To the Graduate Council:

I am submitting herewith a thesis written by Wilbur Thomas Mahoney entitled "Basin Tillage for Erosion Control." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Mechanization.

Fred Tompkins

Fred Tompkins, Major Professor

We have read this thesis and recommend its acceptance:

C. H. Shelton

Donald Tyler

Accepted for the Council:

L Evans Roth

Vice Chancellor
Graduate Studies and Research

BASIN TILLAGE FOR EROSION CONTROL

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Wilbur Thomas Mahoney

June 1983

ACKNOWLEDGMENTS

I wish to thank the following:

The Department of Agricultural Engineering and its head, Dr. Houston Luttrell, for accepting me in the Agricultural Mechanization program.

Dr. Fred Tompkins, my major professor, for his guidance, instruction, and assistance during my tenure as a graduate research assistant.

Professor Curtis Shelton, committee member, who provided technical assistance and advice during the experiment.

Dr. Donald Tyler, another committee member, who also provided advice and assisted me at the site of the experiment at the Milan Experiment Station.

The personnel of the Agricultural Engineering Research Shop for their assistance and instruction during the construction of the basin tillage implement.

The personnel of the Milan Experiment Station for their technical assistance and physical labor.

My fellow graduate students, who provided unlimited assistance.

ABSTRACT

A three-unit basin tillage machine which mechanically formed earthen dams in the tilled soil of bedded row middles was designed, constructed, and field tested. The objectives of the test were to evaluate the operation of the machine and to evaluate the effectiveness of diked bedded row middles in controlling soil loss by water erosion.

Diked and undiked treatments were compared during six tests using slopes of 2 and 5 percent and slope lengths of 65 feet and 50 feet, respectively. A test consisted of subjecting two plots, one diked and the other undiked on the same ground slope and of the same slope length, to simulated rainfall of a given intensity. Rainfall application intensities ranged from 0.68 to 4.89 inches per hour.

Runoff samples from each plot were manually collected at 4-minute intervals from type HS flumes installed at each plot outlet. Runoff rates were determined by measuring the depths of flow in the flumes. Sediment concentrations in the runoff water samples were determined by laboratory analyses and subsequently translated to mass of soil loss.

The prototype machine operated relatively trouble-free under typical field conditions throughout the experiment. Diked plots, when compared to undiked plots, generally exhibited lower runoff rates, contained less sediment in the runoff water, and allowed more water to infiltrate the soil.

TABLE OF CONTENTS

CHAPTER PAGE

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

CHAPTER I

INTRODUCTION

I. BACKGROUND AND PROBLEM DEFINITION

"Soil erosion poses a serious hazard to row crop production on sloping land in humid regions" (Langdale et al., 1979). The Tennessee Market Bulletin (1979) reported that one-fourth of the total land area in West Tennessee has serious sheet and gully erosion problems, and indicated that annual water erosion losses from agricultural lands in West Tennessee often exceed 30 tons per acre.

Erosion, at rates higher than the natural soil replacement rate, affects crop yields and eventually removes tillable land from production. Buntley and Bell (1976) estimated crop yield reductions on moderately eroded Class II land and severely eroded Class IV land on selected Tennessee soils. They reported crop yield reductions due to soil loss for fescue, wheat, cotton, corn, and soybeans as 25, 28, 33, 42, and 50 percent, respectively, on Grenada silt loams.

Soil conservation measures such as no tillage for row crop production have proven effective in reducing soil losses to acceptable levels. However, cotton continues to be planted and cultivated by conventional methods. Conventional tillage offers little protection against water erosion, and the soil losses under conventional cultivation are particularly high in West Tennessee

Public Law 92-500 and the Clean Water Act of 1977 require the control of non-point pollution including sediment from agricultural land. The objective of the legislation is fishable and swimmable waters in flowing streams by 1983 (Langdale et al., 1979).

Erosion control methods are needed to reduce soil losses, especially when conventional cultivation is employed. Basin tillage, the practice of forming small earthen dams in row middles, appears to have potential in reducing overland flow and erosion. Wesley and Williford (1981) investigated basin tillage with conventionally tilled cotton and soybeans in the Mississippi Delta. The objective of their test was to evaluate rainfall retention for crop improvement. However, they noted that no runoff occurred from the basin tilled test areas.

II. OBJECTIVES

The purpose of this study was to evaluate the effectiveness of basin tillage as an erosion control measure for conventionally tilled cropland. Specific objectives were:

1. To design, construct, and field test a basin tillage implement to mechanically form earthen dams at specified intervals in bedded row middles.
2. To evaluate the practice of basin tillage for effectiveness in reducing soil loss due to water erosion.

CHAPTER II

REVIEW OF LITERATURE

I. MECHANICS OF EROSION

Raindrop Erosion

Ellison (1944) described several factors that affected raindrop erosion. These factors include rainfall, slope of the land, soil characteristics, and the amount of cover provided by vegetation. The general belief was that the soil was loosened by the impact of falling water droplets and subsequently eroded entirely by surface flow (Smith and Wischmeier, 1962).

McIntyre (1958) furthered the work of Ellison (1944). He described four successive phases of splash erosion. First, there was a rapid wetting of the soil surface which caused low cohesion and high splash rates. Second, a surface crust was formed which decreased the splash rate and caused an accumulation of surface water. Third, the crust was partially removed by turbulent surface flow and permeability was increased. Lastly, the water infiltrated into the soil in the absence of the crust and the splash increased. The process of crusting began once again.

Sheet Erosion

Sheet and microchannel erosion become the next phase of the erosion process once the soil is detached by raindrop splash. The resulting loss of a thin layer of erosion is termed sheet erosion.

"Detachment of soil particles by rainfall impact and splash is probably the only process by which a fairly uniform layer of soil is removed from field surfaces" (Smith and Wischmeier, 1957). Raindrop splash has been shown to detach significant amounts of soil but transport little. However, when splash is coupled with surface flow, the erosion process can reach serious proportions (Smith and Wischmeier, 1962).

Woodruff (1947) compared soil loss when water was applied as sheet flow without raindrop impact to that when water was applied as simulated rainfall. His results showed that sheet flow erosion without drop impact was only 10 percent of simulated raindrop erosion on slopes of 8 percent or less. He noted that an increase in slope caused a greater detachment of soil by surface flow. Woodruff concluded that raindrop impact was responsible for most soil loss on level ground.

Rill and Gully Erosion

The combination of raindrop impact and surface flow produces the primary forces of soil detachment. As rainfall rate exceeds infiltration rate of the soil, the runoff often becomes channelized. Buntley and Shelton (1979) defined this type of soil loss through small channels as rill erosion. The concentration of water in these small channels causes increasingly greater soil loss due to the scouring effect of water traveling at relatively high velocity. At this stage, the channels or rills can be eliminated by using conventional tillage equipment.

Buntley and Shelton (1979) described gully erosion as that resulting from two or more rills joining down the slope. The combined volume of water causes deepening and widening of channels, creating gullies that cannot be eliminated through the use of conventional tillage equipment. Gullies may range in depth from 1 foot to approximately 100 feet (Donahue et al., 1971).

II. FACTORS AFFECTING FIELD SOIL EROSION

Smith and Wischmeier (1962) related five factors to soil loss in agricultural watersheds. They were rainfall, soil erodibility, topography, soil cover, and management.

Rainfall

Rainfall was indicated as the major contributing climatic factor to the erosion process. Smith and Wischmeier (1957) used plots tilled to a degree appropriate for planting corn and cotton to evaluate rainstorm characteristics correlated with field soil loss. The plots used had no protective vegetative cover. The results showed that soil loss was poorly correlated with the amount of rainfall. Good correlation with maximum 30-minute rainfall intensities was found only on steep slopes or sandy loam soils. They concluded that soil loss was more closely correlated with rainfall intensity than with quantity of rainfall. Wischmeier and Smith (1978) noted that the rainstorm parameter most highly correlated with soil loss was a product term, kinetic energy times the maximum 30-minute intensity. They called this term the "rainfall index."

The maximum 30-minute intensity was defined as twice the greatest amount of rain falling in any 30-minute period.

Rainstorm energy is a function of the amount of rain and all the component intensities of the storm (Wischmeier and Smith, 1978). Drop sizes and terminal velocities, which are directly related to the energy of a falling droplet, have been shown to increase with intensity (Laws, 1941). Wischmeier and Smith (1978) expressed the relationship between intensity and kinetic energy of a given storm segment with the equation,

$$E = 916 + 331 \log I$$

where E is kinetic energy in foot-tons per acre-inch of rainfall and I is rainfall intensity in inches per hour.

Soil Erodibility

Hudson (1971) defined soil erodibility as its susceptibility to erosion, the reciprocal of its resistance to erosion. He further described erodibility as being a function of two factors: actual physical characteristics of the soil and treatments of the soil.

Attempts to describe soil erodibility due to its physical characteristics are not new. Bryan (1968) reviewed more than 30 studies of attempts to relate soil erodibility to physical characteristics. The pioneering work to quantify the erodibility of soil was begun in this country in the early 1930's.

Bouyoucos (1935) attempted to describe the physical characteristics of soil mechanically. He suggested that erodibility is proportional to the ratio of total sand and silt to clay. Several other researchers in this country and abroad made similar efforts to relate erosion to soil physical characteristics.

Hudson (1971) concluded that describing soil erodibility solely on the basis of physical characteristics was not accurate. In some cases physical characteristics indicated relative resistance to erosion inherent in different soil types. He found no evidence that the properties which can be measured on a soil sample in the laboratory are the properties which determine how much erosion takes place from undisturbed soil in the field. Laboratory analysis of soil does not account for the condition of the soil surface, the moisture content of the soil, and the permeability of the soil profile (Baver et al., 1972). The erosive potential of a soil is the result of a combination of the physical and chemical characteristics of the soil and agronomic practices.

Topography

"Field soil loss is affected by the degree of slope, the length of slope, and the curvature of the slope" (Smith and Wischmeier, 1962). The first two effects have been extensively studied. However, little research has been conducted to evaluate the effect of slope curvature.

Smith and Wischmeier (1957) evaluated plot data gathered by several researchers to determine the relationship between percentage slope and soil loss. The data were a result of 17 years of soil loss measurements from slopes of 3, 8, 13, and 18 percent on Fayette soil exposed to natural rainfall. The plots were cropped to continuous barley for 5 years followed by 12 years of corn-oats-meadow rotation with across-the-slope tillage. They concluded that soil loss did increase with slope and developed the equation:

$$A = 0.43 + 0.3\ S + 0.04\ S^2$$

where A is soil loss in tons per acre and S is percentage slope.

More recently, Wischmeier and Smith (1978) concluded that soil losses increased as slope and slope length increased. However, the rate of erosion did not increase uniformly with increases in slope length and steepness.

Cover and Management

The greatest deterrent to soil erosion is vegetative cover. Cover and management influence both the infiltration rate and the susceptibility of the soil to erosion. The most effective vegetative cover is a well-managed, dense sod. Most severe erosion occurs when erosive rainstorms coincide with periods in the rotation when the soil surface is essentially bare and freshly tilled. Sod-based rotations traditionally have played a predominant role in runoff and erosion control (Smith and Wischmeier, 1962).

Baver et al. (1972) listed four major effects of vegetation on runoff and erosion: interception of rainfall; decreases in the velocity of runoff and the cutting action of the water; root effects in increasing granulation and porosity; and the transpiration of water leading to subsequent drying of the soil.

Interception of raindrops by a vegetative canopy affects erosion in two ways. First, some of the water never reaches the soil but is evaporated after striking the vegetative cover. The water which fails to contact the soil surface is not a factor in runoff and erosion. Secondly, the vegetative canopy absorbs some of the destructive energy of the falling droplets (Baver et al., 1972).

Increased leaf area during the growing season intercepts the raindrops and transpires water, thus reducing the amount of runoff. By reducing the surface flow velocity, vegetation reduces the scouring and cutting action of water.

The root network of vegetative cover also provides protection against erosion by contributing to stable granulation and increasing soil porosity. The roots themselves act as a binding agent to hold soil against moving water (Baver et al., 1972).

III. EROSION CONTROL

"Adequate control of water erosion requires integrated use of the best agronomic and engineering practices that will protect the soil and reduce runoff" (Baver et al., 1972). Baver described agronomic practices as those that provide maximum plant cover, tillage practices that give optimum absorption of rainfall, and use of residues to provide protection from raindrop impact.

Mechanical Control Measures

Mechanical measures which shape the soil control the velocity of runoff, increase infiltration, prevent scouring, and prevent the transportation of soil detached by raindrop impact. Hudson (1971) suggested confining mechanical erosion controls to arable land for two reasons. First, the measures are expensive and the low value of non-arable land cannot support the cost. Secondly, arable land is generally more vulnerable to erosion because of its cultivated state. Establishing agronomic control measures while the crop is growing is sometimes impossible.

Hudson (1971) further cautioned against poor planning and implementation of mechanical controls. First, surface water is concentrated in channels where it is potentially dangerous and likely to scour the soil. Secondly, failure of a poorly planned control structure is almost always more destructive than if the structure had not existed.

IV. BASIN TILLAGE

Basin tillage, or furrow diking, is the practice of forming earthen dams across bedded row middles to impound rainfall (see Figure 1). Dikes are generally created at specific intervals by tractor-mounted machines.

Early Efforts

The benefits of retaining rainfall on the land to provide soil moisture has long been recognized. In the arid parts of the United States and elsewhere, the retention of moisture is of utmost importance. Prevention of runoff for erosion control has not been the primary consideration for using basin tillage.

"The idea of preparing the soil surface to prevent runoff has perhaps been in the human mind for centuries" (Lyle and Dixon,

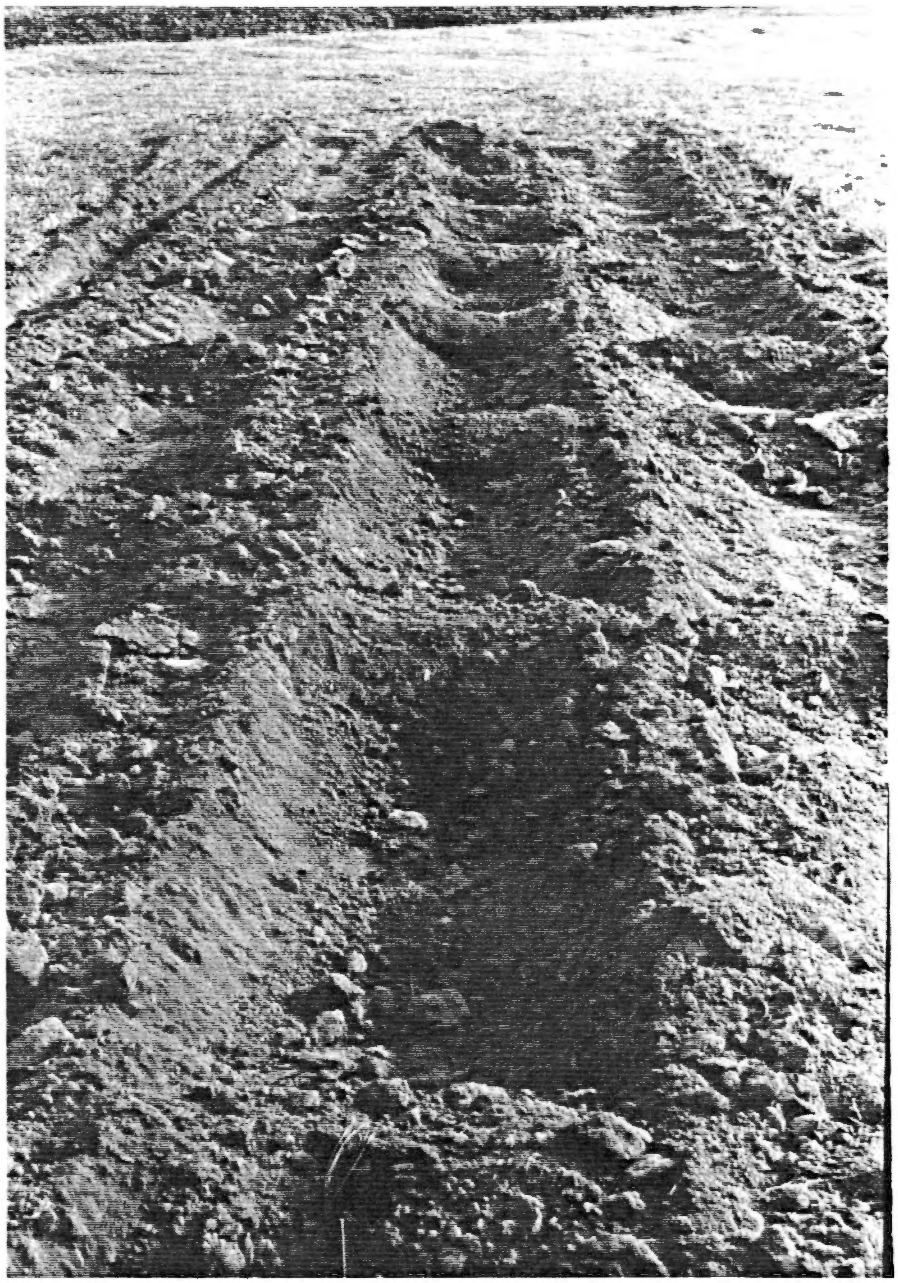

Figure 1. Dikes formed between bedded rows using an experimental basin tillage machine.

1977). There were several tillage concepts in the 1930's to control runoff. However, the "waffle cultivator" built by The Bureau of Chemistry and Soils at Hays, Kansas in 1930 was probably the first basin tillage type tool in this country (Knight and Hyde, 1931). The "waffle cultivator" had a series of alternating shovels that scooped depressions in the tilled soil on plowed smooth ground.

The following comments by Ivan D. Wood, a University of Nebraska Agricultural Engineer, at a meeting of the Land Reclamation Division of the American Society of Agricultural Engineers described the popular trend of thought (Wood, 1933).

> A machine which digs 10,000 holes per acre, each having a capacity of three gallons, is in the experimental stage of development. Land worked with this machine would be capable of holding one inch of rainfall without loss if it fell in one minute. Suppose behind the lister there was arranged a device to construct a dam of earth in the trench at intervals of 15 to 20 feet on level ground and eight to ten feet on slopes. A series of dams along the course of the trench at frequent intervals would certainly help prevent erosion and produce a pocket to hold water or snow.

C. T. Peacock patented and tested a machine in 1931 to form dams at regular intervals in furrows. He used the machine on his Arriba, Colorado farm and claimed substantial benefits when used on summer fallow (Shedd et al., 1935).

Two dam forming machines were described by Hughes (1933) in the Iowa State Agricultural Experiment Station Annual Report. The first was called a furrow-damming attachment for a lister. Its purpose was to make dams at specified intervals in the lister furrows to obstruct the flow of water. The dams aided in preventing soil from washing and allowed the water to infiltrate the soil. Hughes reported that a 3-inch rain broke the dams in several places, but the soil was retained in adjoining basins. An oscillating cultivator was also described in that report. A series of shovels were said to oscillate vertically to form water-holding depressions in the soil.

A basin lister was developed and evaluated at Iowa State University by C. K. Shedd et al. (1935). The purpose of the experiment was to evaluate the basin method of planting and the operational characteristics of the basin tillage lister. The basin lister was comprised of a damming attachment mounted behind a corn lister which was commonly used in some parts of the Corn Belt. The rear attachment formed dams at regular intervals in the listed furrows.

The damming attachment was described as "paddle-wheel scraper" positioned to run in the furrows. The paddles were metal blades shaped to fit the bottom and sides of the furrow. Four paddles were positioned 90 degrees apart around a horizontal metal shaft. As the machine moved forward, one of the paddles was in a near-vertical position to scrape soil into a dam. A tripping mechanism, which also acted as a stop, was released to allow the next paddle to rotate about the shaft and assume the scraping position.

Two machines with different tripping mechanisms were constructed and tested. No significant advantage was attributed to either machine. The first mechanism described was a gear-driven shaft with behavior similar to that of the throws of a crankshaft. The shaft was mounted such that one of the paddles rested against the shaft for an unspecified amount of time. The shaft was driven in an arc such that at some point it no longer contacted the paddle. The forward motion of the paddle in contact with the ground caused the paddles to rotate. The trip mechanism then traveled back through its original arc to stop the revolving paddle.

The other trip mechanism was described as a device which utilized an automobile shock absorber. A roller mounted on the shock absorber arm engaged a blade of the paddle wheel to keep the blade from turning. As the pressure increased, the shock absorber arm was gradually pushed out of the way and the rotated paddle was stopped by the returning shock absorber arm. The implement was designed to dam two row middles. The paddle wheels were free to move vertically to adjust their position as the ground surface changed.

Basin tillage experiments were conducted during 1933 at Ames, Iowa. Fifteen acres of corn were grown on ground which was basin listed in mid-April and left in that condition until the latter part of May. The ground was then double-disked and basin listed: planting in the basin followed. A yield of 92.8 bushels per acre of corn was reported.

In 1934 experiments were conducted to compare yields for basin listing, ordinary listing, and surface drill planting; to compare labor and power expenditures in producing basin listed corn; and to compare implements for cultivating basin listed corn. The basins were designed to have a capacity of 1.16 inches of rainfall. The damming interval was set at 4 feet, with each dam having an effective height of 5 inches. The actual amount of rainfall retained by the basin was a function of the permeability of the soil, the intensity of the storm, and the ground slope.

Several advantages were listed. Basin tillage was reported to reduce water erosion of the soil, lessen the danger of washing out the seed, reduce the tendency of water to pool at low points in the field, and conserve moisture (Call and Aicher, 1963). For a period of 10 years, increases in wheat yield of 10 to 20 percent were obtained.

A successful basin lister was constructed to mechanically form earthen dams in row furrows in 1935. The damming implement was attached behind a rebuilt two-row lister. Auxiliary cam rollers were mounted on each ground wheel to lift the dammers at intervals of 10 feet. A blade was attached to the rear of the lister to form the dams. The blade was shaped such that it conformed to the furrow made by the lister. As the implement was pulled forward, the blade formed dams by scraping the previously loosened soil. Cams located in the ground wheels caused the blades to lift momentarily, leaving an earthen dam. A speed not to exceed 3 miles per hour was recommended for optimum efficiency. The height of the dams was controlled by the depth the blade was positioned in the furrow. In 1936 a field with 4 percent slope was basin listed on the contour. A 2.5-inch rain of unreported duration was successfully held in the basins.

Following the successful operation of the basin lister, it was demonstrated in 30 counties of Western Kansas. Blueprints were made available and sold at cost to 500 individuals. Machinery manufacturers produced several types of basin-forming implements shortly thereafter and continued to do so for the remainder of the decade.

Basin tillage was further evaluated by several researchers, but the results were inconclusive. Most experiments were conducted on fallow wheat ground. Although the practice was shown to greatly reduce surface runoff, basin tillage had little effect on yield improvement (Kuska and Mathews, 1956).

Locke and Mathews (1953) concluded that fallow cropping methods in wheat were unproductive. Therefore, one might conclude that basin tillage on fallow wheat ground would be equally unproductive. Nicholls and Chambers (1938) concluded that basin tillage provided little advantage in row crop production because the dams were soon destroyed by cultivation.

After experimenting with basin tillage on fallow wheat ground, Kuska and Mathews (1956) stated that, "the results of the study provided no evidence that impounding water with the basin lister or with dikes has improved yields of wheat."

By 1950 much of the interest in basin tillage had been lost as a result of the findings in the Wheat Belt. Lyle and Dixon (1977) speculated that another contributing factor to lack of interest in the practice was the jarring ride when tillage operations were performed following the construction of the dams.

Basin Tillage Abroad

The 1942-1943 Progress Report of the Empire Cotton Growing Corporation contained the results of tied-ridging with maize and cotton production tests. During a particularly dry year, the tied-ridge cultivation outperformed conventional tillage methods (Faulkner, 1944). Apparently no mechanical device was used to construct the basins. Hand labor was used to form dikes in the mechanically formed furrows.

Dagg and Macartney (1967) reported favorable results using tied-ridging in Kenya. The objective of the experiment was to impound rainfall in the basins for moisture conservation. Yield increases as well as soil conservation benefits were reported. The yields for tied-ridging and conventional or flat cultivation of cotton were reported as 2824 pounds per acre and 2389 pounds per acre, respectively. The prototype implement was constructed by the National Institute of Agricultural Engineering in the United Kingdom. The machine was capable of ripping, ridging, and planting. The diking unit was a disk at the end of a lever arm that was raised and lowered by means of a step wheel. The findings of Dagg and Macartney were considerably more promising than those reported by American researchers.

Recent Use

New interest appeared in the United States in the early 1970's (Aarstad and Miller, 1973). They reported a reduction in runoff from 40 percent to about 1 percent from center-pivot irrigated field using basins between rows. Water retention is typical of current basin tillage applications in the United States. The sometimes high application rate of irrigation systems lends itself to potential runoff. When this happens, upslopes receive too little water, depressions receive too much, and valuable water is lost. Investigations were conducted in 1971 on four center-pivot irrigation systems in the Prosser, Washington area. Comparisons of conventional tillage, mulch residue on the surface, mulch residue incorporated, and shallow basins were made to determine water retention characteristics of each practice and compare crop yields.

Lyle and Dixon (1977) conducted extensive experimentation with basin tillage for rainfall retention in arid Southwest Texas. Their primary concern was the development of a superior design in diking implements. Two diking machines were constructed. The criteria for developing the models were:

1. Trouble-free operation
2. Attachable to row crop implements
3. High speed operation
4. Dam spacing adjustments
5. Simple in design and construction.

A tripping shovel consisted of a four-paddle shovel that could be tripped and rolled 90 degrees by retracting the shovel support arm with a lever system actuated by a rotating cam and ball bearing roller. A spring caused the shovel arm to resume its original position and stop the next paddle as it rotated about its shaft.

The raising-shovel diking implement was a blade or shovel attached to a lever arm which was lifted by a raising arm actuated by a cam lobe rotated about a shaft. Each revolution of the shaft caused the raising arm to move upward, lifting the lever arm and the shovel.

Both the tripping shovel and the raising shovel were powered by hydraulic motors, the speed of which could be adjusted to control the tripping rate and the dam spacing. A 3.2-foot spacing was the shortest interval recorded. Both prototypes were reported to operate relatively trouble free. The torque requirement to lift the raising shovel was substantially greater than that required for the tripping design.

The raising shovel diker began to form dams that were wide and spread soil across the row when operated at speeds higher than 3.1 miles per hour. This might be attributed to the time interval required to raise and lower the shovel. The tripping shovel was capable of field speeds of 7.1 miles per hour. Each prototype required well-tilled soil to produce adequate dams. Lyle and Dixon (1977) concluded that the tripping shovel design was superior to the raising shovel design. A variable speed hydraulic motor to actuate the diking process was recommended.

Spurred by three consecutive dry growing seasons, Wesley and Williford (1981) initiated studies to evaluate basin tillage for cotton and soybean production in the Mississippi Delta. "The studies were designed to evaluate the effect of basin tillage on (1) cotton and soybean yields, (2) the potential for increased water infiltration and storage in both sandy loam and clay loam soils, and (3) the conservation of water and soil" (Wesley and Williford, 1981).

The study began in 1978 with the construction of a basin tillage implement as described by Lyle and Dixon (1977). The machine was a five-unit device. Each unit consisted of a four-bladed shovel that rolled 90 degrees after being tripped by a shovel support arm.

Wesley and Williford (1981) reported considerable problems in maintaining proper adjustments in the support arm and mechanical linkage to the cam and ball bearing rollers. This was contrary to published data of Lyle and Dixon (1977). The operating speeds were also somewhat lower than those obtained by the Texas Experiment Station.

The 1978 version of the diker was altered to eliminate the adjustment problems. Wesley and Williford removed the ball bearing roller and cam and replaced them with a 1-inch diameter shaft connected to the hydraulic motor. A cam assembly was then chain driven by a hydraulic motor, eliminating the need for a mechanical linkage. The revisions resulted in trouble-free operation.

The experiments were conducted for a 2-year period. Initially, the study was designed to determine the effect of basin tillage on seed cotton yields on find sandy loam soils. The test included diking all rows, diking alternate rows, two diking intervals, and conventionally-tilled bedded cotton.

The results of the 1978 test indicated that basin tillage did significantly increase cotton yields. Only one rain was recorded after the formation of the dikes. The rain of 2.45 inches occurred during the fruiting stage. No runoff was recorded from the basin tilled plots. Runoff from the conventionally tilled plots was described as considerable.

CHAPTER III

DESIGN OF THE BASIN TILLAGE IMPLEMENT

A three unit, hydraulically powered, cam-actuated basin tillage machine was designed and constructed to form small earthen dams at specified intervals across row middles. The device was integrally mounted on the tractor with a category II three-point hitch.

The implement was constructed in The University of Tennessee Agricultural Engineering shop during the summer of 1980. Most components were fabricated in-house. Chains, sprockets, a hydraulic motor, and other drive line components were purchased from local vendors.

The implement was designed and built using some concepts from prototype machines developed at the Texas Agricultural Experiment Station (Lyle and Dixon, 1977) and the United States Department of Agriculture Experiment Station at Stoneville, Mississippi (Wesley and Williford, 1981). Although similar in appearance and overall performance, the Texas and Mississippi machines employed different tripping mechanisms to control the four-paddle shovel. The tripping mechanism of the Texas prototype consisted of a series of linkage arms. The Stoneville diker trip mechanism employed a device similar in function to an automobile crankshaft. As the crankshaft revolved, a stop arm traveled in a reciprocating fashion. When the attached stop arm was fully retracted, the paddles were freed to rotate due to the frictional resistance provided by the soil.

The University of Tennessee implement was designed to operate over a wide range of ground speeds and diking intervals. Dams were formed by the scraping action of the paddle blades on loosened soil between the crop rows. The interval between earthen dams was controlled by regulating the fluid flow rate through the hydraulic motor that powered the tripping mechanisms. A stop arm was momentarily retracted by a revolving cam to allow the paddle to rotate one-quarter turn. The rotation released the accumulated soil, creating the dam or dike. The next blade contacting the ground surface began collecting soil to form the next dike.

I. MAIN FRAME

The main frame consisted of a 4-inch square tubular steel tool bar equipped with a category II three-point hitch. Three 2-inch by 4-inch vertical tubular steel standards were welded to the tool bar on 40-inch centers. A hydraulic motor mount and bearing mounts were also attached to the tool bar to support the driving shaft. A 1-inch diameter shaft driven by the motor was supported along its length by flange bearing units (see Figure 2).

II. DIKING UNITS

The three diking units consisted of:

1. Diking unit frame
2. Paddle shovel assembly

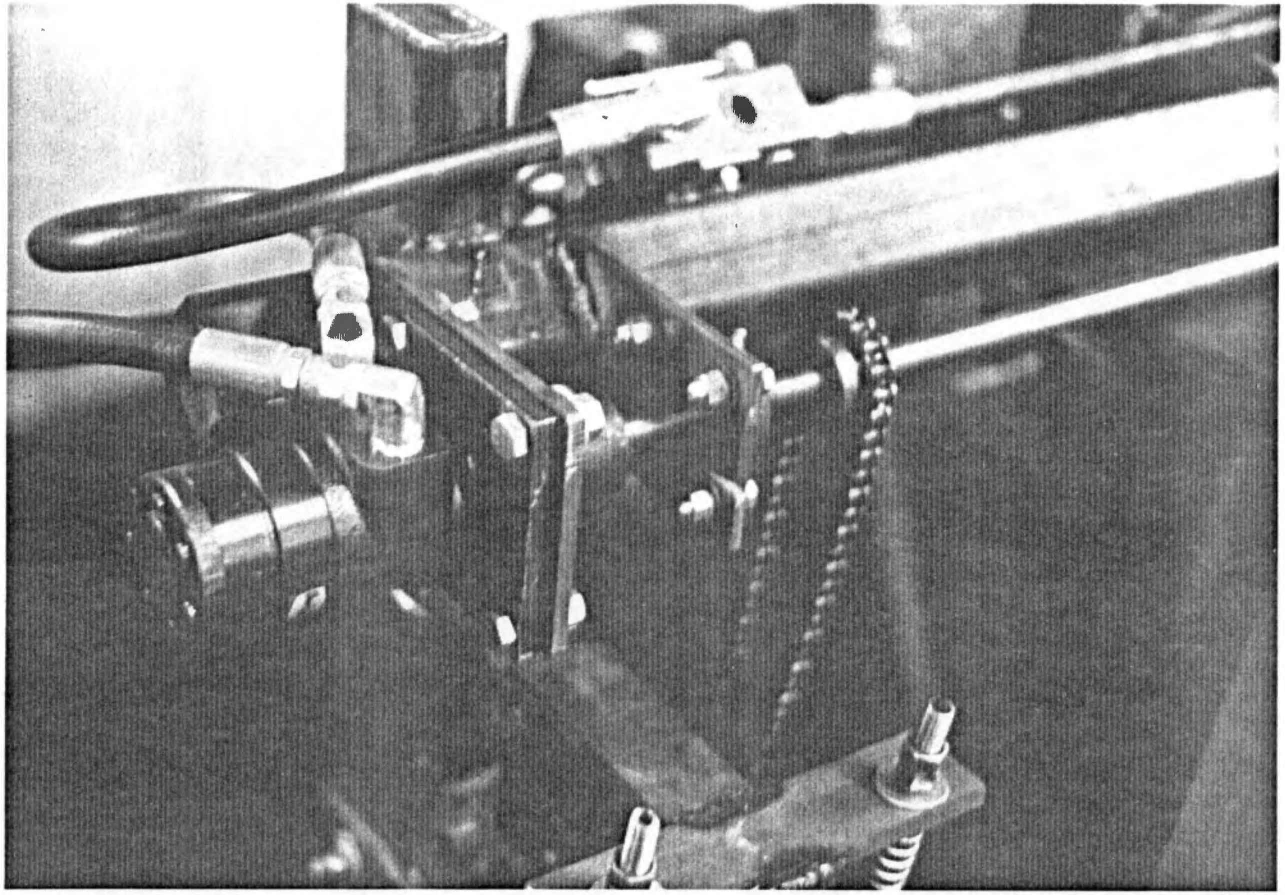

Figure 2. Hydraulic motor and chain used to drive the tripping mechanism on the experimental basin tillage implement.

3. Transport arm

4. Tripping mechanism (see Figure 3)

Diking Unit Frame

The diking unit frame provided a mount for the four-bladed paddle, a base for the tripping mechanism, and a point of attachment to the implement main frame. The diking unit frame was constructed from 1 1/2-inch by 1/2-inch cold rolled steel. Supporting members were also fashioned from cold rolled steel bars and angle iron (see Figure 4).

Paddle Assembly

The paddle assembly consisted of four blades of 3/16-inch cold rolled steel plate welded at 90 degree angles about a length of 1-inch inside diameter schedule-80 pipe (see Figure 4). The paddle assembly rotated about a 15/16-inch axle through the schedule-80 pipe.

Transport Arm Assembly

The function of the transport arm was twofold. The arm (1) restricted the upward and downward movement of the diking units and (2) dampened bouncing during operation.

The assembly was constructed from 1/2-inch by 2-inch cold rolled steel bar stock, two 7/16-inch diameter steel rods, a length of schedule-80 pipe, and two coil springs. The assembly was bolted to the vertical standard and was pinned to the diking frame by a 9/16-inch steel shaft. Two 3/8-inch diameter steel rods were attached

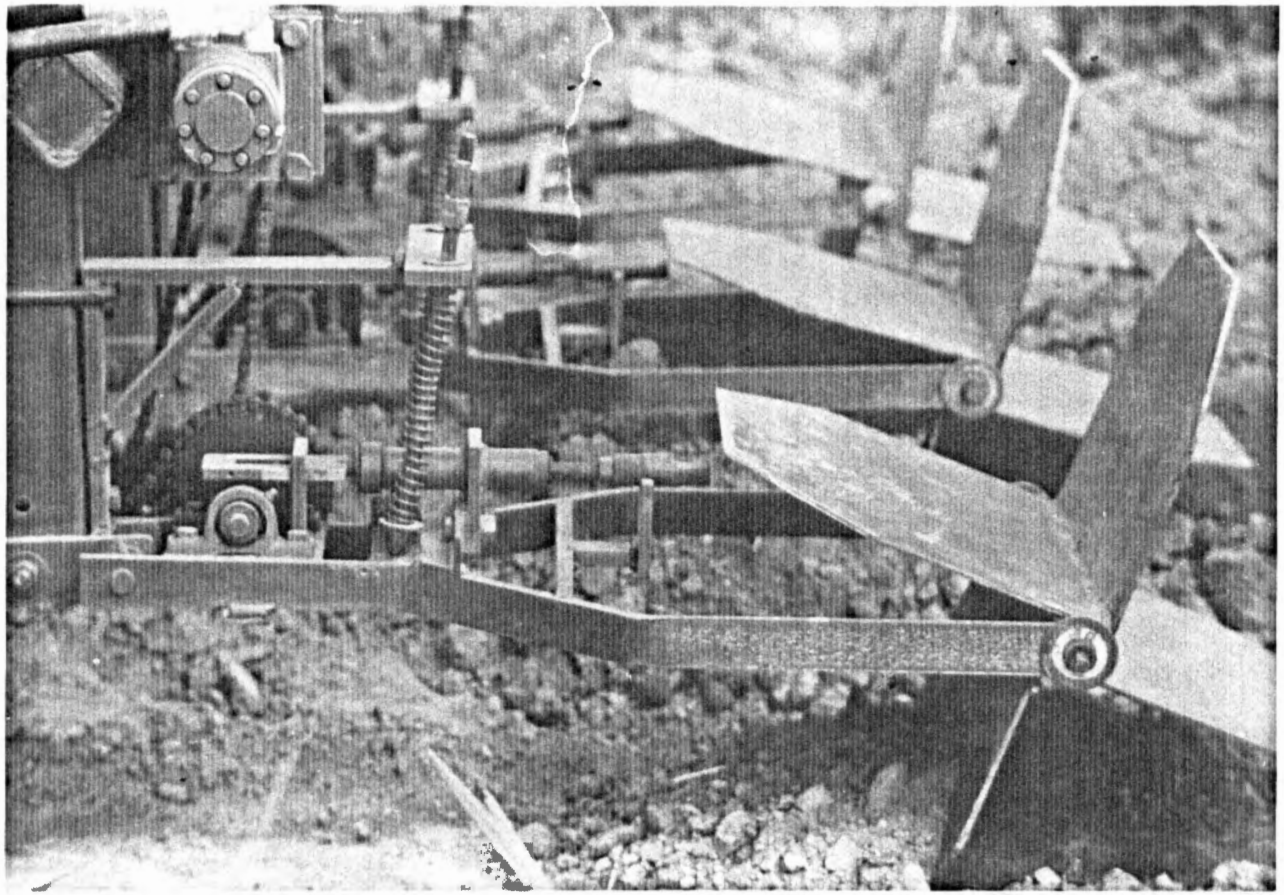

Figure 3. Diking units of the experimental basin tillage machine.

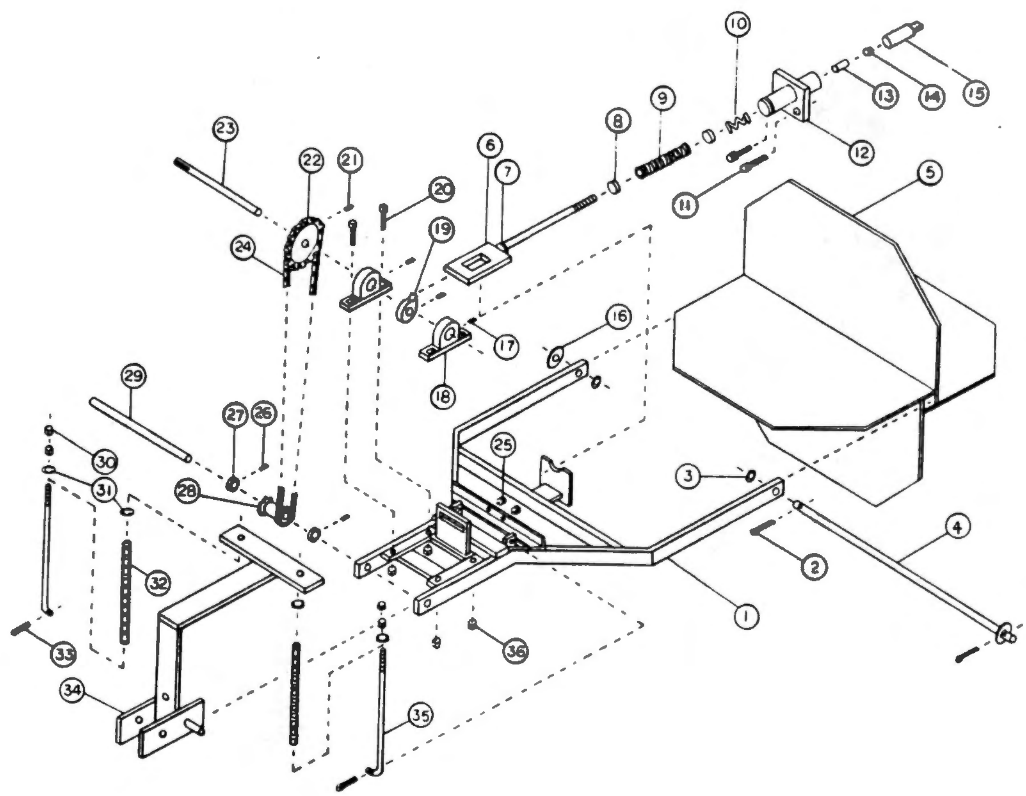

Figure 4. Exploded view of experimental tripping-shovel diking unit showing relationship of components. Numbered components are identified on p. 71.

to the diking frame by cotter pins. The upper ends of those rods protruded through holes in the cross-member of the transport arm assembly and were secured by jam nuts. The location of the jam nuts controlled the position of the diking assembly relative to the machine main frame. A compression spring was positioned around each rod between the diking frame and the cross-member of the transport arm (see Figure 5) to provide downward pressure on the diking unit during implement operation.

III. TRIPPING MECHANISM ASSEMBLY

The tripping mechanism allowed the diking paddles to rotate one-quarter revolution as the stop arm was momentarily retracted. A chain drive was used to transmit power from the implement driving shaft to the cam shaft on the individual diking units.

The assembly was comprised of:

1. An actuating cam (see Figures 4 and 6)
2. A slide (see Figures 4 and 6)
3. A stop arm assembly (see Figures 4 and 6)
4. A chain drive (see Figures 2 and 5).

Actuating Cam

The actuating cam was machined from bar stock steel and mounted on a 1/2-inch diameter steel shaft which was held by two pillow block bearings. The lobe of the cam was designed to move the slide forward 1 1/2 inches to release the paddle for rotation.

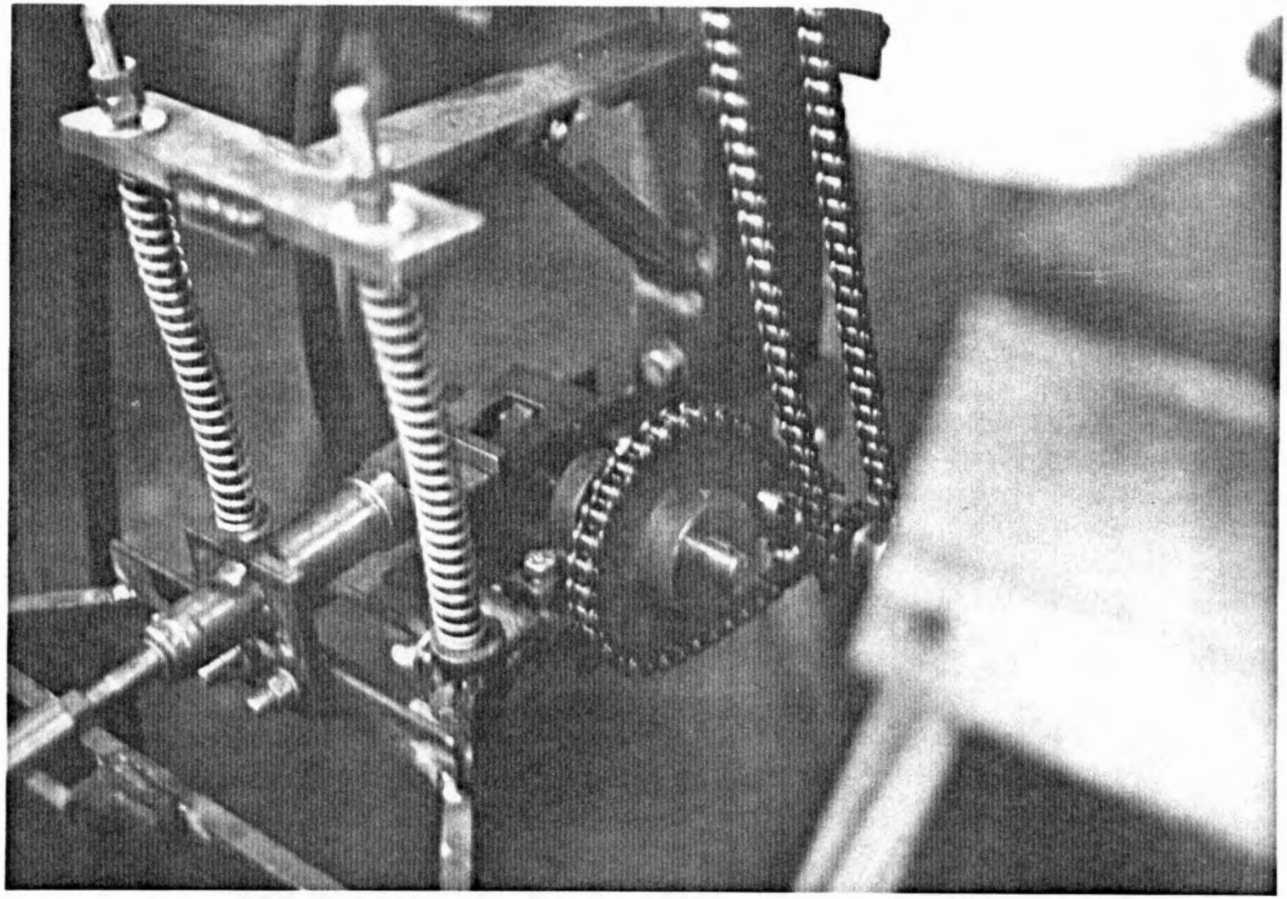

Figure 5. Drive train and transport arm assembly of one diking unit on the basin tillage implement.

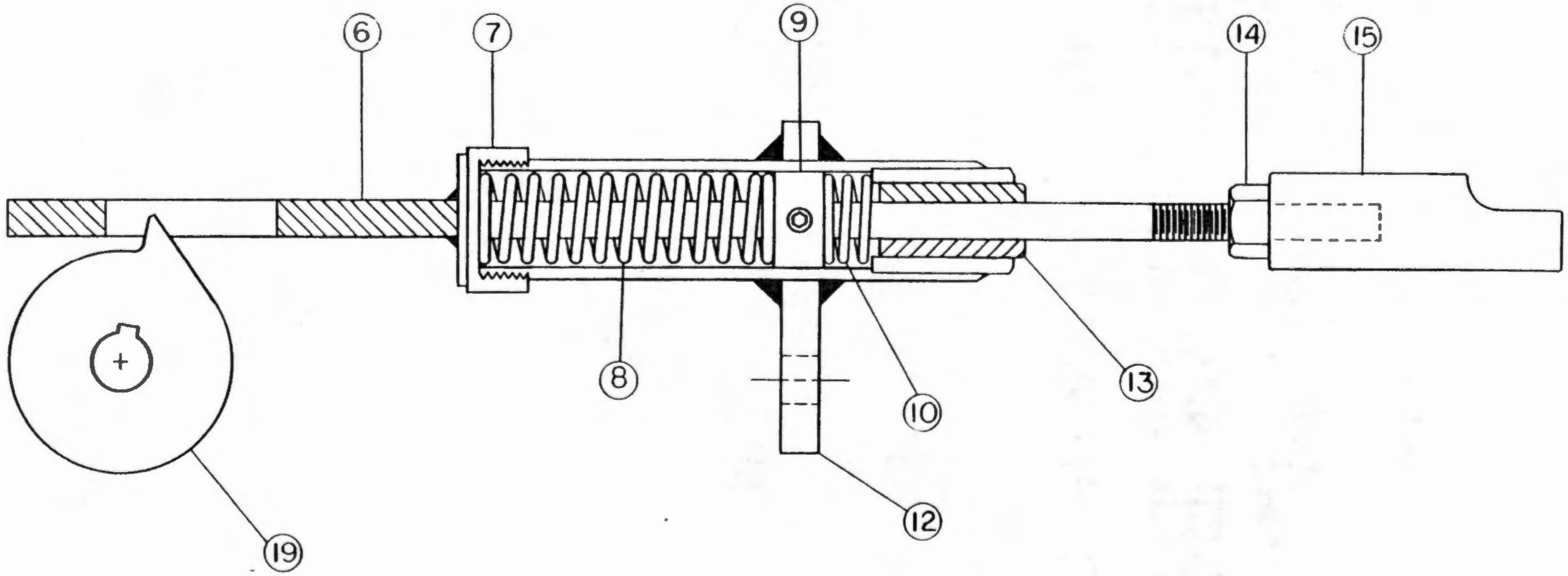

Figure 6. A cut-away view of the tripping mechanism used to control the interval between dikes. Numbered components are identified on page 72.

The cam configuration allowed quick return of the slide to catch the next paddle blade.

Slide

A slide was machined from cold rolled steel bar stock. Protection against rapid wear as the cam operated against the slide was provided by a hardened steel pin secured in a hole drilled at the point of contact between the slide and the cam face. A vertical slotted support member acted as a guide and prevented the slide from shifting from side to side.

Rotational motion was converted to reciprocating motion as the cam lobe struck the inner face of the slide. Coil compression springs in the stop arm assembly rapidly returned the slide to its original position to complete the tripping cycle (see Figure 6).

Stop Arm Assembly

The stop arm assembly consisted of a machined section of schedule-80 pipe, a 1/2-inch steel shaft, two coil springs, a locking collar, an adjustable stop, and two 1/2-inch diameter bushings. The complete assembly was bolted to the diking frame and was welded to the slide. The assembly served as a stop to prohibit paddle rotation and housed a spring-loaded return mechanism (see Figure 6).

The action of the revolving cam lobe on the slide caused the stop arm to retract. A spring in the stop arm assembly compressed during retraction and propelled the stop arm in the opposite direction when the cam no longer contacted the slide.

The machined pipe housed the stop arm shaft. This shaft was supported at each end of the housing by bushings. One end of the pipe was sealed while the other end of the housing was enclosed using a threaded removable cap.

Two compression springs, separated by an adjustable collar, were positioned around the shaft of the stop arm. The larger spring propelled the stop arm back to its original position after retraction. The remaining spring applied a constant pressure on the stop arm to hold it stationary until the next retraction. Tension adjustments were made by changing the position of the collar on the shaft.

A threaded adjustable stop was machined from cold rolled steel round stock and attached at the end of the stop arm. The stop was threaded to vary the amount of contact surface between the stop and paddle blade. A jam nut was used to secure the stop arm at a given position.

The complete stop arm assembly was bolted to the diking unit frame. Alignment adjustments were made possible by varying the position of the mounting plate. Oversize bolt holes were drilled to facilitate those adjustments.

Chain Drive

Four sprockets were used at each diking unit to transmit the power from the driving shaft to the tripping mechanism. Two lengths of 1/2-inch roller chain connected the sprockets on each unit.

The sprockets for a given diking unit were mounted in a manner that eliminated the need for an idler or tension adjustment. The shaft connecting the frame to the vertical standard was the mounting point of two 12-tooth sprockets (see Figure 5). These two sprockets were welded together and rotated as a pair. The inside sprocket was connected by roller chain to the main driving shaft sprocket. The outside sprocket was connected to a 32-tooth sprocket on the tripping cam drive shaft.

CHAPTER IV

EXPERIMENTAL METHODS AND PROCEDURES

I. EXPERIMENTAL DESIGN

Six field tests were conducted to evaluate the operation of the experimental machine and to evaluate the effectiveness of diking to control water erosion. Each test consisted of two plots which were alternately treated with either diked or undiked bedded rows. Test areas were subjected to simulated rainfall such that intensities for a given test period were not duplicated during the experiment. Rainfall intensities during the test ranged from 0.68 inches per hour to 4.89 inches per hour. Diked and undiked treatments were applied four times on 5 percent slopes and twice on 2 percent slopes. Plots on 5 percent slopes were 50 feet long and those on 2 percent slopes were 65 feet long.

Runoff water from each plot was measured and sampled to determine two dependent variables. Sediment concentration in the runoff water and the quantity of flow through the flumes were used to evaluate the effectiveness of diking.

Analyses of variance were employed to evaluate treatment effects. Specifically, the two null hypotheses were:

1. Total runoff yield from diked plots was not significantly different from the total runoff yield from undiked plots.
2. Total sediment yield from diked plots was not significantly different from the total sediment yield from undiked plots.

II. PLOT PREPARATION

Field measurements were taken at The University of Tennessee Milan Experiment Station near Milan, Tennessee during the fall of 1980 and the spring of 1981. Two plots adjacent to a rainfall simulator (Shelton and Tompkins, 1981) were shaped and instrumented during September of 1980 (see Figure 7).

The plots were situated such that runoff from each plot could be collected separately. A 1-foot HS flume attached to a plywood headwall was installed at the outlet point of each plot to measure runoff rate (see Figure 8).

The site selected for the experiment was plowed and disked to provide loose soil for the shaping necessary to control water flow. A tractor-mounted grader blade was then used to establish a uniform slope in the test area.

Diversions were constructed to channel runoff from the test area to the flumes and to divert runoff occurring outside the test plot to adjacent waterways. Bermuda grass sod was established to stabilize the area around the outlet structures.

A grass waterway was constructed between the plots to carry diverted runoff. The waterway was constructed with a grader blade and sodded with Bermuda grass. Water flowed from the flumes into an existing diversion ditch associated with the area served by the rainfall simulator.

Figure 7. Test plots used to evaluate the effectiveness of diking in reducing water runoff and soil loss.

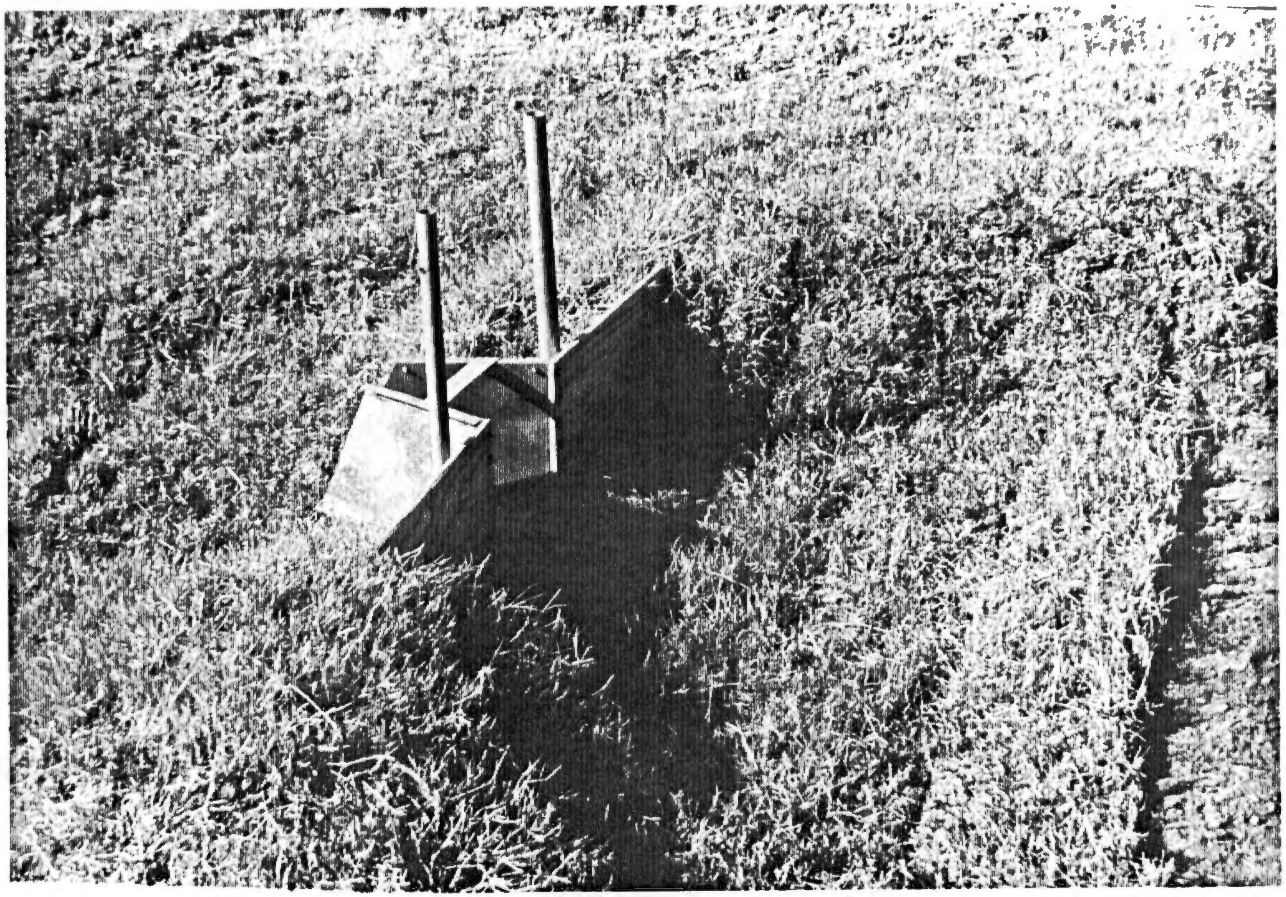

Figure 8. One of the type HS flumes used to measure runoff rate at outlets of basin tillage test plots.

III. TREATMENT APPLICATION

Both instrumented plots were initially prepared by disking an 8-foot swath at an angle to give either 2 or 5 percent slope in the row direction. Identical slopes were used on both plots during a given test. Next, four 40-inch bedded rows were constructed in the tilled swath on each plot. Finally, one of the plots selected at random was diked with the experimental machine such that dikes were 40 inches apart in three row middles.

Hand tools were used to construct temporary diversions on the plots. These diversions were used to terminate each row 50 feet from the flume on 5 percent slopes and 65 feet on 2 percent slopes. The total area including a flume approach apron for 5 percent and 2 percent slopes was 0.016 acres and 0.018 acres, respectively.

Artificial rainfall was directed onto the test area by existing rainfall simulator sprinklers. Two sprinklers were mounted atop each of eight risers spaced at 20-foot intervals along an existing water line associated with the rainfall simulator. Desired application intensity was obtained for a given test by varying the flow rate through the water line and by varying the number of sprinklers operating.

The application of simulated rainfall was continued until dike failure. At that point, water was no longer impounded by the furrow dikes but flowed toward the plot outlet.

IV. DATA COLLECTION

Runoff water samples from the test plots were taken at 4-minute intervals after the simulated rainfall began. The depth of water flow in the flumes was also measured every 4 minutes and recorded to the nearest 0.01 foot.

The intensity of rainfall was determined by measuring the depth of water collected in open cans distributed on each plot with a ruled straight-edge. The total catch per plot was determined and the mean application rate calculated.

Dike failure was recorded at two points on diked plots. Both the time interval to failure of one dike and the time interval until all dikes failed were recorded.

V. DATA REDUCTION

Runoff water samples were analyzed for sediment concentration by the pipette method (Olmstead et al., 1930). Twenty milliliters of an agitated sample were pipetted into trays and oven dried. The oven dry weight of the remaining residue was expressed in grams per liter.

The depth of flow measured in the flumes required a conversion to express the measurements as rates. Each value was converted to cubic feet per second using tables from Agricultural Handbook 224--Fieldbook for Research in Hydrology (USDA, 1962).

Runoff yields (inches) for a given 4-minute sampling period were calculated by multiplying runoff rate by the elapsed time between sampling periods. The total runoff yield (inches) was determined by summing the runoff for the several sampling periods.

Sediment yield (pounds) for a given 4-minute period was calculated by multiplying the sediment concentration in the runoff sample by the quantity of runoff measured for that period. Total sediment yield (pounds) was computed by summing the sediment yields of the several sampling periods.

CHAPTER V

RESULTS AND DISCUSSION

I. MACHINE OPERATION

The basin tillage machine was designed and constructed to be operated in tilled soil. A portion of the tilled soil was accumulated to form dikes spaced at 40-inch intervals between bedded rows. The implement performed satisfactorily during the experiment. No major modifications or repairs were performed although minor adjustments were required. For example, the tripping mechanism initially tended to bind. Although the slide would retract under the force of the cam, the slide would not return to its original position. Tolerances between the slide and vertical support were minimal. Consequently, any misalignment of the stop arm housing prevented smooth retraction of the stop arm.

The tripping mechanism was operated at low speed to locate the cause of the malfunction. The mounting bolts were loosened slightly and the housing was shifted until the mechanism was aligned. The mounting bolts were retightened, and a thin coat of machine oil was placed on the slide. This adjustment was made periodically in the course of the field work.

II. RUNOFF AND SEDIMENT CONCENTRATION

Runoff hydrographs and curves of sediment concentration versus time plotted for tests three, five, and six show the effects of diking on runoff and sediment concentration as an indicator of soil loss (Figures 9-14) and typify the data collected. Complete data for tests one through six are shown in tabular form in the Appendix.

A test was considered completed when each dike was breached by impounded water. Simulated rainfall was discontinued and measurement and collection of runoff water ceased. Conclusions regarding soil loss are based only upon data collected until total dike failure. Had the simulated rainfall continued past the dike failure point, soil losses from the diked plots might be expected to exceed losses recorded from undiked plots.

Hydrographs of runoff from diked and undiked plots for test three (Figure 9) on a 5 percent slope and 50-foot slope length showed diked runoff rates to be less than undiked runoff rates for approximately 40 minutes from the beginning of the test. After the dikes began to fail, runoff rates from the plot were substantially higher than runoff rates from the undiked plot. The runoff yield for the diked plot was less until 48 minutes after the test began. Total runoff volume for the diked and undiked plots was 0.20 inches and 0.33 inches, respectively. Of the 2.08 inches of water applied to the diked plot and 2.19 inches applied to the undiked plot, 15 percent and 10 percent, respectively, were measured as runoff.

Sediment concentrations for diked plots in test three were less until dike failure (Figure 10). The large sediment concentration increase at the 48-minute sampling time coincided with the influx of water during dike failure (Figure 9). However, the total

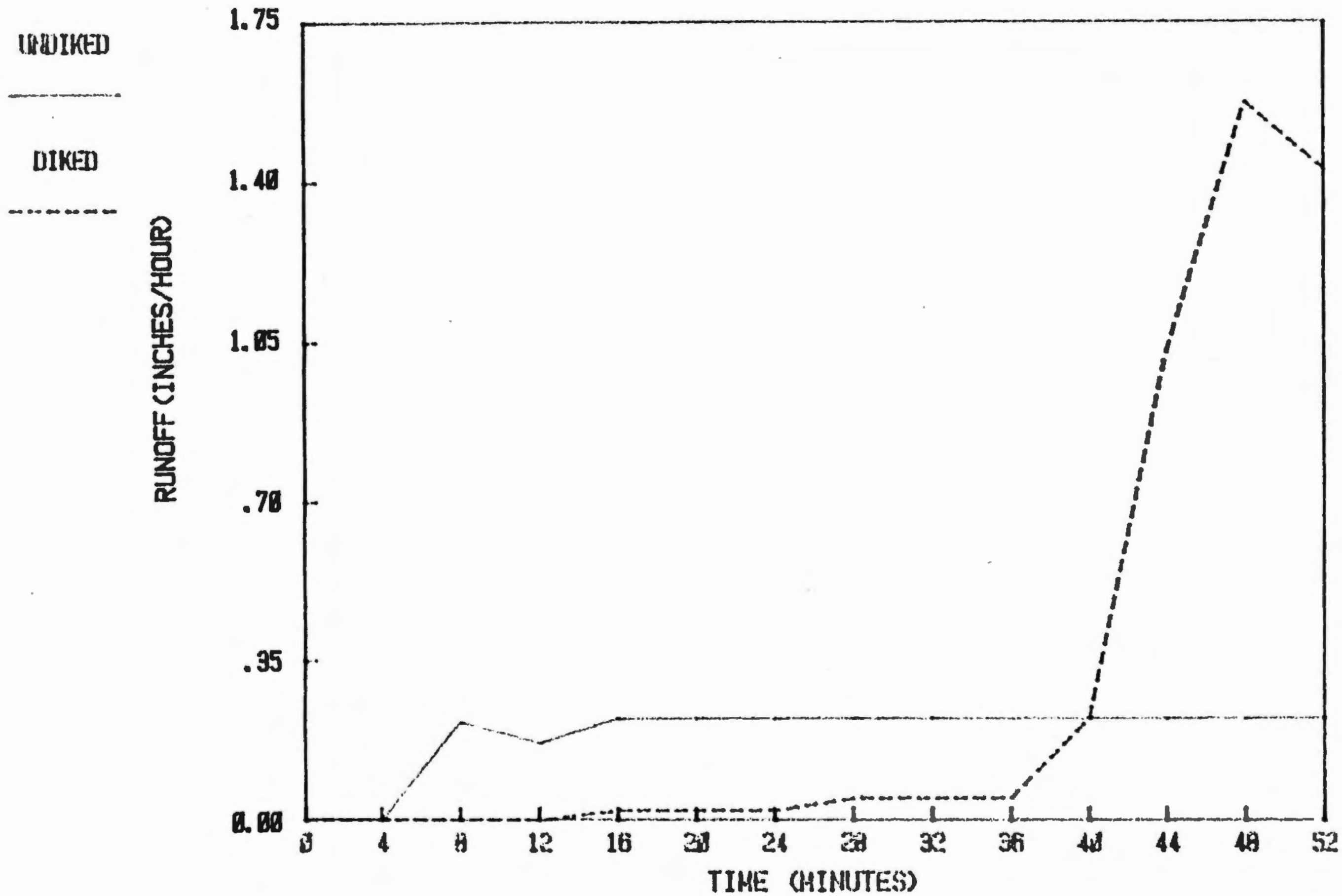

Figure 9. Runoff rate as a function of time for diked and undiked plots subjected to simulated rainfall during test three. Plot slope was 5 percent, and slope length was 50 feet.

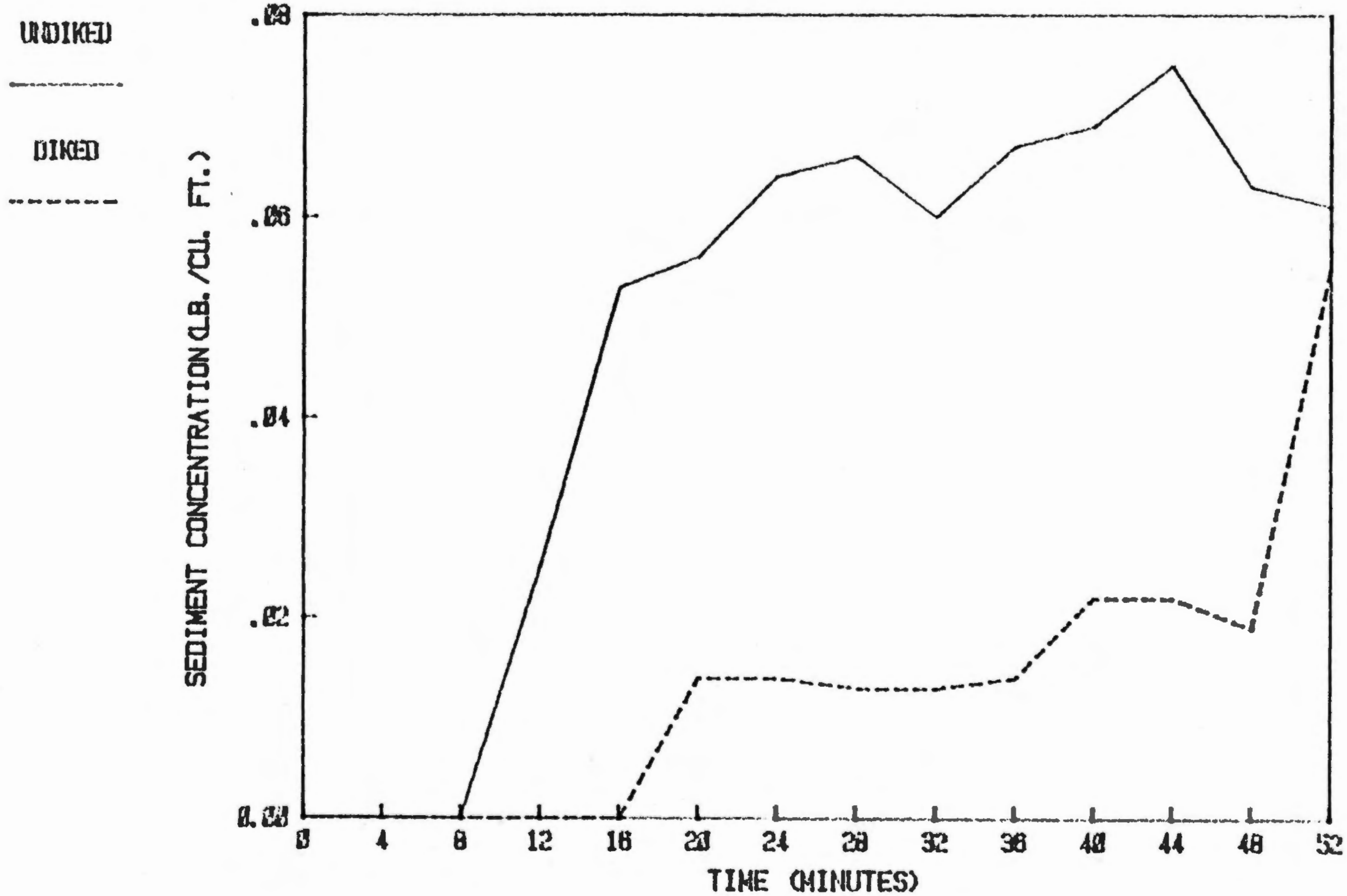

Figure 10. Sediment concentration in runoff water from diked and undiked plots subjected to simulated rainfall during test three. Plot slope was 5 percent, and slope length was 50 feet.

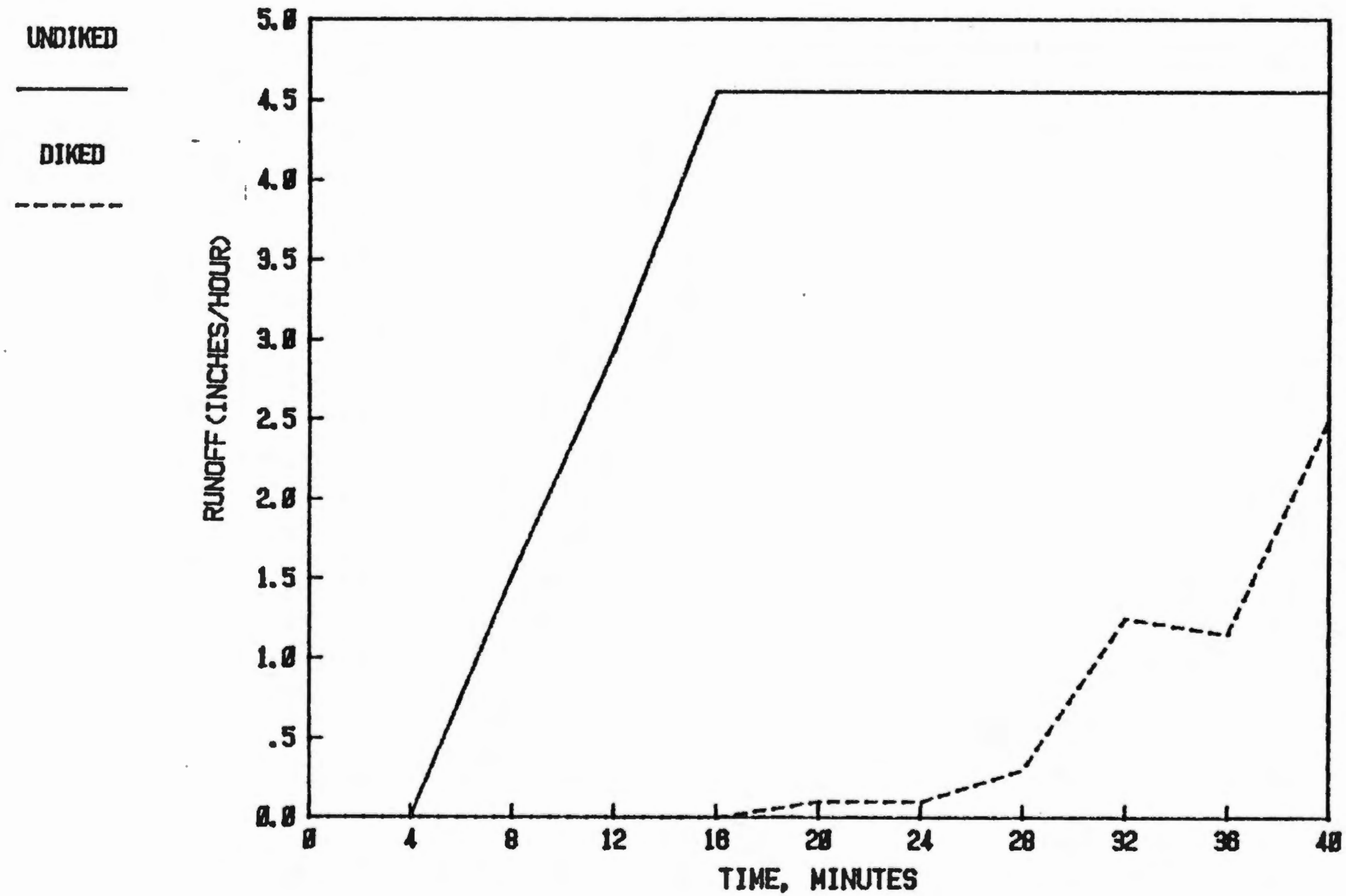

Figure 11. Runoff rate as a function of time for diked and undiked plots subjected to simulated rainfall during test five. Plot slope was 2 percent, and slope length was 65 feet.

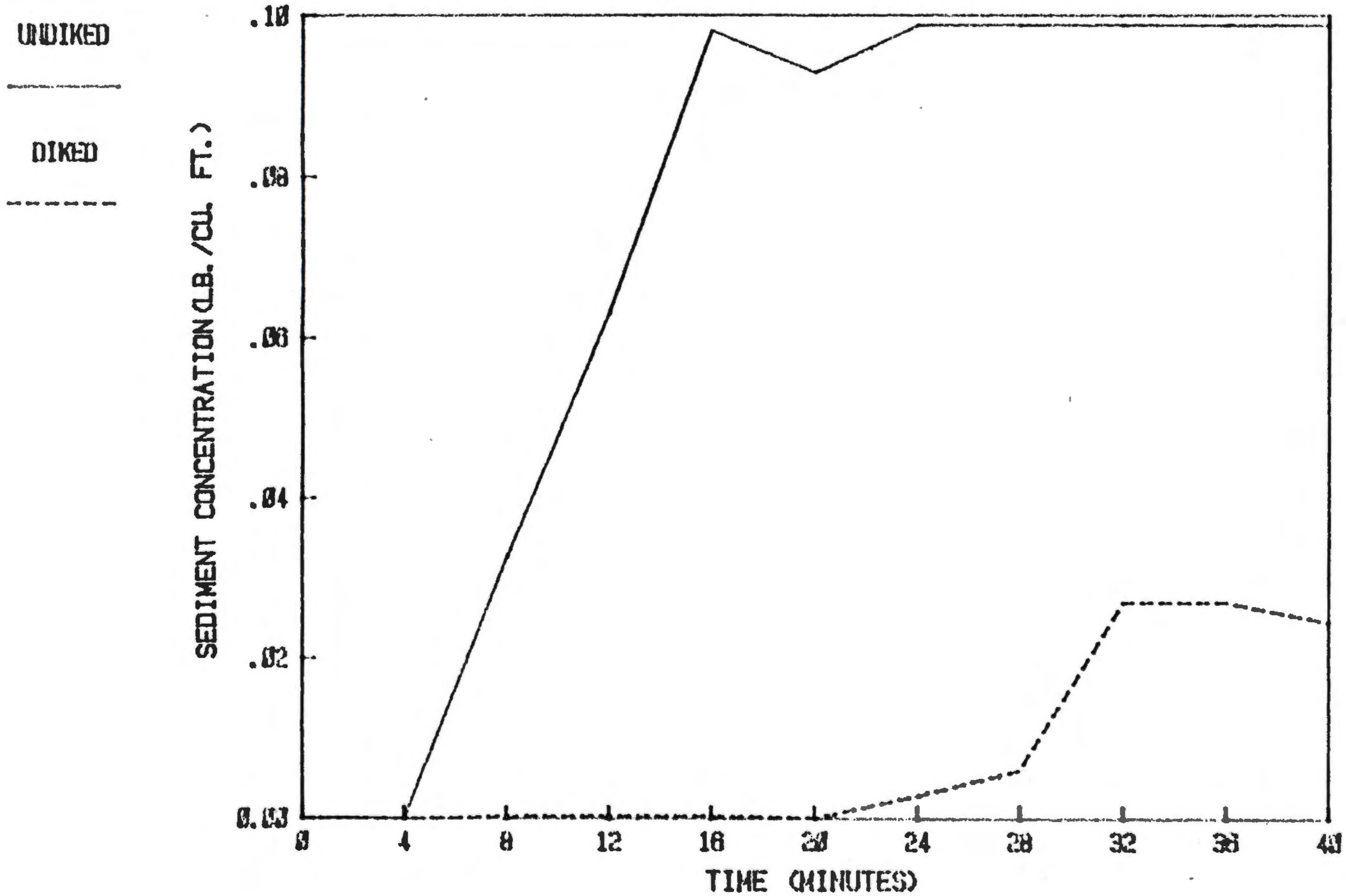

Figure 12. Sediment concentration in runoff water from diked and undiked plots subjected to simulated rainfall during test five. Plot slope was 2 percent, and slope length was 65 feet.

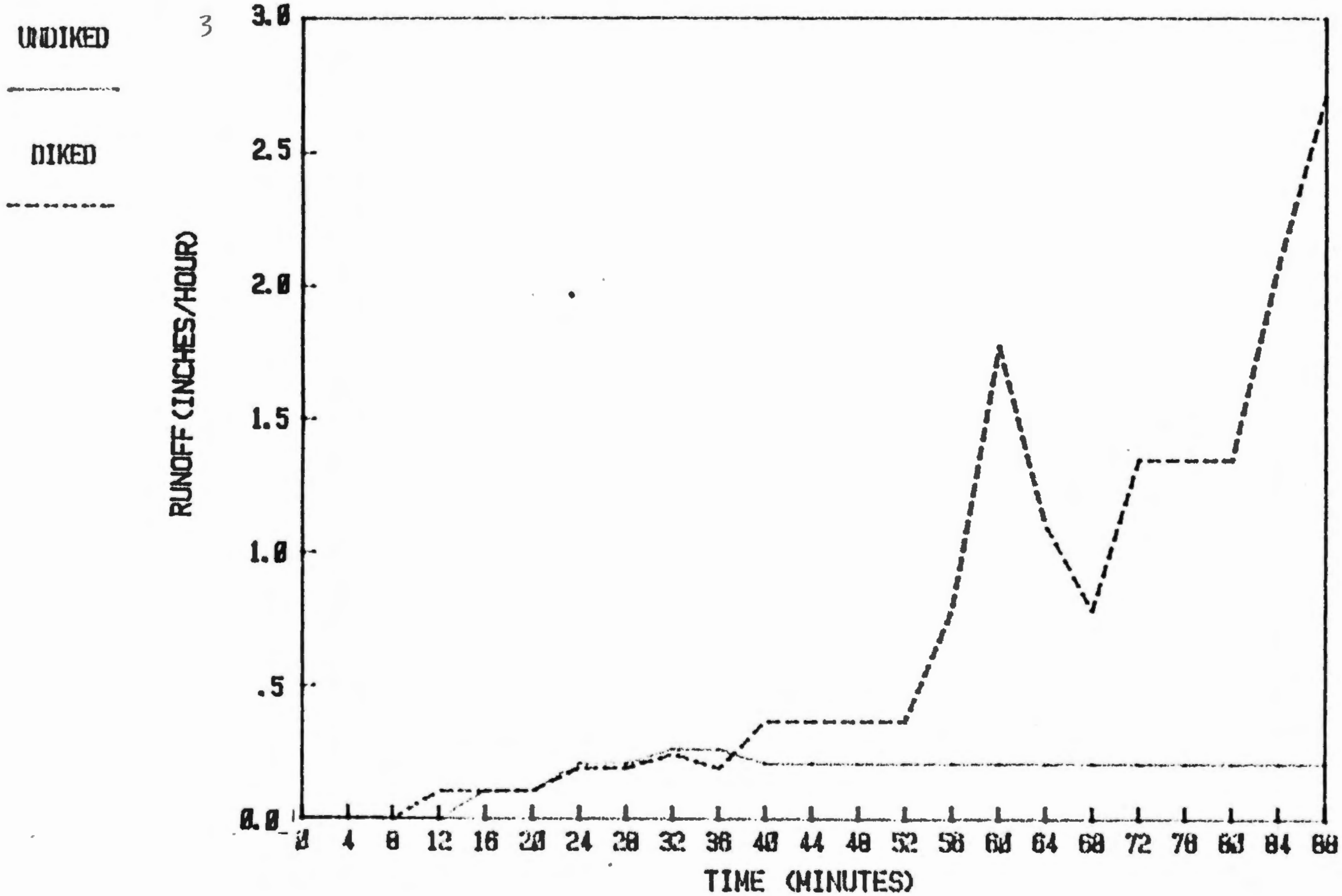

Figure 13. Runoff rate as a function of time for diked and undiked plots subjected to simulated rainfall during test six. Plot slope was 2 percent, and slope length was 65 feet.

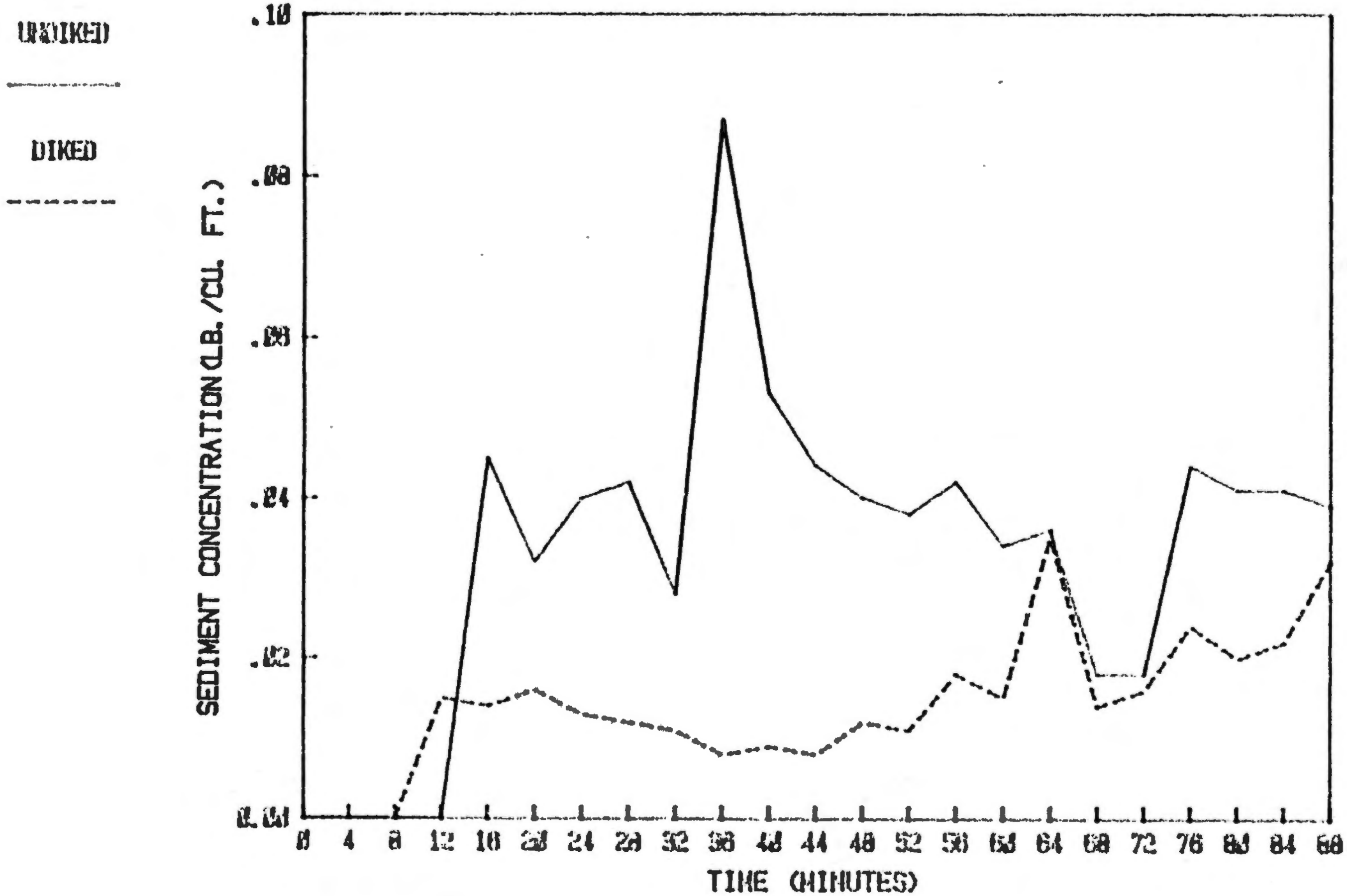

Figure 14. Sediment concentration in runoff water from diked and undiked plots subjected to simulated rainfall during test six. Plot slope was 2 percent, and slope length was 65 feet.

sediment yield was slightly less for the diked plot (34 pounds per acre) than for the undiked plot (35 pounds per acre).

Hydrographs for test five (Figure 11) on a 2 percent slope and 65-foot slope length showed runoff rates to be less from the diked plot than from the undiked plot throughout the test. Total runoff volume from the diked plot (0.52 inches) was substantially less than the runoff from the undiked plot (2.72 inches). However, the sprinklers were not properly adjusted resulting in a significant difference in the quantity of rainfall each plot received during the test. The diked plot was subjected to 2.03 inches of simulated rainfall while 3.25 inches was measured on the undiked plot. Runoff on the diked plot was 25 percent of measured rainfall, while that on the undiked plot was 84 percent of rainfall. High sediment concentrations for test five (Figure 12) were attributed to sediment deposited close to the flumes by runoff associated with earlier tests and the tilled condition of the soil in each plot. Concentrations indicated by both curves decreased after the large rise at the outset. Total sediment yield for the diked plot and undiked plot was 72 pounds per acre and 261 pounds per acre, respectively.

Hydrographs of diked and undiked runoff rates for test six (Figure 13) on 2 percent slope and 65-foot slope length showed runoff rates to be less from the diked plot until approximately 84 minutes after the test began. The total runoff volume for the diked plot (1.15 inches) was less than runoff yield from the undiked plot (2.62 inches). Of the 3.40 inches and 3.20 inches of water applied as simulated rainfall to the diked and undiked plots, respectively, 34 percent and 81 percent were measured as runoff.

Sediment concentration curves for test six (Figure 14) showed concentrations from diked plots to be less at all sampling times until 76 minutes after the test began. Total sediment yield for the diked and undiked plot was 7 pounds per acre and 34 pounds per acre, respectively.

Bar graphs of tests one through six (Figures 15 and 16) show the amount of simulated rainfall (inches) and runoff (inches) for each plot. Figure 15 illustrates the relationship between water applied and runoff from undiked plots while Figure 16 illustrates the relationship existing between total water applied and total runoff from diked plots.

III. DATA COLLECTION PROBLEM AREAS

Errors were introduced in the experiment that undoubtably affected the final results. Several conditions which contributed to test errors were:

1. Soil accumulation at the flume
2. Non-uniformity of rainfall distribution between plots
3. The method used to divert runoff.
4. Insufficient number of test replications.

Soil Accumulation

Soil accumulated on the approach apron of the flumes during the course of the experiment. Each successive test deposited more sediment. Two effects were noted. The sediment concentration during the first minutes of the tests was higher than later times during the same test. Also, the soil transported from the upper portions of

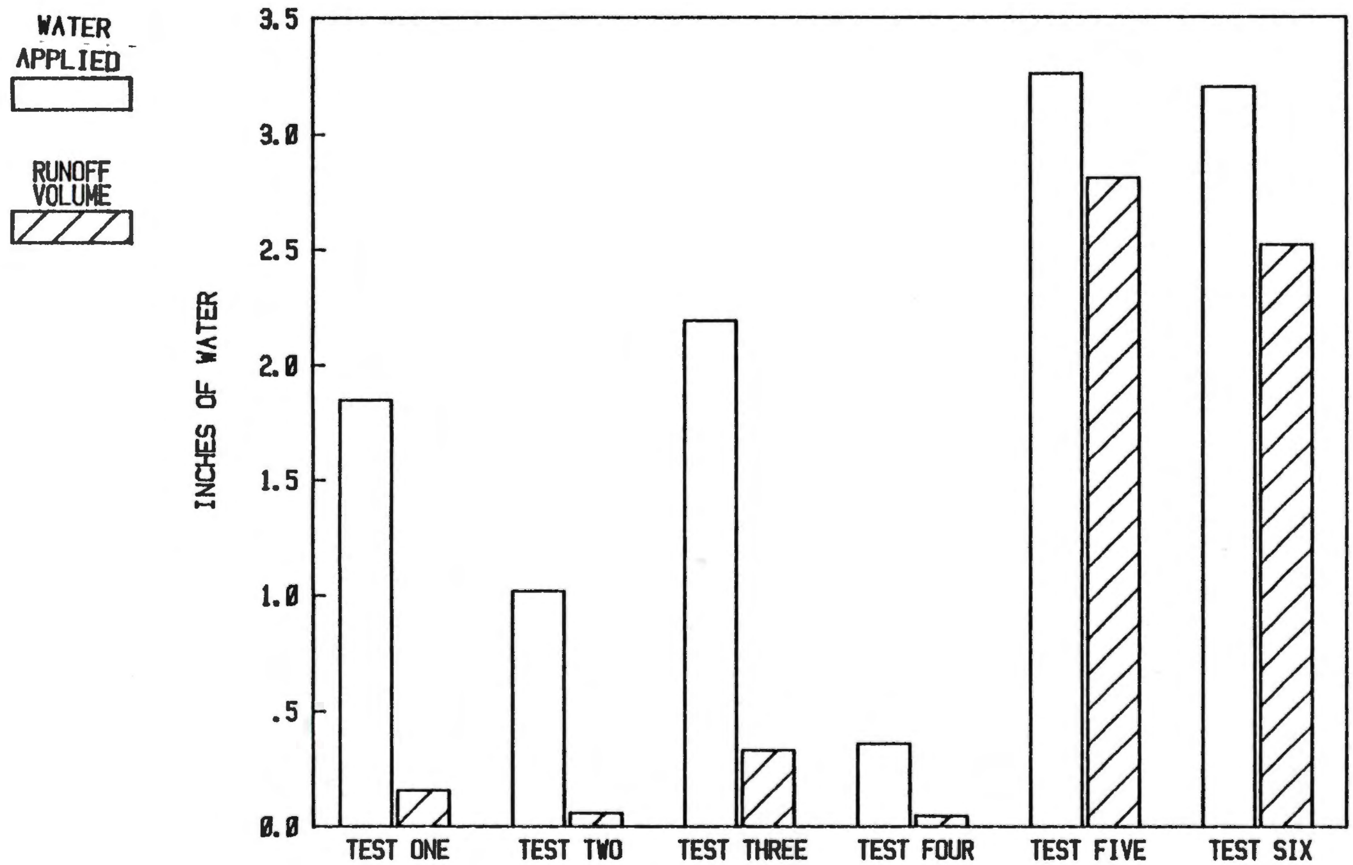

Figure 15. Total simulated rainfall and resulting runoff from each undiked plot for tests one through six.

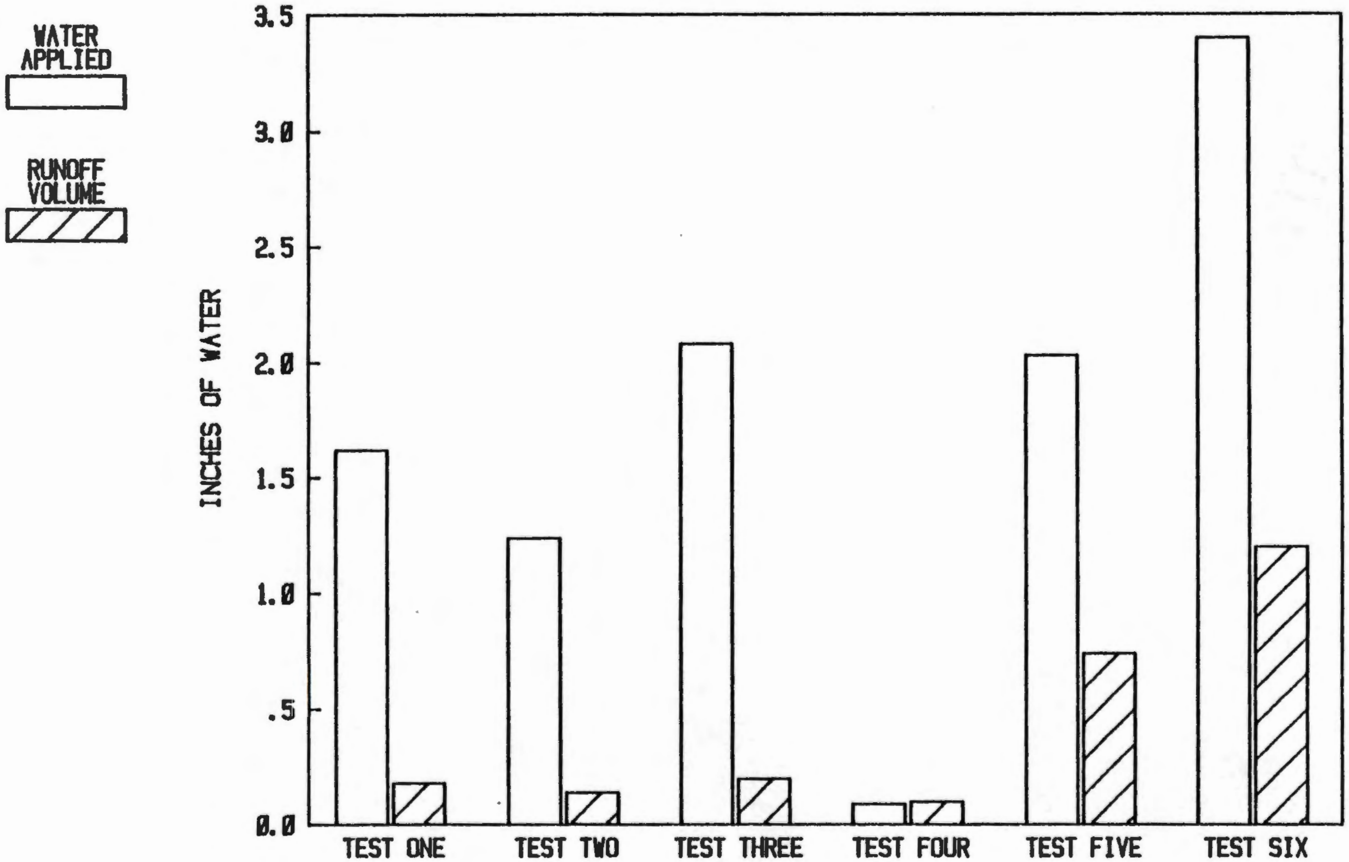

Figure 16. Total simulated rainfall and resulting runoff from each diked plot for tests one through six.

the plots during previous tests created a physical barrier for water approaching the flume.

Non-uniformity of Simulated Rainfall

Lack of uniformity of rainfall between treatments was attributed to two conditions: wind effects and improper sprinkler adjustment. Wind gusts, even though slight, caused the simulated rain drops to mist and draft. When this occurred, one plot invariably received more rainfall than the other.

Sprinklers occasionally failed to travel through the established arc. Although they still discharged water, the rainfall was concentrated on a small area of the plot. When the sprinkler heads directing water onto the diked plots stopped rotating, localized premature dike failures often resulted. The high volume of water on a relatively small area conceivably altered the characteristics of diked treatments and yielded misleading data.

Some diked plots exhibited higher runoff rates at the beginning of a test. This was attributed to poor sprinkler coverage. In this case, the sprinkler ceased to travel through an arc and directed a disproportionate amount of water on the approach apron of the flume.

Rainfall Rate Determination

Rainfall intensity was calculated by dividing the total volume of rainfall collected in cans by the number of cans on the plot. When a sprinkler ceased to move through an arc, it subjected a particular area of the plot to a high volume of water. The volume of water in each collection can was often significantly different than the volume of water in adjacent cans.

Water Diversion

The method of diverting runoff from the plots occasionally introduced errors. Mounded soil diversions and ditches sometimes failed to control runoff and undetermined volumes of external water were allowed to enter the test area.

Mounded soil diversions also contributed additional sediment to the runoff by the very nature of their construction. The inside portion of each temporary diversion was within the watershed of the test area. Invariably, some loose soil from the diversions was transported and measured in the runoff water.

CHAPTER VI

SUMMARY AND CONCLUSIONS

I. SUMMARY

A three-row basin tillage tool was designed and constructed in the Agricultural Engineering Research Shop at The University of Tennessee, Knoxville. Field tests were conducted at The University of Tennessee Milan Experiment Station during the fall of 1980 and spring of 1981.

The tillage machine was designed to create earthen dikes and basins between bedded rows transverse to the row direction. A cam actuated, hydraulically powered tripping mechanism allowed the diking interval to be infinitely variable.

Analyses were made to determine if diking:

1. Reduced runoff volume
2. Reduced soil loss

Plots consisting of three bedded rows on ground slopes of 2 and 5 percent were diked while the rows of an adjacent plot on an identical slope were undiked. Dikes were spaced 40 inches apart in the row middles for all tests. Attempts were made to subject each plot in a given test to the same intensity simulated rainfall. Intensities were varied from test to test. Rainfall intensities ranged between 0.68 inches per hour and 4.89 inches per hour.

Sediment concentrations were determined from samples of runoff water to allow comparison of sediment yields from diked and undiked treatments as a function of time. Runoff rates were determined by monitoring the flow through 1-foot HS flumes installed at the outlet of each plot. Catch cans were used to determine the intensity of the simulated rainfall on each plot.

II. CONCLUSIONS

Machine Performance

The prototype basin tillage machine functioned satisfactorily on field conditions characterizing the test area. A cam actuated tripping mechanism provided a high speed means of actuating the paddle assembly to form dikes. The mechanism performed well, although minor alignment adjustments were required to ensure smooth stop arm retraction and release. Uniformly shaped and spaced dikes were successfully formed in loosened soil.

Effectiveness of Diking in Erosion Control

When compared to undiked treatments for a given test, diked treatments generally:

1. Reduced runoff until the dikes were broken by accumulated water
2. Exhibited lower sediment yields from diked than undiked plots

Diking would probably be more beneficial on the more nearly level slopes in West Tennessee. Best results were produced on the more gently sloping plots.

III. RECOMMENDATIONS

The tripping mechanism required minor realignment prior to each test. A slight change in alignment caused the slide to bind. Repeated impacts of the paddle blades on the stop arm caused the assembly mounting plate to slip. The bolts used to attach the mounting plate to the diking frame did not prevent the smooth surface of the mounting plate from slipping under the impact of the paddle blades. The problem was compounded because oversize bolt holes were used to adjustments.

An improved method of attachment is needed. Also, the hitch could be improved to allow one person to connect the tillage tool to the tractor.

Plot size was a problem during testing. The small plots were incompatible with the large field-sized equipment actually employed. Also, the small plot size increased the relative magnitude of errors. For example, one improperly adjusted sprinkler in four per plot introduced a substantial error. Increased plot sizes would minimize some errors as well as create a more suitable working environment for field-sized machinery. In addition, plots should be constructed such that no temporary diversions are required within the test area.

The number of tests should be increased such that the effect of error is decreased. A suitable number of tests should be determined to detect differences between plot treatments leading to statistically significant conclusions. Results of obviously defective tests should be deleted from the data included in the analysis.

LITERATURE CITED

LITERATURE CITED

Aarstad, J. S., and D. E. Miller. 1973. Soil management to reduce runoff under center pivot sprinkler system. Journal of Soil and Water Conservation 28(4):171-173.

Baver, L. D., W. H. Gardner, and W. R. Gardner. 1972. Soil physics. John Wiley and Sons, Inc., New York. 497 p.

Bouyoucos, G. J. 1935. The clay ratio as a criterion of susceptibility of soils to erosion. Journal of American Society of Agronomy 27:738-741.

Bryan, R. B. 1968. The development, use and efficiency of indices of soil erodibility. Geoderma 2(1):5-26.

Buntley, G. J., and F. F. Bell. 1976. Yield estimates for the major crops grown on the soils of West Tennessee. Bulletin 561. University of Tennessee Agricultural Extension Service.

Buntley, G. J., and C. H. Shelton. 1979. Basic concepts of soil erosion. Bulletin 807. University of Tennessee Agricultural Extension Service.

Call, L. E., and L. C. Aicher. 1963. A history of the Fort Hays, Kansas Branch Experiment Station 1901-1962. Bulletin 453.

Dagg, M., and J. C. Macartney. 1967. The agronomic efficiency of the N.I.A.E. mechanized tied ridge system of cultivation. Experimental Agriculture 4:279-294.

Donahue, R. L., J. C. Shickluna, and L. S. Robertson. 1971. Soils, an introduction to soils and plant growth. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 301 p.

Ellison, W. D. 1944. Studies of raindrop erosion. Agricultural Engineering 25:131-136, 181, 182, 306.

Faulkner, O. T. 1944. Experiment on ridged cultivation in Tanganyika and Nigeria. Tropical Agriculture 21(9):177-178.

Hudson, N. 1971. Soil conservation. Cornell University Press, Ithaca. 320 p.

Hughes, R. M. 1933. Report on agricultural research for the year ending June 30, 1933. Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts.

Knight, H. G., and A. M. Hyde. 1931. Annual report of the Bureau of Soil Chemistry, pp. 45-46.

Kuksa, J. B., and O. R. Mathews. 1956. Dryland crop rotation and tillage experiments at the Colby (Kansas) Branch Experiment Station. United States Department of Agricultural Circular 979.

Langdale, G. W., J. E. Box, R. A. Leonard, A. P. Barnett, and W. G. Fleming. 1979. Corn yield reduction on eroded southern Piedmont soils. Journal of Soil and Water Conservation 34(5):226-228.

Laws, J. O. 1941. Recent studies in raindrops and erosion. Agricultural Engineering 21:431-433.

Locke, L. F., and O. R. Mathews. 1953. Relation of cultural practices to winter wheat production, Southern Great Plains Field Station, Woodward, Oklahoma. United States Department of Agriculture Circular 917.

Lyle, W. R., and W. R. Dixon. 1977. Basin tillage for rainfall retention. Transactions of American Society of Agricultural Engineers 20:1013-1017, 1021.

McIntyre, D. S. 1958. Soil splash and the formation of surface crust by raindrop impact. Soil Science 85:185-189.

Olmstead, L. B., L. T. Alexander, and H. E. Middleton. 1930. A pipette method of mechanical analysis of soil. United States Department of Agriculture Technical Bulletin 170. 22 p.

Nicholls, M. L., and T. B. Chambers. 1938. Mechanical measures of erosion control. United States Department of Agriculture Yearbook of Agriculture, pp. 645-665.

Shedd, C. K., E. V. Collins, and J. B. Davidson. 1935. The basin method of planting row crops and a basin lister planter. Agricultural Engineering 16(4):133-136.

Shelton, C. H., and F. D. Tompkins. 1981. Evaluation cropping-tillage systems with large plot rainfall simulators. ASAE 81-2052, St. Joseph, Michigan.

Smith, D. D., and W. H. Wischmeier. 1957. Factors affecting sheet and rill erosion. Transactions of the American Geophysical Union 38:889-896.

Smith, D. D., and W. H. Wischmeier. 1962. Rainfall erosion. Advances in Agronomy: American Society of Agronomy (A. G. Norman, Ed.) 14:109-140. Academic Press, New York.

Tennessee Market Bulletin. 1979. West Tennessee erosion control, water improvement, pp. 4-5.

USDA. 1962. Fieldbook for research in agricultural hydrology. United States Department of Agriculture Handbook 224. 215 p.

Wesley, R. A., and J. R. Williford. 1981. Crop production with conservation in 80's. ASAE Publication 7-81, pp. 207-215.

Wischmeier, W. H., and D. D. Smith. 1978. Predicting rainfall erosion losses--a guide to conservation planning. United States Department of Agriculture Handbook 537.

Wood, I. D. 1933. The future of moisture conservation. Agricultural Engineering 14(6):152.

Woodruff, C. M. 1947. Erosion in relation to rainfall, crop cover, and slope on a greenhouse plot. Soil Science Society of America Proceedings 12:475-478.

APPENDIX

Table 1. Total water applied, total runoff volume, and total sediment yield of diked and undiked plots for tests one through six.

Test	Treatment	Total Water Applied (Inches)	Total Runoff Volume (Inches)	Total Sediment Yield (Pounds/Acre)
1	Undiked	1.85	0.16	6.3
	Diked	1.62	0.18	5.2
2	Undiked	1.02	0.06	6.1
	Diked	1.24	0.14	9.1
3	Undiked	2.19	0.33	35.2
	Diked	2.08	0.20	34.3
4	Undiked	0.36	0.05	2.8
	Diked	0.09	0.10	9.6
5	Undiked	3.26	2.81	261.2
	Diked	2.03	0.74	71.9
6	Undiked	3.20	2.52	342.9
	Diked	3.40	1.20	77.0

Table 2. Runoff rate and sediment concentration data for diked and undiked plots subjected to simulated rainfall during test one. Treated area per plot was 644 square feet, slope was 5 percent, and slope length was 50 feet.

	Undiked Plot		Diked Plot	
Elapsed Time (Minutes)	Sediment Concentration (Pounds/Feet^3)	Runoff Rate (Inches/Hour)	Sediment Concentration (Pounds/Feet^3)	Runoff Rate (Inches/Hour)
4	0.017	0.03	0.008	0.03
8	0.012	0.06	0.005	0.06
12	0.021	0.14	0.005	0.14
16	0.042	0.14	0.008	0.14
20	0.046	0.14	0.007	0.14
24	0.045	0.14	0.009	1.05
28	0.024	0.14	0.005	0.14
32	0.040	0.14	0.006	0.14
36	0.040	0.14	0.017	0.92

Table 3. Runoff rate and sediment concentration data for diked and undiked plots subjected to simulated rainfall during test two. Treated area per plot was 644 square feet, slope was 5 percent, and slope length was 50 feet.

	Undiked Plot		Diked Plot	
Elapsed Time (Minutes)	Sediment Concentration (Pounds/Feet^3)	Runoff Rate (Inches/Hour)	Sediment Concentration (Pounds/Feet^3)	Runoff Rate (Inches/Hour)
4	0.000	0.00	0.034	0.03
8	0.040	0.06	0.032	0.10
12	0.029	0.14	0.044	0.14
16	0.052	0.14	0.038	0.14
20	0.076	0.14	0.035	0.14
24	0.030	0.14	0.050	0.56

Table 4. Runoff rate and sediment concentration data for diked and undiked plots subjected to simulated rainfall during test three. Treated area per plot was 644 square feet, slope was 5 percent, and slope length was 50 feet.

	Undiked Plot		Diked Plot	
Elapsed Time (Minutes)	Sediment Concentration (Pounds/Feet^3)	Runoff Rate (Inches/Hour)	Sediment Concentration (Pounds/Feet^3)	Runoff Rate (Inches/Hour)
4	0.000	0.00	0.000	0.00
8	0.000	0.00	0.000	0.00
12	0.025	0.25	0.000	0.00
16	0.053	0.20	0.000	0.00
20	0.056	0.26	0.014	0.03
24	0.064	0.26	0.014	0.03
28	0.066	0.26	0.013	0.03
32	0.060	0.26	0.013	0.06
36	0.067	0.26	0.014	0.06
40	0.069	0.26	0.022	0.26
44	0.075	0.26	0.022	1.19
48	0.063	0.26	0.019	1.81
52	0.061	0.26	0.055	1.64

Table 5. Runoff rate and sediment concentration data for diked and undiked plots subjected to simulated rainfall during test four. Treated area per plot was 644 square feet, slope was 5 percent, and slope length was 50 feet.

	Undiked Plot		Diked Plot	
Elapsed Time (Minutes)	Sediment Concentration (Pounds/Feet^3)	Runoff Rate (Inches/Hour)	Sediment Concentration (Pounds/Feet^3)	Runoff Rate (Inches/Hour)
4	0.000	0.00	0.000	0.00
8	0.005	0.03	0.007	0.06
12	0.005	0.06	0.015	0.10
16	0.005	0.06	0.006	0.10
20	0.008	0.14	0.007	0.10
24	0.006	0.14	0.015	0.49
28	0.005	0.14	0.007	0.33
32	0.005	0.14	0.007	0.33

Table 6. Runoff rate and sediment concentration data for diked and undiked plots subjected to simulated rainfall during test five. Treated area per plot was 794 square feet, slope was 2 percent, and slope length was 65 feet.

	Undiked Plot		Diked Plot	
Elapsed Time (Minutes)	Sediment Concentration (Pounds/Feet^3)	Runoff Rate (Inches/Hour)	Sediment Concentration (Pounds/Feet^3)	Runoff Rate (Inches/Hour)
4	0.000	0.00	0.000	0.00
8	0.045	1.72	0.001	0.02
12	0.037	3.43	0.001	0.02
16	0.036	5.34	0.001	0.02
20	0.028	5.06	0.002	0.01
24	0.028	5.34	0.047	0.16
28	0.027	5.34	0.004	0.33
32	0.028	5.34	0.014	1.47
36	0.028	5.34	0.016	1.47
40	0.026	5.34	0.029	1.33

Table 7. Runoff rate and sediment concentration data for diked and undiked plots subjected to simulated rainfall during test six. Treated area per plot was 794 square feet, slope was 2 percent, and slope length was 65 feet.

	Undiked Plot		Diked Plot	
Elapsed Time (Minutes)	Sediment Concentration (Pounds/Feet^3)	Runoff Rate (Inches/Hour)	Sediment Concentration (Pounds/Feet^3)	Runoff Rate (Inches/Hour)
4	0.000	0.00	0.000	0.00
8	0.000	0.00	0.000	0.00
12	0.000	0.00	0.015	0.11
16	0.045	0.11	0.014	0.11
20	0.032	0.11	0.016	0.11
24	0.040	0.23	0.013	0.21
28	0.042	0.23	0.012	0.21
32	0.028	0.29	0.011	0.27
36	0.087	0.29	0.008	0.21
40	0.053	0.23	0.009	0.40
44	0.044	0.23	0.008	0.40
48	0.040	0.23	0.012	0.40
52	0.038	0.23	0.011	0.40
56	0.042	0.23	0.018	0.85
60	0.034	0.23	0.015	1.93
64	0.036	0.23	0.035	1.20
68	0.018	0.23	0.014	.85
72	0.018	0.23	0.016	1.47
76	0.044	0.23	0.024	1.47
80	0.041	0.23	0.020	1.47
84	0.041	0.23	0.022	2.27
88	0.039	0.23	0.032	2.95

Table 8. List of diking unit components. Refer to Figure 4 (p. 27).

Number	Component
1	Diking unit frame
2	Cotter pin
3	Washer
4	Paddle assembly shaft
5	Diking paddle
6	Slide
7	Slide stop washer
8	Threaded stop arm assembly cap
9	Tripping spring
10	Recoil spring
11	Stop arm assembly mounting bolts
12	Stop arm assembly mounting plate
13	Bushing
14	Paddle stop adjustment nut
15	Paddle stop
16	Washer
17	Set screw
18	Pillow block bearing
19	Actuating cam
20	Pillow bearing mounting bolts
21	Set screw
22	32-tooth cam shaft sprocket
23	Cam shaft
24	1/2-inch roller chain
25	Stop arm assembly mounting nuts
26	Set screw
27	Double sprocket collar
28	12-tooth double sprocket
29	Pinning shaft
30	Transport arm adjustment nut
31	Washer
32	Transport arm assembly compression spring
33	Cotter pin
34	Transport arm frame
35	Transport arm assembly rod
36	Pillow block mounting nuts

Table 9. List of diking unit tripping mechanism components. Refer to Figure 6, page 30.

Number	Component
6	Slide
7	Threaded stop arm assembly cap
8	Tripping spring
9	Shaft collar
10	Recoil spring
12	Stop arm assembly mounting plate
13	Bushing
14	Paddle stop adjustment nut
15	Paddle stop
19	Actuating cam

VITA

Wilbur Thomas Mahoney was born in Chattanooga, Tennessee on July 25, 1954. He was a resident of East Ridge, Tennessee until graduation from East Ridge High School in June 1972.

The author attended Tennessee Technological University from September 1972 through June 1977. Upon receiving a Bachelor of Science degree in Agriculture, he began a one-year term of employment as a District Scout Executive with the Northeast Georgia Council, Boy Scouts of America. Afterwards, he was employed by the Tennessee Department of Conservation, Division of Forestry, until January 1979.

He entered the Graduate School of The University of Tennessee, Knoxville in January 1979 and completed the requirements for a Master of Science degree, with a major in Agricultural Mechanization, in June 1983.