Q = 10/S \tag{11}$$

where $Q$ = furrow stream, gallons per minute

$S$ = slope of the furrow, percent

They stated that the maximum length of furrow depends on the maximum furrow stream size, the infiltration rate, and the amount of water to be stored during each irrigation.

## Water Efficiency Studies on Controlled Plots

A study of water application efficiency for sprinkler and furrow irrigation of alfalfa on controlled plots conducted by Somerhalder (34) at the University of Nebraska showed the following results: 1) the mean annual irrigation requirements to produce 6.6 tons of alfalfa hay per acre were 27.8 inches and 32.2 inches of water for sprinkler and furrow irrigation, respectively, 2) the quantity of water stored in the root zone of the alfalfa crop was not affected by the method of irrigation. Sprinkler irrigation stored 23.4 inches of water in the root zone out of a total of 27.8 inches applied compared to surface irrigation which stored 23.2 inches out of a total of 32.2 inches.

The mean water application efficiency obtained under the sprinkler method was 84 percent and 72 percent for the surface irrigation method. He reported further that the 12 percent difference in water application efficiency was due to larger amounts of runoff from the surface irrigated plots.

Kruse and others (25) compared the efficiencies of sprinkler and furrow irrigation of grain sorghum under conditions suitable for irrigation. The results of their experiment showed that sprinklers applied water with an average efficiency of 82.5 percent, whereas, the application efficiency obtained with furrow irrigation was significantly lower, 74.4 percent. This difference in application efficiency required the application of 1.1 more inches of irrigation water each year on furrow irrigated plots than on sprinkler irrigated plots.

Pair (32) investigated the effects of irrigation methods on water application efficiency using controlled plots with a silt loam surface and a silty clay loam sub-soil. The results of his studies showed that on shallow soil having a slope of 3 to 5 percent, the water application efficiency was 36 percent for downslope border irrigation, 62 percent for contour border irrigation, and 61 percent for sprinkler irrigation. He also studied the field water application efficiency in relation to the depth of water replaced in the soil root zone and reported lower efficiencies for small amounts of moisture replacement and higher efficiencies for the large amounts of moisture replacement regardless of the method of irrigation used.

Jensen (23) evaluated the performance and operating characteristics of border check irrigation and reported that water application efficiencies of 80 to 95 percent were easily attained. The rate of water application for maximum efficiency and uniformity of irrigation should be from three to five times the average intake rate. He also reported that irrigating crops having high retardance to flow such as sugar beets resulted in lower efficiencies.

Fischbach and Somerhalder (15) studied the efficiencies of automated surface irrigation systems with and without runoff reuse systems and reported that water application efficiencies varied from 56.5 to 73 percent without reuse while water application efficiencies with reuse ranged from 84.4 to 96.8 percent. He concluded that the automated surface irrigation method with reuse can be a very efficient method of applying water, Furthermore, he explained that the reuse system also eliminated the additional labor required to cut back furrow streams.

Water Application Studies Under Actual Field Conditions

Willardson (37) conducted water efficiency tests at Milford, Utah in a potato field using furrow irrigation. The efficiency of water application varied from 24 to 87 percent during the season, depending upon the availability of soil moisture storage capacity.

An evaluation of the use of irrigation water on the Northside Division of Minidoka Project located in Minidoka and Jerome Counties, Idaho was conducted by Corey and others (10) over a 5-year period. The irrigation efficiencies obtained ranged from 42.4 percent in 1958 to 54.8 percent in 1961.

Brockway and others (4) conducted tests on three potato fields and two bordered grain fields in eastern Idaho. They reported that an average of about 15 inches per acre was applied per irrigation on the bordered fields where the irrigation requirement was only 4 to 5 inches.

They also reported that the water application efficiency for furrow irrigation of potato fields early in the season was about 50 percent on wheel compacted furrows and about 20 percent on uncompacted furrows.

# CHAPTER IV

# THE STUDY AREA

The area chosen for this study is in the Snake River Fan which is located in the southeast portion of Jefferson County, Idaho. The approximate location of the area included in the study is shown in Figure 4.

Irrigation water used in the study area is diverted from the South Fork of the Snake River. The Great Feeder Canal is the main irrigation canal in the study area. It supplies water for some twenty major canal systems which in turn deliver irrigation water to some 100,500 acres of agricultural land. Other canal systems, whose headgates are above the point of diversion of the Great Feeder but whose supply of water is controlled by the Great Feeder diversion dam, have been considered as part of the Great Feeder System. These are the Anderson, Farmers Friend and Eagle Rock canals.

## Climate and Soil

The Rigby-Ririe area of Jefferson County lies in a climatological area which is known as the Upper Snake River Plain. This area has moderately warm summers and severe winters. The temperature averages about 68°F in July and 17°F in January and 0°F temperatures or lower occur at least 16 days of each year. The average precipitation in the area is 8.7 inches per annum and the growing season is about

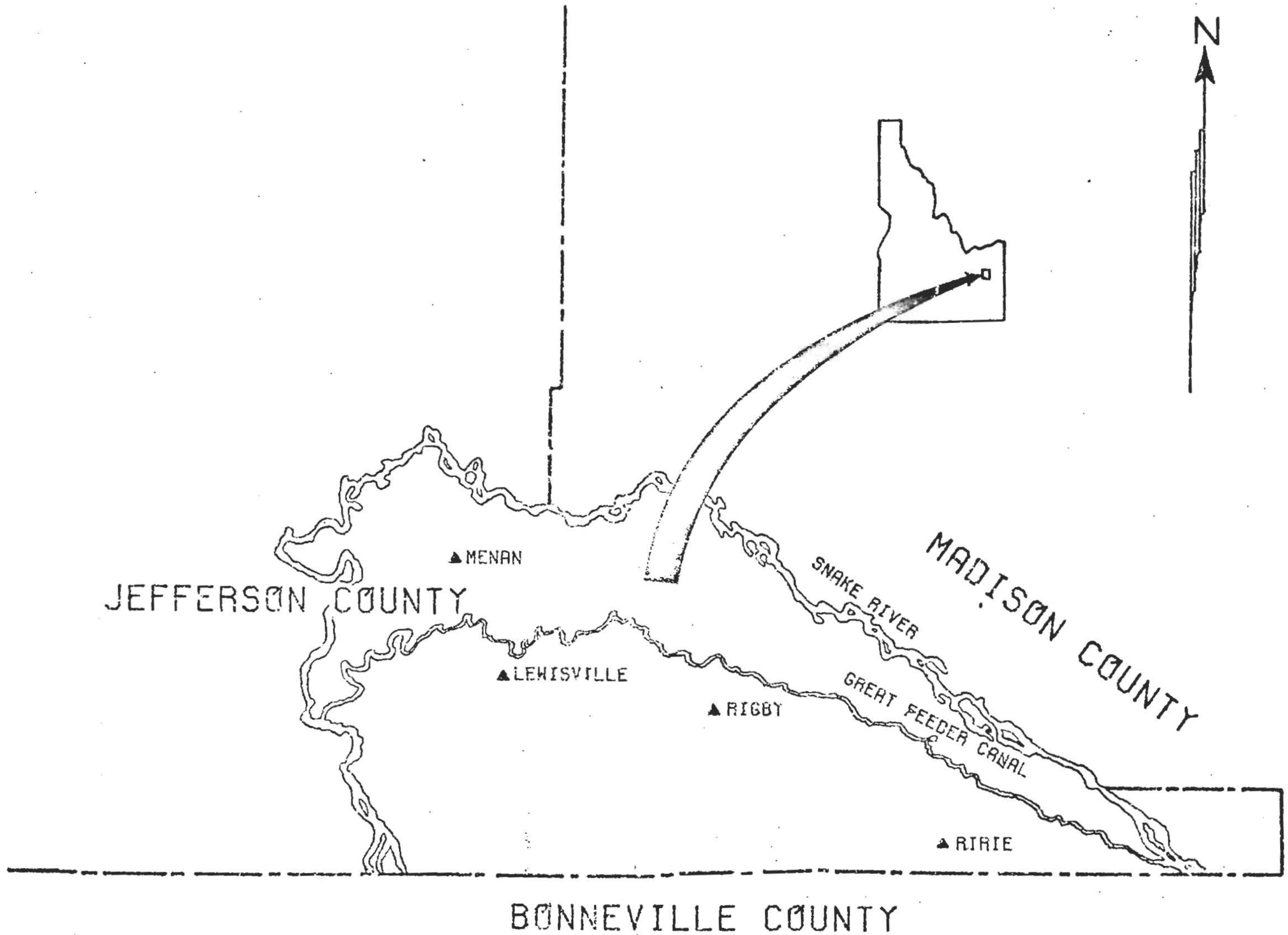



Figure 4. Map of the study area, Jefferson County, Idaho.

123 days (5).

The soils in the study area are dominated by medium-textured soils. The northwest portion of the area is comprised of silt and clay loams which range from 40 to 60 inches in depth. In the southern part of the area, the soils are predominantly Bock and Bannock loams. These soils range from 20 to 60 inches in depth and are underlain by sand and gravel. The northeast portion of the area consists primarily of Blackfoot silt loam which ranges from 20 to 60 inches in depth and is underlain by sand and gravel (4).

## Crops

Brockway and de Sonneville (5) conducted a crop distribution survey in the area in 1972. The results of their investigation are shown in Table 1.

## Physical Characteristics of Irrigation Systems

Gravity methods of irrigation are widely practiced in the area. The main crops are grain, hay, pasture and potatoes. The percent distribution of irrigation methods used in the area is shown in Table 2.

Furrow irrigation on a potato field using siphon tubes to divert water from a stabilizing basin is shown in Figure 5. Irrigation water being diverted to a border using 6-inch siphons is shown in Figure 6.

Table 1. Crop distribution in Snake River Fan, Jefferson County, Idaho.

| Crop | Percent Distribution |
|---|---|
| Mixed Grains | 31.1 |
| Alfalfa Hay | 38.8 |
| Irrigated Pasture | 20.6 |
| Potatoes | 8.1 |
| Corn | 0.4 |
| Sugar Beets | 1.0 |
| T O T A L | 100.0 |

Table 2. Percentage distribution of irrigation methods in Snake River Fan, Jefferson County, Idaho (5).

| Irrigation Method | Percent Distribution |
|---|---|
| Border | 88.1 |
| Furrow | 11.0 |
| Others* | 0.5 |
| None | 0.4 |
| T O T A L | 100.0 |

* include flooding and sprinkler

The length of irrigation runs in the area varies

Figure 5. Water being diverted to a potato field using 2-inch siphon tubes.

Figure 6. Water being diverted to a border strip using 6-inch siphon tubes.

from 924 to 1056 feet. The field streams used range from 4.0 to 6.9 cubic feet per second. The average size of field cultivated per crop ranges from 10 to 14 acres. The data in Table 3 show the average field size, irrigation run and field stream for each crop in the study area.

Table 3. Average field size, irrigation run and field stream for each crop (6).

| Crop | Area (acres) | Irrigation Run (ft.) | Field Stream (cfs) |
|---|---|---|---|
| Mixed Grain | 10 | 924 | 5.7 |
| Alfalfa | 12 | 1023 | 5.9 |
| Irrigated Pasture | 10 | 776 | 5.4 |
| Potatoes | 14 | 956 | 6.9 |
| Others | 10 | 1056 | 4.0 |
| A V E R A G E | 11 | 947 | 5.6 |

Brockway (5) reported that 74 percent of the farmers surveyed indicated that all the applied water was retained on their field with no runoff to drains or adjacent land. A typical farm in the study area with ponded water at the end of a border strip is shown in Figure 7.

Figure 7. Ponded water at the lower end of a border strip.

# CHAPTER V

# METHODS AND PROCEDURES

## Water Application Efficiency Measurement

Assistance from the Soil Conservation Service office at Rigby, Idaho was sought in selecting farms that represented the major soil series in the Snake River Fan area of Jefferson County. Three areas which were designated as Area I, Area II, and Area III were selected for study. The soil type in each area studied is Blackfoot silt loam, Area I; Heisetön loam, Area II, and; Bannock loam and Bannock gravelly loam, Area III. Detailed descriptions of the soil series are given in Appendix B.

The assistance of the agricultural county agent was used to obtain the necessary cooperators. The following criteria were considered in selecting study sites: 1) the representativeness of the farm with respect to soil condition, land preparation, land slope and crop grown; 2) possibility of taking inflow measurements at head ditches; 3) method of irrigation being practiced, and; 4) willingness of the farmer to cooperate in the study. Random sampling was not employed as random samples may not have been representative of the area. When the locations of the farms were established, specific fields within the farm were selected where measurements were made.

In order to calculate the water application efficiency for each field studied, the following measurements were taken:

1. Area of the field to be irrigated, acres
2. Soil moisture before irrigation, percent (dry weight basis)
3. Soil moisture after irrigation, percent (dry weight basis)
4. Apparent specific gravity of the soil
5. Rate of water delivery, cubic feet per second
6. Time spent in irrigation, hours
7. Surface runoff, acre feet per acre

The areas of the individual fields were obtained from the Agricultural Stabilization and Conservation Service, USDA at Rigby, Idaho. The width and length of the representative border strips were measured. An engineer's level was used in obtaining field slopes.

Soil moisture contents were determined gravimetrically. The samples gathered were immediately stored in a cooler to prevent the loss of moisture before weighing. The samples were weighed and placed in an oven for drying. To expedite oven drying of samples, a vacuum pump was used in conjuction with the oven. A vacuum of 20 to 25 inches of mercury (9.8 to 12 pounds per square inch) was maintained at a temperature of 115°C. Ten hours of drying at this temperature and pressure was found satisfactory since there was no significant difference compared to 24 hours of oven drying at atmospheric pressure. Sampling was done at 12 locations in each field and samples were collected at each foot of depth extending through the root zone of the crop. Root zone depths of 4 feet for alfalfa and 3 feet for barley and potatoes were used. A total of 40 samples for alfalfa and 36 for barley and potato fields were gathered. Sampling was done before and after irrigation. These measurements were necessary to find the change of moisture resulting from irrigation. In all cases, a 24-hour interval was used between the sampling periods.

The apparent specific gravity ($A_s$) of each field was also measured. Undisturbed soil samples for $A_s$ determination were collected by driving a cylinder 3.00 centimeters in diameter and 7.75 centimeters in length. The undisturbed sample obtained from the cylinder was oven dried and weighed to determine the $A_s$.

The existing farm ditches in the study area were found to be large with relatively flat grade. In addition, large delivery rates were used. The rate of water delivery was measured with the use of a current meter with a 4-blade impeller capable of measuring stream velocities up to 3 feet per second. Figure 8 shows how streamflow measurements were made in an irrigation lateral, and Figure 9 shows the current

Figure 8. Measuring stream flow in an irrigation lateral.

Figure 9. Current meter and counter used in streamflow measurement.

meter and counter used in streamflow measurement.

All the fields studied had no provisions for surface drainage at the end of the furrows or border strips. Therefore, no runoff measurements were taken.

The time spent in irrigating the border strips and furrow fields were recorded in order to determine the volume of water delivered to each field.

The depth of soil moisture stored in each foot of depth in the root zone was calculated using the following equation:

$$d_f = \frac{(P_{w2} - P_{w1})}{100} A_s \, d_s \qquad (12)$$

where $d_f$ = depth of water stored, inches

$P_{w1}$ = percent moisture in the soil sample before irrigation

$P_{w2}$ = percent moisture in the soil sample after irrigation

$A_s$ = apparent specific gravity of the soil

$d_s$ = depth of soil, inches

The total depth of moisture stored in the root zone was computed as

$$W_s = \sum_{f=1}^{n} d_f \qquad (13)$$

where $W_s$ = total depth of water stored in the root zone. inches

$n$ = number of one-foot increments through the root zone

The water application efficiency was calculated by dividing the total amount of water stored in the root zone available for plant use by the amount of water delivered to the field (equation 3).

## Labor Requirement

The time spent in irrigating the fields under study was recorded. The time spent in setting the checks and siphons, transferring from one furrow to the other, guiding the streams and other associated labor were also noted. The total labor requirement for each field was expressed in hours per acre per irrigation.

## Measurement of Infiltration in Border Strip

Ring infiltrometers were driven in a representative border at four different locations. The rings ranged from 12 to 14 inches in diameter and were 18 inches long. These infiltrometers were driven into the soil until about 4 to 5 inches of their length was left above the soil surface. Before pouring water onto the cylinders a polyethelene sheet was placed over the soil surface to prevent compaction. Water was poured in until the desired level was reached. The polyethelene sheet was then gradually removed. An initial reading of the water level on the scale set inside the cylinder was then made. After several minutes, the level of water was read on the scale and then brought back to the original level. This procedure was continued until sufficient time had elapsed. Figure 10 shows a ring infiltrometer with driving hammer and plate. Figure 11 shows the ring infiltrometer in place during an infiltration test.

## Measurement of Infiltration in Furrow Irrigation

The methods and procedures followed in determining the intake characteristics of irrigation furrows were essentially the same as the ones described in Soil Conservation Handbook No. 82 (9). Trapezoidal flumes were installed in the furrow at a distance of 200 feet from each other. The flumes installed in the upstream portion of the furrow were placed approximately 20 feet from the head of the furrow to avoid the effects of compaction present in the field periphery on the infiltration measurements. The size of the furrow stream was based on what the farmer was using. Siphon tubes were used to divert water from the supply ditch to the furrows. Measurements were made both in the unpacked (center)furrow and packed (wheel) furrow. The packed or wheel furrow refers to that furrow where the tractor wheels travel during cultivation, while the center or unpacked furrow refers to the untravelled furrow during cultivation. Trapezoidal flumes installed at the upstream and downstream stations of a furrow are shown in Figures 12 and 13, respectively.

Figure 10. Ring infiltrometer with driving hammer and plate.

Figure 11. Ring infiltrometer in place during infiltration test.

Figure 12. Trapezoidal flume installed at upstream station of furrow.

Figure 13. Trapezoidal flume installed at downstream station of furrow.

## Water Advance

The rate of water advance was also noted for each of the representative border strips and furrows. Stations were established every 100 feet down the irrigation run. The time when the water arrived at each station was recorded both for the center and wheel furrows.

## Data Processing

Due to the large amount of data obtained from the soil moisture sampling, a digital computer program was written to calculate the average moisture in each foot of depth as well as for the entire root zone. The wet and oven dried weight of samples and their corresponding identification numbers were used as input data. Another program was used to compute the water application efficiency.

A program was also written to process the data obtained from the ring infiltrometer tests, the furrow intake tests and rate of water advance tests. The program was written so that the output would be similar to the standard data form outlined by the Soil Conservation Service (9). The program can be used for any of the tests mentioned above. However, the kind of test, number of tests, number of trials in each test, and the number of observations in each trial must be specified.

In addition, a computer program was written to compute the coefficients <u>K</u> and <u>n</u> to fit the infiltration equation, $I = KT^n$ (equation 1), by a least squares regression technique using a logarithmic transformation.

Programs were also written to draw and plot all the graphs presented using the CALCOMP 936 Plotting System.

The lists of program statements which were coded in FORTRAN IV for a IBM 360/40 computer are shown in Appendix E.

# CHAPTER VI

# RESULTS

## Water Application Efficiency

Five irrigation trials were conducted on border irrigated fields during the irrigation season in 1973. Two of the fields were planted to alfalfa and three were planted to barley. Five irrigation trials were also conducted on furrow irrigated fields planted to potatoes. The physical characteristics of the fields used in this study are shown in Table 4.

The results of water application efficiency tests for border and furrow irrigation are presented in Tables 5 and 6, respectively. The water application efficiency for each method was determined by dividing the amount of water stored in the root zone by the amount of water delivered to the field. The computed water application efficiencies for the border irrigation trials ranged from 19 to 32 percent with an average of 24 percent. The results of the water application efficiency investigations for the furrow irrigation ranged from 47 to 58 percent with an average value of 51 percent.

It is very apparent that the water application efficiencies for the border irrigation trials shown in Table 5 are exceedingly low. One reason for this is the fact that

Table 4. Physical characteristics of the experimental fields.

| Trials | Date of Irrigation 1973 | Location | Crop | Area (acres) | Irrigation run (feet) | Slope (percent) |
|---|---|---|---|---|---|---|
| Border | | | | | | |
| 1B* | July 13 | Area III | Barley | 22.9 | 1200 | 0.29 |
| 2B | July 15 | Area I | Alfalfa | 10.3 | 750 | 0.31 |
| 3B | July 27 | Area III | Barley | 18.1 | 1275 | 0.30 |
| 4B | July 29 | Area III | Alfalfa | 35.5 | 1270 | 0.26 |
| 5B | August 1 | Area III | Barley | 22.9 | 1200 | 0.29 |
| Furrow | | | | | | |
| 1F** | July 14 | Area II | Potatoes | 14.9 | 1275 | 0.22 |
| 2F | July 18 | Area I | Potatoes | 23.5 | 1260 | 0.26 |
| 3F | July 29 | Area I | Potatoes | 23.5 | 1260 | 0.26 |
| 4F | July 30 | Area II | Potatoes | 14.9 | 1275 | 0.22 |
| 5F | July 31 | Area II | Potatoes | 18.0 | 1150 | 0.27 |

* B refers to border irrigation.

** F refers to furrow irrigation.

Table 5. Summary of water application efficiencies and water losses for border irrigation, Snake River Fan, Jefferson County, Idaho.

| Trials | Water applied (in) | Water stored (in) | Water application efficiency* (percent) | Runoff (in) | Deep percolation (in) | Total lost** (percent) |
|---|---|---|---|---|---|---|
| 1B | 12.2 | 3.48 | 28 | 0.00 | 8.72 | 72 |
| 2B | 8.5 | 2.75 | 32 | 0.00 | 5.75 | 68 |
| 3B | 13.2 | 2.54 | 19 | 0.00 | 10.66 | 81 |
| 4B | 14.4 | 2.99 | 21 | 0.00 | 11.41 | 79 |
| 5B | 16.2 | 3.14 | 19 | 0.00 | 13.06 | 81 |
| AVERAGE | 12.5 | 2.98 | 24 | 0.00 | 9.92 | 76 |

* $E_a = \frac{W_s}{W_f} 100$

** percent of water delivered

Table 6. Summary of water application efficiencies and water losses for furrow irrigation, Snake River Fan, Jefferson County, Idaho.

| Trials | Water applied (in) | Water stored (in) | Water application efficiency* (percent) | Runoff (in) | Deep percolation (in) | Total lost** (percent) |
|---|---|---|---|---|---|---|
| 1F | 4.3 | 2.04 | 47 | 0.00 | 2.26 | 53 |
| 2F | 3.6 | 1.84 | 51 | 0.00 | 1.76 | 49 |
| 3F | 3.5 | 2.04 | 58 | 0.00 | 1.46 | 42 |
| 4F | 4.1 | 1.84 | 45 | 0.00 | 2.26 | 55 |
| 5F | 2.8 | 1.51 | 54 | 0.00 | 1.29 | 46 |
| AVERAGE | 3.8 | 1.85 | 51 | 0.00 | 1.81 | 49 |

* $E_a = \frac{W_s}{W_r} 100$

** percent of water delivered

farmers used large irrigation streams of 2.4 to 7.8 cubic feet per second per single border and set. The recorded time of irrigation setting per border per irrigation ranged from 3.5 to 8 hours during the daytime and was more than 10 hours for overnight sets.

The water application efficiencies obtained for the furrow irrigation trials were also rather low with an average of 51 percent, 27 percent greater than the average for border irrigation. The significant difference may be attributed to the longer irrigation times used for the border irrigation. Application times for the furrows ranged from 3.5 to 4 hours per setting using an average furrow stream of 28 gallons per minute on packed furrows and 33 gallons per minute on unpacked furrows. The average water application efficiency for all irrigations, furrow and border, was 32 percent.

## Runoff and Other Losses

On any farm under irrigation, there are unavoidable losses of water. There are also avoidable losses. For each irrigation trial, an effort was made to determine how water was lost.

The computed field losses for each irrigation trial are shown in Tables 5 and 6 for border and furrow irrigation, respectively. None of the fields used in this study had drainage provisions and all tailwater was ponded on the lower ends of the fields. All the applied water, therefore, was retained on the fields with no surface runoff. Hence, the amount of water lost to deep percolation was computed by subtracting the amount of water stored from the amount of water delivered. Since there was no runoff from the fields, this amount represented the total water lost.

The total amount of water lost, expressed as a percentage of water delivered ranged from 68 to 81 percent for the border irrigation and 42 to 55 percent for furrow irrigation. This water obviously percolated below the root zone beyond the reach of crops. Figures 14 and 15 show the total depth of water stored and lost in each irrigation trial.

## Soil Moisture

The soil moisture data were all punched on cards to facilitate routine calculations with the digital computer. Soil moisture contents for each foot of depth for the entire root zone were determined. These data were used in estimating the amount of water stored in the root zone after irrigation.

The average soil moisture contents before irrigation for the entire root zone were also computed. The average soil moisture content (dry-weight basis) prior to irrigation ranged from 14.78 to 18.43 percent with an average of 17

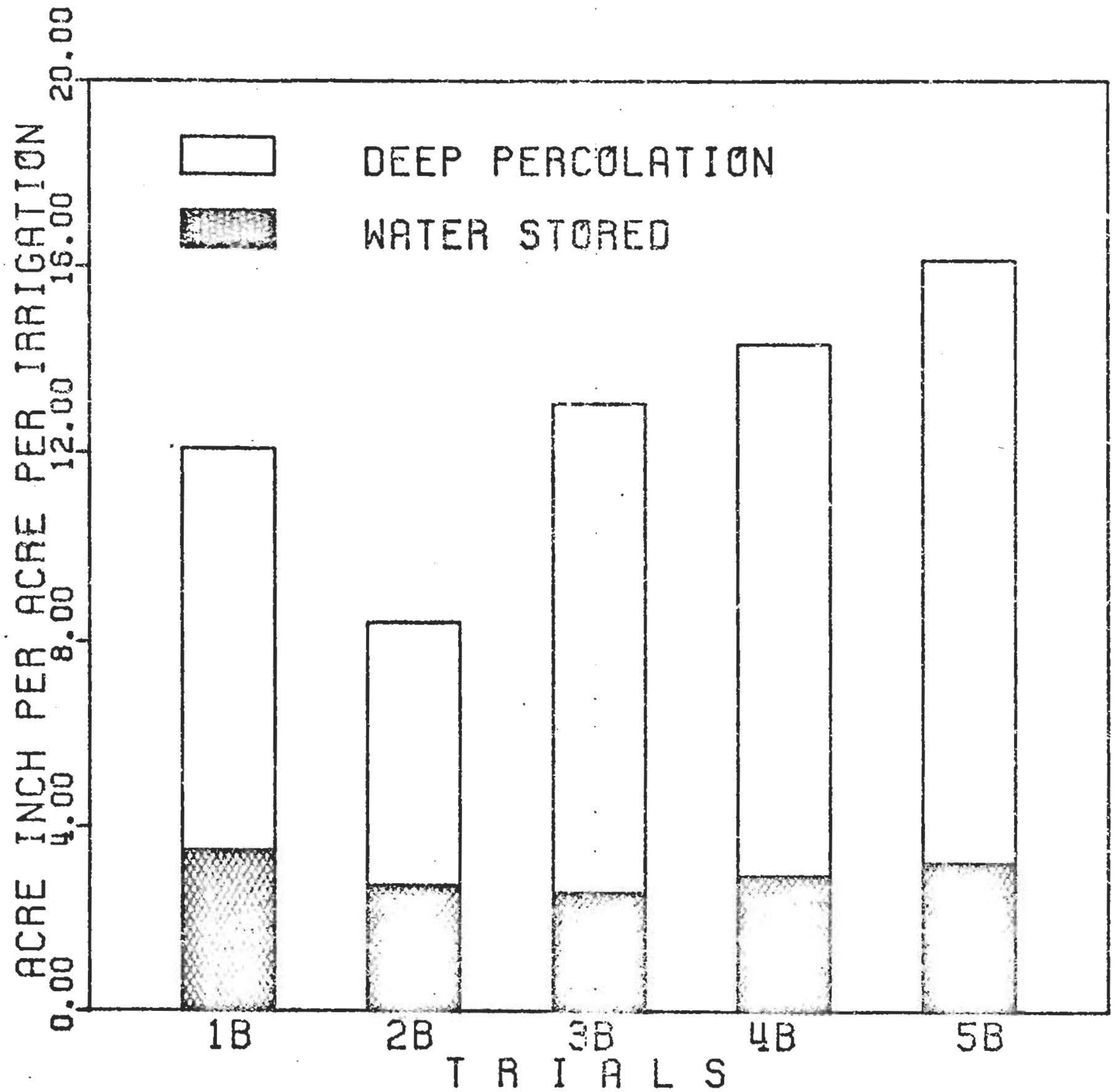



Figure 14. Disposition of water delivered for each border irrigation trial.

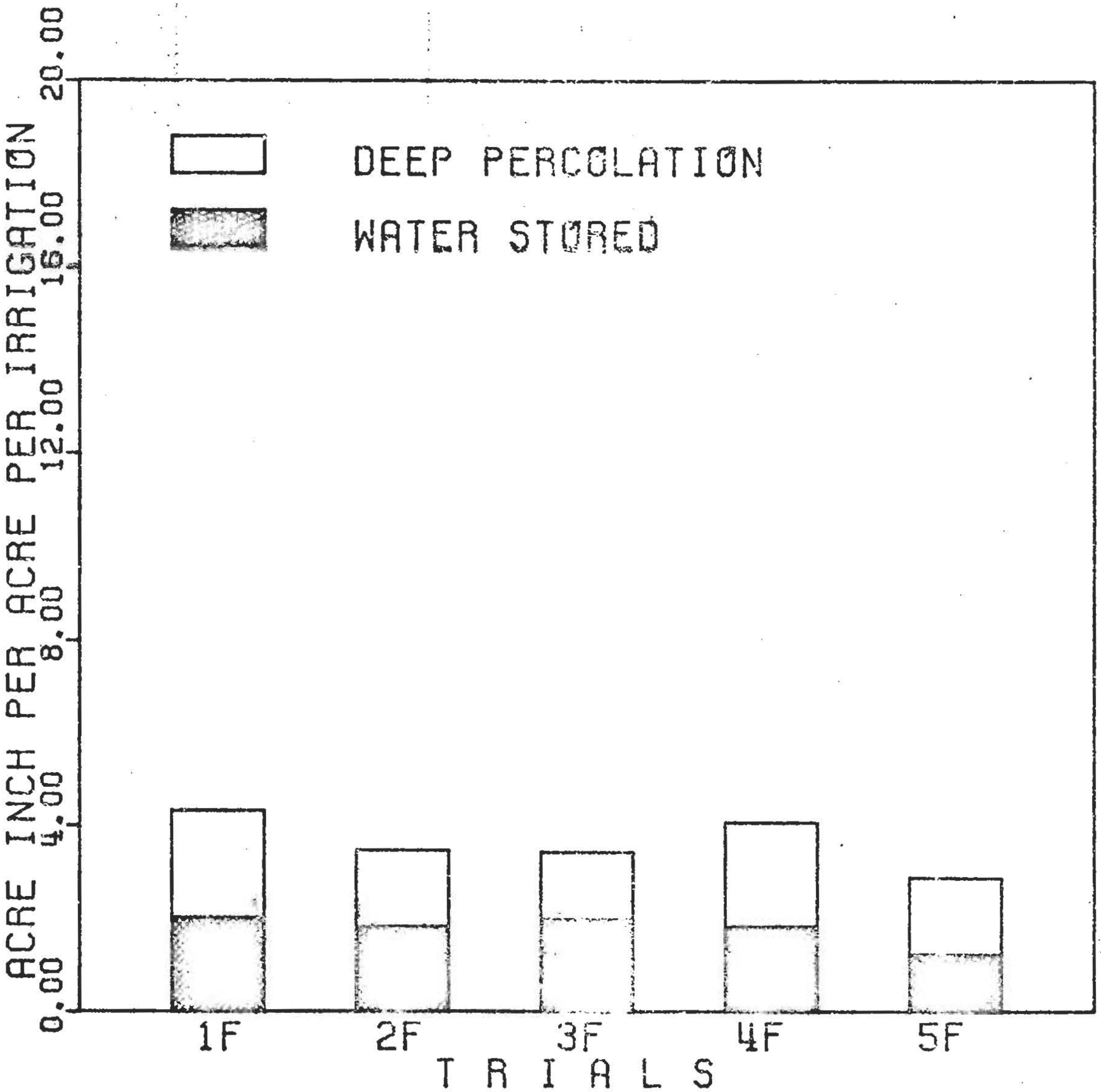



Figure 15. Disposition of water delivered for each furrow irrigation trial.

percent for border irrigation; whereas, it ranged from 18.90 to 19.45 percent with an average of 19 percent for furrow irrigation. The higher figures shown for furrow irrigation do not necessarily indicate that higher moisture levels are maintained for row crops due to the variability of other factors such as soil texture, structural condition and organic matter content. In general, the test fields for border irrigation were located in coarser textured soils.

## Labor Requirement

The amount of labor spent on each experimental field was also obtained. The summary of labor input for border and furrow irrigation is shown in Table 7. In border irrigation, the amount of labor expended to irrigate an acre ranged from 0.25 to 0.41 hours per acre per irrigation with an average of 0.31. In furrow irrigation, the labor input ranged from 0.35 to 0.58 hours per acre per irrigation with an average of 0.45. The higher labor input for furrow irrigation indicates that more time was spent by the farmer in guiding furrow streams, transferring siphons from one location to another and other associated labor. In addition, it was observed that in general, more than one man was required for furrow irrigation whereas only one man was needed for border irrigation.

An attempt was made to find the effect of labor input

Table 7. Summary of labor input for border and furrow irrigation, Jefferson County, Idaho.

| Trials | Method of Delivery | Labor Input (hr/acre/irrigation) | Average |
|---|---|---|---|
| Border | | | |
| 1B | Siphon | 0.32 | |
| 2B | Siphon | 0.41 | |
| 3B | Cutout | 0.28 | |
| 4B | Siphon and turnout | 0.25 | |
| 5B | Siphon | 0.30 | 0.31 |
| Furrow | | | |
| 1F | Siphon | 0.43 | |
| 2F | Siphon | 0.58 | |
| 3F | Siphon | 0.48 | |
| 4F | Siphon | 0.35 | |
| 5F | Siphon | 0.39 | 0.45 |

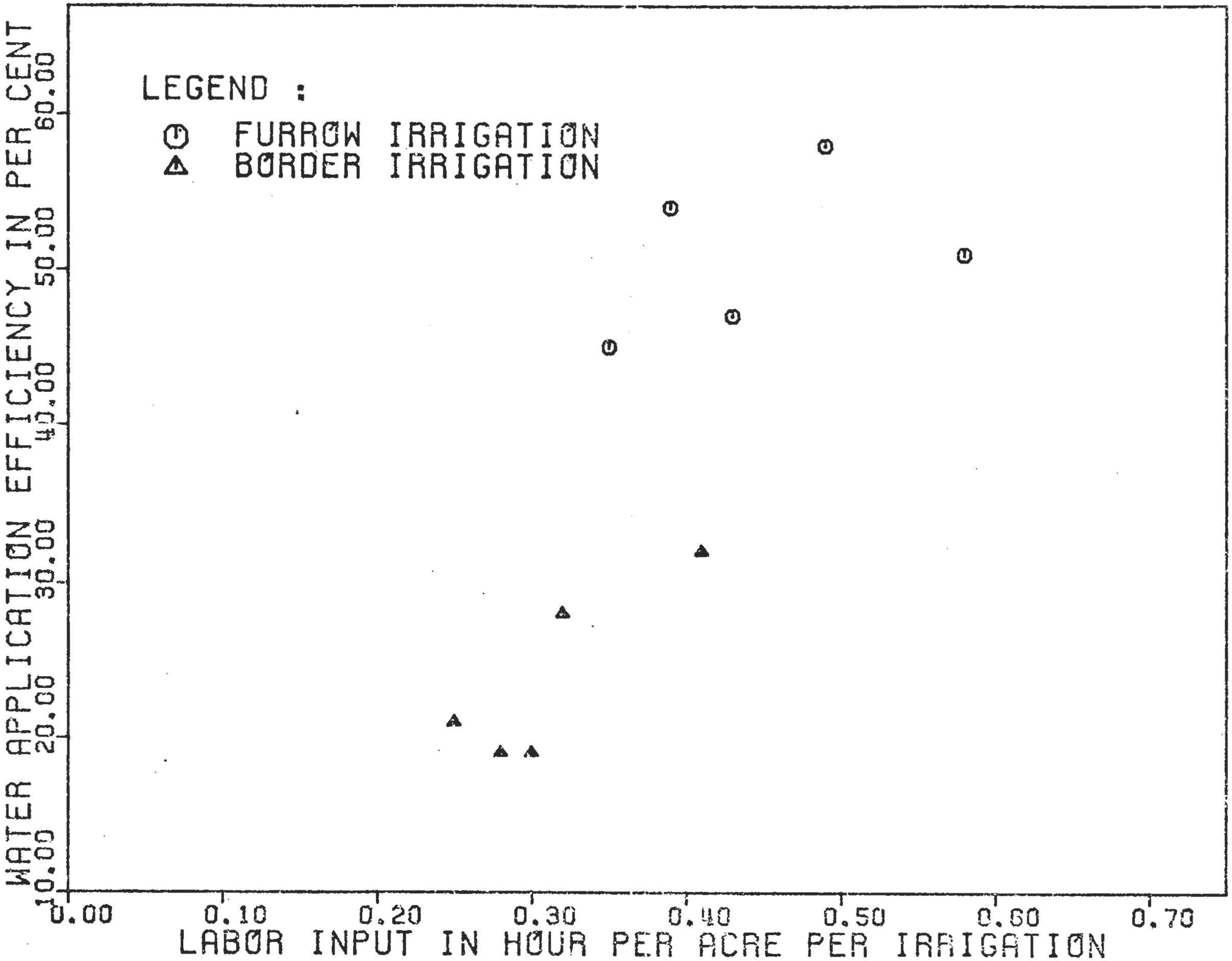



Figure 16. Effect of labor input on water application efficiency.

for border and furrow irrigation on water application efficiency. Labor input data were plotted against water application efficiency in the scatter diagram shown in Figure 16. A simple correlation analysis was run to determine the relationship between the two variables. The correlation coefficients obtained were 0.60 and 0.85, for furrow and border irrigation, respectively. Both show no significant relation at the 5 percent level. This indicates that an increase in the labor input would not necessarily increase the water application efficiency. It is to be noted that the results of the analysis are not very conclusive due to the small sample size.

## Intake Rates

The results of the infiltration tests on the border strips are shown in Figure 17. Two of the intake tests were conducted on Bannock gravelly loam and Bannock loam planted to barley and alfalfa, respectively. The other test was made on Blackfoot silt loam with newly cut alfalfa hay. The basic intake rates for the different border sites were 1.9, 1.2 and 0.7 inches per hour for Bannock gravelly loam, Bannock loam and Blackfoot silt loam, respectively. The accumulated intake depth was represented by the following equations: $D = 0.63T^{0.63}$, for Bannock gravelly loam; $D = 0.23T^{0.66}$, Bannock loam, and; $D = 0.26T^{0.56}$, Blackfoot

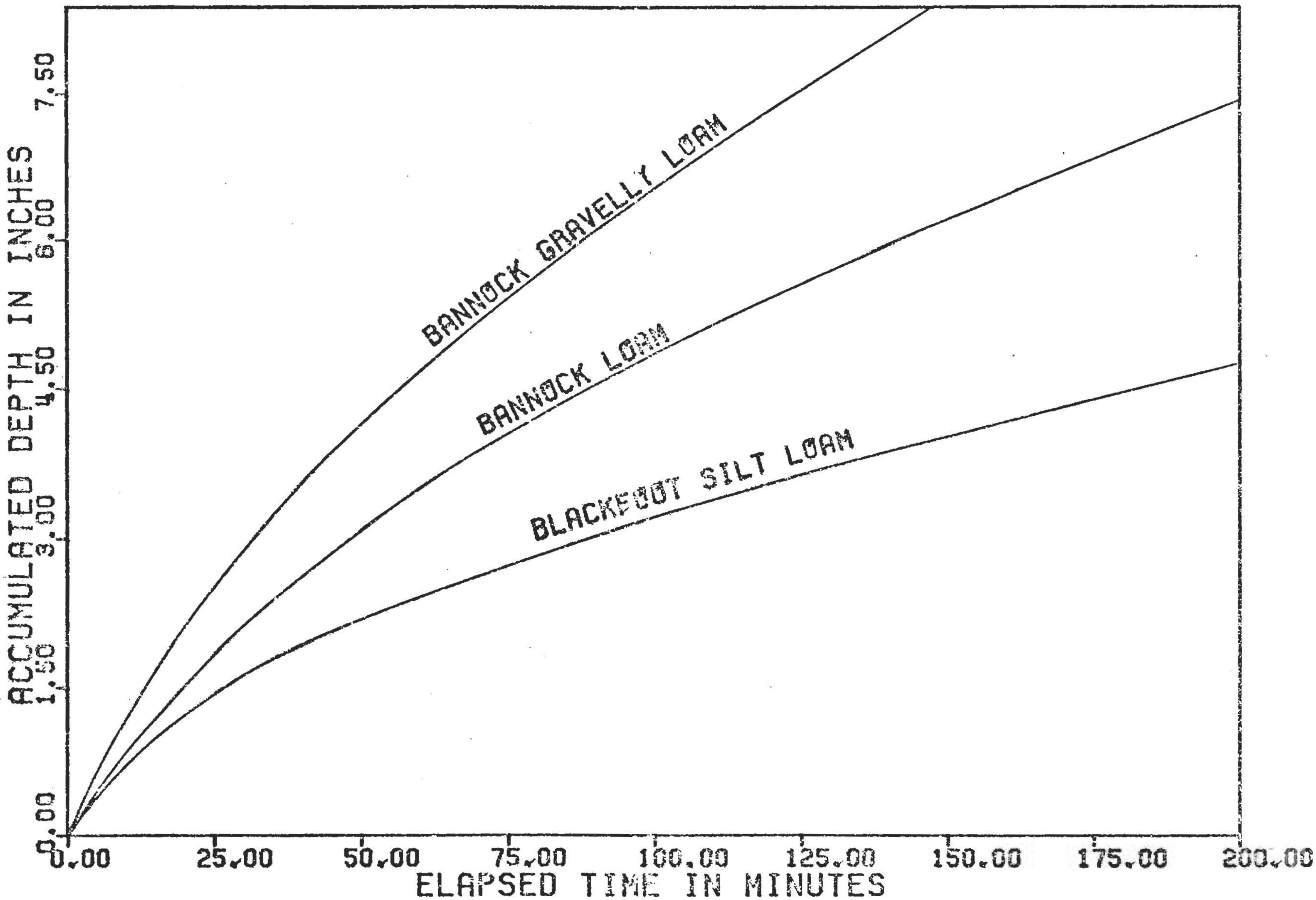



Figure 17. Infiltration characteristics of different border sites.

silt loam.

Examination of Figure 17 shows that the infiltration rates in the border fields are very high. The intake opportunity times to infiltrate 4 inches of water were about 45, 75 and 150 minutes for Bannock gravelly loam, Bannock loam, and Blackfoot silt loam, respectively. The average amount of water needed to bring the soil to field capacity on the border fields was approximately 3 inches. With this depth, the intake opportunity time to replenish the needed soil moisture for the assumed root zone is only 32 minutes for Bannock gravelly loam, 52 minutes for Bannock loam and 87 minutes for Blackfoot silt loam.

The summary of furrow-intake relations developed from inflow-outflow measurements over a given reach is shown in Figure 18. The furrow intake tests were conducted on Blackfoot silt loam and Heiseton loam and both fields were planted to potatoes. For Blackfoot silt loam, the basic intake rate was computed as 1.5 gallons per minute per 100 feet or 0.52 inches per hour and 1.6 gallons per minute per 100 feet or 0.55 inches per hour for packed and unpacked furrows, respectively.

The variation of intake depths for the packed and unpacked furrows is shown in Figure 18. In Blackfoot silt loam, the accumulated intake was represented by the equations: $D = 0.13T^{0.48}$ for the packed furrows and $D = 0.17T^{0.48}$ for

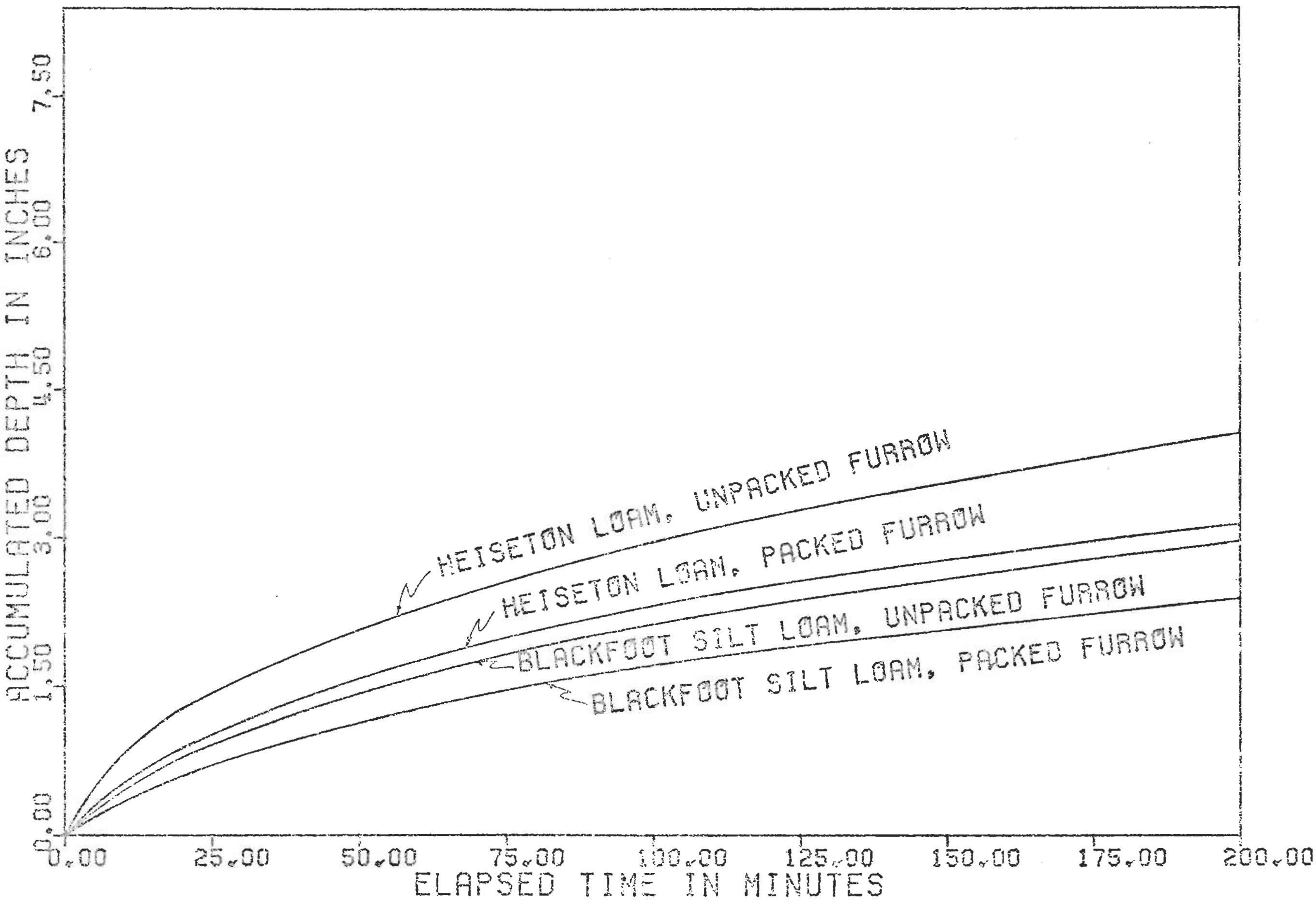



Figure 18. Infiltration characteristics of different furrow sites.

unpacked furrows. In Heiseton loam, the accumulated intake was described by the equations $D = 0.17T^{0.48}$ and $D = 0.28T^{0.51}$ for packed and unpacked furrows, respectively. These equations were derived by integrating the area under the intake rate curves for a row spacing of 36 inches.

Examination of the above equations reveals that furrow intakes are quite high. To infiltrate a depth of 2 inches in a row crop field would require an intake opportunity time of about 95 to 145 minutes in a packed furrow and 45 to 130 minutes in an unpacked furrow. The average depth of water needed to bring the soil to capacity during an irrigation was approximately 2 inches.

Considerable variability of intake depth for the two kinds of furrows was apparent in both soil types. This variability is obviously due to compaction of the packed or wheel furrow during the cultivation process which impedes infiltration into the soil. It should be noted that the infiltration tests were only conducted once at the representative fields. Hence, the results of these tests would be applicable at that time for those specific field conditions. Variation of intake rates might be expected as the irrigation season progresses. Linderman (27) reported that the infiltration rate decreases with successive irrigations thereby increasing the required infiltration opportunity time for a given moisture deficit.

Rate-of-Advance

In developing a predictive equation for advance distance, Fok and Bishop (14) assumed the advance equation to be in the form

$$x = at^b \qquad (o<b<1) \qquad (14)$$

where a and b are the empirical constants. In order to determine whether the field data would satisfy this assumption and to find whether an exponential curve in the form $x = at^b$ would fit the advance data, statistical analyses were run to determine the correlation coefficients between estimated and observed values. The computed correlation coefficients listed in Table 8 are all highly significant at the 1 percent level. This significance indicates that the actual data are well described by the advance function as expressed in equation 14.

The coefficients a and b of the advance function were computed using a least squares regression technique to plot the best fit curve in the standard exponential form. The plotted curves are shown in the subsequent pages (Figures 20, 22, 24, 26 and 28) and all the measured advance data are listed in Appendix D. These rate-of-advance data were gathered from fields where crops were at their vegetative stage.

Table 8. Correlation coefficients and empirical constants of advance equations.

| Trials | Type | Discharge rate | Correlation coefficients r | Advance constants a (ft/min) | b |
|---|---|---|---|---|---|
| 1 | Packed furrow, BSL* | 27 gpm | .997 | 37.14 | 0.776 |
| 2 | Packed furrow, BSL | 30 gpm | .996 | 62.33 | 0.719 |
| 3 | Unpacked furrow, BSL | 32 gpm | .997 | 59.79 | 0.601 |
| 4 | Unpacked furrow, BSL | 40 gpm | .998 | 63.54 | 0.731 |
| 5 | Packed furrow, HL** | 28 gpm | .991 | 67.06 | 0.679 |
| 6 | Packed furrow, HL | 33 gpm | .994 | 71.39 | 0.714 |
| 7 | Unpacked furrow, HL | 33 gpm | .993 | 54 92 | 0.664 |
| 8 | Unpacked furrow, HL | 35 gpm | .996 | 67.38 | 0.664 |
| 9 | Border field, BL*** | 30 gpm/ft w | .999 | 19.61 | 0.815 |
| 10 | Border field, BGL**** | 57 gpm/ft w | .991 | 61.20 | 0.637 |

* Blackfoot silt loam
** Heiseton loam
*** Bannock loam
**** Bannock gravelly loam

## Irrigation System Evaluation

One of the objectives of this study was to evaluate the performance of existing irrigation systems to determine the recommended adjustments in operations, practices and design features which will insure higher irrigation efficiencies in the area. To attain this objective, selected furrows and border strips in the study area were investigated and analyzed to show how these systems could be improved. The methods and procedures discussed in Agricultural Handbook No. 82 (9) and by Meriam (29) were used in evaluating the systems.

### Furrow Irrigation, Area I.

The specific furrows evaluated were in Area I. Area I representing the Blackfoot series is located in the central portion of the study area. The soil type was Blackfoot silt loam with an estimated root zone depth of 3 feet. The field was planted to potatoes and was 1260 feet long with a gradient of 0.26 percent. One siphon was used to divert water to the packed furrows and 2 siphons were used on the unpacked furrows. Two flow rates were used in each type of furrow: 27 and 30 gallons per minute for the packed furrows, and 32 and 40 gallons per minute for the unpacked furrows. The depth of water needed to refill the root zone was estimated to be 1.8 inches.

The intake characteristics of the soil are shown in

Figures 19 and 21, and the advance curves are presented in Figures 20 and 22.

Adding 1.8 inches of water to the soil would require an intake opportunity time of 130 and 88 minutes for the packed and unpacked furrows, respectively. To attain 'efficient' irrigation, the stream front must reach the lower end of the furrow in one-fourth of the intake opportunity time. The one-fourth irrigation concept was discussed in Chapter II. Using the one-fourth irrigation criterion, only 33 and 28 minutes are required for the stream to reach the lower end of the furrows. From the advance curves for the 27 and 32 gallons per minute used by the farmer, as shown in Figures 20 and 22, the stream fronts reached the end of the furrow in 105 and 176 minutes, respectively, for the packed and unpacked furrows. The furrow streams were run by the farmer for 225 minutes for both furrows.

A summary of the analysis made to determine the effects of furrow length and stream size on irrigation efficiencies for Blackfoot silt loam is shown in Table 9. The packed furrow had a water application efficiency of 66 percent and a distribution efficiency of 69 percent. For the unpacked furrow, the water application efficiency was 60 percent and the distribution efficiency was 60 percent. The distribution efficiency was obtained by dividing the minimum amount of

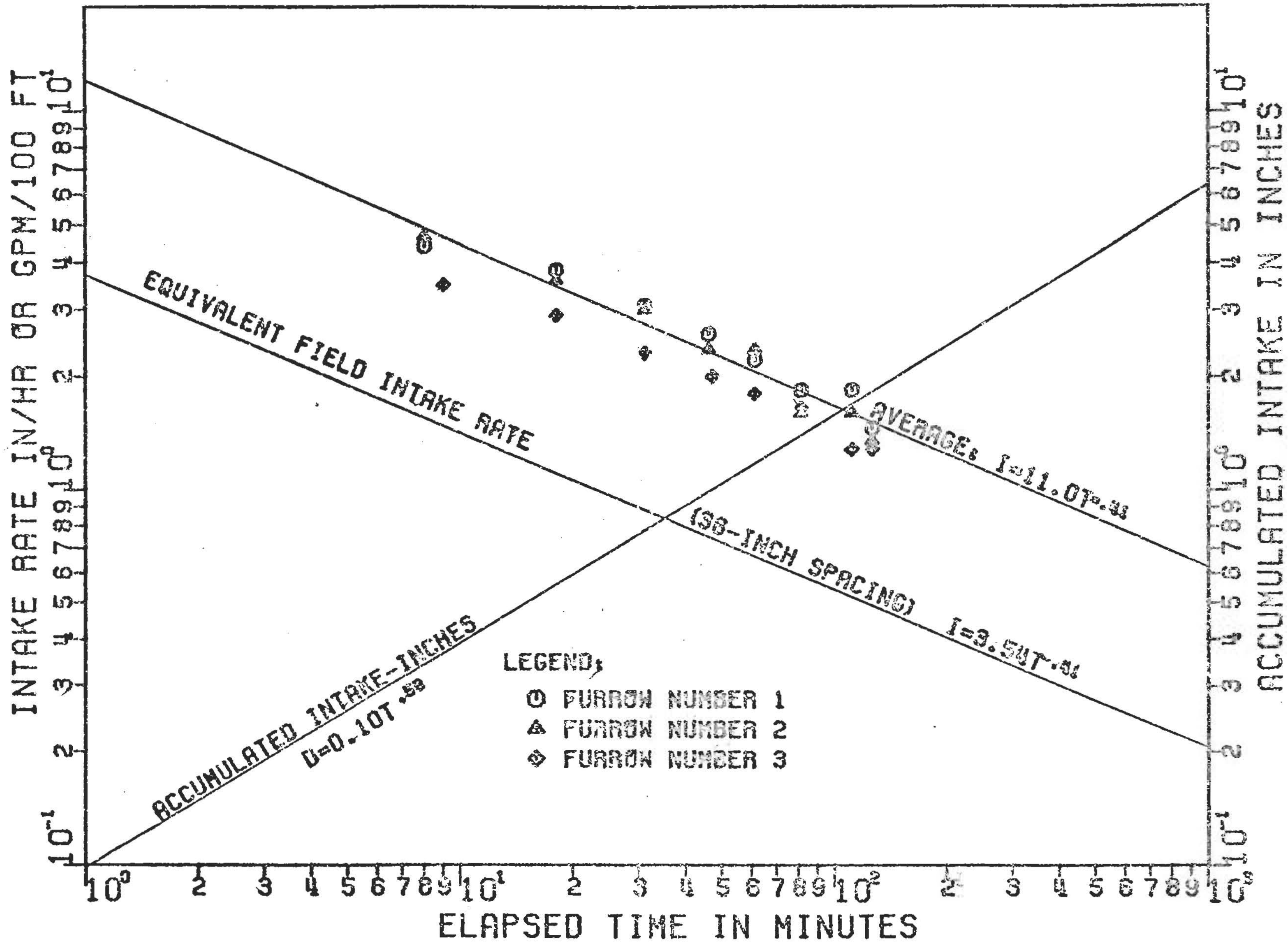



Figure 19. Intake characteristics of packed furrow, Blackfoot silt loam.

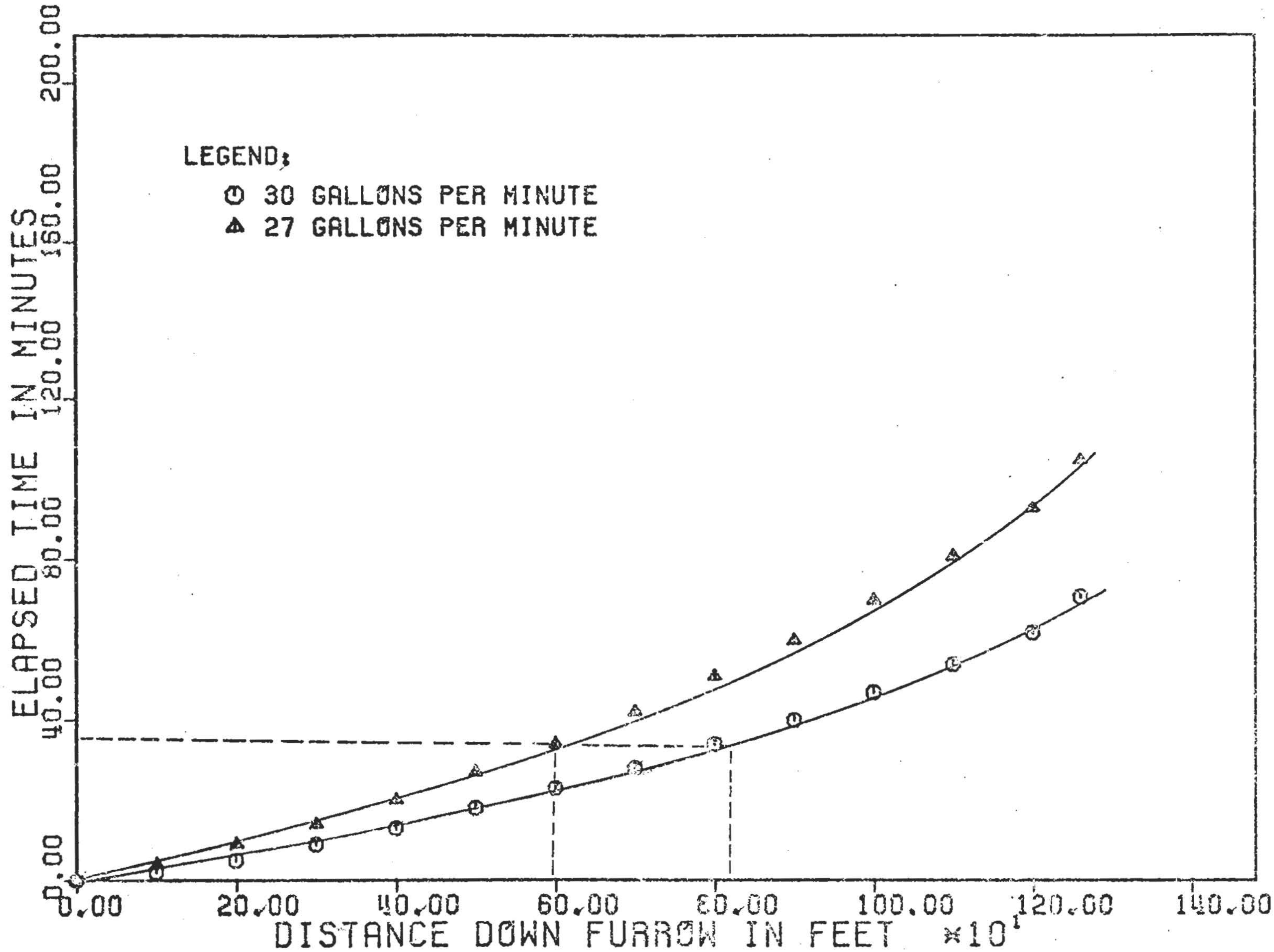



Figure 20. Advance of water on packed furrow, Blackfoot silt loam.

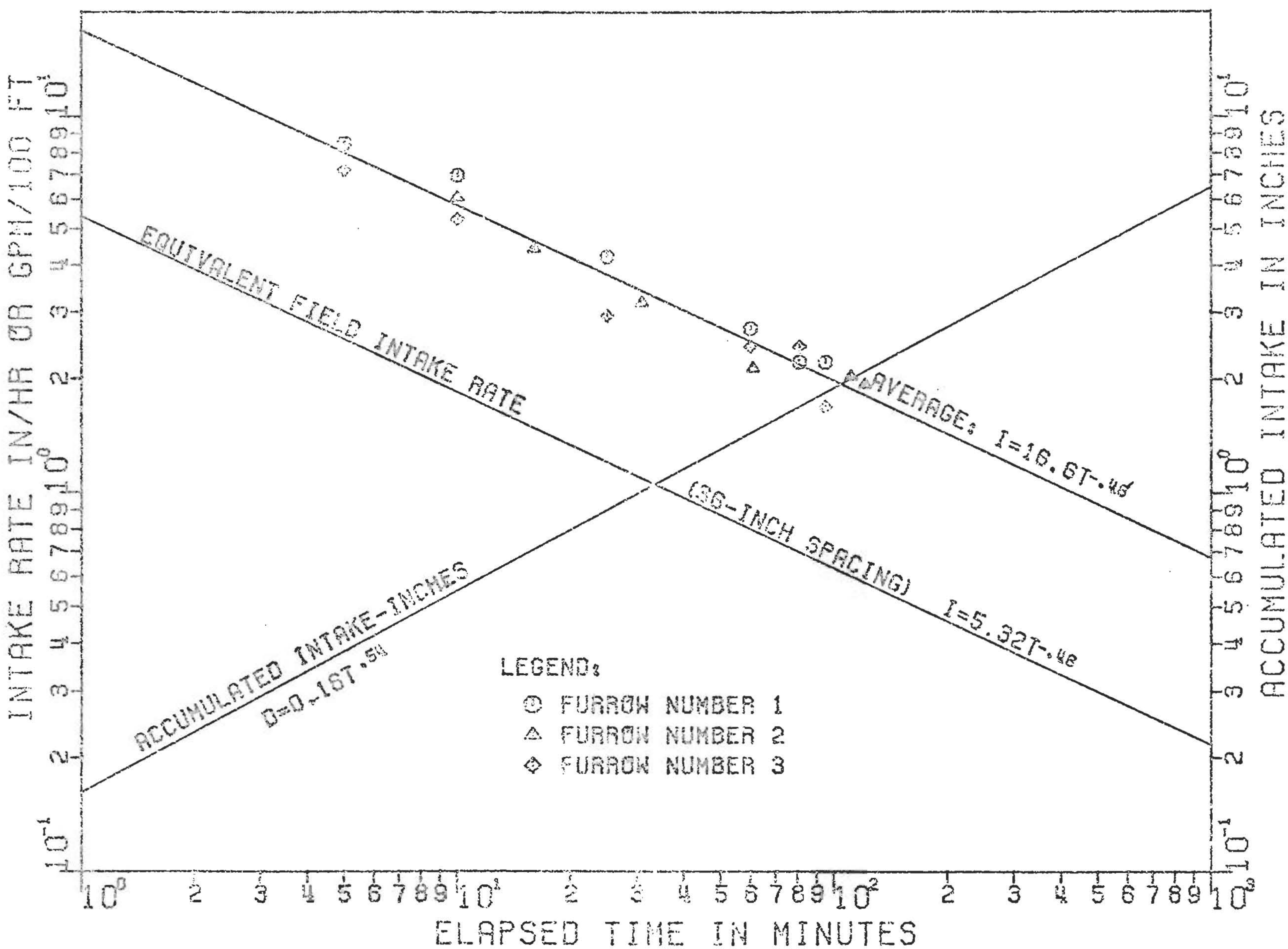



Figure 21. Intake characteristics of unpacked furrow, Blackfoot silt loam.

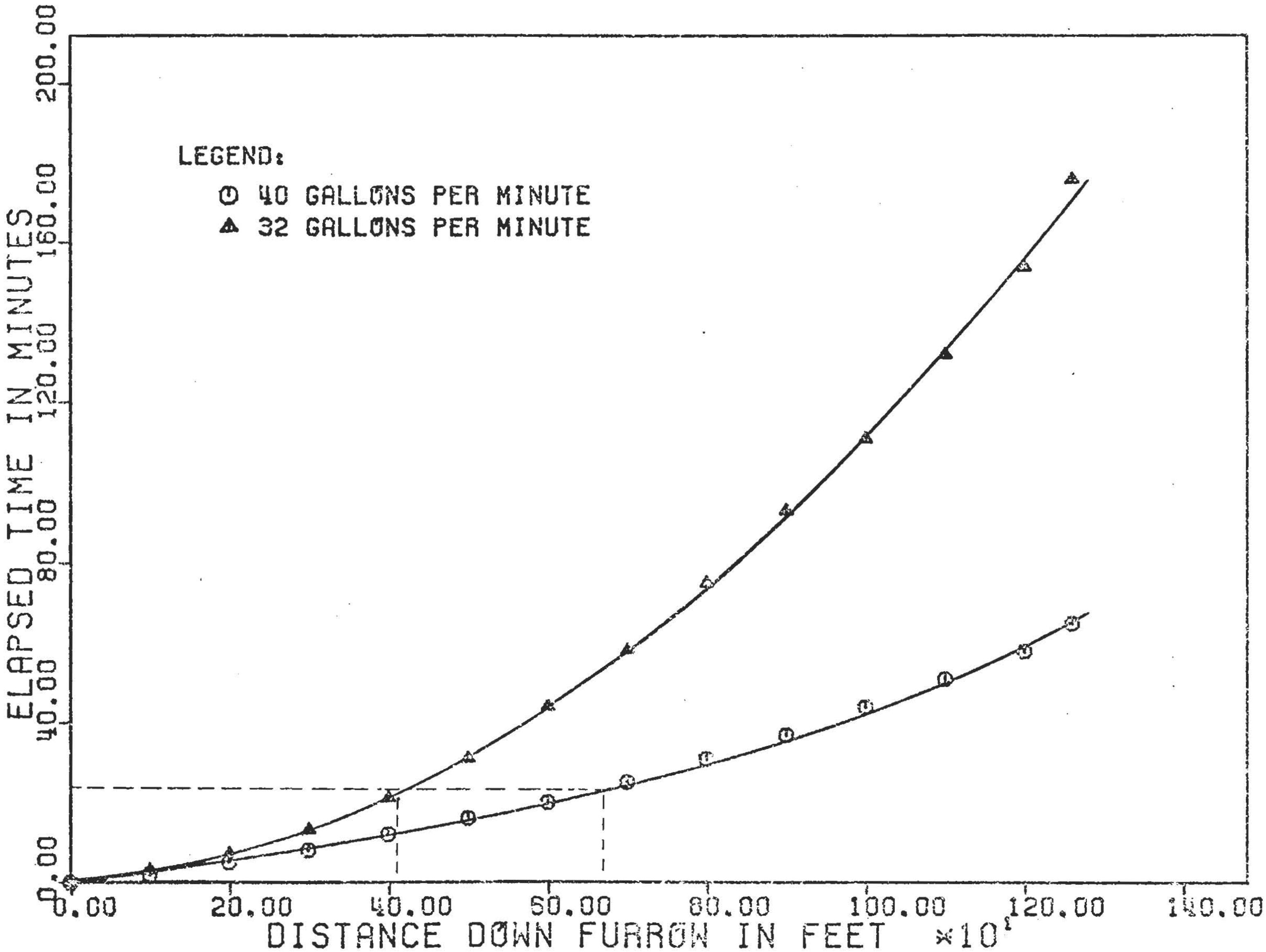



Figure 22. Advance of water on unpacked furrow, Blackfoot silt loam.

Table 9. Effects of furrow length and stream size on furrow irrigation system efficiencies, Blackfoot silt loam.

| | Length of run (ft) | Stream size (gpm) | Application time (min) | Advance time (min) | Intake time (min) | Deep percolation* (%) | Runoff* (%) | $E_d$ (%) | $E_a$ (%) |
|---|---|---|---|---|---|---|---|---|---|
| Packed furrow | | | | | | | | | |
| Present system: | 1260 | 27 | 225 | 105 | 120 | 34 | $-\omega$ | 69 | 66 |
| Variations | 600 | 27 | 163** | 33 | 130 | 3 | 51 | 94 | 46 |
| | 800 | 30 | 163** | 33 | 130 | 3 | 42 | 94 | 53 |
| | 1000 | 33 | 163** | 33 | 130 | 3 | 33 | 94 | 64 |
| | 1200 | 36 | 163** | 33 | 130 | 3 | 26 | 94 | 71 |
| Unpacked furrow | | | | | | | | | |
| Present system: | 1260 | 32 | 225 | 176 | 49 | 40 | $-\omega$ | 60 | 60 |
| Variations | 400 | 32 | 110** | 22 | 88 | 3 | 56 | 94 | 41 |
| | 600 | 38 | 110** | 22 | 88 | 3 | 47 | 94 | 50 |
| | 700 | 41*** | 110** | 22 | 88 | 3 | 44 | 94 | 53 |

* expressed as a percentage of water applied.
** based on one-fourth irrigation criterion for 'efficient' irrigation.
*** exceeded the maximum allowable stream size, $Q_{max}$ = 10/S, 38 gpm.
$-\omega$ no runoff because tailwater was ponded.

water infiltered by the average amount of water infiltered (29). Distribution efficiency describes the uniformity of water intake without regard to the adequacy of irrigation.

Several variations on furrow length and stream size were analyzed to determine their effects on water application and distribution efficiencies. The length of run was chosen and the corresponding stream size was either taken or extrapolated from the advance curves to meet the one-fourth irrigation criterion. The data in Table 9 indicate that the application and distribution efficiencies are increased by increasing the furrow stream size. This flow increase would improve the rate-of-advance. For the unpacked furrow, the water application efficiency did not appear to improve without decreasing the distribution efficiency. For high distribution efficiency, the maximum allowable length of run is 600 feet. This would give a water application efficiency of 50 percent. Since it is not practical to maintain two furrow lengths in a single field, an average length of 900 feet is recommended for this field. At this length a water distribution efficiency of about 94 percent and a water application efficiency of about 61 percent would be expected.

Furrow Irrigation, Area II.

The procedure followed in evaluating furrow irrigation in this area was essentially the same as that used in Area I.

Area II is located in the central section of the study area and is represented by the Heiseton series. The soil type was Heiseton loam. The field was 1150 feet long with an average gradient of 0.27 percent. It was planted to potatoes. The flow rates used in the test were 28 and 30 gallons per minute for the packed furrows, and 33 and 35 gallons per minute for the unpacked furrows. The duration of irrigation in each case was 215 minutes. The depth of water to be applied was estimated as 2.00 inches. The furrow spacing was 36 inches.

The intake characteristics for this test are shown in Figures 23 and 25, and advance curves are shown in Figures 24 and 26.

This investigation shows that it takes about 95 minutes to apply 2 inches of water to the packed furrow, and 48 minutes in the unpacked furrow. This indicates that the furrow streams should be run about 119 and 60 minutes in the packed and unpacked furrows, respectively, to satisfy the one-fourth criterion.

A summary of analysis for this test is shown in Table 10. Data in this table show that the highest attainable water distribution and water application efficiencies for the packed furrow occur when the length of run is decreased to 800 feet and the furrow stream size is increased to 36 gallons per minute. With this variation, the estimated

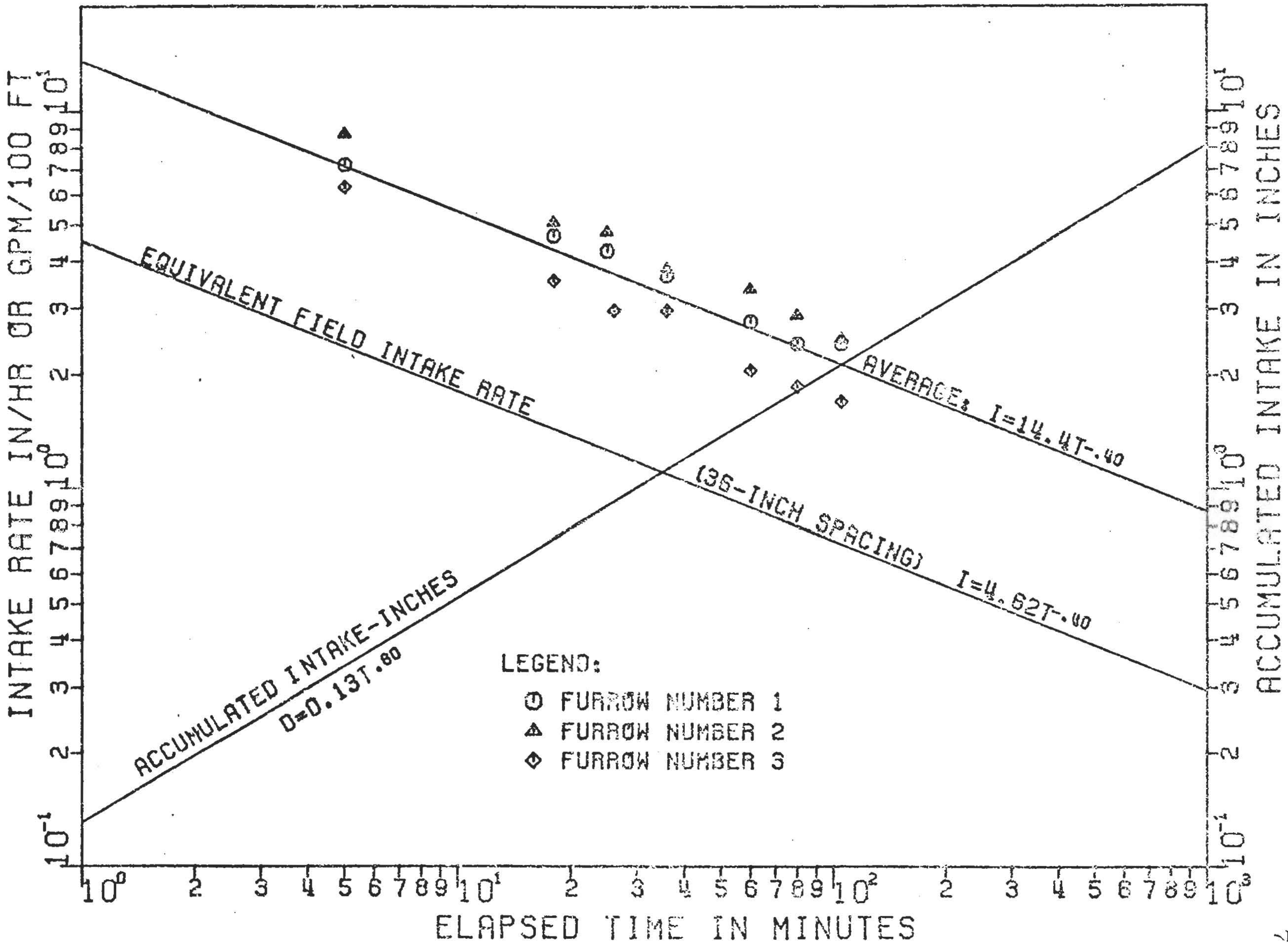



Figure 23. Intake characteristics of packed furrow, Heiseton loam.

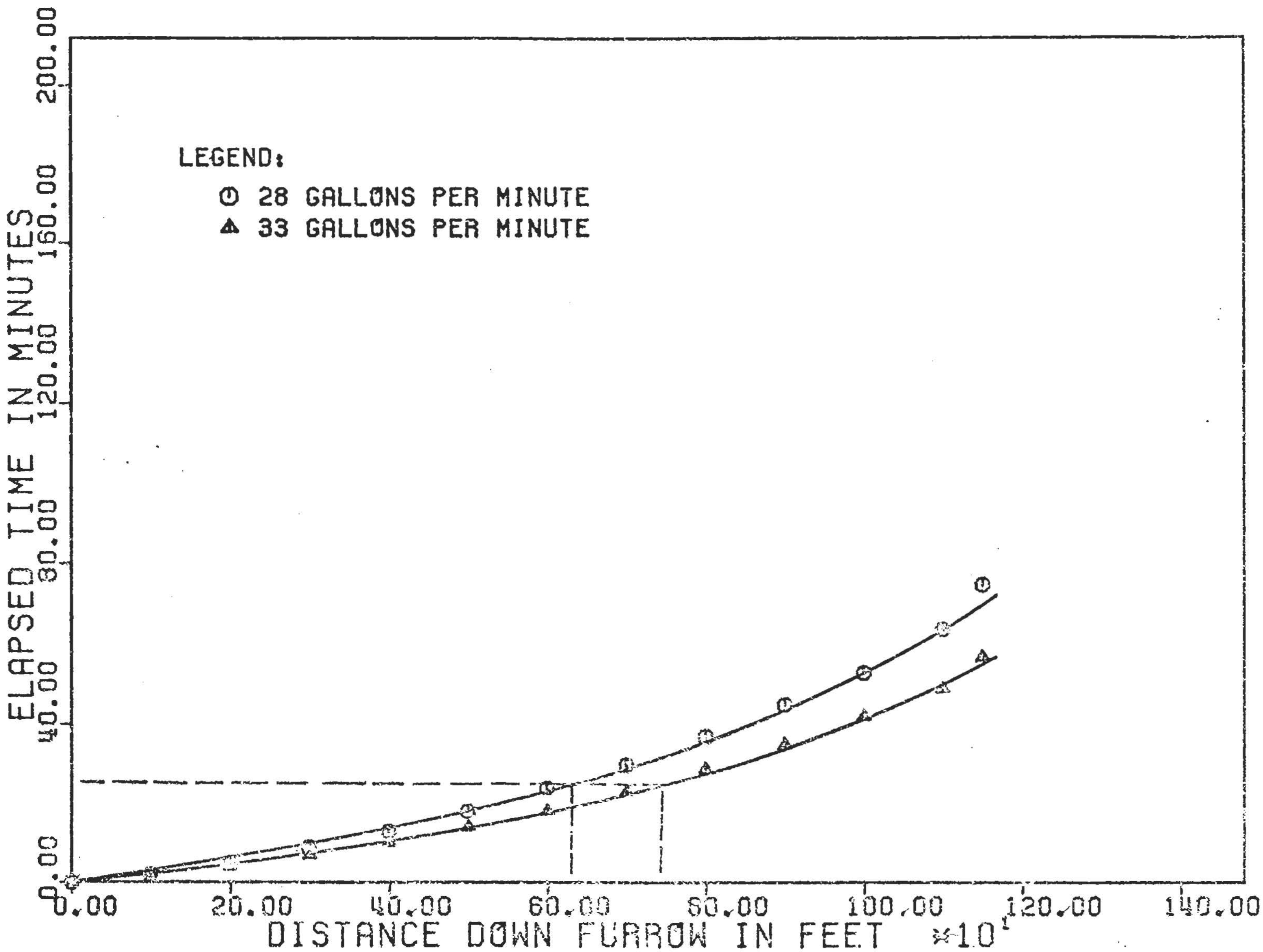



Figure 24. Advance of water on packed furrow, Heiseton loam.

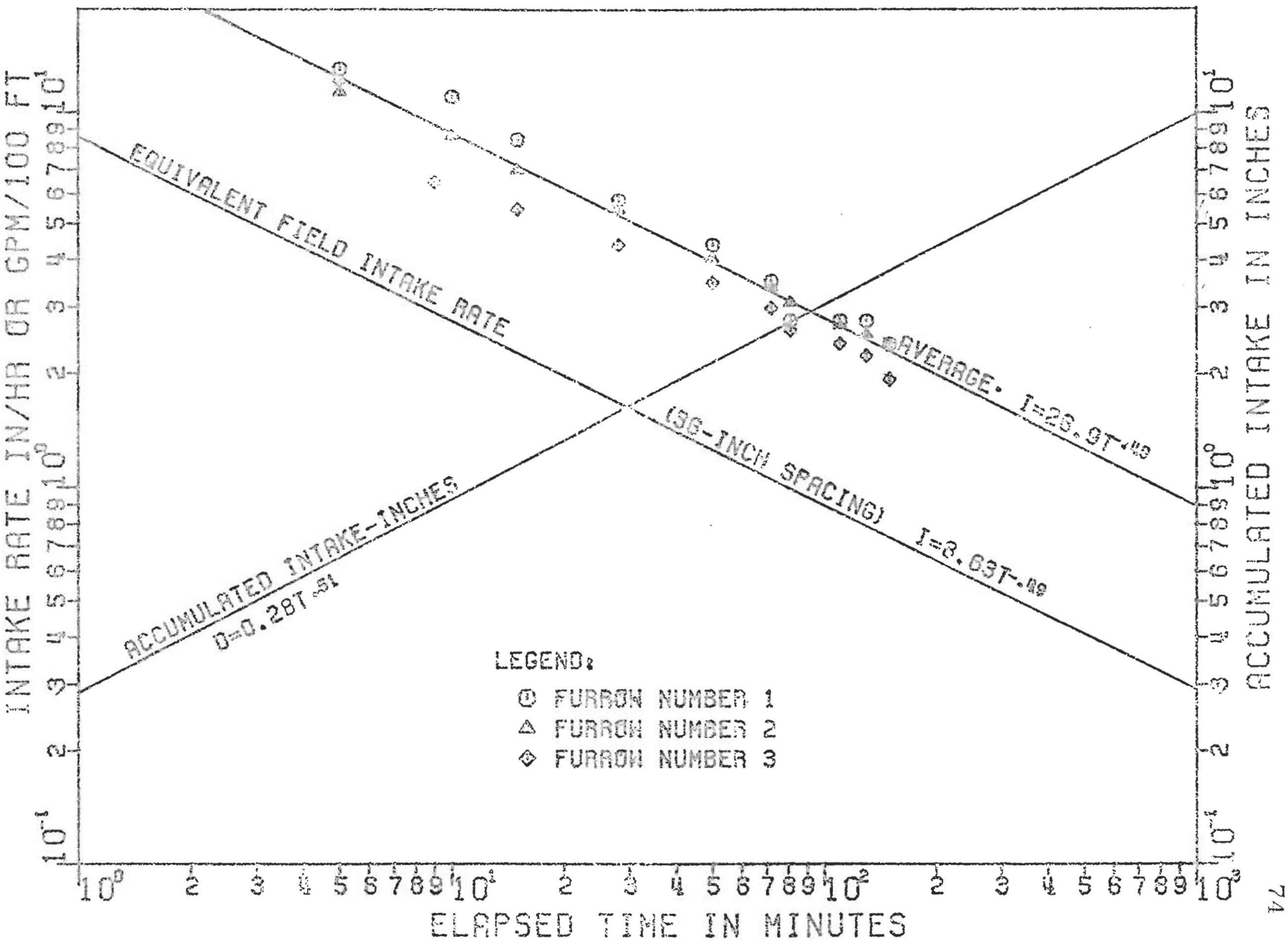



Figure 25. Intake characteristics on unpacked furrow, Heiseton loam.

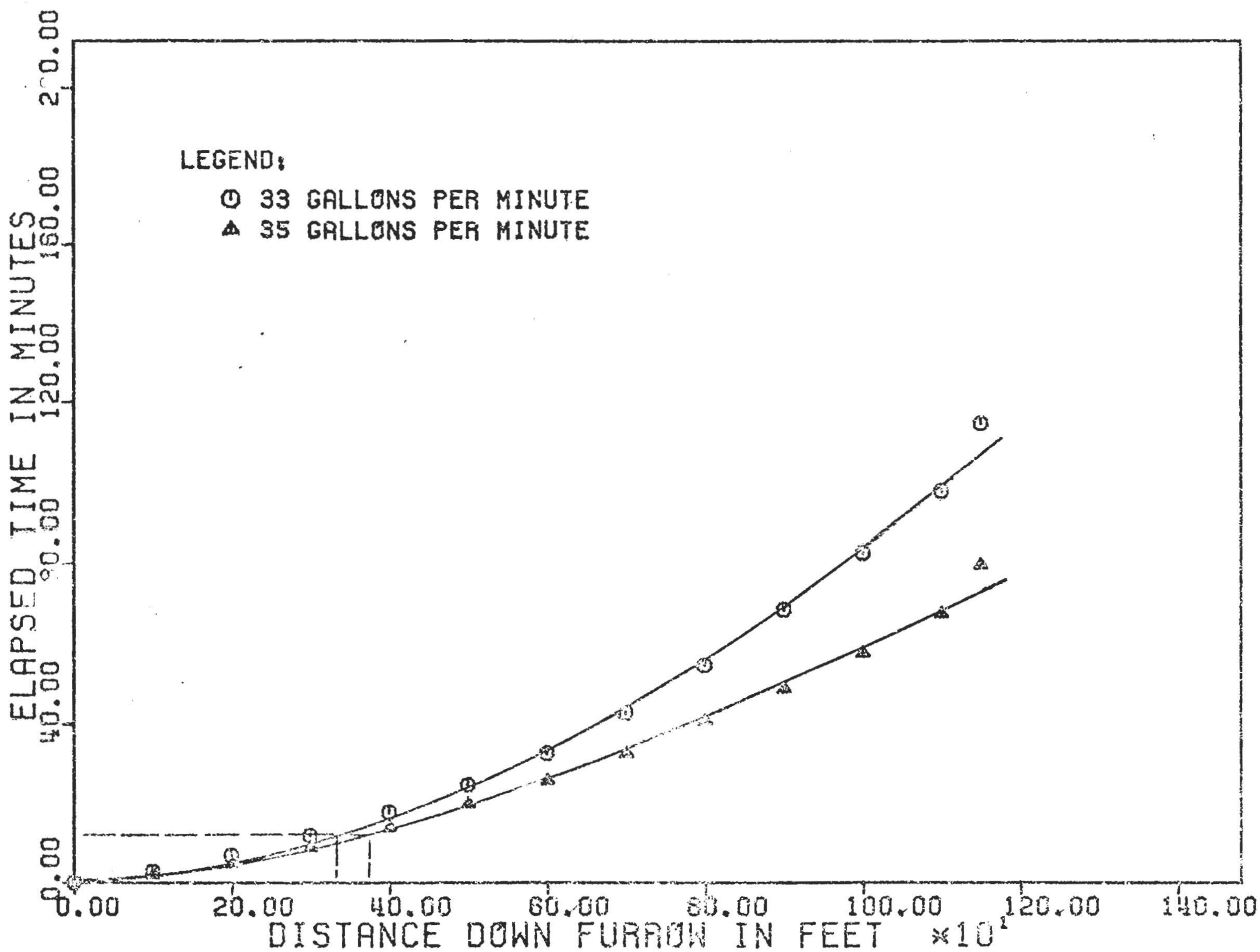



Figure 26. Advance of water on unpacked furrow, Heiseton loam.

Table 10. Effects of furrow length and stream size on furrow irrigation system efficiencies, Heiseton loam.

| | Length of run (ft) | Stream size (gpm) | Application time (min) | Advance time (min) | Intake time (min) | Deep percolation* (%) | Runoff* (%) | $E_d$ (%) | $E_a$ (%) |
|---|---|---|---|---|---|---|---|---|---|
| **Packed furrow** | | | | | | | | | |
| Present system: | 1150 | 28 | 215 | 78 | 137 | 29 | -ω | 79 | 71 |
| Variations | 600 | 26 | 119** | 24 | 95 | 2 | 31 | 93 | 67 |
| | 800 | 36 | 119** | 24 | 95 | 2 | 28 | 93 | 70 |
| | 900 | 38*** | 119** | 24 | 95 | 2 | 23 | 93 | 75 |
| | 1000 | 41*** | 119** | 24 | 95 | 2 | 21 | 93 | 77 |
| **Unpacked furrow** | | | | | | | | | |
| Present system: | 1150 | 33 | 215 | 115 | 100 | 40 | -ω | 82 | 60 |
| Variations | 340 | 33 | 60** | 12 | 48 | 2 | 18 | 93 | 80 |
| | 400 | 37 | 60** | 12 | 48 | 2 | 17 | 93 | 82 |
| | 500 | 43*** | 60** | 12 | 48 | 2 | 6 | 93 | 91 |

* Expressed as a percentage of water applied.
** Based on one-fourth irrigation criterion for 'efficient' irrigation.
*** Exceeded maximum allowable stream size, $Q_{max}$ = 10/S, 37 gpm
-ω No runoff because tailwater was ponded.

water distribution efficiency is 93 percent and the water application efficiency is 77 percent for the packed furrow. Similarly, by decreasing the length to 400 feet and increasing the furrow stream to 37 gallons per minute, the water distribution and water application efficiencies for the unpacked furrow are 93 and 82 percent, respectively. The recommended length for this field is 600 feet for 'efficient' irrigation.

Border Irrigation, Area III.

This area is located in the southern section of the study area and represented by Bannock series. The soil type was Bannock loam with an estimated root zone of 4 feet. The border was 1270 feet long, 65 feet wide with an average gradient of 0.31 percent. The stream flow used by the farmer was 4.2 cubic feet per second. The application time was 370 minutes. The soil moisture deficit was estimated to be 3.00 inches. Recession data were not gathered at all stations because the field was covered with a heavy stand of alfalfa which made observations difficult. In addition, recession was extremely fast after the water supply to the border strip was turned off due to the high intake rate of the soil.

The field data from cylinder infiltrometer tests and water advance observations are presented in Appendices C and D, respectively. The intake characteristics of the soil are shown in Figure 27. The basic intake rate was estimated to be 1.2 inches per hour. The advance curve is presented in Figure 28. As shown in Figure 27, 45 minutes are required to replenish a 3-inch deficit of water. The data in Figure 28 show the stream front reached the lower end of the border in 160 minutes.

It is apparent for this field that the duration of irrigation was too long. Since the intake opportunity time to replace the moisture deficit is only 50 minutes, deep percolation will occur if water is held in the border longer than this length of time. The deep percolation losses could be decreased by increasing the flow rate in the border so that the stream front would reach the end of the irrigation run faster. The water could then be turned off sooner. Another alternative is to lessen the border width to increase the unit flow rate. The length of the border should definitely be shortened. Using the unit stream concept (9), replenishing the 3-inch water deficit with the present irrigation layout would require a unit stream of 0.016 cubic feet per second (from Appendix F). The farmer used 0.0051 cubic feet per second which suggests that the unit stream has to be increased to improve efficiency. The maximum length of run for the present stream size used by the farmer was estimated to be 380 feet. This was computed by dividing the present stream size (4.2 cfs) by the recommended unit stream and

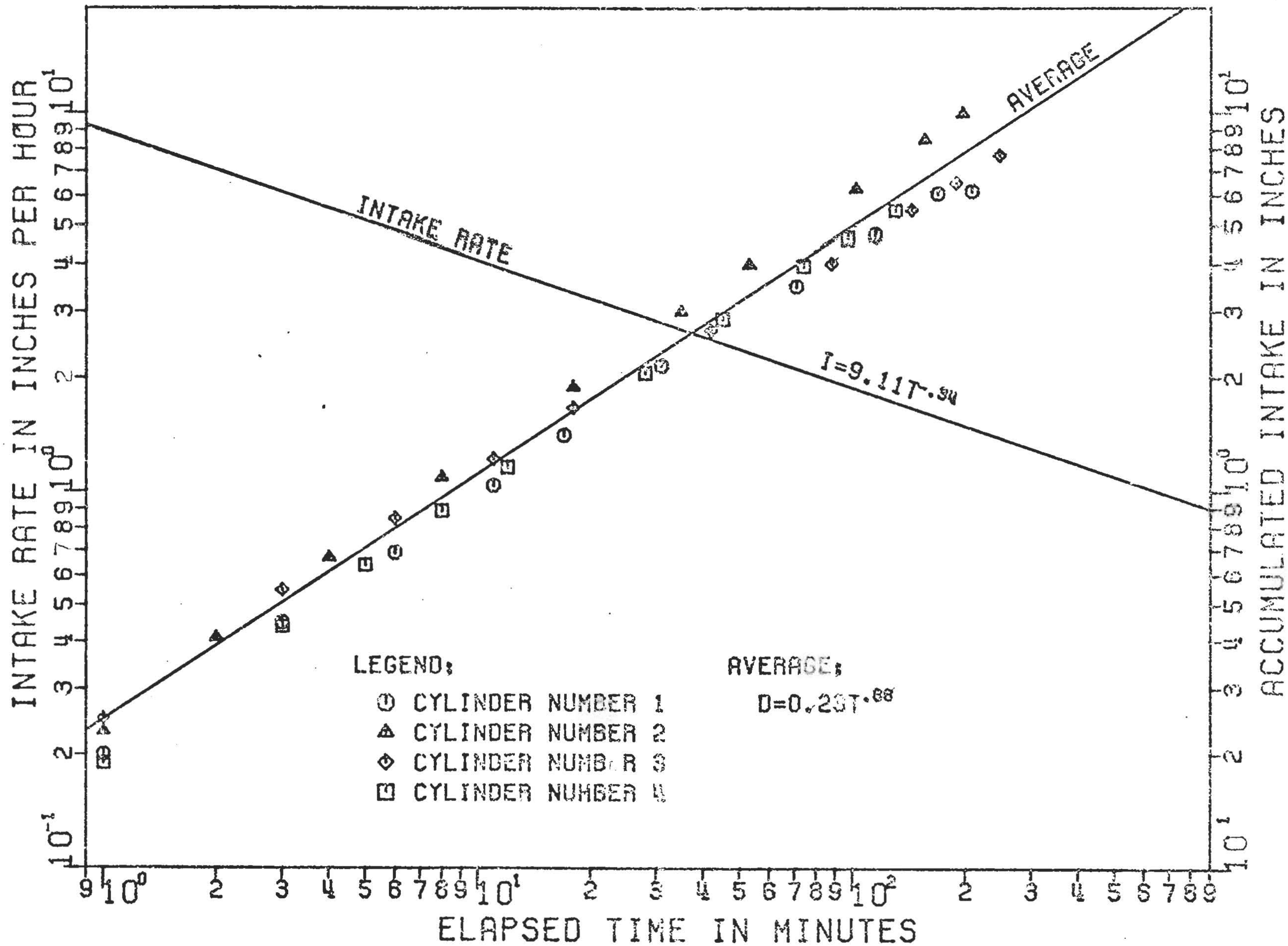



Figure 27. Intake characteristics of Bannock loam.

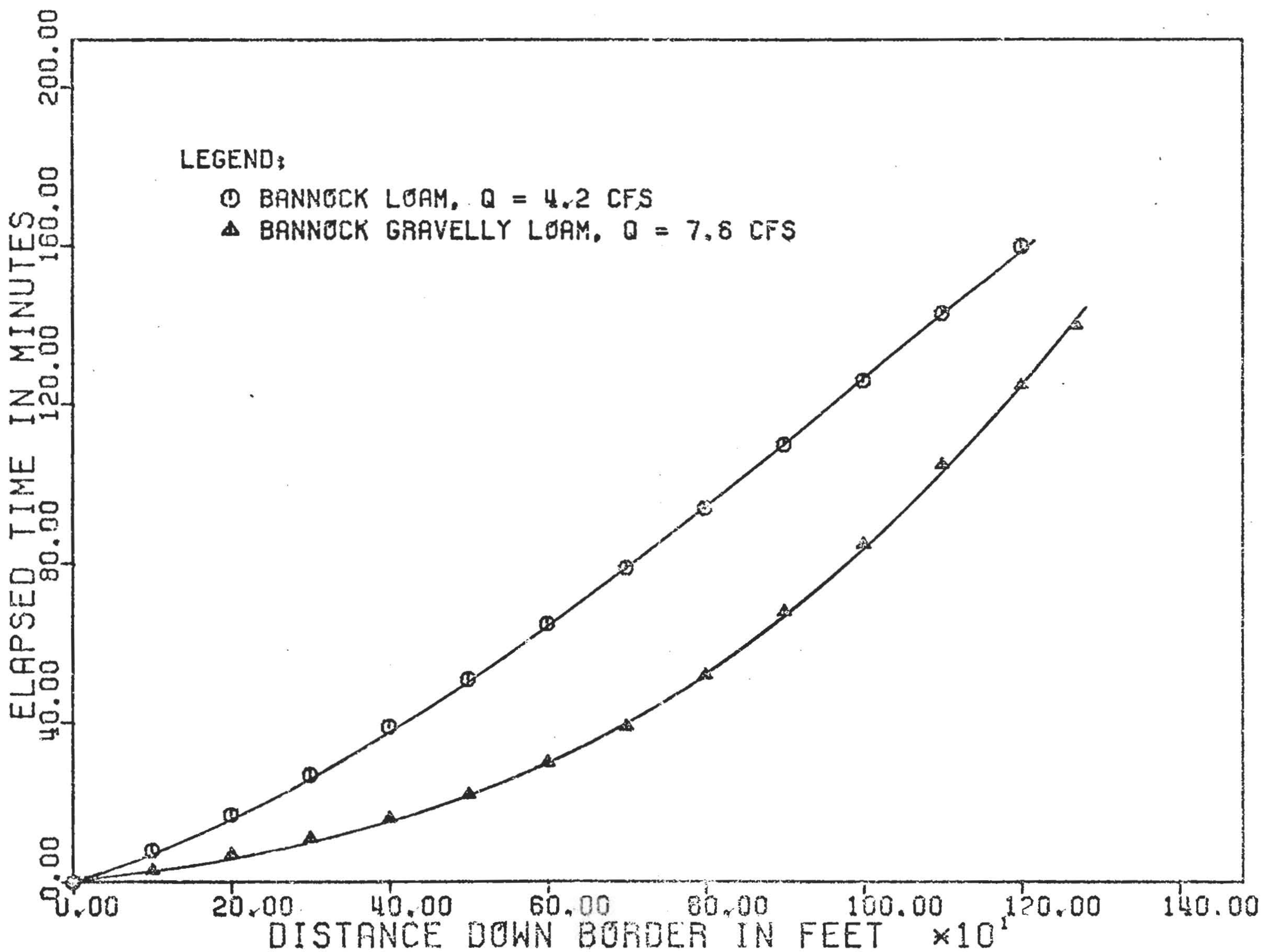



Figure 28. Advance of water in border strips, Bannock loam and Bannock gravelly loam.

and present width of border, multiplied by 100. Although this estimated unit-border stream was not tried for this specific condition, it could be used as an approximate value for evaluation of the present system.

Border Irrigation, Area III.

The representative border strip evaluated was planted to barley, and was 1200 feet long and 66 feet wide. The soil was Bannock gravelly loam with a field slope of 0.29 percent. The irrigation stream used by the farmer was 7.8 cubic feet per second. The estimated water deficiency was 3.5 inches for an assumed root zone of 3.0 feet.

The results of the infiltration test for this soil are shown in Figure 29. As shown in this figure, the infiltration in this field was very high. The basic infiltration rate was estimated to be 1.9 inches per hour. To add 3.5 inches of moisture to the soil would only require 38 minutes whereas the farmer applied water to this strip in 195 minutes.

Again, similar to the first border test, the duration of irrigation was too long for this strip. Therefore, it must be lessened to prevent excessive water losses. The farmer used a unit stream of 0.0098 cfs and the recommended unit stream is 0.020 cfs. The maximum length for the present stream size in this field for 'efficient' irrigation would

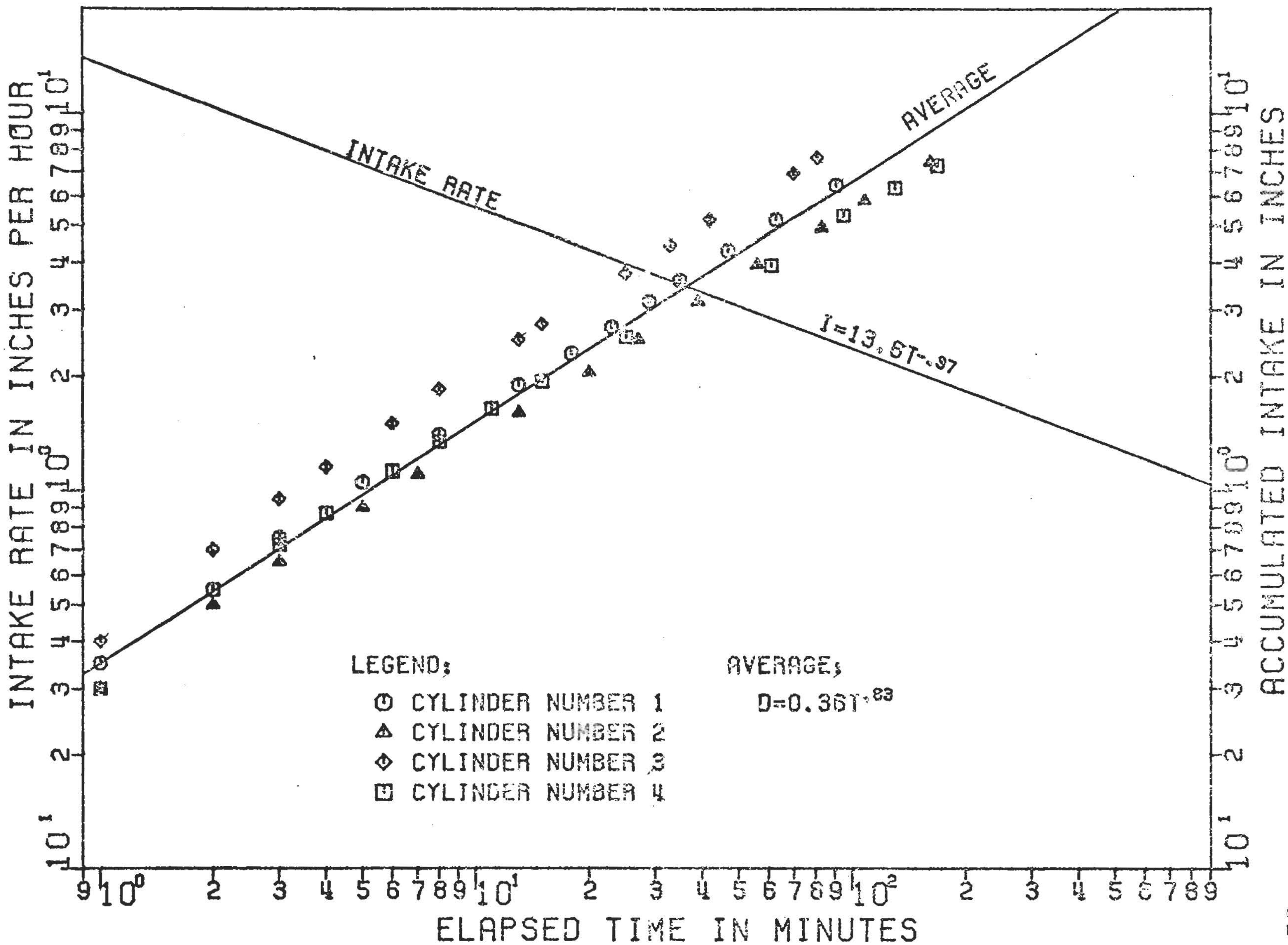



Figure 29. Intake characteristics of Bannock gravelly loam.

be 600 feet and this represents about 50 percent of the existing field length. Additional observations from adjacent strips showed that water advance was not even and that the irrigator applied water until all land surfaces were wetted. This resulted in a build-up of water at the lower end of the border, and excessive water loss.

Border Irrigation, Area I.

The border strip evaluated was planted to alfalfa. The soil type was Blackfoot silt loam. The border was 750 feet long and 58 feet wide with a gradient of 0.23 percent. The stream size used by the farmer in this strip was 2.4 cubic feet per second. The estimated water deficiency was 2.8 inches for a root zone depth of 4.0 feet. The rate-of-advance data were taken during the start of the test but, were discontinued because of extremely uneven movement of the stream front. The uneven movement was caused by the non-uniform gradient of this strip.

The intake characteristics of the soil are presented in Figure 30. The basic intake rate was estimated to be 0.75 inches per hour. As shown in Figure 30, it would require approximately 72 minutes to replenish the 2.8 water deficit. This strip was irrigated by the farmer for approximately 200 minutes.

Again, the duration of irrigation was too long for this

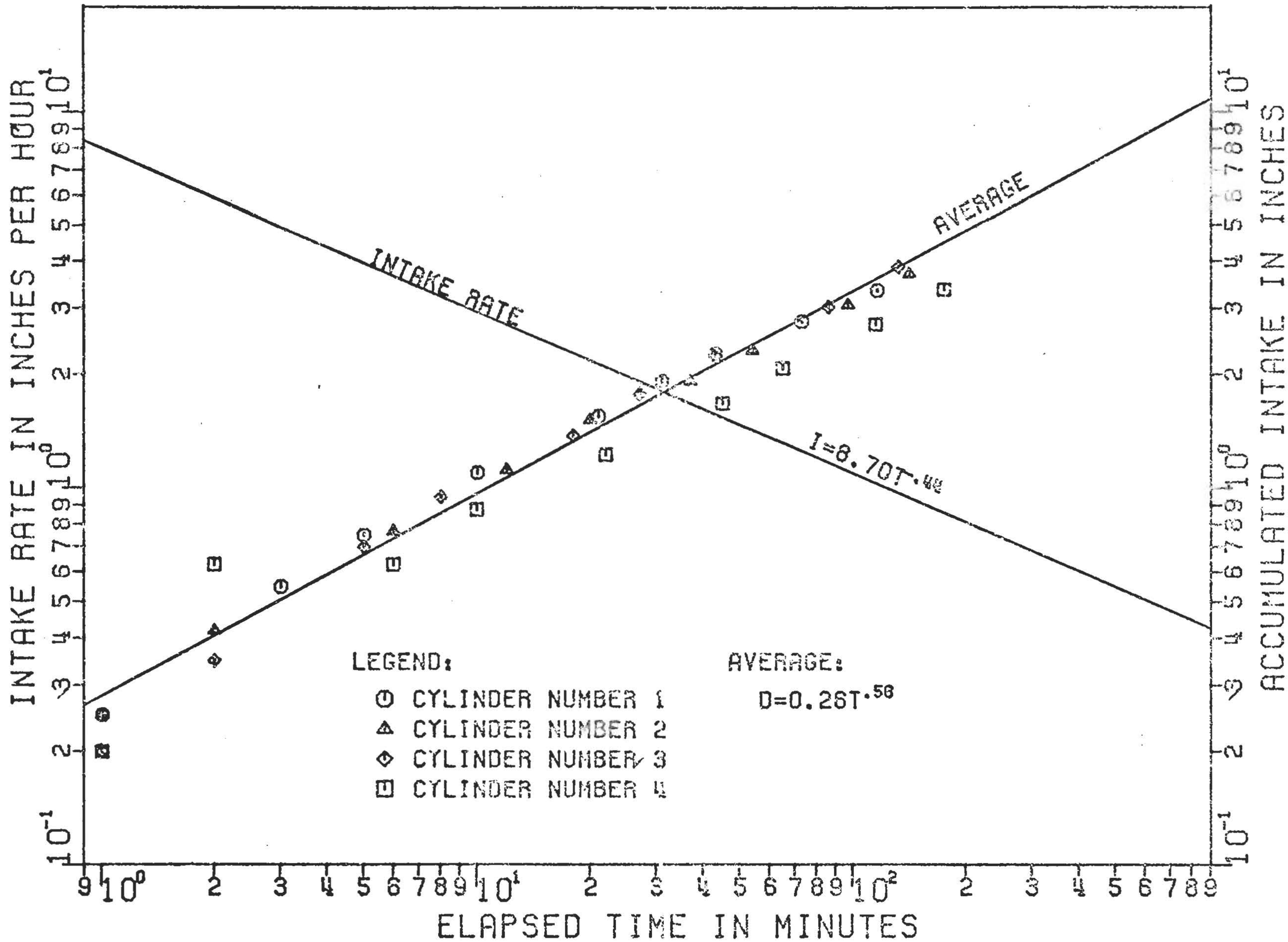



Figure 30. Intake characteristics of Blackfoot silt loam.

border strip. The water must be turned off sooner to reduce water losses. In addition, additional land leveling should be done to insure even movement for the advancing stream front. The unit stream used by the farmer was 0.0055 cfs and the recommended unit stream is 0.009 cfs for 'efficient' irrigation. The allowable length of the field for the present condition would be 480 feet.

# CONCLUSIONS

The results of the field tests conducted indicate that inefficient irrigation is practiced in the study area. They indicate that the present irrigation systems and practices should be improved. The results of the tests show average water application efficiencies of 24 percent and 51 percent for border and furrow irrigation, respectively.

Since all the sampled fields have no drainage systems to carry runoff, all excess water was ponded at the end of the irrigation run. Hence, percolation amounted to 76 and 49 percent of the water delivered to border and furrow irrigated fields, respectively.

The primary factors that cause low water application efficiencies in the study area are high water intake rates of soils, long set times and long field runs. The first factor is beyond the control of the irrigator but the systems could be modified to suit the prevailing conditions. The second is a management factor and can be controlled by proper attention and intelligent judgement of the farmer during irrigation. The third is a design factor which can be adjusted by redesigning the system.

The labor input in both border and furrow irrigation did not seem to significantly affect water application efficiencies in the study area.

Although large streams were recorded during the tests, it appears that stream size needs to be increased to improve rate-of-advance due to the high intake rates of the soils and long irrigation runs. Care, however, should be taken not to use streams large enough to cause erosion.

No specific length of border and furrow irrigated field can be defined for efficient irrigation although the estimated allowable length of each sampled field can be good approximations. The estimated maximum allowable length of fields irrigated, for most soils encountered, is 775 feet for furrow irrigation and 485 feet for border irrigation.

Although the results in this study were obtained from fields believed to be representative of the area, several variables actually exist and it might be misleading to apply these data to the entire Snake River Fan area of Jefferson County.

In general, it could be stated, based on this study, that the present irrigation practices, operations and system designs need to be improved. The question, however, is would the farmer be willing to invest additional labor, time and capital to reduce water loss and improve water application efficiency? Is he willing to improve his existing system from the standpoint of water conservation? It appears that there is no economic incentive at the present time for the farmer to improve his irrigation practices and systems because water is plentiful in the area and low in cost. If it could be shown that excessive water application leaches soluble plant nutrients and causes water logging thus decreasing crop yields there would be more incentive for improving irrigation practices and systems in the study area.

# BIBLIOGRAPHY


1. Annual Report, 1972-73. Dept. of Agricultural Engineering. College of Agriculture. Miscellaneous Series 19. University of Idaho.

2. Bondurant, J.A. 1960. Hydraulics of surface irrigation. Proc. of the ARS-SCS Workshop on Hydraulics of Surface Irrigation, ARS41-43, Denver, Colorado.

3. Bondurant, J.A. 1957. Developing furrow infiltrometer. ASAE J. 38 (7):602-604.

4. Brockway, C. E., J.A. Bondurant and R. V. Worstell. 1971. Systems analysis of irrigation water management of eastern Idaho. Progress Report No. 1. University of Idaho Engr. Expt. Sta., 36 p.

5. Brockway, C. E. and J. de Sonneville. 1973. Systems analysis of irrigation water management in eastern Idaho. WRRI, University of Idaho Research Tech. Completion Report, 73 p.

6. Brockway, C.E. 1971. Unpublished research data on water management survey, Jefferson County, Idaho. University of Idaho, Kimberly, Idaho.

7. Buckman, H.O. and N.C. Brady. 1961. The nature and properties of soils. The Macmillan Co., New York.

8. Christiansen J.E., A.A. Bishop, F.W. Kiefer, and Yu-si Fok. 1966. Evaluation of intake rate constants as related to advance of water in surface irrigation. ASAE Trans. 9(5):671-674.

9. Criddle, W.D., S. Davis, C.H. Pair and D. G. Shockley. 1956. Methods for evaluating irrigation systems. Agricultural Handbook No. 82., Soil Conservation Service, USDA, Washington, D. C.

10. Corey, G. L., C. L. Tyler and L. R. Swarner. 1964. Evaluating water use on a new irrigation project. Idaho Agricultural Expt. Sta. Bull. No. 62. 24 p.

11. Corey, G. L., and V. I. Myers. 1955. Irrigation of Russett Burbank Potatoes in Idaho. Idaho Agricultural Experiment Station Bull. No. 246, Oct. 1955.

12. Davis, J.R. 1961. Estimating rate of advance from irrigation furrows. ASAE Trans. 4(1):52-54.

13. Erie, L.J. 1968. Management: Key to irrigation efficiency. ASCE Proc. 94(IR3):285-292.

14. Fok, Yu-Si, and A.A. Bishop. 1965. Analysis of water advance in surface irrigation. ASCE Proc. 91(IR1): 99-116.

15. Fischback, P.E. and B.R. Somerhalder. 1971. Efficiencies of an automated surface irrigation system with and without a runoff re-use system. ASCE Trans. 14(4):717-719.

16. Gilley, J.R. 1968. Intake function and border irrigation. Unpublished Master's thesis. Colorado State University, Fort Collins, Colorado.

17. Hall, W.A. 1960. Performance parameters of irrigation systems. ASAE Trans. 3(1):75-76,81.

18. Hall, W.A. 1956. Estimating border flow. ASAE J. 37(4):263-265.

19. Hansen, V.E. 1957. New concepts in irrigation efficiencies. Paper presented at the Annual Meeting, ASAE, East Lansing, Michigan, June 24, 1957.

20. Humphreys, A.S. 1971. Automatic furrow irrigation systems. ASAE Trans. 14(3):466-470.

21. Israelsen, O.W. and V.E. Hansen. 1962. Irrigation principles and practices. John Wiley and Sons, Inc., New York.

22. Israelsen, O.W. 1939. Water application efficiencies in irrigation and soil conservation. ASAE J. 20(11): 423-425.

23. Jensen, M.E. and O.W. Howe. 1965. Performance and design of border checks on sandy soil. ASAE Trans. 8(1):141-145.

24. Jensen, M.E. 1967. Evaluating irrigation efficiency. ASCE Proc. 98(IR2):239-246.

25. Kruse, E.G., P.E. Schleusener, W.E. Selby and B.R. Somerhalder. 1962. Sprinkler and furrow irrigation efficiencies. ASAE J. 43(11):636-639.

26. Korven, G.C. 1962. Border ditch and border dike irrigation. ASAE Trans. 5(2):192-196.

27. Linderman, C.L. 1968. An analysis of factors affecting surface irrigation efficiencies. Unpublished Master's Thesis. North Dakota State University, Fargo, North Dakota.

28. Linsley, R.K. and J.B. Franzini. 1972. Water-resources engineering. McGraw Hill Book Co., New York.

29. Meriam, J.L. 1968. Irrigation systems evaluation and improvement. Blake Printery, Monterey, San Luis Obispo, California. 57p.

30. Monson, O.W. 1960. Mathematical analysis of border flooding for efficient irrigation. Agricultural Expt. Sta. Paper No. 477, Montana State College.

31. Phelan, J.T. and W.D. Criddle. 1955. Surface irrigation methods, In water, The Yearbook of Agriculture. U.S. Department of Agriculture, Washington, D.C., U.S. Government Printing Office.

32. Pair, C.H. 1962. Effects of irrigation methods and system management on water application efficiency. Trans. of the 5th Congress of Irrigation and Drainage, Tokyo, Japan, Question 16, pp. 145-159.

33. Shockley, D.G., H.J. Woodward and J.T. Phelan. 1964. A quasi-rational method of border irrigation design. ASAE Trans. 7(4):420-423,426.

34. Somerhalder, B.R. 1958. Comparing efficiencies in irrigation water application. ASAE J. 39(3):156-159.

35. Steele, R.G.D. and J. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York.

36. United States Bureau of Reclamation. 1969. Use of water on federal irrigation projects. Detailed Report of Region 7, Denver, Colorado.

37. Willardson, L.S. 1972. Attainable irrigation efficiencies. ASCE Proc. 98(IR2):239-246.

# APPENDICES

# APPENDIX A

## GLOSSARY OF TERMS

# GLOSSARY OF TERMS

Apparent specific gravity (bulk density) - the ratio of the weight of a given volume of dry soil, including the air space, to the weight of equal volume of water.

Available moisture - the difference in moisture content between the field capacity and permanent wilting point.

Border irrigation - method of applying irrigation water to a sloping area usually rectangular in shape bounded by borders on the sides to guide a moving sheet of water as it flows down the border strip.

Consumptive use (evapotranspiration) - the sum of the amount of water transpired by the plant plus evaporation from adjacent soil surfaces.

Consumptive use efficiency - the ratio of the normal consumptive use of water to the net amount of water depleted from the root zone in the soil.

Correlation coefficient - a number indicating how closely two variables are related. This number varies between plus one and minus one. Plus one indicates a perfect correlation, zero indicates no correlation and minus one indicates perfect negative correlation, that is, as one variable increases the other decreases.

Cut back - the process of reducing the stream size in a furrow or border strip in order to reduce excessive runoff.

Deep percolation - the portion of the water delivered to the field which percolates beyond the soil root zone and is therefore unavailable for consumptive use.

Field capacity - the moisture content of the soil when all gravitational water has been drained. About one third atmosphere tension in the soil is normally considered the field capacity.

Furrow irrigation - the method of applying water to a small, sloping channel cut or pressed into the soil.

Infiltration rate - the rate at which water can enter the surface of the soil.

Length of run - the actual length of field where the stream of water will run during irrigation.

Method of least squares - a method of obtaining the slope of a line which best fits a number of plotted points.

Packed furrow (wheel furrow) - the furrow where the tractor wheels travel during cultivation.

Permanent wilting point - the moisture content of the soil when a plant wilts permanently. A plant will not recover after being placed in a saturated atmosphere where little or no evapotranspiration occurs.

Soil series - a group of soils developed from the same kind of parent material by the same genetic combination of processes, and whose horizons are similar in their arrangement and general characteristics. An example is Blackfoot series.

Soil type - the subdivision of the soil series on the basis of the A horizon. An example is Blackfoot silt loam.

Unpacked furrow (center furrow) - the untravelled furrow during cultivation.

Unit stream - the total stream applied to a border strip divided by the width of the strip and the length of the field in hundreds of feet.

Water application efficiency - the ratio of the amount of water stored in the root zone depth divided by the amount of water delivered.

# APPENDIX B

## DETAILED DESCRIPTION OF THE SOIL SERIES IN THE STUDY AREA

# BLACKFOOT SERIES*

The Blackfoot series is a member of the fine-loamy, mixed, frigid family of Fluventic Haploxerolls. Typically, Blackfoot soils have a grayish brown silt loam Ap horizon, light brownish gray silt loam and silty clay loam C horizons, and stratified silt loam and sandy loam from 35 to more than 60 inches.

Range of characteristics. The mean soil temperature ranges from 42° to 46°F. The organic carbon has an irregular decrease with depth to a level of 0.3 percent or less within 50 inches of the surface. The soil is usually moist but dry between 10 and 40 inches for 60 to 90 consecutive days during the summer months. The 10 to 40-inch control section has 18 to 27 percent clay as a weighted average. The soil is slightly to moderately calcareous. Some pedons have stratified sandy loams, loams and loamy sand below 25 inches. Depth to sand and gravel is greater than 60 inches. The Ap horizon has color values of 5 or 6 dry, and 3 moist, and chroma of 1 or 2. Textures are loams and silt loams.

Setting. These soils are on nearly level or channeled river terraces. Elevations are 4,700 to 5,000 feet. Slopes are between 0 to 1 percent. These soils are formed in mixed alluvium.

Drainage and permeability. Moderately well drained; runoff is very slow; moderately permeable. The formation of the profile was under somewhat poorly drained conditions but it is presently moderately well drained. The water table fluctuates between 4 and 6 feet.

Use. Used mostly for irrigated hay, small grains, pasture, potatoes and some sugar beets.

---

* This series description was supplied by the Soil Conservation Service, Rigby, Idaho.

## HEISETON SERIES*

The Heiseton series is a member of the coarse, mixed, calcareous, frigid family of Xeric Torriorthents. Typically, Heiseton soils have a grayish brown or brown loam A1 or Ap horizon and light gray and light brownish gray sandy loam, very fine sandy loam, and loamy sand C horizons that have mottles below 20 inches.

Range in characteristics. The mean annual soil temperature ranges from 42 to 46°F, and the mean summer temperature at a depth of 20 inches ranges from 60 to 66°F. The 10 to 40 inches control section contains less than 18 percent clay and less than 15 percent rock fragments. The solum ranges from 5 to 10 inches thick. The entire profile is slightly to moderately calcareous, but no distinct calcic horizon is commonly present. The profile ranges from mildly to moderately alkaline. The A horizon when mixed to 7 inches has a value of 5 or 6 dry and 3.5 moist, with chroma of 2 or 3. The C1 horizon has value of 5.5 to 6.5 dry, 3.5 to 4.5 moist, and chroma of 2 or 3. It is dominantly sandy loam or loam but may be silt loam or loamy sand.

Setting. The soils are on level river flood plains and low stream terraces at elevations of 4,200 to 5,000 feet. Slopes range from 0 to 1 percent. The soil is formed mainly in moderately coarse textured mixed alluvium which may overlay sand and gravel or other stratified sediments at depths greater than 60 inches.

Drainage and permeability. Moderately well drained; slow or medium runoff; moderately rapid permeability.

Use. Primarily cultivated under irrigation for hay, small grains, pasture and some potatoes.

---

* This series description was supplied by the Soil Conservation Service, Rigby, Idaho.

## BANNOCK SERIES*

The Bannock series is a member of the coarse-loamy over sandy skeletal, mixed, frigid family of Aridic Calcixerolls. Typically, Bannock soils have grayish brown loam A1 or Ap horizons, grayish brown and light brownish gray loam B horizons, strongly calcareous Cca horizons, and gravel and sand within 40 inches of the surface.

Range in characteristics. The mean annual soil temperature ranges from 41 to 47°F and the mean summer soil temperature at a depth of 20 inches ranges from 59 to 66°F. The soils are usually dry and are dry for about 60 to 85 consecutive days during the late summer. The mollic epipedon is 6 to 11 inches thick. The A and B horizons range from moderately calcareous to non-calcareous. The A1 horizons have value of 4.5 to 5.5 dry and 2.5 to 3.5 moist and chroma of 2 or 3. The B horizon has value of 5 or 6 dry and 3 to 4 moist and a chroma of 2 or 3. It is dominantly loam but is gravelly or silt loam in some pedons.

Setting. The soils are on level to sloping stream terraces and alluvial fans at elevations of 4,200 to 5,900 feet. Slopes range from 0 to 10 percent. The soils formed mostly in medium textured alluvium over gravel and sand. The alluvium is dominantly from quartzite and sedimentary rock sources.

Drainage and permeability. Well drained; slow or medium runoff; moderate permeability in A and B horizons and very rapid in the gravel and sand.

Use. Mostly cultivated under irrigation for hay, pasture, potatoes and small grains.

---

* This series description was supplied by the Soil Conservation Service, Rigby, Idaho.

# APPENDIX C

# INFILTRATION TEST DATA

# RING INFILTROMETER TEST

AREA 1
BLACKFOOT SILT LOAM
SLOPE = 0.31 %
ALFALFA FIELD
NEWLY CUT FIELD

| CLOCK TIME HR MIN | TIME DIFFER-ENCE (MIN) | TIME CUMULA-TIVE (MIN) | READING BEFORE FILLING (IN) | READING AFTER FILLING (IN) | INTAKE DEPTH DURING PERIOD (IN) | INTAKE RATE DURING PERIOD (IN) | ACCUMULATED INTAKE DEPTH (IN) |
|---|---|---|---|---|---|---|---|
| | | | CYLINDER NUMBER 1 | | | | |
| 3:28 | 0. | 0. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3:29 | 1. | 1. | 0.25 | 0.0 | 0.25 | 15.00 | 0.25 |
| 3:31 | 2. | 3. | 0.30 | 0.0 | 0.30 | 9.00 | 0.55 |
| 3:33 | 2. | 5. | 0.20 | 0.0 | 0.20 | 6.00 | 0.75 |
| 3:38 | 5. | 10. | 0.35 | 0.0 | 0.35 | 4.20 | 1.10 |
| 3:49 | 11. | 21. | 0.45 | 0.0 | 0.45 | 2.45 | 1.55 |
| 3:59 | 10. | 31. | 0.37 | 0.0 | 0.37 | 2.22 | 1.92 |
| 4:11 | 12. | 43. | 0.35 | 0.0 | 0.35 | 1.75 | 2.27 |
| 4:41 | 30. | 73. | 0.50 | 0.0 | 0.50 | 1.00 | 2.77 |
| 5:24 | 43. | 116. | 0.58 | 0.0 | 0.58 | 0.81 | 3.35 |
| | | | CYLINDER NUMBER 2 | | | | |
| 3:46 | 0. | 0. | 0.0 | 2.00 | 0.0 | 0.0 | 0.0 |
| 3:47 | 1. | 1. | 2.25 | 2.00 | 0.25 | 15.00 | 0.25 |
| 3:48 | 1. | 2. | 2.17 | 2.00 | 0.17 | 10.20 | 0.42 |
| 3:52 | 4. | 6. | 2.35 | 2.00 | 0.35 | 5.25 | 0.77 |
| 3:58 | 6. | 12. | 2.35 | 2.00 | 0.35 | 3.50 | 1.12 |
| 4: 6 | 8. | 20. | 2.40 | 2.00 | 0.40 | 3.00 | 1.52 |
| 4:23 | 17. | 37. | 2.40 | 2.00 | 0.40 | 1.41 | 1.92 |
| 4:40 | 17. | 54. | 2.40 | 2.00 | 0.40 | 1.41 | 2.32 |
| 5:23 | 43. | 97. | 2.75 | 2.00 | 0.75 | 1.05 | 3.07 |
| 6: 7 | 44. | 141. | 2.65 | 2.00 | 0.65 | 0.89 | 3.72 |
| | | | CYLINDER NUMBER 3 | | | | |
| 3:55 | 0. | 0. | 0.0 | 2.30 | 0.0 | 0.0 | 0.0 |
| 3:56 | 1. | 1. | 2.50 | 2.00 | 0.20 | 12.00 | 0.20 |
| 3:57 | 1. | 2. | 2.15 | 2.00 | 0.15 | 9.00 | 0.35 |
| 4: 0 | 3. | 5. | 2.35 | 2.00 | 0.35 | 7.00 | 0.70 |
| 4: 3 | 3. | 8. | 2.25 | 2.00 | 0.25 | 5.00 | 0.95 |
| 4:13 | 10. | 18. | 2.43 | 2.00 | 0.43 | 2.58 | 1.38 |
| 4:22 | 9. | 27. | 2.40 | 2.00 | 0.40 | 2.67 | 1.78 |
| 4:38 | 16. | 43. | 2.47 | 2.00 | 0.47 | 1.76 | 2.25 |
| 5:21 | 43. | 86. | 2.78 | 2.00 | 0.78 | 1.09 | 3.03 |
| 6: 7 | 46. | 132. | 2.85 | 2.00 | 0.85 | 1.11 | 3.88 |

(CONTINUATION)

| CLOCK TIME HR MIN | TIME DIFFER-ENCE (MIN) | TIME CUMULA-TIVE (MIN) | READING BEFORE FILLING (IN) | READING AFTER FILLING (IN) | INTAKE DEPTH DURING PERIOD (IN) | INTAKE RATE DURING PERIOD (IN) | ACCUMULATED INTAKE DEPTH (IN) |
|---|---|---|---|---|---|---|---|
| | | | CYLINDER NUMBER 4 | | | | |
| 4:15 | 0. | 0. | 0.0 | 1.00 | 0.0 | 0.0 | 0.0 |
| 4:16 | 1. | 1. | 1.20 | 0.0 | 0.20 | 12.00 | 0.20 |
| 4:17 | 1. | 2. | 0.13 | 0.0 | 0.13 | 7.80 | 0.33 |
| 4:21 | 4. | 6. | 0.30 | 0.0 | 0.30 | 4.50 | 0.63 |
| 4:25 | 4. | 10. | 0.25 | 0.0 | 0.25 | 3.75 | 0.88 |
| 4:37 | 12. | 22. | 0.35 | 0.0 | 0.35 | 1.75 | 1.23 |
| 5: 0 | 23. | 45. | 0.45 | 0.0 | 0.45 | 1.17 | 1.68 |
| 5:20 | 20. | 65. | 0.40 | 0.0 | 0.40 | 1.20 | 2.08 |
| 6:10 | 50. | 115. | 0.65 | 0.0 | 0.65 | 0.78 | 2.73 |
| 7:10 | 60. | 175. | 0.65 | 0.0 | 0.65 | 0.65 | 3.38 |

# RING INFILTROMETER TEST

AREA 3
PANNOCK LOAM
SLOPE = 0.26 %
ALFALFA FIELD
HEAVY STAND

| CLOCK TIME HR MIN | TIME DIFFER-ENCE (MIN) | TIME CUMULA-TIVE (MIN) | READING BEFORE FILLING (IN) | READING AFTER FILLING (IN) | INTAKE DEPTH DURING PERIOD (IN) | INTAKE RATE DURING PERIOD (IN) | ACCUMULATED INTAKE DEPTH (IN) |
|---|---|---|---|---|---|---|---|
| | | | CYLINDER NUMBER 1 | | | | |
| 9:49 | 0. | 0. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9:50 | 1. | 1. | 0.20 | 0.0 | 0.20 | 12.00 | 0.20 |
| 9:52 | 2. | 3. | 0.25 | 0.0 | 0.25 | 7.50 | 0.45 |
| 9:55 | 3. | 6. | 0.24 | 0.0 | 0.24 | 4.80 | 0.69 |
| 10: 0 | 5. | 11. | 0.35 | 0.0 | 0.35 | 4.20 | 1.04 |
| 10: 6 | 6. | 17. | 0.37 | 0.0 | 0.37 | 3.70 | 1.41 |
| 10:20 | 14. | 31. | 0.74 | 0.0 | 0.74 | 3.17 | 2.15 |
| 11: 0 | 40. | 71. | 1.35 | 0.0 | 1.35 | 2.02 | 3.50 |
| 11:44 | 44. | 115. | 1.25 | 0.0 | 1.25 | 1.70 | 4.75 |
| 12:38 | 54. | 169. | 1.35 | 0.0 | 1.35 | 1.50 | 6.10 |
| 1:17 | 39. | 208. | 0.09 | 0.0 | 0.09 | 0.14 | 6.19 |
| | | | CYLINDER NUMBER 2 | | | | |
| 10: 1 | 0. | 0. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10: 2 | 1. | 1. | 0.23 | 0.0 | 0.23 | 13.80 | 0.23 |
| 10: 3 | 1. | 2. | 0.18 | 0.0 | 0.18 | 10.80 | 0.41 |
| 10: 5 | 2. | 4. | 0.26 | 0.0 | 0.26 | 7.80 | 0.67 |
| 10: 9 | 4. | 8. | 0.42 | 0.0 | 0.42 | 6.30 | 1.09 |
| 10:19 | 10. | 18. | 0.80 | 0.0 | 0.80 | 4.80 | 1.89 |
| 10:36 | 17. | 35. | 1.10 | 0.0 | 1.10 | 3.88 | 2.99 |
| 10:54 | 18. | 53. | 1.00 | 0.0 | 1.00 | 3.33 | 3.99 |
| 11:43 | 49. | 102. | 2.30 | 0.0 | 2.30 | 2.82 | 6.29 |
| 12:37 | 54. | 156. | 2.20 | 0.0 | 2.20 | 2.44 | 8.49 |
| 1:18 | 41. | 197. | 1.50 | 0.0 | 1.50 | 2.20 | 9.99 |
| | | | CYLINDER NUMBER 3 | | | | |
| 10:11 | 0. | 0. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10:12 | 1. | 1. | 0.25 | 0.0 | 0.25 | 15.00 | 0.25 |
| 10:14 | 2. | 3. | 0.30 | 0.0 | 0.30 | 9.00 | 0.55 |
| 10:17 | 3. | 6. | 0.30 | 0.0 | 0.30 | 6.00 | 0.85 |
| 10:22 | 5. | 11. | 0.37 | 0.0 | 0.37 | 4.44 | 1.22 |
| 10:29 | 7. | 18. | 0.45 | 0.0 | 0.45 | 3.86 | 1.67 |
| 10:53 | 24. | 42. | 1.00 | 0.0 | 1.00 | 2.50 | 2.67 |
| 11:39 | 46. | 88. | 1.35 | 0.0 | 1.35 | 1.76 | 4.02 |
| 12:35 | 56. | 144. | 1.50 | 0.0 | 1.50 | 1.61 | 5.52 |
| 1:20 | 45. | 189. | 1.00 | 0.0 | 1.00 | 1.33 | 6.52 |
| 2:18 | 58. | 247. | 1.20 | 0.0 | 1.20 | 1.24 | 7.72 |

CYLINDER NUMBER 4

| CLOCK TIME HR MIN | TIME DIFFER- ENCE (MIN) | TIME CUMULA- TIVE (MIN) | READING BEFORE FILLING (IN) | READING AFTER FILLING (IN) | INTAKE DEPTH DURING PERIOD (IN) | INTAKE RATE DURING PERIOD (IN) | ACCUMULATED INTAKE DEPTH (IN) |
|---|---|---|---|---|---|---|---|
| 10:23 | 0. | 0. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10:24 | 1. | 1. | 0.19 | 0.0 | 0.19 | 11.40 | 0.19 |
| 10:26 | 2. | 3. | 0.25 | 0.0 | 0.25 | 7.50 | 0.44 |
| 10:28 | 2. | 5. | 0.20 | 0.0 | 0.20 | 6.00 | 0.64 |
| 10:31 | 3. | 8. | 0.25 | 0.0 | 0.25 | 5.00 | 0.89 |
| 10:35 | 4. | 12. | 0.27 | 0.0 | 0.27 | 4.05 | 1.16 |
| 10:51 | 16. | 28. | 0.90 | 0.0 | 0.90 | 3.37 | 2.06 |
| 11: 8 | 17. | 45. | 0.80 | 0.0 | 0.80 | 2.82 | 2.86 |
| 11:37 | 29. | 74. | 1.10 | 0.0 | 1.10 | 2.28 | 3.96 |
| 12: 0 | 23. | 97. | 0.70 | 0.0 | 0.70 | 1.83 | 4.66 |
| 12:33 | 33. | 130. | 0.85 | 0.0 | 0.85 | 1.55 | 5.51 |

# RING INFILTROMETER TEST

AREA 3
BANNOCK GRAVELLY LOAM
SLOPE = 0.29 %
BARLEY FIELD
HEAVY STAND

| CLOCK TIME HR MIN | TIME DIFFER-ENCE (MIN) | TIME CUMULA-TIVE (MIN) | READING BEFORE FILLING (IN) | READING AFTER FILLING (IN) | INTAKE DEPTH DURING PERIOD (IN) | INTAKE RATE DURING PERIOD (IN) | ACCUMULATED INTAKE DEPTH (IN) |
|---|---|---|---|---|---|---|---|
| | | | CYLINDER NUMBER 1 | | | | |
| 5:42 | 0. | 0. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5:43 | 1. | 1. | 0.35 | 0.0 | 0.35 | 21.00 | 0.35 |
| 5:44 | 1. | 2. | 0.20 | 0.0 | 0.20 | 12.00 | 0.55 |
| 5:45 | 1. | 3. | 0.20 | 0.0 | 0.20 | 12.00 | 0.75 |
| 5:47 | 2. | 5. | 0.30 | 0.0 | 0.30 | 9.00 | 1.05 |
| 5:50 | 3. | 8. | 0.35 | 0.0 | 0.35 | 7.00 | 1.40 |
| 5:55 | 5. | 13. | 0.50 | 0.0 | 0.50 | 6.00 | 1.90 |
| 6: 0 | 5. | 18. | 0.40 | 0.0 | 0.40 | 4.80 | 2.30 |
| 6: 5 | 5. | 23. | 0.40 | 0.0 | 0.40 | 4.80 | 2.70 |
| 6:11 | 6. | 29. | 0.45 | 0.0 | 0.45 | 4.50 | 3.15 |
| 6:17 | 6. | 35. | 0.45 | 0.0 | 0.45 | 4.50 | 3.60 |
| 6:29 | 12. | 47. | 0.70 | 0.0 | 0.70 | 3.50 | 4.30 |
| 6:45 | 16. | 63. | 0.90 | 0.0 | 0.90 | 3.37 | 5.20 |
| 7:13 | 28. | 91. | 1.25 | 0.0 | 1.25 | 2.68 | 6.45 |
| | | | CYLINDER NUMBER 2 | | | | |
| 5:51 | 0. | 0. | 0.0 | 1.70 | 0.0 | 0.0 | 0.0 |
| 5:52 | 1. | 1. | 2.00 | 2.00 | 0.30 | 18.00 | 0.30 |
| 5:53 | 1. | 2. | 2.20 | 2.00 | 0.20 | 12.00 | 0.50 |
| 5:54 | 1. | 3. | 2.15 | 2.00 | 0.15 | 9.00 | 0.65 |
| 5:56 | 2. | 5. | 2.25 | 2.00 | 0.25 | 7.50 | 0.90 |
| 5:58 | 2. | 7. | 2.20 | 2.00 | 0.20 | 6.00 | 1.10 |
| 6: 4 | 6. | 13. | 2.50 | 2.00 | 0.50 | 5.00 | 1.60 |
| 6:11 | 7. | 20. | 2.45 | 2.00 | 0.45 | 3.86 | 2.05 |
| 6:18 | 7. | 27. | 2.45 | 2.00 | 0.45 | 3.86 | 2.50 |
| 6:30 | 12. | 39. | 2.65 | 2.00 | 0.65 | 3.25 | 3.15 |
| 6:47 | 17. | 56. | 2.80 | 2.00 | 0.80 | 2.82 | 3.95 |
| 7:14 | 27. | 83. | 3.00 | 2.00 | 1.00 | 2.22 | 4.95 |
| 7:39 | 25. | 108. | 2.90 | 2.00 | 0.90 | 2.16 | 5.85 |
| 8:33 | 54. | 162. | 3.60 | 2.00 | 1.60 | 1.78 | 7.45 |
| | | | CYLINDER NUMBER 3 | | | | |
| 6: 6 | 0. | 0. | 0.0 | 1.00 | 0.0 | 0.0 | 0.0 |
| 6: 7 | 1. | 1. | 1.40 | 1.00 | 0.40 | 24.00 | 0.40 |
| 6: 8 | 1. | 2. | 1.30 | 1.00 | 0.30 | 18.00 | 0.70 |
| 6: 9 | 1. | 3. | 1.25 | 1.00 | 0.25 | 15.00 | 0.95 |
| 6:10 | 1. | 4. | 1.20 | 1.00 | 0.20 | 12.00 | 1.15 |
| 6:12 | 2. | 6. | 1.35 | 1.00 | 0.35 | 10.50 | 1.50 |
| 6:14 | 2. | 8. | 1.35 | 1.00 | 0.35 | 10.50 | 1.85 |
| 6:19 | 5. | 13. | 1.65 | 1.00 | 0.65 | 7.80 | 2.50 |
| 6:21 | 2. | 15. | 1.25 | 1.00 | 0.25 | 7.50 | 2.75 |
| 6:31 | 10. | 25. | 2.00 | 1.00 | 1.00 | 6.00 | 3.75 |
| 6:39 | 8. | 33. | 1.70 | 1.00 | 0.70 | 5.25 | 4.45 |
| 6:48 | 9. | 42. | 1.75 | 1.00 | 0.75 | 5.00 | 5.20 |
| 7:16 | 28. | 70. | 2.75 | 1.00 | 1.75 | 3.75 | 6.95 |
| 7:27 | 11. | 81. | 1.70 | 1.00 | 0.70 | 3.82 | 7.65 |

(CONTINUATION)

| CLOCK TIME HR MIN | TIME DIFFER- ENCE (MIN) | TIME CUMULA- TIVE (MIN) | READING BEFORE FILLING (IN) | READING AFTER FILLING (IN) | INTAKE DEPTH DURING PERIOD (IN) | INTAKE RATE DURING PERIOD (IN) | ACCUMULATED INTAKE DEPTH (IN) |
|---|---|---|---|---|---|---|---|
| CYLINDER NUMBER 4 | | | | | | | |
| 8:10 | 0. | 0. | 0.0 | 1.00 | 0.0 | 0.0 | 0.0 |
| 8:11 | 1. | 1. | 1.30 | 0.0 | 0.30 | 18.00 | 0.30 |
| 8:12 | 1. | 2. | 0.25 | 0.0 | 0.25 | 15.00 | 0.55 |
| 8:13 | 1. | 3. | 0.17 | 0.0 | 0.17 | 10.20 | 0.72 |
| 8:14 | 1. | 4. | 0.15 | 0.0 | 0.15 | 9.00 | 0.87 |
| 8:16 | 2. | 6. | 0.25 | 0.0 | 0.25 | 7.50 | 1.12 |
| 8:18 | 2. | 8. | 0.22 | 0.0 | 0.22 | 6.60 | 1.34 |
| 8:21 | 3. | 11. | 0.30 | 1.00 | 0.30 | 6.00 | 1.64 |
| 8:25 | 4. | 15. | 1.30 | 1.00 | 0.30 | 4.50 | 1.94 |
| 8:35 | 10. | 25. | 1.60 | 1.00 | 0.60 | 3.60 | 2.54 |
| 9:11 | 36. | 61. | 2.40 | 1.00 | 1.40 | 2.33 | 3.94 |
| 9:45 | 34. | 95. | 2.40 | 1.00 | 1.40 | 2.47 | 5.34 |
| 10:20 | 35. | 130. | 2.00 | 1.00 | 1.00 | 1.71 | 6.34 |
| 10:59 | 39. | 169. | 1.95 | 1.00 | 0.95 | 1.46 | 7.29 |

# FURROW INFILTRATION TEST

AREA 1
BLACKFOOT SILT LOAM
SLOPE = 0.26 %
POTATO FIELD
FURROW SPACING = 36 INCHES
PACKED(WHEEL) FURROW

| T I M E | | | STATION-A | | STATION-B | | | |
|---|---|---|---|---|---|---|---|---|
| CLOCK TIME HR MIN | DIFFER-ENCE (MIN) | CUMULA-TIVE (MIN) | HEAD RDG (IN) | FLOW (GPM) | HEAD RDG (IN) | FLOW (GPM) | LOSS GPM/ 200 FT | LOSS GPM/ 100 FT |
| | | | FURROW NUMBER 1 | | | | | |
| 12:20 | 0. | 0. | 3.90 | 25.00 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12:28 | 8. | 8. | 3.80 | 23.50 | 3.22 | 14.80 | 8.87 | 4.43 |
| 12:38 | 10. | 18. | 3.80 | 23.50 | 3.33 | 16.00 | 7.67 | 3.83 |
| 12:51 | 13. | 31. | 3.80 | 23.50 | 2.40 | 17.50 | 6.17 | 3.08 |
| 1: 6 | 15. | 46. | 3.80 | 23.50 | 3.50 | 18.50 | 5.17 | 2.58 |
| 1:21 | 15. | 61. | 3.80 | 23.50 | 3.55 | 19.25 | 4.42 | 2.21 |
| 1:41 | 20. | 81. | 2.80 | 23.50 | 3.60 | 20.25 | 3.42 | 1.71 |
| 2:11 | 30. | 111. | 3.80 | 23.50 | 3.60 | 20.00 | 3.67 | 1.83 |
| 2:26 | 15. | 126. | 3.80 | 23.50 | 3.65 | 20.75 | 2.92 | 1.46 |
| AVERAGE FLOW AT STATION A = 23.67 | | | | | | | | |
| | | | FURROW NUMBER 2 | | | | | |
| 12:21 | 0. | 0. | 3.66 | 20.70 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12:29 | 8. | 8. | 3.65 | 20.75 | 3.00 | 11.30 | 9.44 | 4.72 |
| 12:39 | 10. | 18. | 3.65 | 20.75 | 3.10 | 13.50 | 7.24 | 3.62 |
| 12:52 | 13. | 31. | 3.65 | 20.75 | 3.20 | 14.70 | 6.04 | 3.02 |
| 1: 7 | 15. | 46. | 3.65 | 20.75 | 3.30 | 16.00 | 4.74 | 2.37 |
| 1:22 | 15. | 61. | 3.65 | 20.75 | 3.30 | 16.00 | 4.74 | 2.37 |
| 1:42 | 20. | 81. | 3.65 | 20.75 | 3.40 | 17.50 | 3.24 | 1.62 |
| 2:12 | 30. | 111. | 3.65 | 20.75 | 3.40 | 17.50 | 3.24 | 1.62 |
| 2:27 | 15. | 126. | 3.65 | 20.75 | 3.45 | 18.00 | 2.74 | 1.37 |
| AVERAGE FLOW AT STATION A = 20.74 | | | | | | | | |
| | | | FURROW NUMBER 3 | | | | | |
| 12:22 | 0. | 0. | 3.56 | 19.40 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12:31 | 9. | 9. | 3.56 | 19.40 | 3.00 | 12.30 | 7.00 | 3.50 |
| 12:40 | 9. | 18. | 3.56 | 19.40 | 3.10 | 13.50 | 5.80 | 2.90 |
| 12:53 | 13. | 31. | 3.55 | 19.25 | 3.20 | 14.70 | 4.60 | 2.30 |
| 1: 9 | 16. | 47. | 3.55 | 19.25 | 3.25 | 15.30 | 4.00 | 2.00 |
| 1:23 | 14. | 61. | 3.55 | 19.25 | 3.28 | 15.70 | 3.60 | 1.80 |
| 1:43 | 20. | 81. | 3.55 | 19.25 | 3.30 | 16.00 | 3.30 | 1.65 |
| 2:13 | 30. | 111. | 3.55 | 19.25 | 3.30 | 16.00 | 3.30 | 1.65 |
| 2:28 | 15. | 126. | 3.55 | 19.25 | 3.35 | 16.75 | 2.55 | 1.27 |
| AVERAGE FLOW AT STATION A = 19.30 | | | | | | | | |

# FURROW INFILTRATION TEST

AREA 1
BLACKFOOT SILT LOAM
SLOPE = 0.26 %
POTATO FIELD
FURROW SPACING = 36 INCHES
UNPACKED(CENTER) FURROW

| T I M E | | | STATION-A | | STATION-B | | | |
|---|---|---|---|---|---|---|---|---|
| CLOCK TIME HR MIN | DIFFER-ENCE (MIN) | CUMULA-TIVE (MIN) | HEAD RDG (IN) | FLOW (GPM) | HEAD RDG (IN) | FLOW (GPM) | LOSS GPM/ 200 FT | LOSS GPM/ 100 FT |
| FURROW NUMBER1 | | | | | | | | |
| 10:35 | 0. | 0. | 4.45 | 36.00 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10:40 | 5. | 5. | 4.40 | 35.00 | 3.50 | 18.50 | 16.93 | 8.46 |
| 10:45 | 5. | 10. | 4.40 | 35.00 | 3.70 | 21.50 | 13.93 | 6.96 |
| 11: 0 | 15. | 25. | 4.40 | 35.00 | 4.00 | 27.00 | 8.43 | 4.21 |
| 11:35 | 35. | 60. | 4.45 | 35.00 | 4.20 | 30.00 | 5.43 | 2.71 |
| 11:56 | 21. | 81. | 4.45 | 36.00 | 4.30 | 31.00 | 4.43 | 2.21 |
| 12:10 | 14. | 95. | 4.45 | 36.00 | 4.30 | 31.00 | 4.43 | 2.21 |
| AVERAGE FLOW AT STATION A = 35.43 | | | | | | | | |
| FURROW NUMBER 2 | | | | | | | | |
| 3:44 | 0. | 0. | 4.35 | 33.00 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3:54 | 10. | 10. | 4.35 | 33.00 | 3.71 | 21.70 | 12.16 | 6.08 |
| 4: 0 | 6. | 16. | 4.35 | 33.00 | 3.90 | 25.00 | 8.86 | 4.43 |
| 4:15 | 15. | 31. | 4.35 | 33.00 | 4.04 | 27.50 | 6.36 | 3.18 |
| 4:45 | 30. | 61. | 4.40 | 35.00 | 4.18 | 29.60 | 4.26 | 2.13 |
| 5:35 | 50. | 111. | 4.40 | 35.00 | 4.19 | 29.80 | 4.06 | 2.03 |
| 5:45 | 10. | 121. | 4.40 | 35.00 | 4.20 | 30.00 | 3.86 | 1.93 |
| AVERAGE FLOW AT STATION A = 33.86 | | | | | | | | |
| FURROW NUMBER 3 | | | | | | | | |
| 10:37 | 0. | 0. | 4.40 | 35.00 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10:42 | 5. | 5. | 4.40 | 35.00 | 3.70 | 21.50 | 14.36 | 7.18 |
| 10:47 | 5. | 10. | 4.40 | 35.00 | 3.91 | 25.20 | 10.66 | 5.33 |
| 11: 2 | 15. | 25. | 4.40 | 35.00 | 4.20 | 30.00 | 5.86 | 2.93 |
| 11:37 | 35. | 60. | 4.50 | 37.00 | 4.30 | 31.00 | 4.86 | 2.43 |
| 11:58 | 21. | 81. | 4.50 | 37.00 | 4.30 | 31.00 | 4.86 | 2.43 |
| 12:12 | 14. | 95. | 4.50 | 37.00 | 4.32 | 32.50 | 3.36 | 1.68 |
| AVERAGE FLOW AT STATION A = 35.86 | | | | | | | | |

# FURROW INFILTRATION TEST

AREA 2
HEISETON LOAM
SLOPE = 0.27 %
POTATO FIELD
FURROW SPACING = 36 INCHES
PACKED(WHEEL) FURROW

| T I M E | | | STATION-A | | STATION-B | | | |
|---|---|---|---|---|---|---|---|---|
| CLOCK TIME HR MIN | DIFFER-ENCE (MIN) | CUMULA-TIVE (MIN) | HEAD RDG (IN) | FLOW (GPM) | HEAD RDG (IN) | FLOW (GPM) | LOSS GPM/ 200 FT | LOSS GPM/ 100 FT |

FURROW NUMBER1

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10:40 | 0. | 0. | 3.70 | 21.50 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10:45 | 5. | 5. | 3.65 | 20.75 | 2.35 | 6.40 | 14.44 | 7.22 |
| 10:58 | 13. | 18. | 3.65 | 20.75 | 2.90 | 11.50 | 9.34 | 4.67 |
| 11: 5 | 7. | 25. | 3.65 | 20.75 | 3.00 | 12.30 | 8.54 | 4.27 |
| 11:16 | 11. | 36. | 3.65 | 20.75 | 3.10 | 13.50 | 7.34 | 3.67 |
| 11:40 | 24. | 60. | 3.65 | 20.75 | 3.25 | 15.30 | 5.54 | 2.77 |
| 12: 0 | 20. | 80. | 3.65 | 20.75 | 3.30 | 16.00 | 4.84 | 2.42 |
| 12:25 | 25. | 105. | 3.65 | 20.75 | 3.30 | 16.00 | 4.84 | 2.42 |

AVERAGE FLOW AT STATION A = 20.84

FURROW NUMBER 2

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10:41 | 0. | 0. | 3.86 | 24.40 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10:46 | 5. | 5. | 3.85 | 24.25 | 2.40 | 6.80 | 17.45 | 8.72 |
| 10:59 | 13. | 18. | 3.85 | 24.25 | 3.15 | 14.10 | 10.15 | 5.07 |
| 11: 6 | 7. | 25. | 3.85 | 24.25 | 3.20 | 14.70 | 9.55 | 4.77 |
| 11:17 | 11. | 36. | 3.84 | 24.10 | 3.35 | 16.60 | 7.65 | 3.82 |
| 11:41 | 24. | 60. | 3.85 | 24.25 | 3.40 | 17.50 | 6.75 | 3.37 |
| 12: 1 | 20. | 80. | 3.85 | 24.25 | 3.50 | 18.50 | 5.75 | 2.87 |
| 12:26 | 25. | 105. | 3.85 | 24.25 | 3.55 | 19.25 | 5.00 | 2.50 |

AVERAGE FLOW AT STATION A = 24.25

FURROW NUMBER 3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10:42 | 0. | 0. | 3.65 | 20.75 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10:47 | 5. | 5. | 3.55 | 19.25 | 2.40 | 6.80 | 12.61 | 6.30 |
| 11: 0 | 13. | 18. | 3.55 | 19.25 | 3.00 | 12.30 | 7.11 | 3.55 |
| 11: 8 | 8. | 26. | 3.45 | 19.30 | 3.10 | 12.30 | 7.11 | 3.55 |
| 11:18 | 10. | 36. | 3.55 | 19.25 | 3.10 | 13.50 | 5.91 | 2.95 |
| 11:42 | 24. | 60. | 3.55 | 19.25 | 3.25 | 15.30 | 4.11 | 2.05 |
| 12: 2 | 20. | 80. | 3.55 | 19.25 | 3.25 | 15.70 | 3.71 | 1.85 |
| 12:27 | 25. | 105. | 3.55 | 19.25 | 3.30 | 16.00 | 3.41 | 1.70 |

AVERAGE FLOW AT STATION A = 19.41

# FURROW INFILTRATION TEST

AREA 2
HEISETON LOAM
SLOPE = 0.27 %
POTATO FIELD
FURROW SPACING = 36 INCHES
UNPACKED(CENTER) FURROW

## FURROW NUMBER1

| TIME CLOCK TIME HR MIN | TIME DIFFERENCE (MIN) | TIME CUMULATIVE (MIN) | STATION-A HEAD RDG (IN) | STATION-A FLOW (GPM) | STATION-B HEAD RDG (IN) | STATION-B FLOW (GPM) | LOSS GPM/ 200 FT | LOSS GPM/ 100 FT |
|---|---|---|---|---|---|---|---|---|
| 8: 0 | 0. | 0. | 4.00 | 27.00 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8: 5 | 5. | 5. | 4.00 | 27.00 | 0.0 | 0.0 | 26.27 | 13.14 |
| 8:10 | 5. | 10. | 4.00 | 27.00 | 2.00 | 4.20 | 22.07 | 11.04 |
| 8:15 | 5. | 15. | 3.95 | 26.00 | 2.65 | 9.40 | 16.87 | 8.44 |
| 8:28 | 13. | 28. | 3.95 | 26.00 | 3.20 | 14.70 | 11.57 | 5.79 |
| 8:50 | 22. | 50. | 3.95 | 26.00 | 3.40 | 17.50 | 8.77 | 4.39 |
| 9:12 | 22. | 72. | 3.95 | 26.00 | 3.55 | 19.25 | 7.02 | 3.51 |
| 9:21 | 9. | 81. | 3.95 | 26.00 | 3.65 | 20.75 | 5.52 | 2.76 |
| 9:50 | 29. | 110. | 3.95 | 26.00 | 3.65 | 20.75 | 5.52 | 2.76 |
| 10:10 | 20. | 130. | 3.95 | 26.00 | 3.65 | 20.75 | 5.52 | 2.76 |
| 10:30 | 20. | 150. | 3.95 | 26.00 | 3.70 | 21.50 | 4.77 | 2.39 |

AVERAGE FLOW AT STATION A = 26.27

## FURROW NUMBER 2

| TIME CLOCK TIME HR MIN | TIME DIFFERENCE (MIN) | TIME CUMULATIVE (MIN) | STATION-A HEAD RDG (IN) | STATION-A FLOW (GPM) | STATION-B HEAD RDG (IN) | STATION-B FLOW (GPM) | LOSS GPM/ 200 FT | LOSS GPM/ 100 FT |
|---|---|---|---|---|---|---|---|---|
| 8: 1 | 0. | 0. | 3.80 | 23.50 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8: 6 | 5. | 5. | 3.80 | 23.50 | 0.0 | 0.0 | 22.77 | 11.39 |
| 8:11 | 5. | 10. | 3.80 | 23.50 | 2.20 | 5.50 | 17.27 | 8.64 |
| 8:16 | 5. | 15. | 3.75 | 22.50 | 2.63 | 8.80 | 13.97 | 6.99 |
| 8:29 | 13. | 28. | 3.75 | 22.50 | 2.95 | 11.80 | 10.97 | 5.49 |
| 8:51 | 22. | 50. | 3.75 | 22.50 | 3.20 | 14.70 | 8.07 | 4.04 |
| 9:13 | 22. | 72. | 3.75 | 22.50 | 3.30 | 16.00 | 6.77 | 3.39 |
| 9:22 | 9. | 81. | 3.75 | 22.50 | 3.36 | 16.60 | 6.17 | 3.09 |
| 9:51 | 29. | 110. | 3.75 | 22.50 | 3.40 | 17.40 | 5.37 | 2.69 |
| 10:11 | 20. | 130. | 3.75 | 22.50 | 3.42 | 17.70 | 5.07 | 2.54 |
| 10:31 | 20. | 150. | 3.75 | 22.50 | 3.45 | 18.00 | 4.77 | 2.39 |

AVERAGE FLOW AT STATION A = 22.77

## FURROW NUMBER 3

| TIME CLOCK TIME HR MIN | TIME DIFFERENCE (MIN) | TIME CUMULATIVE (MIN) | STATION-A HEAD RDG (IN) | STATION-A FLOW (GPM) | STATION-B HEAD RDG (IN) | STATION-B FLOW (GPM) | LOSS GPM/ 200 FT | LOSS GPM/ 100 FT |
|---|---|---|---|---|---|---|---|---|
| 8: 2 | 0. | 0. | 3.92 | 25.00 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8: 7 | 5. | 5. | 3.92 | 25.00 | 0.0 | 0.0 | 24.45 | 12.23 |
| 8:11 | 4. | 9. | 3.90 | 25.00 | 2.90 | 11.50 | 12.95 | 6.48 |
| 8:17 | 6. | 15. | 3.85 | 24.25 | 3.10 | 13.50 | 10.95 | 5.48 |
| 8:30 | 13. | 28. | 3.85 | 24.25 | 3.28 | 15.70 | 8.75 | 4.38 |
| 8:52 | 22. | 50. | 3.85 | 24.25 | 3.40 | 17.50 | 6.95 | 3.48 |
| 9:14 | 22. | 72. | 3.85 | 24.25 | 3.50 | 18.50 | 5.95 | 2.98 |
| 9:23 | 9. | 81. | 3.88 | 24.25 | 3.55 | 19.25 | 5.20 | 2.60 |
| 9:52 | 29. | 110. | 3.85 | 24.25 | 3.57 | 19.65 | 4.80 | 2.40 |
| 10:12 | 20. | 130. | 3.85 | 24.25 | 3.60 | 20.00 | 4.45 | 2.23 |
| 10:32 | 20. | 150. | 3.85 | 24.25 | 3.64 | 20.60 | 3.85 | 1.93 |

AVERAGE FLOW AT STATION A = 24.45

# APPENDIX D

# RATE-OF-ADVANCE DATA

WATER ADVANCE DATA

AREA 1
BLACKFOOT SILT LOAM
SLOPE = 0.26 %
POTATO FIELD
FURROW SPACING = 36 INCHES
PACKED(WHEEL) FURROW

Q = 27.00 GPM

| STATION | CLOCK TIME HR MIN | T I M E DIFFER-ENCE (MIN) | CUMULA-TIVE (MIN) |
|---|---|---|---|
| 0+ 0 | 6:40 | 0. | 0. |
| 1+ 0 | 6:44 | 4. | 4. |
| 2+ 0 | 6:49 | 5. | 9. |
| 3+ 0 | 6:54 | 5. | 14. |
| 4+ 0 | 7: 0 | 6. | 20. |
| 5+ 0 | 7: 7 | 7. | 27. |
| 6+ 0 | 7:14 | 7. | 34. |
| 7+ 0 | 7:22 | 8. | 42. |
| 8+ 0 | 7:31 | 9. | 51. |
| 9+ 0 | 7:40 | 9. | 60. |
| 10+ 0 | 7:50 | 10. | 70. |
| 11+ 0 | 8: 1 | 11. | 81. |
| 12+ 0 | 8:13 | 12. | 93. |
| 12+60 | 8:25 | 12. | 105. |

WATER ADVANCE DATA

AREA 1
BLACKFOOT SILT LOAM
SLOPE = 0.26 %
POTATO FIELD
FURROW SPACING = 36 INCHES
PACKED(WHEEL) FURROW

Q = 30.00 GPM

| STATION | T I M E<br>CLOCK TIME HR MIN | DIFFER-ENCE (MIN) | CUMULA-TIVE (MIN) |
|---|---|---|---|
| 0+ 0 | 6:42 | 0. | 0. |
| 1+ 0 | 6:44 | 2. | 2. |
| 2+ 0 | 6:47 | 3. | 5. |
| 3+ 0 | 6:51 | 4. | 9. |
| 4+ 0 | 6:55 | 4. | 13. |
| 5+ 0 | 7: 0 | 5. | 18. |
| 6+ 0 | 7: 5 | 5. | 23. |
| 7+ 0 | 7:10 | 5. | 28. |
| 8+ 0 | 7:16 | 6. | 34. |
| 9+ 0 | 7:22 | 6. | 40. |
| 10: 0 | 7:29 | 7. | 47. |
| 11+ 0 | 7:36 | 7. | 54. |
| 12+ 0 | 7:44 | 8. | 62. |
| 12+60 | 7:53 | 9. | 71. |

WATER ADVANCE DATA

AREA 1
BLACKFOOT SILT LOAM
SLOPE = 0.26 %
POTATO FIELD
FURROW SPACING = 36 INCHES
UNPACKED(CENTER) FURROW

Q = 32.00 GPM

| STATION | CLOCK TIME HR MIN | TIME DIFFERENCE (MIN) | TIME CUMULATIVE (MIN) |
|---|---|---|---|
| 0+ 0 | 6:40 | 0. | 0. |
| 1+ 0 | 6:43 | 3. | 3. |
| 2+ 0 | 6:47 | 4. | 7. |
| 3+ 0 | 6:53 | 6. | 13. |
| 4+ 0 | 7: 1 | 8. | 21. |
| 5+ 0 | 7:11 | 10. | 31. |
| 6+ 0 | 7:24 | 13. | 44. |
| 7+ 0 | 7:38 | 14. | 58. |
| 8+ 0 | 7:55 | 17. | 75. |
| 9+ 0 | 8:13 | 18. | 93. |
| 10+ 0 | 8:31 | 18. | 111. |
| 11+ 0 | 8:52 | 21. | 132. |
| 12+ 0 | 9:14 | 22. | 154. |
| 12+60 | 9:36 | 22. | 176. |

WATER ADVANCE DATA

AREA 1
BLACKFOOT SILT LOAM
SLOPE = 0.26 %
POTATO FIELD
FURROW SPACING = 36 INCHES
UNPACKED(CENTER) FURROW

Q = 40.00 GPM

| STATION | CLOCK TIME HR MIN | TIME DIFFER-ENCE (MIN) | TIME CUMULA-TIVE (MIN) |
|---|---|---|---|
| 0+ 0 | 6:36 | 0. | 0. |
| 1+ 0 | 6:38 | 2. | 2. |
| 2+ 0 | 6:41 | 3. | 5. |
| 3+ 0 | 6:44 | 3. | 8. |
| 4+ 0 | 6:48 | 4. | 12. |
| 5+ 0 | 6:52 | 4. | 16. |
| 6+ 0 | 6:56 | 4. | 20. |
| 7+ 0 | 7: 1 | 5. | 25. |
| 8+ 0 | 7: 7 | 6. | 31. |
| 9+ 0 | 7:13 | 6. | 37. |
| 10+ 0 | 7:20 | 7. | 44. |
| 11+ 0 | 7:27 | 7. | 51. |
| 12+ 0 | 7:34 | 7. | 58. |
| 12+60 | 7:43 | 9. | 67. |

WATER ADVANCE DATA

AREA 2
HEISETON LOAM
SLOPE = 0.27 %
POTATO FIELD
FURROW SPACING = 36 INCHES
PACKED(WHEEL) FURROW

Q = 28.00 GPM

| | | T I M E | |
|---|---|---|---|
| STATION | CLOCK TIME HR MIN | DIFFER-ENCE (MIN) | CUMULA-TIVE (MIN) |
| 0+ 0 | 10:36 | 0. | 0. |
| 1+ 0 | 10:38 | 2. | 2. |
| 2+ 0 | 10:41 | 3. | 5. |
| 3+ 0 | 10:45 | 4. | 9. |
| 4+ 0 | 10:49 | 4. | 13. |
| 5+ 0 | 10:54 | 5. | 18. |
| 6+ 0 | 11: 0 | 6. | 24. |
| 7+ 0 | 11: 6 | 6. | 30. |
| 8+ 0 | 11:13 | 7. | 37. |
| 9+ 0 | 11:21 | 8. | 45. |
| 10+ 0 | 11:29 | 8. | 53. |
| 11+ 0 | 11:40 | 11. | 64. |
| 11+50 | 11:54 | 14. | 78. |

WATER ADVANCE DATA

AREA 2
HEISETON LOAM
SLOPE = 0.27 %
POTATO FIELD
FURROW SPACING = 36 INCHES
PACKED(WHEEL) FURROW

Q = 33.00 GPM

| | | T I M E | |
|---|---|---|---|
| STATION | CLOCK TIME HR MIN | DIFFER-ENCE (MIN) | CUMULA-TIVE (MIN) |
| 0+ 0 | 10:41 | 0. | 0. |
| 1+ 0 | 10:43 | 2. | 2. |
| 2+ 0 | 10:45 | 2. | 4. |
| 3+ 0 | 10:48 | 3. | 7. |
| 4+ 0 | 10:51 | 3. | 10. |
| 5+ 0 | 10:55 | 4. | 14. |
| 6+ 0 | 10:59 | 4. | 18. |
| 7+ 0 | 11: 4 | 5. | 23. |
| 8+ 0 | 11:10 | 6. | 29. |
| 9+ 0 | 11:16 | 6. | 35. |
| 10+ 0 | 11:23 | 7. | 42. |
| 11+ 0 | 11:30 | 7. | 49. |
| 11+50 | 11:38 | 8. | 57. |

WATER ADVANCE DATA

AREA 2
HEISETON LOAM
SLOPE = 0.27 %
POTATO FIELD
FURROW SPACING = 36 INCHES
UNPACKED(CENTER) FURROW

Q = 35.00 GPM

| | T I M E | | |
|---|---|---|---|
| STATION | CLOCK TIME HR MIN | DIFFER-ENCE (MIN) | CUMULA-TIVE (MIN) |
| 0+ 0 | 7:56 | 0. | 0. |
| 1+ 0 | 7:58 | 2. | 2. |
| 2+ 0 | 8+ 1 | 3. | 5. |
| 3+ 0 | 8: 5 | 4. | 9. |
| 4+ 0 | 8:10 | 5. | 14. |
| 5+ 0 | 8:16 | 6. | 20. |
| 6+ 0 | 8:22 | 6. | 26. |
| 7+ 0 | 8:29 | 7. | 33. |
| 8+ 0 | 8:37 | 8. | 41. |
| 9+ 0 | 8:45 | 8. | 49. |
| 10+ 0 | 8:54 | 9. | 58. |
| 11+ 0 | 9: 4 | 10. | 68. |
| 11+50 | 9:24 | 20. | 88. |

WATER ADVANCE DATA

AREA 2
HEISETON LOAM
SLOPE = 0.27 %
POTATO FIELD
FURROW SPACING = 36 INCHES
UNPACKED(CENTER) FURROW

Q = 33.00 GPM

| STATION | CLOCK TIME HR MIN | TIME DIFFERENCE (MIN) | TIME CUMULATIVE (MIN) |
|---|---|---|---|
| 0+ 0 | 7:55 | 0. | 0. |
| 1+ 0 | 7:58 | 3. | 3. |
| 2+ 0 | 8: 2 | 4. | 7. |
| 3+ 0 | 8: 7 | 5. | 12. |
| 4+ 0 | 8:13 | 6. | 18. |
| 5+ 0 | 8:20 | 7. | 25. |
| 6+ 0 | 8:28 | 8. | 33. |
| 7+ 0 | 8:38 | 10. | 43. |
| 8: 0 | 8:50 | 12. | 55. |
| 9+ 0 | 9: 4 | 14. | 69. |
| 10+ 0 | 9:18 | 14. | 83. |
| 11+ 0 | 9:33 | 15. | 98. |
| 11+50 | 9:50 | 17. | 115. |

WATER ADVANCE DATA

AREA 3
BANNOCK LOAM
SLOPE = 0.31 %
BARLEY FIELD
HEAVY STAND

BORDER WIDTH = 65 FT
Q = 4.20 CFS

| STATION | TIME CLOCK TIME HR MIN | DIFFERENCE (MIN) | CUMULATIVE (MIN) |
|---|---|---|---|
| 0+ 0 | 2:15 | 0. | 0. |
| 1+ 0 | 2:18 | 3. | 3. |
| 2+ 0 | 2:22 | 4. | 7. |
| 3+ 0 | 2:26 | 4. | 11. |
| 4+ 0 | 2:31 | 5. | 16. |
| 5+ 0 | 2:37 | 6. | 22. |
| 6+ 0 | 2:45 | 8. | 30. |
| 7+ 0 | 2:54 | 9. | 39. |
| 8+ 0 | 3: 7 | 13. | 52. |
| 9+ 0 | 3:23 | 16. | 68. |
| 10+ 0 | 3:40 | 17. | 85. |
| 11+ 0 | 4: 0 | 20. | 105. |
| 12+ 0 | 4:20 | 20. | 125. |
| 12+70 | 4:35 | 15. | 140. |

WATER ADVANCE DATA

AREA 3
BANNOCK GRAVELLY LOAM
SLOPE = 0.29 %
BARLEY FIELD
HEAVY STAND

BORDER WIDTH = 66 FT
Q = 7.80 CFS

| | TIME | | |
|---|---|---|---|
| STATION | CLOCK TIME HR MIN | DIFFER-ENCE (MIN) | CUMULA-TIVE (MIN) |
| 0+ 0 | 12: 0 | 0. | 0. |
| 1+ 0 | 12: 8 | 8. | 8. |
| 2+ 0 | 12:17 | 9. | 17. |
| 3+ 0 | 12:27 | 10. | 27. |
| 4+ 0 | 12:39 | 12. | 39. |
| 5+ 0 | 12:51 | 12. | 51. |
| 6+ 0 | 1: 5 | 14. | 65. |
| 7+ 0 | 1:19 | 14. | 79. |
| 8+ 0 | 1:34 | 15. | 94. |
| 9+ 0 | 1:50 | 16. | 110. |
| 10+ 0 | 2: 6 | 16. | 126. |
| 11+ 0 | 2:23 | 17. | 143. |
| 12+ 0 | 2:40 | 17. | 160. |

# APPENDIX E

# COMPUTER PROGRAMS

```
C
C     PROGRAM TO CALCULATE SOIL MOISTURE
C
C REMARKS:THIS PROGRAM WILL CALCULATE THE AVERAGE SOIL MOISTURE FOR EACH
C     FOOT OF DEPTH OF SOIL SAMPLED AND ALSO THE AVERAGE MOISTURE
C     PRESENT IN THE ROOT ZONE, BEFORE AND AFTER IRRIGATION
C
C**********************************************************************
C OUTPUT TO THIS PROGRAM CONSISTS OF THE FOLLOWING VARIABLES
C
C     KAREA-------IDENTIFIES THE LOCATION OF THE TEST AREA
C        1-AREA NUMBER 1
C        2-AREA NUMBER 11
C        3-AREA NUMBER 111
C     NFIELD------IDENTIFIES THE KIND OF CROP GROWN IN THE TEST AREA
C        1-ALFALFA FIELD
C        2-BARLEY FIELD
C        3-POTATO FIELD
C     IRRIG-------IDENTIFIES TIME OF SAMPLING
C        1-BEFORE IRRIGATION
C        2-AFTER IRRIGATION
C     NUM---------IDENTIFIES THE NUMBER OF SAMPLE
C     FW----------FRESH WEIGHT OF SAOIL SAMPLE +WEIGTH OF CAN
C     ODCAN-------OVEN DRIED WEIGHT OF SOIL +CAN
C     CAN---------WEIGHT OF CAN
C     NDEP--------IDENTIFIES THE DEPTH OF SAMPLED LAYER
C        1-FIRST FOOT OF DEPTH
C        2-SECOND FOOT OF DEPTH
C        3-THIRD FOOT OF DEPTH
C        4-FOURTH OF DEPTH
C     NZONE-------IDENTIFIES THE ASSUMED ROOTING DEPTH OF CROP
C        3-ASSUMED ROOTING DEPTH IS 3 FEET
C        4-ASSUMED ROOTING DEPTH IS 4 FEET
C
C  OUTPUT OF THE PROGRAM CONSISTS OF THE FOLLOWING VARIABLES
C
C     KAREA,NFIELD,IRRIG,NUM,FW,ODCAN,CAN,NDEP ---> PREVIOUSLY DEFINED
```

```
C       ODW---------OVEN DRIED WEIGHT OF SOIL
C       TLOSS------MOISTURE LOST DUE TO OVEN DRYING
C       PERCEN-----MOISTURE LOST DUE TO OVEN DRYING
C       FTMOIS-----SUM TOTAL OF MOISTURE AT EACH FOOT OF DEPTH
C       FTAVE------AVERAGE MOISTURE FOR EACH FOOT OF DEPTH
C       TOTMOI-----SUM TOTAL OF THE AVERAGE MOISTURE FOR THE ROOT ZONE
C       AVEMOI-----AVERAGE MOISTURE FOR THE ENTIRE ROOT ZONE
C*************************************************************************
C
C                           <-----------------------------READ CARD--------------
C
        READ(1,2)K,R,S
      2 FORMAT(I2,2F2.0)
C
C       INITIALIZE COUNTER
C
        LCTR=0
    200 IF(LCTR.GE.K)GO TO 600
C
C                           <-----------------------------READ CARD--------------
        READ(1,3)KAREA,NFIELD,IRRIG
      3 FORMAT(3I1)
        LCTR=LCTR+1
        IF(KAREA-2)10,20,30
C
C       PRINT DESCRIPTION OF TEST AREA
C
     20 WRITE(3,22)
     22 FORMAT(1H1,' AREA NUMBER II')
        GO TO 40
     10 WRITE(3,12)
     12 FORMAT(1H1,' AREA NUMBER I')
        GO TO 40
     30 WRITE(3,33)
     33 FORMAT(1H1,' AREA NUMBER III')
     40 IF(NFIELD-2)50,60,70
     60 WRITE(3,66)
```

```
   66 FORMAT('  BARLEY FIELD')
      GO TO 80
   50 WRITE(3,55)
   55 FORMAT('  ALFALFA FIELD')
      GO TO 80
   70 WRITE(3,77)
   77 FORMAT('  POTATO FIELD')
   80 IF(IRRIG-2)90,91,91
   90 WRITE(3,97)
   97 FORMAT('  SOIL MOISTURE BEFORE IRRIGATION'/)
      GO TO 99
   91 WRITE(3,98)
   98 FORMAT('  SOIL MOISTURE AFTER IRRIGATION'/)
   99 WRITE(3,100)
C
C     PRINT COLUN HEADING
C
  100 FORMAT('  SAMPLE NO FRESH WT OD+CAN  WT CAN  O DRY WT  LOSS  % MOI
     1STURE')
C
C     INTIALIZE COUNTERS
C
      FIRST=0.
      SECON=0.
      THIRD=0.
      FOURT=0.
      KTR=0
      NFTR=0
      FTMOIS=0.
      TOTMOI=0.
C
C                        <----------------------------READ CARD-------------
  300 READ(1,5)NUM,FW,ODCAN,CAN,NDEP,NZONE
    5 FORMAT(I2,F4.1,F4.1,F3.1,2I1)
      IF(NZONE.GT.1)GO TO 111
      IF(FIRST.NE.0.)GO TO 113
C
```

```
C      PRINT DEPTH OF SAMPLED LAYER
       WRITE(3,112)
   112 FORMAT('  FIRST FOOT')
       FIRST=FIRST+1.
       GO TO 113
   111 IF(NZONE.GT.2) GO TO 114
       IF(SECON.NE.0.)GO TO 113
       WRITE(3,115)
   115 FORMAT('  SECOND FOOT')
       SECON=SECON+1.
       GO TO 113
   114 IF(NZONE.GT.3)GO TO 116
       IF(THIRD.NE.0.)GO TO 113
       WRITE(3,117)
   117 FORMAT('  THIRD FOOT')
       THIRD=THIRD+1.
       GO TO 113
   116 IF(FOURT.NE.0.)GO TO 113
       WRITE(3,118)
   118 FORMAT('  FOURTH FOOT')
       FOURT=FOURT+1.
C
C      COMPUTE OVEN DRIED WEIGHT, MOISTURE LOSS, PERCENT MOISTURE
C
   113 KTR=KTR+1
       NFTR=NFTR+1
       ODW=ODCAN-CAN
       TLOSS=FW-ODCAN
       PERCEN=TLOSS/ODW*100.
       FTMOIS=FTMOIS+PERCEN
C
C      PRINT RESULTS
C
       WRITE(3,119)NUM,FW,ODCAN,CAN,ODW,TLOSS,PERCEN
   119 FORMAT(T6,I2,T14,F5.1,T22,F5.1,T31,F4.1,T40,F4.1,T48,F4.1,T56,F6.2
      2)
       IF(NFTR.NE.12)GO TO 300
```

```
C
C     COMPUTE AVERAGE MOISTURE FOR ONE FOOT OF DEPTH
C
      FTAVE=FTMOIS/12.
      NFTR=0
      WRITE(3,122)FTAVE
  122 FORMAT(T48,'AVERAGE',T56,F6.2)
      TOTMOI=TOTMOI+FTAVE
      FTMOIS=0.
      IF(KTR-S)350,400,400
  350 IF(KTR-R)300,360,360
  360 IF(NDEP-3)400,400,300
C
C     COMPUTE AVERAGE MOISTURE FOR THE ENTIRE ROOT ZONE
C
  400 AVEMOI=TOTMOI/NDEP
C
C     PRINT AVERAGE MOISTURE FOR THE ENTIRE ROOT ZONE
C
      WRITE(3,123)AVEMOI
  123 FORMAT(T22,'AVERAGE MOISTURE IN ROOT ZONE (%)',T56,F6.2)
      FIRST=0.
      SECON=0.
      THIRD=0.
      FOURT=0.
      GO TO 200
  600 STOP
      END
```

```
C      PROGRAM TO CALCULATE INFILTRATION DATA
C
C***********************************************************************
C   INPUT TO THE PROGRAM CONSISTS OF THE FOLLOWING VARIABLES
C      METHOD-----IDENTIFIES WHETHER FURROW OR RING INFILTRATION TEST
C         1-FURROW INFILTRATION TEST
C         2-RING INFILTRATION TEST
C      AREA-------IDENTIFIES THE LOCATION OF TEST
C         1-AREA 1
C         2-AREA 2
C         3-AREA 3
C      NSLOPE-----IDENTIFIES THE SLOPE OF THE FIELD
C         1-0.26%
C         2-0.29 %
C         3-0.31 %
C         4-0.36 %
C      NSOIL------IDENTIFIES THE TYPE OF SOIL IN THE TEST AREA
C         1-BLACKFOOT SILT LOAM
C         2-HEISLTON LOAM
C         3-BANNOCK GRAVELLY LOAM
C         4-BANNOCK LOAM
C      NFUR-------IDENTIFIES THE KIND OF FURROW
C         1-UNPACKED (CENTER) FURROW
C         2-PACKED (WHEEL) FURROW
C      NKIND------IDENTIFIES THE TYPE OF WATER ADVANCE
C         1-FURROW WATER ADVANCE
C         2-BORDER WATER ADVANCE
C      NQ---------IDENTIFIES THE DISCHARGE AT BORDER STRIP
C         1-2.36 CFS,AREA 1
C         2-4.22 CFS, AREA 11
C         3-7.70 CFS, AREA 111
C      KQ---------IDENTIFIES THE DISCHARGE AT FURROW
C         1-32.00 GPM, REGULAR STREAM, CENTER FURROW, AREA 1
C         2-60.00 GPM, LARGE STREAM, WHEEL FURROW, AREA 1
C         3-27.00 GPM, REGULAR STREAM, WHEEL FURROW, AREA 1
C         4-30.00 GPM, LARGE STREAM, WHEEL FURROW, AREA 1
C         5-33.00 GPM, REGULAR STREAM, CENTER FURROW, AREA 11
```

```
C         6-35.00 GPM, LARGE STREAM, CENTER FURROW, AREA 11
C         7-28.00 GPM, REGULAR STREAM, WHEEL FURROW, AREA 11
C         8-33.00 GPM, LARGE STREAM, WHEEL FURROW, AREA 11
C      NHOUR------HOUR-CLOCK TIME OF OBSERVATION
C      MIN--------MINUTE-CLOCK TIME OF OBSERVATION
C      DIFF-------TIME DIFFERENCE BETWEEN OBSERVATION, MINUTES
C      CUM--------CUMULATIVE TIME, MINUTES
C      HEADA------HEAD READING IN TRIANGULAR FLUME AT STATION A, INCHES
C      HEADB------HEAD READING IN TRIANGULAR FLUME AT STA B 200 FT FR A
C      FLOWA------EQUIVALENT DISCHARGE IN GPM AT STATION A
C      FLOWB------EQUIVALENT DISCHARGE IN GPM AT STATION B
C      BEFORE-----READING IN THE RING INFILTROMETER BEFORE FILLING,INCHES
C      AFTER------READING IN THE RING INFILTROMETER AFTER FILLING,IN
C
C   OUTPUT OF THE PROGRAM CONSISTS OF THE FOLLOWING VARIABLES
C
C      NSTAND-----IDENTIFIES THE NATURE OF CROP GROWN IN BORDER STRIP
C         1-NEWLY CUT
C         2-HEAVY STAND
C      FLOSSA-----LOSS IN FURROW, GPM PER 200 FT
C      FLOSSB-----LOSS IN FURROW,GPM PER 100 FT
C      TFLOWA-----SUM TOTAL OF FLOW IN ALL OBSERVATIONS IN STATION A
C      AVEFLOW----AVERAGE FLOW AT STATION A FOR THE DURATION OF TEST
C      ENDEP------INTAKE DEPTH DURING THE PERIOD,INCHES
C      ENRATE-----INTAKE RATE DURING THE PERIOD,INCHES
C      ENCUM------ACCUMULATED INTAKE DEPTH FOR THE PERIOD,INCHES
C
C   OTHER VARIABLES USED IN THE PROGRAM
C
C      N----------NUMBER OF OBSERVATIONS PER TRIAL
C      L----------NUMBER OF TRIALS
C      NUM--------TOTAL NUMBER OF TEST
C*****************************************************************************
C
      DIMENSION NHOUR(20),N1(20),MIN(20),DIFF(20),CUM(20),HEADA(20),FLOW
     2A(20),HEADB(20),FLOWB(20),FLOSSA(20),FLOSSB(20),BEFORE(20),AFTER(2
     20),ENDEP(20),ENRATE(20),ENCUM(20),NSTA1(20),N2(20),NSTA2(20)
```

```
C
C                     <-----------------------------READ CARD-------------
C
      READ(1,2)NUM
    2 FORMAT(I2)
      NCTR=0
C
C                     <-----------------------------READ CARD-------------
C
  206 READ(1,3)METHOD
    3 FORMAT(I1)
      IF(METHOD-2)100,101,999
  100 WRITE(3,4)
    4 FORMAT(1H1,T20,'FURROW INFILTRATION TEST'/)
C
C                     <-----------------------------READ CARD-------------
C
  125 READ(1,5)KAREA,NSOIL,NSLOPE,NFIELD,NFUR,NSTAND,NKIND,NQ,KQ
    5 FORMAT(9I1)
      IF(KAREA-2)102,103,104
C
C     PRINT DESCRIPTION OF TEST AREA
C
  102 WRITE(3,6)
    6 FORMAT(1X,'   AREA 1')
      GO TO 105
  103 WRITE(3,7)
    7 FORMAT(1X,'   AREA 2')
      GO TO 105
  104 WRITE(3,8)
    8 FORMAT(1X,'   AREA 3')
  105 GO TO (106,107,108,811),NSOIL
  106 WRITE(3,9)
    9 FORMAT(1X,'   BLACKFOOT SILT LOAM')
      GO TO 109
  107 WRITE(3,10)
   10 FORMAT(1X,'   HEISETON LOAM')
```

```
      GO TO 109
  108 WRITE(3,11)
   11 FORMAT(1X,'  BANNOCK GRAVELLY LOAM')
      GO TO 109
  811 WRITE(3,812)
  812 FORMAT(1X,'  BANNOCK LOAM')
  109 GO TO(110,111,112,113),NSLOPE
  110 WRITE(3,12)
   12 FORMAT(1X,'  SLOPE = 0.26 %')
      GO TO 114
  111 WRITE(3,13)
   13 FORMAT(1X,'  SLOPE = 0.29 %')
      GO TO 114
  112 WRITE(3,14)
   14 FORMAT(1X,'  SLOPE = 0.31 %')
      GO TO 114
  113 WRITE(3,15)
   15 FORMAT(1X,'  SLOPE = 0.27 %')
  114 IF(NFIELD-2)501,502,503
  501 WRITE(3,504)
  504 FORMAT(1X,'  ALFALFA FIELD')
      GO TO 505
  502 WRITE(3,506)
  506 FORMAT(1X,'  BARLEY FIELD')
      GO TO 505
  503 WRITE(3,507)
  507 FORMAT(1X,'  POTATO FIELD')
  505 IF(METHOD-2)123,124,7002
  123 WRITE(3,16)
   16 FORMAT(1X,'  FURROW SPACING = 36 INCHES')
      IF(NFUR-2)115,116,116
  115 WRITE(3,17)
   17 FORMAT(1X,'  UNPACKED(CENTER) FURROW'/)
      GO TO 117
  116 WRITE(3,18)
   18 FORMAT(1X,'  PACKED(WHEEL) FURROW'/)
C
```

```
C     PRINT COLUMN HEADING
C
  117 IF(METHOD.EQ.3)GO TO 7003
      WRITE(3,19)
   19 FORMAT(T6,'T  I  M  E           STATION-A    STATION-B')
      WRITE(3,20)
   20 FORMAT(T3,'CLOCK DIFFER- CUMULA- HEAD          HEAD          LOSS
     2 LOSS')
      WRITE(3,21)
   21 FORMAT(T3,'TIME   ENCE    TIVE   RDG   FLOW   RDG   FLOW   GPM/
     2 GPM/')
      WRITE(3,22)
   22 FORMAT(T2,'HR MIN (MIN)   (MIN)   (IN)  (GPM)  (IN)  (GPM)  200 FT
     2  100 FT')
C
C                 <------------------------------READ CARD--------------
C
      READ(1,50)N,L
   50 FORMAT(I2,I1)
      DO 200 J=1,L
      READ(1,51)(NHOUR(K),N1(K),MIN(K),HEADA(K),FLOWA(K),HEADB(K),FLOWB(
     2K),K=1,N)
   51 FORMAT(I2,A1,I2,F3.2,F4.2,F3.2,F4.2)
C
C     COMPUTE TIME DIFFERENCE
C
  696 DO 201 K=1,N
      IF(K.GT.1) GO TO 803
      DIFF(K)=0.0
      GO TO 201
  803 IF(NHOUR(K).NE.NHOUR(K-1))GO TO 118
      DIFF(K)=MIN(K)-MIN(K-1)
      GO TO 201
  118 DIFF(K)=60.-MIN(K-1)+MIN(K)
  201 CONTINUE
C
C     COMPUTE CUMULATIVE TIME OF OBSERVATION
```

```
C
      DO 700 K=1,N
      IF(K.GT.1) GO TO 805
      CUM(K)=0.0
      GO TO 700
  805 IF(K.GT.2)GO TO 806
      CUM(K)=DIFF(K)
      GO TO 700
  806 CUM(K)=DIFF(K)+CUM(K-1)
  700 CONTINUE
      IF(METHOD-2)2222,2223,2229
 2222 TFLOWA=0.0
      DO 203 K=1,N
  203 TFLOWA=TFLOWA+FLOWA(K)
      AVFLOW=TFLOWA/N
C
C     COMPUTE LOSS IN FURROW PER 200 FT
      DO 204 K=1,N
      IF(K.GT.1)GO TO 800
      FLOSSA(K)=0.0
      GO TO 204
  800 FLOSSA(K)=AVFLOW-FLOWB(K)
  204 CONTINUE
C
C     COMPUTE LOSS IN FURROW PER 100 FEET
C
      DO 205 K=1,N
      IF(K.GT.1)GO TO 801
      FLOSSB(K)=0.0
      GO TO 205
  801 FLOSSB(K)=FLOSSA(K)/2.
  205 CONTINUE
      GO TO(119,120,121),J
C
C     PRINT FURROW NUMBER
C
  119 WRITE(3,52)
```

```
 52 FORMAT(/T24,'FURROW NUMBER1'/)
    GO TO 122
120 WRITE(3,53)
 53 FORMAT(/T24,'FURROW NUMBER 2'/)
    GO TO 122
121 WRITE(3,54)
 54 FORMAT(/T24,'FURROW NUMBER 3'/)
C
C      PRINT RESULTS (FURROW INFILTRATION TEST)
C
122 WRITE(3,55)(NHOUR(K),N1(K),MIN(K),DIFF(K),CUM(K),HEADA(K),FLOWA(K)
   2,HEADB(K),FLOWB(K),FLOSSA(K),FLOSSB(K),K=1,N)
 55 FORMAT(T2,I2,A1,I2,T10,F3.0,T17,F4.0,T24,F4.2,T31,F5.2,T38,F4.2,
   2T44,F5.2,T51,F5.2,T59,F5.2)
    WRITE(3,822)AVFLOW
822 FORMAT(T2,'AVERAGE FLOW AT STATION A =',T30,F5.2)
    TFLOWA=0.0
200 CONTINUE
133 NCTR=NCTR+1
    IF(NCTR.EQ.NUM)GO TO 1000
    GO TO 206
C
C      COMPUTATION FOR INFILTROMETER TEST
C
101 WRITE(3,56)
 56 FORMAT(1H1,T23,'RING INFILTROMETER TEST'/)
    GO TO 125
124 IF(NSTAND.EQ.2)GO TO 126
    WRITE(3,57)
 57 FORMAT(1X,'  NEWLY CUT FIELD')
    GO TO 127
126 WRITE(3,58)
 58 FORMAT(1X,'  HEAVY STAND')
127 IF(METHOD.EQ.3)GO TO 7003
C
C      PRINT COLUMN HEADING
C
```

```
      NTRE=0
  761 WRITE(3,23)
   23 FORMAT(T42,'INTAKE  INTAKE')
      WRITE(3,25)
   25 FORMAT(T10,'TIME     TIME    READING READING  DEPTH    RATE  ACCUMUL
     2ATED')
      WRITE(3,26)
   26 FORMAT(T3,'CLOCK DIFFER- CUMULA- BEFORE  AFTER   DURING  DURING
     3 INTAKE')
      WRITE(3,27)
   27 FORMAT(T3,'TIME    ENCE     TIVE    FILLING FILLING  PERIOD  PERIOD
     2  DEPTH')
      WRITE(3,28)
   28 FORMAT(T2,'HR MIN  (MIN)     (MIN)   (IN)     (IN)     (IN)    (IN)
     2    (IN)')
      NTRE=NTRE+1
      IF(NTRE.EQ.2)GO TO 762
C
C                    <------------------------------READ CARD--------------
C
      READ(1,29)N,L
   29 FORMAT(I2,I1)
C
C                    <------------------------------READ CARD--------------
C
      DO 2000 J=1,L
      READ(1,30)(NHOUR(K),N1(K),MIN(K),BEFORE(K),AFTER(K),K=1,N)
   30 FORMAT(I2,A1,I2,F3.2,F3.2)
      GO TO 696
C
C     COMPUTE INTAKE DEPTH DURING PERIOD
C
 2223 DO 209 K=1,N
      IF(K.GT.1)GO TO 485
      ENDEP(K)=0.0
      GO TO 209
  485 ENDEP(K)=BEFORE(K)-AFTER(K-1)
```

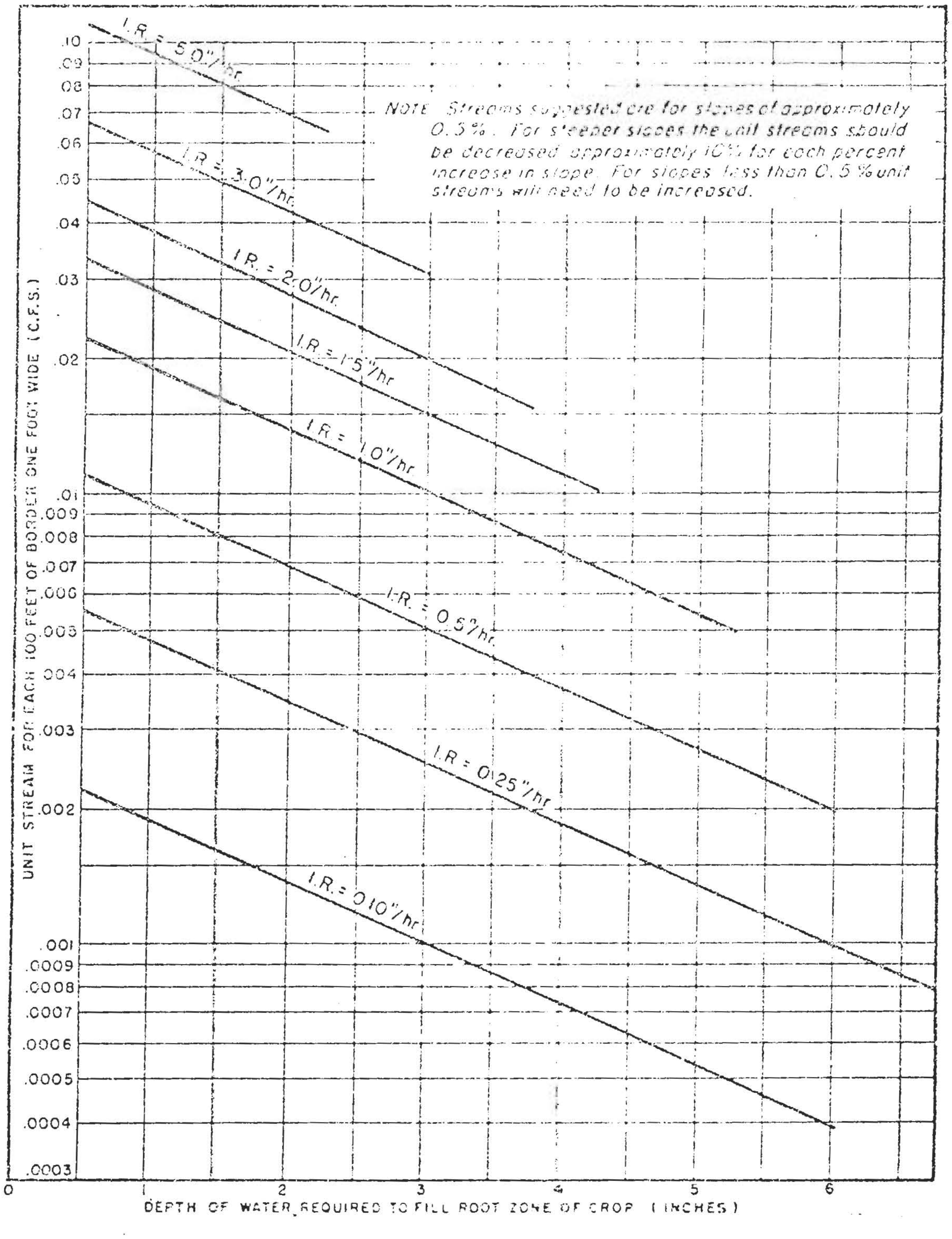
```
  209 CONTINUE
C
C     COMPUTE INTAKE RATE DURING PERIOD
C
      DO 210 K=1,N
      IF(K.GT.1)GO TO 400
      ENRATE(K)=0.0
      GO TO 210
  400 ENRATE(K)=ENDEP(K)*60./DIFF(K)
  210 CONTINUE
C
C     COMPUTE ACCUMULATED INTAKE DEPTH
C
      DO 130 K=1,N
      IF(K.GT.1)GO'TO 211
      ENCUM(K)=0.0
      GO TO 130
  211 IF(K.GT.2)GO TO 222
      ENCUM(K)=ENDEP(K)
      GO TO 130
  222 ENCUM(K)=ENDEP(K)+ENCUM(K-1)
  130 CONTINUE
  131 GO TO(212,213,214,215),J
  212 WRITE(3,31)
   31 FORMAT(/T26,'CYLINDER NUMBER  1'/)
      GO TO 132
  213 WRITE(3,32)
   32 FORMAT(/T26,'CYLINDER NUMBER 2'/)
      GO TO 132
  214 WRITE(3,33)
   33 FORMAT(/T26,'CYLINDER NUMBER 3'/)
      GO TO 132
  215 WRITE(3,34)
   34 FORMAT(1H1,'   (CONTINUATION)'//)
      GO TO 761
  762 WRITE(3,763)
  763 FORMAT(/T26,'CYLINDER NUMBER  4'/)
```

```
      NTRE=0
C
C     PRINT RESULTS (RING INFILTROMETER TEST)
C
  132 WRITE(3,35)(NHOUR(K),N1(K),MIN(K),DIFF(K),CUM(K),BEFORE(K),
     2AFTER(K),ENDEP(K),ENRATE(K),ENCUM(K),K=1,N)
   35 FORMAT(T2,I2,A1,I2,T11,F3.0,T19,F4.0,T26,F4.2,T34,F4.2,T43,F4.2,
     2T51,F5.2,T60,F5.2)
 2000 CONTINUE
      GO TO 133
  999 WRITE(3,7001)
 7001 FORMAT(1H1,T25,'WATER ADVANCE DATA'/)
      GO TO 125
 7002 IF(NKIND.GT.1)GO TO 124
      GO TO 123
 7003 IF(NKIND.GT.1)GO TO 4340
      GO TO (251,252,253,254,255,256,257,258),KQ
C
C     PRINT DISCHARGE
C
  251 WRITE(3,261)
      GO TO 7004
  252 WRITE(3,262)
      GO TO 7004
  253 WRITE(3,263)
      GO TO 7004
  254 WRITE(3,264)
      GO TO 7004
  255 WRITE(3,265)
      GO TO 7004
  256 WRITE(3,266)
      GO TO 7004
  257 WRITE(3,267)
      GO TO 7004
  258 WRITE(3,268)
  261 FORMAT(1X,'  Q = 32.00 GPM'/)
  262 FORMAT(1X,'  Q = 60.00 GPM'/)
```

```
  263 FORMAT(1X,'   Q = 27.00 GPM'/)
  264 FORMAT(1X,'   Q = 30.00 GPM'/)
  265 FORMAT(1X,'   Q = 33.00 GPM'/)
  266 FORMAT(1X,'   Q = 35.00 GPM'/)
  267 FORMAT(1X,'   Q = 28.00 GPM'/)
  268 FORMAT(1X,'   Q = 33.00 GPM'/)
 7004 WRITE(3,7010)
 7010 FORMAT(//T20,'T  I  M  E'/T14,'CLOCK    DIFFER-  CUMULA- '/T14,'TIM
     2E      ENCE      TIVE'/T3,'STATION    HR MIN    (MIN)     (MIN)'/)
      READ(1,6001)N
 6001 FORMAT(I2)
C
C                    <------------------------------READ CARD-------------
C
      READ(1,6002)(NSTA1(K),N2(K),NSTA2(K),NHOUR(K),N1(K),MIN(K),K=1,N)
 6002 FORMAT(I2,A1,2I2,A1,I2)
      GO TO 696
 4340 GO TO(271,272,273),NQ
  271 WRITE(3,281)
      GO TO 7004
  272 WRITE(3,282)
      GO TO 7004
  273 WRITE(3,283)
  281 FORMAT(/1X,'   BORDER WIDTH = 67 FT'/'    Q = 7.70 CFS'/)
  282 FORMAT(/1X,'   BORDER WIDTH = 65 FT'/'    Q = 4.20 CFS'/)
  283 FORMAT(/1X,'   BORDER WIDTH = 66 FT'/'    Q = 7.80 CFS'/)
      GO TO 7004
C
C     PRINT RESULTS (WATER ADVANCE DATA)
C
 2229 WRITE(3,299)(NSTA1(K),N2(K),NSTA2(K),NHOUR(K),N1(K),MIN(K),DIFF(K)
     2,CUM(K),K=1,N)
  299 FORMAT(T4,I2,A1,I2,T13,I2,A1,I2,T23,F3.0,T31,F4.0,/)
      GO TO 133
 1000 STOP
      END
```

# APPENDIX F

## CURVES FOR ESTIMATING UNIT-BORDER STREAMS




CURVES FOR DETERMINING DESIRABLE SIZE OF STREAMS TO USE ON A BORDER STRIP 1' WIDE AND 100' LONG FOR SOILS HAVING DIFFERENT BASIC INTAKE RATES (9).