EROSION EVALUATION STUDY

Final Report

by

Sheldon M. Law
Assistant Research Engineer

and

Samuel J. Vaccaro
Research Specialist III

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF TABLES

ABSTRACT

Much expense, time and work is expended each year in evaluating new erosion products, such as mulches or chemical additives for retarding soil erosion or promoting grass stand growth. Test locations in the field are now hard to find; therefore, a better method of first checking these products has to be found.

This study is concerned with attempting to develop a laboratory procedure by which these products can be evaluated, as quickly as possible after they appear on the market, in order to screen them so that the best ones can be further tested in the field.

Primarily there were two phases to the study, a field phase where the products available were installed on selected test slopes in North Louisiana and observed, and a laboratory phase where the products were installed (1) on plots containing grass seed and fertilizer and observed to obtain seed germination data, and (2) on soil in test pans and tested under a rainfall-simulator to get some comparative soil loss data.

Essentially there were two types of products used: (1) wood fiber mulches, and (2) chemical soil binders or erosion retardants. The principal factors affecting the results obtained on this study in the field were the weather conditions, the size, shape and steepness of the slopes and the types of soil present. Most of the slopes were fairly large and steep.

One part of the laboratory phase of the study consisted of reviewing any reports and data dealing with (1) the construction and operation of rainfall-simulators, (2) erosion results from other studies and (3) pertinent information relating to the aims of this study. An evaluation of the various pieces of equipment or parts of equipment relating to rainfall-simulators was undertaken also. The construction details to the rainfall-simulator as developed in this study are found in the Appendix. The prototype of this rainfall-simulator was built and used in the study. A test procedure

was also established and checked out during the laboratory phase of this study.

Generally speaking, the laboratory test results followed the same pattern as the field test results. After data analysis and careful consideration of all conditions and needs, a tentative test procedure was developed and a copy of the recommended "Tentative Method of Test for Simulated Rainfall Soil loss Values" is found in the Appendix of this report. Although there were several aims of this study, the development of this procedure was the primary aim.

The primary conclusions reached on this study were as follows:

1. A rainfall-simulator is constructible, practical and low cost (approximately $600) for providing a good consistent tool to test erosion control products in the laboratory. Some construction details are shown in the Appendix and operational details are described in the body of the report.
2. There is only an observed general relationship between the field phase test results and the laboratory test results; however, the laboratory results bear out the field observations.
3. Grass stand growth was slow in beginning on all field slopes; however, as shown in the laboratory results, all of the wood fiber mulches did well in seed germination and establishment of grass stand growth. The soil stabilizers were poor in this category generally.
4. Product Number 1B, a soil stabilizer, was the most effective in retarding erosion with the following products listed in order of effectiveness: Product Numbers 2A, 5A, 5B, 2B. Product Number 3 showed erratic results and was not satisfactory. The combination of products, Numbers 5C and 5D generally were borderline rated.

Recommendations included:

1. A laboratory test procedure entitled "Tentative Method of Test for Simulated Rainfall Soil Loss Values," found in the Appendix, is recommended for use in testing new erosion control products placed on the market to determine whether these products are promising enough to be field checked.
2. The construction of a Rainfall-Simulator, as shown in construction details found in the Appendix, is recommended as a necessary tool in

performing the aforementioned test procedure.

3. Implementation of recommendations 1 and 2 above is recommended if the number of new erosion control products on the market now and in the future warrants such action.

4. The authors recommend that work should be continued in this effort to check for repeatability of soil loss results using the rainfall-simulator and the tentative test procedure.

IMPLEMENTATION

Administrative decisions will be needed for acceptance and use of the tentative laboratory test procedure and construction of the rainfall-simulator. Plans are available on the rainfall-simulator, and the New Productions Evaluation Committee will be a key to the recommendation for the implementation of the report findings. Laboratory space, financial requirements or needs, adoption of the tentative laboratory test procedure and test needs are some of the items and/or steps to be taken care of in the implementation procedure. The beginning of this process should lead to a useful new test procedure and test device to evaluate erosion retarding materials in the new products evaluation field.

INTRODUCTION

New erosion control products are continuously being introduced to state and federal highway agencies for evaluation. For proper evaluation these products must be thoroughly tested, and in order for this to be accomplished, test plots must be prepared in the field. Field test plots are expensive to prepare, require large maintenance crews for installation, require many pieces of equipment and often take months to obtain results. Much time and work is necessarily expended each year to evaluate such new products as chemical soil additives, soil erosion retardants and mulches. Test locations in the field are becoming increasingly difficult to find.

Many of these products prove infeasible for use either because of unsuccessful tests or because they are not economical, while others are found to be effective and economical to use. There is a need for a selective testing system which will enable research agencies or testing laboratories to test and check these products for possible use. The Louisiana Department of Highways is essentially interested in developing a tentative laboratory procedure by which these products can be evaluated as quickly as they appear on the market. The laboratory testing procedure is dependent on the use of a well constructed and standardized rainfall-simulator as well as constant laboratory conditions.

In the laboratory it is possible to subject the test sample to controlled conditions somewhat comparable to those conditions found in the field. Those materials which show the most promise would then be tested in the field. Although it is not possible to exactly simulate the condition present on an actual field test plot, it is possible to obtain more controlled conditions in the laboratory. Much expense can be avoided by testing in the field only those materials which look good in the laboratory.

This final report is a continuation of and includes the interim report on the field phase of this study, plus the construction and evaluation of the rainfall-simulator along with the proposed laboratory testing procedure for the evaluation of the erosion control materials.

PURPOSE AND SCOPE

The specific aims of this study were (1) to develop a tentative testing procedure by which chemical soil additives and mulches may be evaluated in the laboratory, (2) to determine a relationship between laboratory and field testing, (3) to determine the degree of effectiveness of the various additives tested in controlling or retarding erosion, (4) to undertake selective field testing of the most effective soil agents and mulches and (5) to determine the effectiveness of various agents on seed germination and grass stand growth.

These aims were to be carried out in two phases as follows:

Phase I - An initial testing period to develop the laboratory procedures and research plan for the laboratory and field tests. Laboratory tests to be carried out at this time.

Phase II - The actual field testing and evaluation period.

Due to unforeseen circumstances and delays necessitated by the inability to initially purchase a rainfall-simulator, the study scheduling had to be rearranged. The field phase of the study was rescheduled to be accomplished first, then construction of the rainfall-simulator, the development of laboratory procedures, the actual laboratory tests and the evaluation period.

METHODOLOGY

A. Field Test Slopes

The slopes or sites that were used in this study were located in North Louisiana on State Highway 2 near Homer. Originally five slopes were to be used, however, it was decided not to use one of the slopes because this slope was not in need of any extensive maintenance work. Location of these test slopes is shown in Figure 1 on the following page.

Slopes 1, 2, 3 and 5 were shaped and prepared for the installation of seeding and mulching materials. These areas were first cleared of all grass and all other foreign materials. One of the slopes (No. 5) had to have some new material brought in, placed and spread where it was needed; this was on the lower part of the slope. The areas were staked off, measured and shaped, with the shaping being accomplished with a Highway Department motor grader. All of the slopes were approximately on a 3:1 slope.

The larger size and location of these slopes and the availability of a fairly new hydroseeder in this district made the work much easier. A good water supply was nearby along with a good loading area for charging or filling the hydroseeder. Safety and ease of installation were prime factors, together with the need for maintenance of these slopes, in selection of these particular areas. Rainfall data was acquired from the United States Geological Survey's rain gage located approximately two miles away from these slopes.

The hydroseeder used in this study was a hydromulcher supplied by District 04 of the Louisiana Department of Highways. A representative of the company distributing the hydromulcher was present at the installation and provided technical assistance in its operation. The hydromulcher was used because it is one of the best, quickest and easiest methods of seeding, fertilizing, mulching and watering slopes, all in one operation.

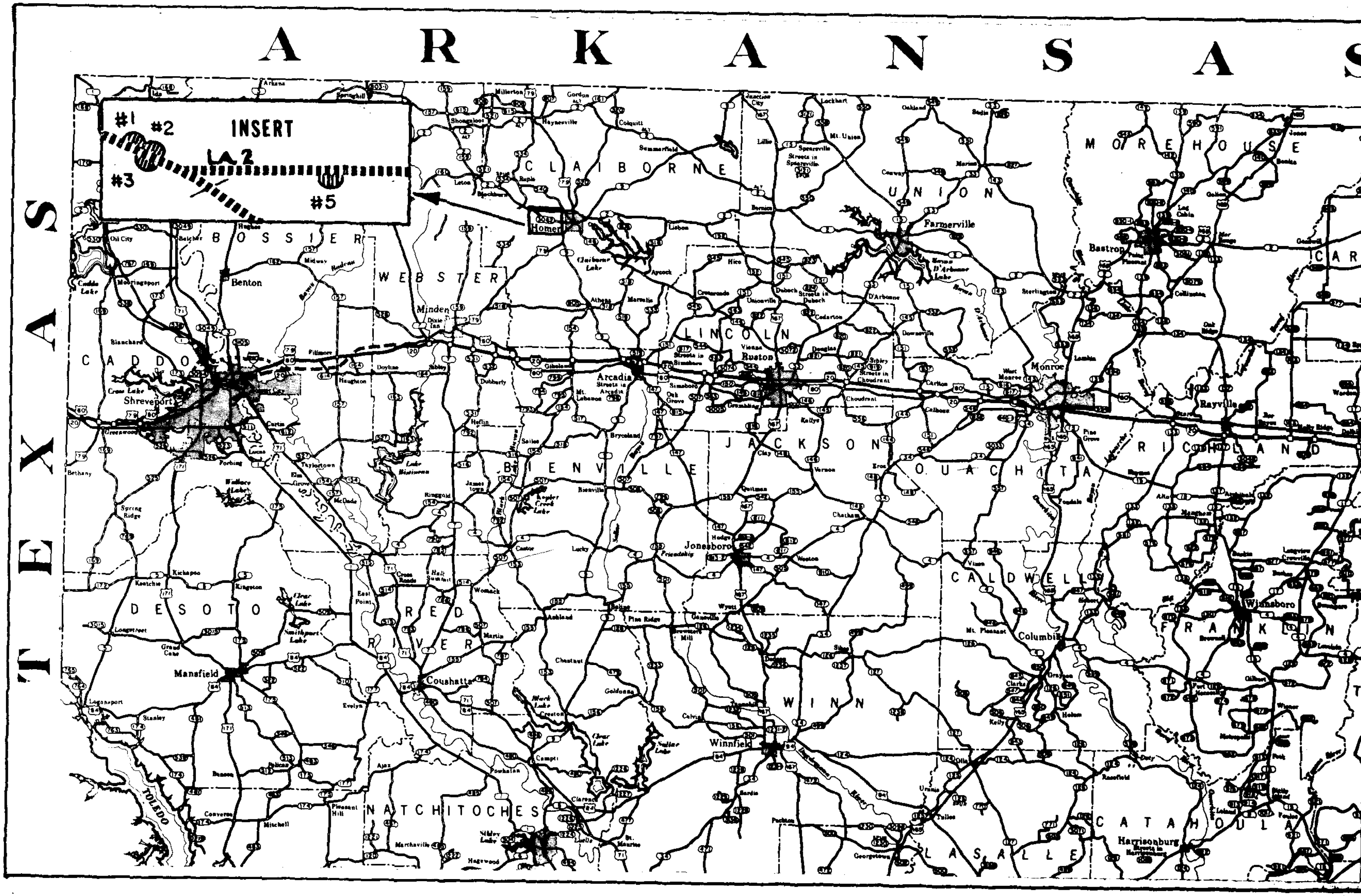

Figure 1

Location of Slopes in
Northwest Louisiana

In this report the authors may in some places refer to a hydromulcher and in other places refer to a hydroseeder, however these are the same. Each material and slope was worked the same way and the hydroseeder installation was uniformly done for all the products.

The application rates recommended by the companies were used and some of the representatives of these material companies were present at the installation. The hydroseeder in operation is shown in Figure 2 below.

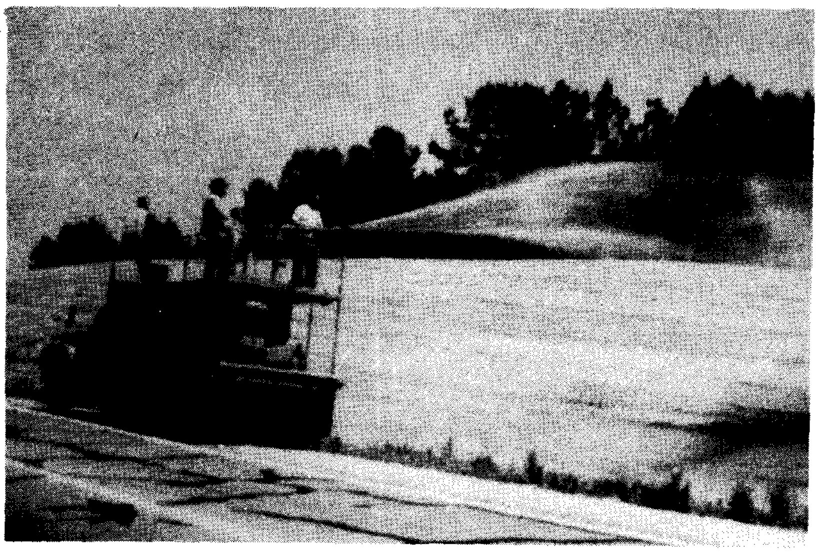

Figure 2
Hydroseeder in Operation

Several different type mulches or erosion retardant materials were used in the installation, including some combinations of these. Table 1 on the following page gives the application rates, type materials and amounts of materials used in these installations, plus any pertinent data.

The slopes were measured and staked out, and pictures were taken some of which are included in the discussion of results. A series of evaluations were set up at varying intervals: two weeks, four weeks, two months, four months and one year. Rainfall data was acquired from the beginning of the installation on May 24 and 25 until the end of September, four months later. Observations were taken and the slopes evaluated at each prescribed date or interval of time, plus pictures were taken to show the condition of each slope at that time.

A series of field measurements for erosion loss data was attempted, however, this was abandoned due to the difficulty of taking these measurements. the improbability of obtaining any reasonable erosion data and the infeasibility of this type setup. Too many variables were presented by the conditions on these slopes and type measurements. Therefore an evaluation was made strictly on results of visual observations and by the backup use of pictures. Some rough estimates of soil erosion were made as an aid to the evaluation.

Part A of Slope No. 1 (1A) was used as a control section and Part B (1B) was used to install a soil stabilizer, which is an emulsion or chemical product. The control section had only grass seed, fertilizer and water spread over it, while the other part of the slope had these elements plus the emulsion spread over it uniformly by the hydroseeder.

Slope No. 2 and two different mulches along with grass seed, fertilizer and water applied to it. The first half of the slope (2A) had defibrated wood chips as the mulch while the second half (2B) had wood cellulose fibers as the mulch. These are two very simular products.

Slope No. 3 (a very small slope) was treated with a powder type product along with grass seed, fertilizer and water spread as a slurry to form a slight crust on the surface. In every instance the erosion retardant material or mulch was placed with the company recommended application rates, which are shown in Table

TABLE 1

APPLICATION RATES AND MATERIALS FOR FIELD TEST SLOPES

Slope & Product	Control Plot 1A	1B	2A	2B	3	5A	5B	5C	5D
Date Installation	5/25/72	5/25/72	5/25/72	5/24/72	5/25/72	5/24/72	5/24/74	5/24/72	5/24/72
Size Plot, Acres	0.199	0.532	0.341	0.347	0.243	0.091	0.128	0.314	0.324
1) Type & Wt. Grass Seed, Lbs.	Bermuda 2.0	Bermuda 6.75	Bermuda 5.6	Bermuda 5.6	Bermuda 3.5	Bermuda 1.75	Bermuda 1.75	Bermuda 5.0	Bermuda 5.0
2) Type & Wt. Grass Seed, lbs.	-	-	Pennlawn Fescue- 5.6	Bahia 5.6	- -	Bahia 1.75	Bahia 1.75	Bahia 5.0	Bahia 5.0
Type & Wt. Fertilizer, lbs.	13:13:13 81	13:13:13 275	13:13:13 200	13:13:13 200	13:13:13 150	13:13:13 75	13:13:13 75	13:13:13 200	13:13:13 200
1) Amount Mat'l or Mulch	-	65 gal.	550 lbs.	550 lbs.	12 lbs.	338 lbs.	570 lbs.	14 lbs.	14 lbs.
2) Amount Mat'l or Mulch	-	-	-	-	-	-	-	150 lbs.	150 lbs.
Amount Water, gal.	410	1485	1200	1200	480	900	900	600	600
Ph Soil	4.6	4.6	5.2	5.2	5.2	6.1	6.1	6.1	6.1

1 on page 7. Slope No. 4 was not used on this study.

Slope No. 5 was a very large slope. Several products were used on this slope. A newer type of ground wood fiber was placed on Part A (5A) of this slope and an older type of ground wood fiber was placed on Part B (5B) of this slope. A combination of the products placed on 2A and 3 was spread on Part C (5C) of this slope, while a combination of the products placed on 2B and 3 was spread on Part D (5D) of the slope.

B. Seed Germination Plots

Seed germination tests were conducted in the laboratory using the same material as used in the field, except they were placed in rectangular boxes 12" x 18" (30.5 cm x 45.7 cm) and 4" (10.2 cm) deep under semi-controlled conditions. Standard Specifications for Raods and Bridges, October 1971, (Green Book) was used for the material amounts needed for seed and fertilizer. Soil samples from the actual field slopes were used in the seed germination boxes, Bermuda grass seed was used in these tests along with 8:8:8: fertilizer and the same mulches and erosion retardants as used in the field. A comparison was made between the results of these boxes, plus aganist a control seed germination box.

The boxes were placed in a location where normal sunlight and temperature would be obtained on the boxes. However, they were sufficiently sheltered so that rain would not normally hit directly on the boxes but, if rain did hit, it would not be excessive. The plots were periodically watered at a fixed, consistent rate which would be sufficient for normal grass growth. The plots were evaluated at set intervals and pictures were taken at the conclusion of this first seed germination test. These pictures are shown in the Appendix, Figures 28-30. Application rates, type materials and amount of materials for the seed germination plots are listed in Table 2 on the following page. A total of three sets of seed germination tests were attempted, primarily to have two sets of tests as a backup to the original set of seed germination tests.

C. Literature Review and Construction of Rainfall-Simulator and the Establishment of Study Laboratory Test Procedures.

In order to develop a successful laboratory test procedure. it was necessary to design, build and check the operation of a rainfall-simulator which can

TABLE 2

APPLICATION RATES AND MATERIALS FOR SEED GERMINATION PLOTS

PLOT	1 & 10	2 & 11	3 & 12	4 & 13	5	6 & 14	7	8	9
Comparable Field Slopes	Control Slope - 1A	1B	2A	2B	3	5A	5B	5C	5D
Date Installation	7/1772	7/17/72	7/17/72	7/17/72	7/17/72	7/17/72	7/17/72	7/17/72	7/17/72
Size Plot	12" x 18"	12" x 18"	12" x 18"	12" x 18"	12" x 18"	12" x 18"	12" x 18"	12" x 18"	12" x 18"
1) Type & Wt. Grass Seed, grams	Bermuda 0.24	Bermuda 0.24	Bermuda 0.24	Bermuda 0.24	Bermuda 0.24	Bermuda 0.24	Bermuda 0.24	Bermuda 0.24	Bermuda 0.24
2) Type & Wt. Grass Seed, grams	Bahia 0.24	Bahia 0.24	Bahia 0.24	Bahia 0.24	Bahia 0.24	Bahia 0.24	Bahia 0.24	Bahia 0.24	Bahia 0.24
Type & Wt. Fertilizer, grams.	8:8:8 15.63	8:8:8 15.63	8:8:8 15.63	8:8:8 15.63	8:8:8 15.63	8:8: 15.63	8:8:8 15.63	8:8:8 15.63	:8:8 15.63
1) Amount Mat'l or Mulch	-	47.3 cc.	21.9 gr.	23.5 gr.	0.785 gr.	5.285 gr.	8.913 gr.	0.785 gr.	0.785 gr.
2) Amount Mat'l or Mulch	-	-	-	-	-	-	-	7.85 gr.	7.85 gr.
At Installation- Amount Water, cc.	265	425	405	405	260	1024	1024	260	260
Watering Amounts, cc. (when needed)	500	500	500	500	500	500	500	500	500

Application Rates: Grass Seed - 15 lbs./Acre each, Fertilizer - 1000 lbs./Acre of 8:8:8:, Water - varies according to the recommendations, Product 2A - 1400 lbs./Acre, Product 2B - 1500 lbs./Acre, Product 3 - 50 lbs./Acre, Product 5A (on study) - 200 lbs./Acre, Product 5B (on study) - 3000 lbs./Acre, Slope 5C - Product 2A/with 3,500 lbs./Acre and 50 lbs./Acre, and Product 1B - 0.075 gal./sq. yd. (on study).

be used to test erosion control materials under carefully controlled conditions. Many different types of rainfall-simulators have been built and operated throughout the country. Some have been successful in their intent of operation while others have not. An attempt was made in this study to take the best features of each different rainfall-simulator, combine them into one which would fit the purpose of this study and produce the best simulated rainfall data as possible at the least cost practical.

Of course, rainfall-simulators do not eliminate the need for evaluation of materials in the field on slope plots using natural rainfall conditions, however laboratory tests using the rainfall-simulator can help to eliminate inadequate materials to where only the promising materials need be checked in the field.

Naturally one will never exactly reproduce rainfall because there are too many changing variables present in rainfall to duplicate. Therefore the features most desirable and which reasonably can be simulated were to be chosen.

The first step in the study of rainfall-simulators was to determine, from literature and by experimentation, those desired characteristics of natural rainfall, and how to duplicate them and measure them. To eliminate duplication of effort much reliance was to be made on the literature review and the results obtained by others.

The review of literature was made for three purposes:

1. To become acquainted with the methods and equipment which others have used to simulate rainfall, to distinquish between the advantages and disadvantages of those systems and to evaluate these systems.
2. To determine the characteristics of natural rainfall which were desirable for this study.
3. To select methods by which these characteristics could be best used or measured with the facilities available on this study.

A report on a study which was reviewed, quoted and greatly relied on is Special Report No. 81, <u>An Investigation of Methods for Simulating Rainfall on Standard</u>

Runoff Plots and A Study of the Drop Size, Velocity and Kinetic Energy of Selected Spray Nozzles, by L. Donald Meyer, May 1958 (6).

The prime consideration for the rainfall-simulator to be used on this research project was the consistency of operation (the minimum of changing variables and the maximum of constants) but the rainfall-simulator still had to have features which would, as closely as possible, reproduce actual rainfall and be within the realm of the objectives of this research project.

Features desired in a rainfall-simulator were as follows:

1. Realistic drop size distribution.
2. Uniform velocity and fall direction with drop velocities approaching terminal velocities.
3. Ability to reproduce a given storm.
4. Sufficient intensity and coverage over the test area.
5. Variable realistic rainfall intensity ranges similar to natural rain.
6. Freedom from the effects of outside weather, especially wind.
7. Uniformity of application.
8. Adaptability for ease of assembly, disassembly, handling, proper and adequate water supply, drainage, sample placement and cleanup.

These conditions will never be fully achieved, however the objective is to do the best one can with the available information, test devices and know how, then to build a rainfall-simulator and check it out. Literature sources of information are given in the Bibliography.

The first step in the construction of the rainfall-simulator was choosing the type of equipment to be used and testing various possible pieces of equipment. Preliminary information was acquired from literature or from other known sources. In the process, some of the constants used on the study, such as height of nozzle above the test sample, were selected also.

The second step was to design and construct this apparatus. A slotted steel type framing was selected for use and appropriate dimensions incorporated in the design and construction. Material costs for this construction were approximately $600. Improvements and increases in costs may cause the construction expenses in the future to be higher.

From past studies, the type of spray nozzle from which water was forced by pressure was a consideration, and one type needed to be selected. These included USDA nozzle types, such as D, E and F, along with other nozzles. Irrigation nozzles or sprinklers were found to be undesirable, while household nozzles had intensities that were too great. Some of the type nozzles that were studies and found to have characteristics which were desirable were the Veejet and Fulljet nozzles, manufactured by Spraying Systems Company, Bellwood, Illinois, and the WF nozzles, manufactured by Delavan Manufacturing Company, West Des Moines, Iowa. The principal references and results were obtained from the Purdue University study (6).

The Fulljet nozzle is a square pattern nozzle and was eventually chosen for use in this study with the rainfall-simulator. As with the Purdue University study (6), the decision was made to use this type nozzle in a position spraying downward perpendicular to the ground level in order to decrease the wind interference and take advantage of the initial velocity imparted to the drops by the water pressure. It is hoped, however, that the wind problem will be totally eliminated in the laboratory test procedure to be proposed through the use of the rainfall-simulator, in an inside location (covered building).

The final design of the rainfall-simulator or the constants selected for the operation of the rainfall-simulator are as follows:

1.	Test Nozzle	Spraying Systems Company, Fulljet 3/4 HH50SQ
2.	Height of nozzle	Eight feet (2.44 meters) above the test surface
3.	Spray Direction	Downward in a vertical position perpendicular to the floor or ground level
4.	Water pressure	6.0 psi (0.422 kgs. per sq. cm)
5.	Water flow	4.0 gpm (15.14 liters per minute)
6.	Water intensity	2 1/2 inches per hour (6.35 cm per hour)
7.	Slope angle of test pan	4° (.07 radians)

8. Time of test application   12 minutes

Dual pressure gages at the nozzle assembly should eliminate any chance of erroneous single pressure gage readings during operation and give the ability to keep a constant water pressure reading.

All of the characteristics incorporated in the design of the rainfall-simulator should produce simulated rainfall data which will give intensity of rainfall similar to that of natural rain, artificial rainfall of realistic drop size, drop velocities in an acceptable range, uniformity of distribution and reproducible intensities. The main objective is consistency and this should be achieved.

The rainfall-simulator is constructed of slotted steel which makes the erection much simpler. Figures 23 through 27 in the Appendix show the construction details of the rainfall-simulator. Construction costs were very low.

D. Laboratory Testing

While construction of the rainfall-simulator was progressing, plans, testing schedules and procedures were reviewed and finalized for the laboratory testing phase of the study. After a review of available literature and consideration of variables with a thought to the ultimate objective of the study, the preliminary steps and specifications outlined in the subsequent paragraphs were decided upon.

The following parts were used with the rainfall-simulator.

1) Three (3) small pans, each essentially 4" (10.2 cm) deep and 32 3/8" (82.2 cm) square and three (3) large pans, each essentially 4" (10.2 cm) deep and 45 3/4" (116.2 cm) square were designed and built to be used as test pans for the soil samples with the seed, fertilizer and mulch material to be added to the soil.

2) A 2' x 2' x 2' (61.0 cm x 61.0 cm x 61.0 cm) open topped calibrated tank was built to divert runoff, with markings on the side to be used to determine the volume of solution collected as runoff.

3) Two flumes, one large and one small, were built to divert the runoff from the pans to the collecting tank.

Two test times were established. The first was an immediate test (originally designated within three days of material installation, but primarily to be run within four hours of the material installation). The second test was a three week test. Immediate test times were revised later. One small pan and one large pan were tested at each period of time. Two different measurements on runoff amounts were made on each small pan (an oven dried method and a suspension method), while only the suspension method was used on each large pan.

The first step in the laboratory study procedure was the procurement of a suitable soil to be used as the test soil.

A good top soil was eventually decided upon as the best available type soil to be used. A local source was found and the top soil delivered at the test site, where it was stockpiled and covered. It was realized stockpiling was less than perfect, however all the test samples were obtained from the same source and tested the same with the emphasis being on consistency.

The other variable which presented a problem was the outside location of the test site. During the time of the study this location, was the best location available for use.

Wind will substantially affect results of rainfall-simulator tests; therefore, to cut down or eliminate the effects of wind, tarpaulins were placed around the testing apparatus. Of course, if this device is used in the future under tentative test procedures, it should be placed inside a building which would eliminate variables such as wind and weather. Stockpiles of soil should also be stored inside.

Next, test samples were placed in the pans, with soil being loosely compacted in the pans to a depth of 3" (7.6 cm) and smoothed over. A soil moisture sample was taken and the moisture content was determined. With the empty pan weight having been previously obtained and then the weight of the pan and soil together being obtained, the weight of the soil could be calculated. With the moisture content of the soil known, then the dry weight of the soil was determined.

Using standard recommended amounts of grass seed, fertilizer and mulch along with the quantity of water recommended for the pan areas, the materials were placed on the soil and immediate tests run. Appropriate pans were set aside for three weeks for the grass to germinate and grow. Tests were then run at three weeks, with a check being made on erosion retarding ability of the grass which had been helped to grow by the mulch, plus on the erosion retarding ability of the remainder of the mulch on the soil. Comparison were also made against a control set of test pans.

Water flow and water pressure at the nozzle were checked prior to testing to make sure adequate flow was present with a 6 psi (0.422 kgs. per sq. cm) water pressure. Position of the nozzle perpendicular to the platform and downward was checked also.

Actual testing procedures which were followed included: (1) placing the appropriate pan with soil in a position exactly centered on the platform and with a slope of 4% (.07 radians), (2) attaching the appropriate flume to the pan at the low end in a position to drop the runoff into the collection tank, (3) making sure the collection tank was clean, in a condition to easily mark the volume of runoff solution collected, (4) having cans available for runoff sampling for the suspension tests, (5) having timing device (watch) available for 12 minutes time test and (6) having tarpaulins in place for wind protection of water drops.

Water was then turned on with a 6 psi (0.422 kgs per sq.cm) water pressure and kept on for exactly 12 minutes. At two minute intervals, beginning at the one minute mark, six equal portions of suspended runoff sample were collected in a can, from the flow at the dropoff point at the tank. This sample can was sent to the soil unit for determination of the amount of sediment collected in the can. The dry weight of solid runoff material collected in the can was determined in grams and converted to pound weights. This amount of sediment was then converted to a projected value for the total runoff of the test. Multiplication values varied depending on the size of the test pans. Since the small pans were 1/6000 of acre in area and a ton being 2000 lbs. (907.2 kg.), the multiplication factor would be 3. In other words, the weight of the runoff sample in pounds times three would result in the soil loss value in tons/acre. With the large pans, since the pan area is 1/3000 acre, then the multiplication factor would be 1 1/2.

A sampling and testing block diagram is shown in Table 3.

TABLE 3

SAMPLING AND TESTING BLOCK DIAGRAM

Product	Test Period	Small Pan		Large Pan
		Oven	Drop-off	Drop off
Control Plot 1A	Immed.	x	x	x
	3 Wks.	x	x	x
1B	Immed.	x	x	x
	3 Wks	x	x	x
2A	Immed.	x	x	x
	3 Wks.	x	x	x
2B	Immed.	x	x	x
	3 Wks.	x	x	x
3	Immed.	x	x	x
	3 Wks.	x	x	x
5A	Immed.	x	x	x
	3 Wks.	x	x	x
5B	Immed.	x	x	x
	3 Wks.	x	x	x
5C	Immed.	x	x	x
	3 Wks.	x	x	x
5D	Immed.	x	x	x
	3 Wks.	x	x	x

E. Evaluation of Test Results and Development of Tentative Test Procedures

After all testing, both field and laboratory, was complete, then an analysis of the test results was to be made and the literature review information combined with this to come up with a laboratory testing procedure for the evaluation of erosion retarding materials. A standard plan for the rainfall-simulator was to be part of this package. Conclusions and recommendations were to be made concerning the rainfall-simulator, the testing procedures, the relationship between the laboratory and field testing, the degree of effectiveness of the various erosion control materials tested and the necessity and/or practicality of implementing the package of information acquired from this study.

DISCUSSION OF RESULTS

A. General Discussion

The general discussion which follows is a compilation of general statements and facts which has been obtained from the literature review of several referenced reports pertaining to the subject or erosion. The researchers feel that these statements and facts are applicable to this study also and should be repeated herein, but in shortened, excerpted and revised form.

One of the major factors that determines soil loss rate at any particular location is soil erodibility. This term has been described by Wischmeier and Meyer (17) as the inherent susceptibility of a soil to detachment and transport by rainfall and runoff. Other factors include the effects of rainfall pattern, slope steepness, slope length, slope shape, cover and management and conservation practices.

J. W. Turelle (16) has stated that among the items deemed essential for controlling erosion and sediment on road construction sites are soil management, soil and water conservation, landscape engineering and plant ecology. Unless the surface is protected with vegetation or some form of mulch or stabilization of some kind, then considerable soil loss occurs from rainfall, flowing runoff water or possibly wind.

Mulching is necessary in establishing plants on construction sites. A mulch is described by W. T. Plass (13) as any organic or inorganic material applied to the soil surface to protect the seed, maintain more uniform soil temperatures, reduce evaporation, enrich the soil, or reduce erosion by absorbing raindrop impact and intercepting surface runoff. Mulch should be applied uniformly and held in place by some form of anchoring. Anchoring should be done simultaneously with the application of the mulch or immediately after the mulch is spread. Asphalt emulsions are good to be used with hydromulchers for this purpose.

A soil stabilizer is also described by W. T. Plass (13) as any organic or inorganic material applied in an aqueous solution that will penetrate the soil surface and reduce erosion by physically binding the soil particles together. These materials can also reduce evaporation and protect the seed.

Mulches appear to be more effective than soil stabilizers in aiding the establishment of the seed or vegetation. Treatments do affect the vegetation growth. Vegetation germination and growth were much more rapid on plots treated with a mulch or a combination of soil stabilizer and wood fiber. These treatments were expected to have their greatest effect on sediment loss during the time from application until a vegetative cover could be established. Generally speaking, a protective cover can be established in 8 to 10 weeks with suitable installation and adequate fertilization.

Common types of mulch materials as listed by J. W. Turelle (16) are hay, small grain straw, wood chips or wood-based mulches, jute matting, cotton and paper netting, fiberglass netting, plastics, rubber compounds, polymers and asphalt products. Much research has shown that vegetative mulches such as straw or hay are very effective in reducing erosion and runoff on steeply sloping soils. Wood chips are also very effective in erosion protection.

There is a growing trend toward including a mulching material such as wood fiber with a soil stabilizer. This combination may hasten the germination of the vegetative cover on some sites. The type of stabilizer may affect the seed germination and grass growth rate.

W. T. Plass (13) has suggested there is a need to document differences in sediment loss from plots treated with several rates of application at different soil moisture levels, to evaluate soil stabilizers combined with other mulching materials, and to compare sediment loss from soils with specific chemical and physical properties. Hopefully from this study a standard method of evaluating the new erosion control products that enter the market each year will be established.

B. Discussion of Field Test Slopes

Remarks in this section of the report will be limited to a discussion of the degree of effectiveness of the various additives, either mulch or chemicals that were field tested for both erosion retardant capabilities and improvement of grass stand growth.

Many variables were present in the study, both planned and unplanned, to confound the issue or the evaluation of the products as to performance. These included the weather, the size and shape of the slopes, the steepness of the slopes, the effect of the proximity of trees to the tops of the slopes, the type of soil and the recommended rates of application of the materials. In addition to these performance variables, cost is another variable which has to be considered when making recommendations as to the use of the products.

The many variables that were present in the study make it difficult to reach definitive comparisons of the various products and their effects on the slopes. Individual opinions may differ on the degree of effectiveness of each product for the various uses of the product and on the reasons for what happened in the study.

However, we will attempt to discuss what occurred and possibly why. It was intended in this study to evaluate the soil erosion retardant capabilities of the products used on the field slopes by making field observations and taking measurements on stakes laid out on set patterns to determine the amount of soil loss due to erosion on each slope. Pictures were also taken before the project installation began, during installation of the materials and at each evaluation period to show grass stand growth and any soil erosion that had occurred and to attempt to show the progressive nature of the erosion and increase in grass coverage. Evaluation periods included inspections at two weeks, four weeks, two months, four months and one year.

It became readily apparent that measurements on slope stakes as set up in this study were not going to be practical, accurate or even workable. Therefore, visual observations, pictures and some rough measurements for estimates of soil losses were the only means of evaluation used after the first two evaluation periods. In evaluating the products this was probably adequate, however, it produced problems in determining the relationship between the laboratory and field testing results.

Rainfall data was acquired from the United States Geological Survey for the installation and evaluation periods. A rain gage was located near the field test plots. Table 4 on the following page shows this rainfall data.

Of five slopes originally selected, four were finally used on this study. A portion of the first slope was used as a control plot where only grass seed, fertilizer and water were applied and results compared with all of the other plots. For identification purposes this portion of the slope was labeled 1A. The other portion of the first slope was labeled 1B with a soil stablizing product used. This product was applied at the manufacturer's recommended rate along with recommended rates by State Specifications for grass seed, fertilizer and water. Figure 3 shows this slope before the installation and Figure 4 shows the slope at one of the evaluation periods. Weather played a big part in the grass stand growth and ultimately, the amount of erosion resulting on all of the slopes. Several days after the installation there was a small rainfall, enough to start the germination process, then a two week dry spell which probably killed or retarded the growth of grass.

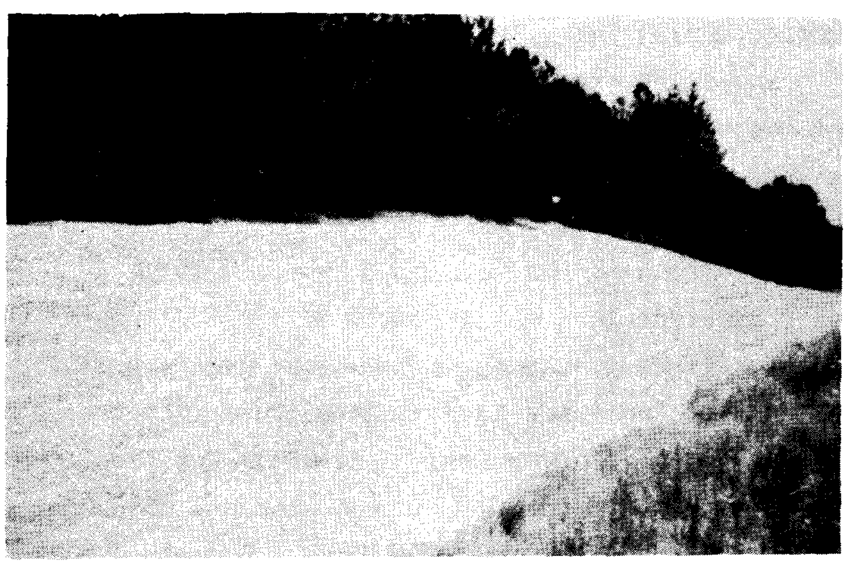

Figure 3
Prepared Slope No. 1 Before Installation

TABLE 4

RAINFALL DATA

USGA

CANEY CREEK TRIBUTARY NEAR HOMER

Sta. No. 7-3487.55
8.7 mi. NW of Homer
on La. 2

DAY	MAY 1972	JUNE 1972	JULY 1972	AUGUST 1972	SEPT. 1972
1		0	0	0	0
2		0	0	0	.37
3		0	1.16	0	.56
4		0	.24	0	.12
5		0	0	0	0
6		0	0	0	0
7		0	0	0	0
8		0	.03	0	0
9		0	0	0	0
10		0	.04	0	0
11		0	0	0	0
12		0	0	0	0
13		.42	.01	0	0
14		.99	0	0	0
15		.01	0	0	0
16		0	0	0	.59
17		0	.34	0	.30
18		0	.01	0	.02
19		0	0	0	.05
20		0	0	0	.01
21		0	.03	0	.54
22		.78	0	.89	.01
23		0	0	.04	.12
24	.01	0	0	.29	.05
25	0	.80	0	.03	.34
26	0	0	0	.28	.73
27	0	0	0	0	
28	.02	0	0	0	
29	.08	2.25	2.95	0	
30	.02	.67	0	0	
31	0	-	0	0	
In. Rainfall during Evaluation Period	.13	5 92	4.81	1.53	3.81

Total Evaluation Period Rainfall - 16.20 inches and Average Daily Rainfall - 0.13 inches.

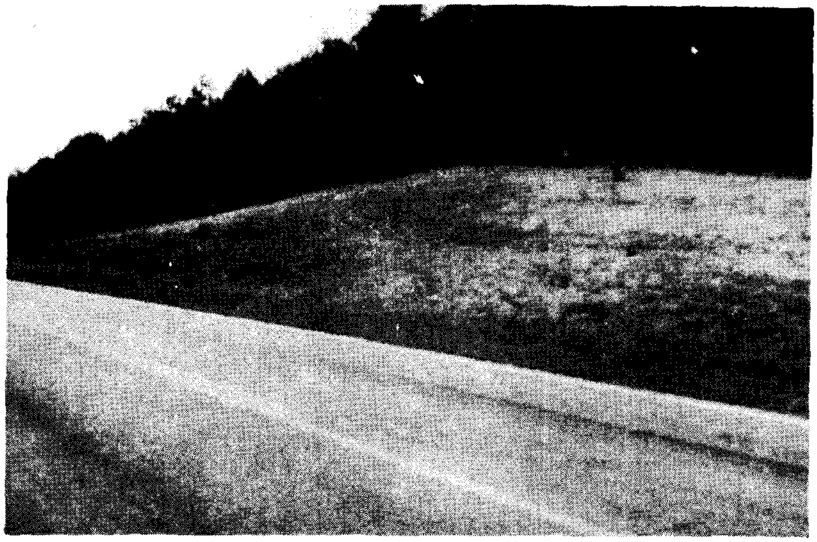

Figure 4
Long Range View Slope No. 1B at 4 Months

This dry spell seriously affected the amount and rate of grass stand growth. After this there were several heavy rains at various intervals which caused a good bit of erosion and serious rutting, especially at locations where the shape and steepness of the particular slope affected the runoff. Figures 5 and 6 show some of the effects of this on Slope No. 5.

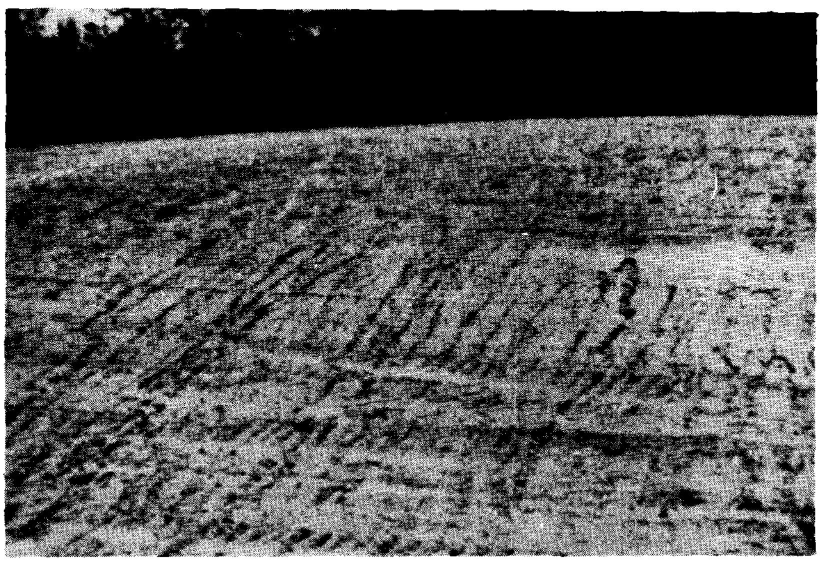

Figure 5
Long Range View Slope No. 5 at 1 Month

Figure 6
Closeup View Slope No. 5 at 1 Month

The soil stablizier on 1B seemed to hold the soil intact very well, forming approximately a 1/8 inch (0.32 cm) crust on top of the soil. This helped prevent serious erosion to begin with, thus there was very little erosion during the first few evaluations. However, grass stand growth seemed to be affected; it was retarded a little more than normal. Figure 7 on the following page shows installation of the chemical product. One disadvantage of this soil stabilizer is the cost. Bulk cost was around two dollars a gallon at the installation time. Another drawback is the difficulty in handling and cleanup.

The No. 2 slope had two different mulch products, Product 2A and Product 2B, installed on it. Actually both of these products are very similar. On the following pages, Figure 8 shows pre-installation conditions while Figures 9 and 10 show conditions at the one month and four month evaluation periods on 2B. Grass growth was somewhat sparse but much better than that obtained with the retardant used on the 1B slope. Installation costs for both these products are about average and well within the economic realm of usefulness. Erosion was limited at first and not nearly as extensive as on some of the other slopes.

There was generally little difference in results between either the 2A or 2B installations. This slope was a fairly large one of approximately 0.715 acres in area, with each product occupying approximately one half of the slope. The shape of Slope No. 2 had an affect on the type and extent of erosion found on it. This slope was large, steep and tended to pool water at the top creating a tendency for the water to flow towards the bottom of the slope.

The No. 3 slope was a small slope of approximately 0.25 acres in area and not steep. Trees helped to shield the top of the slope. One product, Product No. 3, was applied on this slope without mulch on an experimental basis. At first there was very little erosion, and no grass growth; eventually a little grass did start, however the erosion increased markedly. Figure 11 shows the pre-installation conditions while Figure 12 depicts conditions at the four month evaluation period. This product did not seem to adequately do the job by itself, however, in combination with other products, as on Slope No. 5, it seemed to do much better.

Figure 7
Installation of Product on Slope No. 1B

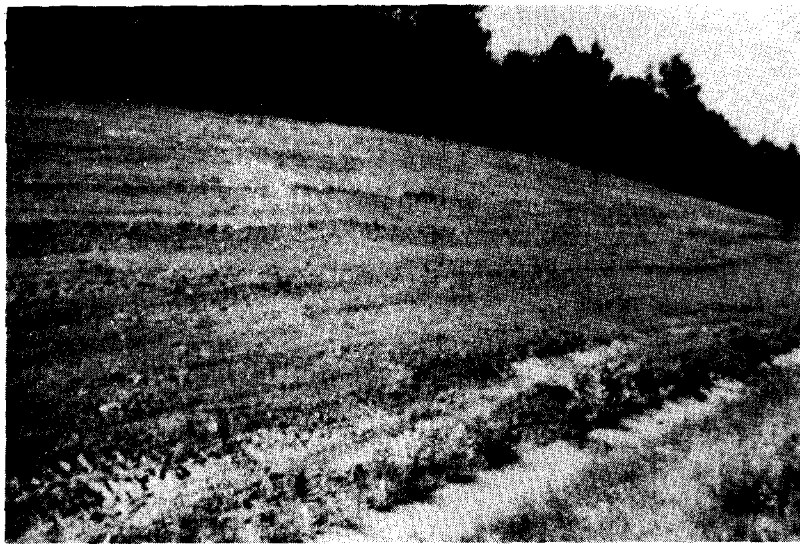

Figure 8
General View Showing Prepared Slope No. 2

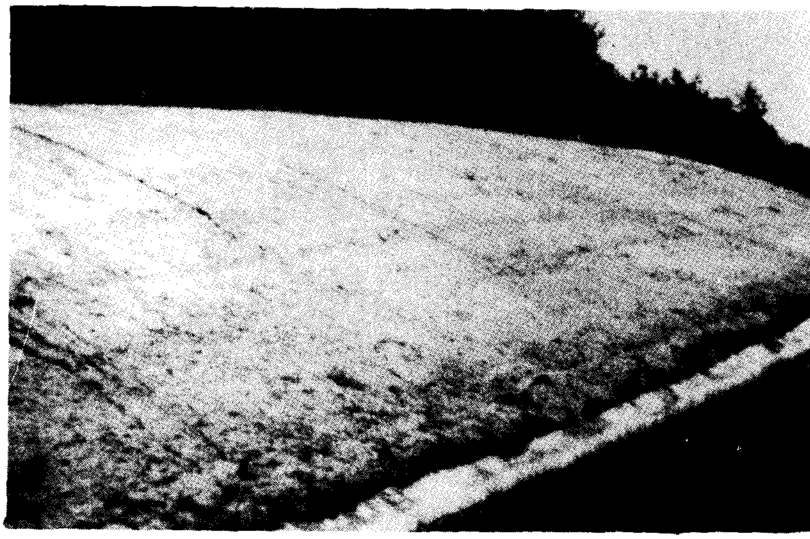

Figure 9
Slope No. 2B at 1 Month

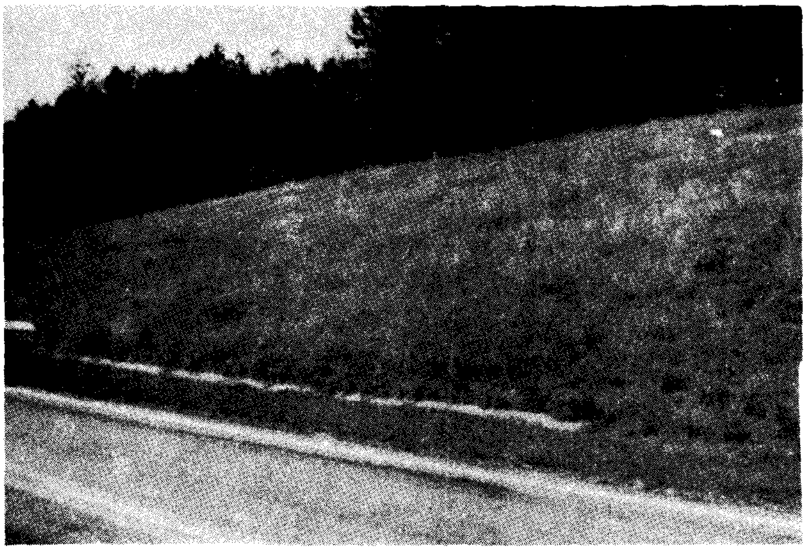

Figure 10
Slope No. 2B at 4 Months

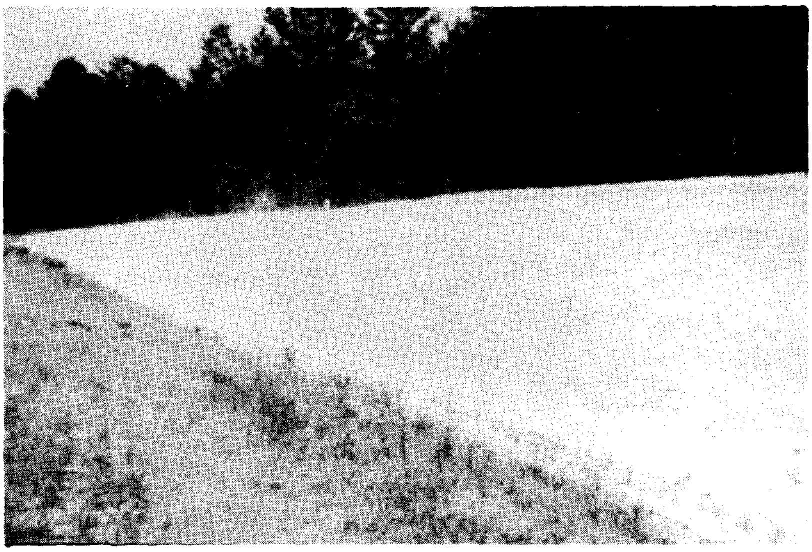

Figure 11
General View Showing Prepared Slope No. 3

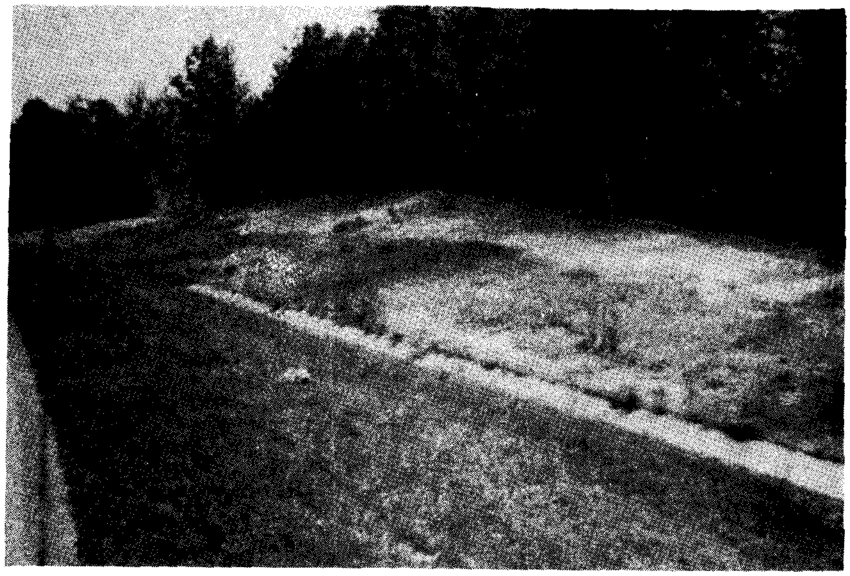

Figure 12
Slope No. 3 at 4 Months

Slope No. 5 was a very large slope of approximately 0.857 acres in area and was very steep and shaped in such a way as to produce a large amount of runoff. Four combinations of products were used on this slope. These were: Product 5A, Product 5B, Products 2A and 3 in combination on Slope 5C and Products 2B and 3 in combination on Slope 5D. Figure 15 on page 29 shows a general diagram of this slope and the other slopes with the locations of the various products.

Slope No. 5 seemed to have most of the serious erosion problems. Deep ruts were formed especially on 5B; 5A and 5C were nearly as bad, but 5D eroded to a lesser degree. However in the authors' opinion Slope No. 5 probably would have eroded just as much no matter what mulch product was used. The rainfall along with the shape and steepness of slope were the prime variables causing this erosion. Unless there would have been some very fast growth of grass to bind the soil in place or a large thickness of wood chips, the results would have probably been the same. The grass cover was late in forming, but accelerated fast once it did start and then generally covered the entire slope. Figure 13 and 14 show the erosion and grass cover at the one month and two month evaluation periods.

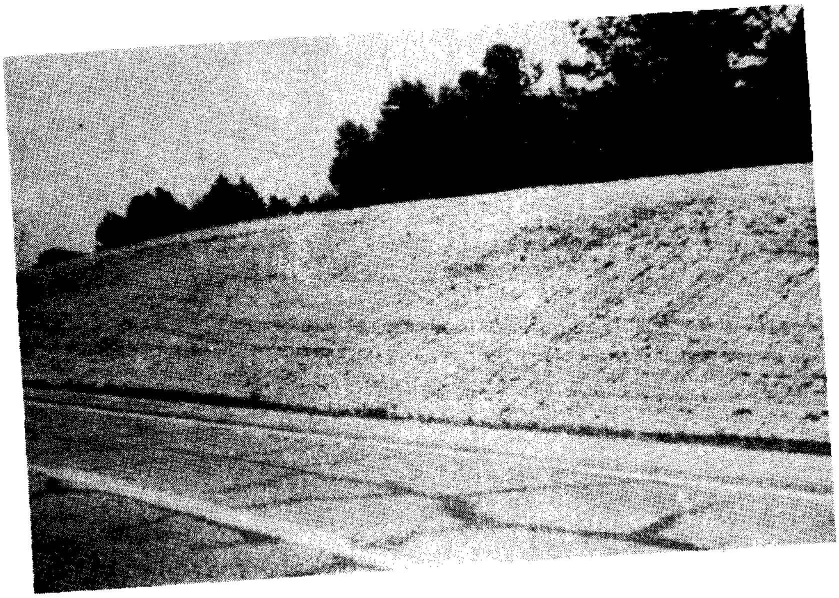

Figure 13
Slope No. 5 at 1 Month

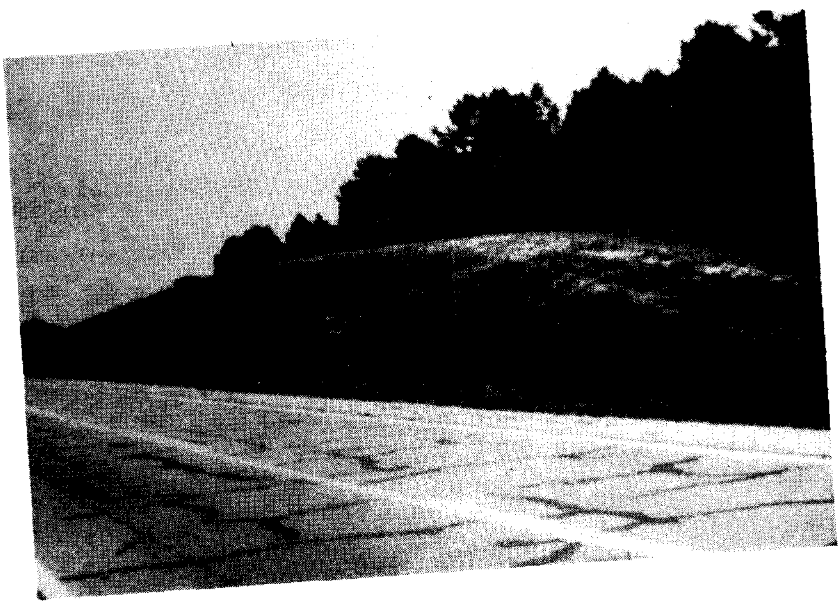

Figure 14
Slope No. 5 at 2 Months

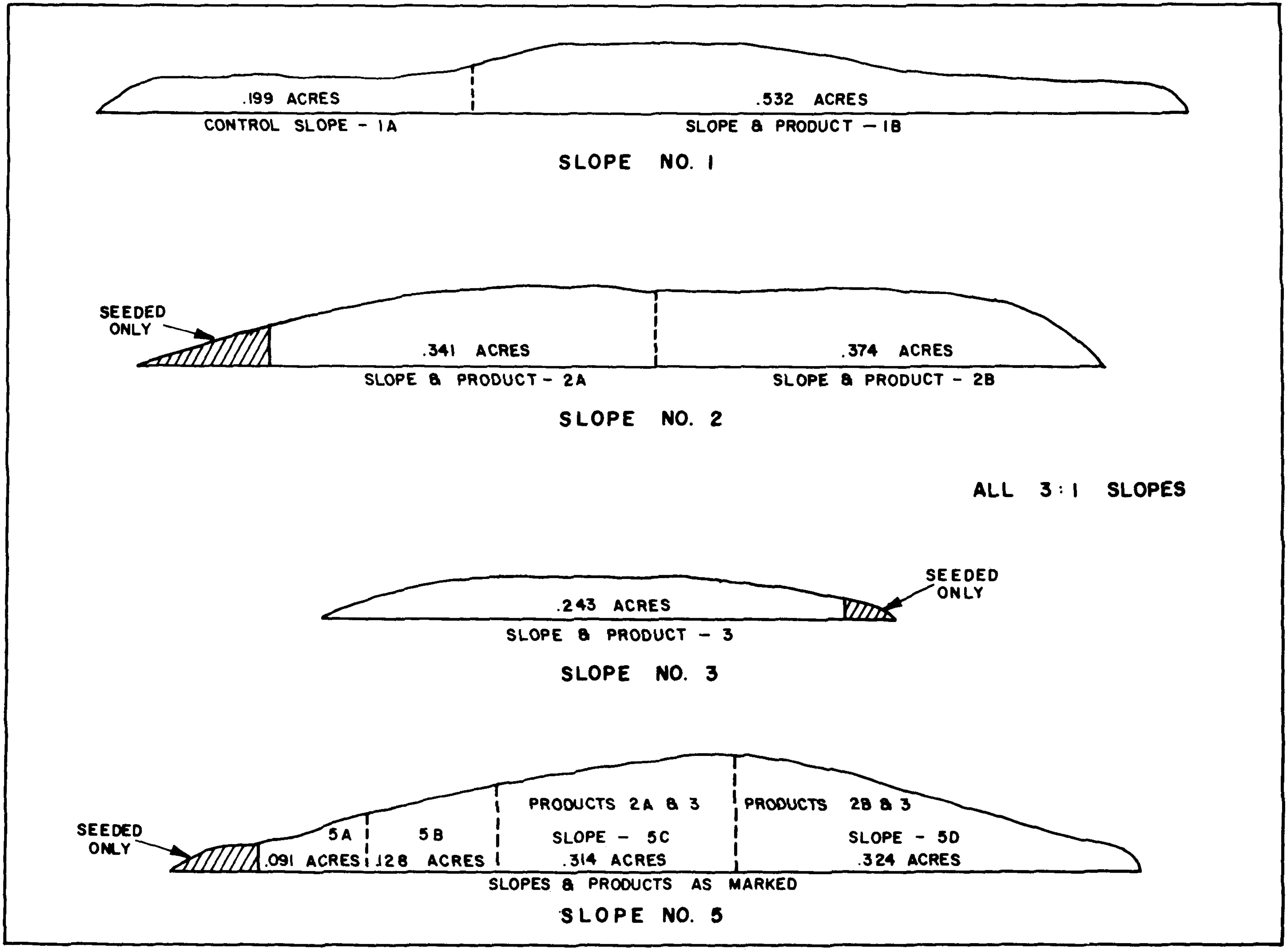

Figure 15

Diagrams-All Slopes

Grass stand growth could have been affected by segregation of the grass seed in the hydroseeder. This would lead to uneven distribution of grass seed especially at the tops of slopes where the seed have to travel a great distance.

Because of the hydroseeder, the actual installations were fairly efficient and easy to accomplish. However, the chemical product, a liquid, was shipped in drums. These drums were hard to handle and load into the hydroseeder. In addition, the hydroseeder required a good cleanup afterwards to keep the solution from setting up and creating problems at that time. This seemed to be the only major problem associated with the installation.

Table 5 on page 31 gives percent grass coverage and subjective erosion ratings of the slopes and products at three evaluation periods. Remarks pertinent to the slopes are also included. Table 6 shows cost data for the various products.

Results from the completed first set of laboratory seed germination (grass stand) plots generally corroborated the field tests results except in one notable case. The plot with Product No. 3 exhibited more grass cover under controlled conditions when compared to what No. 3 slope showed in the field. Still, it seemed that the amount of grass cover should have been much more than was realized on all of the plots.

C. Discussion of Seed Germination Plots (Grass Cover)

As previously stated in the discussion of field test results, the first set of laboratory seed germination plots generally corroborated the field test results, except in one case. Product No. 3 exhibited more grass cover under controlled laboratory conditions than was shown on the field slope. The second and third set of seed germination plots did not turn out very well, essentially showing erratic results. One can only speculate as to what happened and why. Therefore only the first set of plots will be used in this discussion of results. Table 7 gives grass cover data (%) on the first set of seed germination plots.

Figure 16 on page 34 also shows the grass cover as shown on the first set of seed germination plots.

TABLE 5

EVALUATIONS OF FIELD PLOTS

SLOPE AND TYPE PRODUCT	PERCENT GRASS COVERAGE			EROSION RATING			REMARKS
	4 WKS.	2 MOS.	4 MOS.	4 WKS.	2 MOS.	4 MOS.	
Control Plot, 1A Grass Seed and Fertilizer	Slight	35	75	0	1	2	Small Average Slope
1B Petroleum Emulsion and Soil Binder	Slight	50	65	0	1	2	Average Slope
2A Mulch	Slight	40	80	3	4	5	High Slope
2B Mulch	Slight	50	90	4	5	5	High Slope
3 Powder Slurry	0	15	45	2	3	4	Small Average Slope
5A Wood Chips	Slight	75	90	6	7	7	Very High Slope
5B Wood Chips	8	75	90	7	8	8	Very High Slope
5C Mulch with Powder Slurry	4	80	90	7	8	8	Very High Slope
5D Mulch with Powder Slurry	8	80	90	6	6	7	Very High Slope

Erosion Rating, 0 - 10 with the higher figure being the least desirable.

All slopes on approximately 3:1 ratio.

TABLE 6

COST DATA FOR THE VARIOUS PRODUCTS

Product	Recommended Rate of Application	Unit Cost	Cost per Acre and Remarks
2A	1400-1500 lbs/Acre	$100/ton	$70 - $75
2B	1400-1500 lbs/Acre	$100/ton	$70 - $75
3	50 lbs/Acre	$2/lb.	$100
5C	2A - 500 lbs/Acre 3 - 50 lbs/Acre	2A - $100/ton 3 - $ 2/lb.	2A - $ 25 3 - $100 Total - $125
5D	2B - 500 lbs/Acre 3 - 50 lbs/Acre	2B - $100/ton 3 - $ 2/lb.	2A - $ 25 3 - $100 Total $125
5A	2000 lbs/Acre*	$88/ton	$88
5B	3000 lbs/Acre*	$88/ton	$132
1B	0.075 gal./sq. yd.* (363 gal./Acre)	$ 2.00/gal.	$726

* Rate on Study

TABLE 7

GRASS COVER-SEED GERMINATION DATA

PERCENT GRASS COVER

Plot No.	1 Wks.	2 Wks.	3 Wks.	5 Wks.	7 Wks.	9 Wks.
Control 1A	0.9	25.0	32.5	17.0	19.0	18.5
1B	0.2	12.0	20.5	7.0	5.0	8.0
2A	0.9	22.5	27.5	9.0	10.5	10.5
2B	4.9	31.5	35.0	17.0	18.5	14.5
3	1.5	46.0	68.0	34.0	30.0	28.0
5A	12.7	49.0	58.0	23.0	25.0	30.0
5B	6.7	39.5	42.0	22.5	18.5	16.0
5C	0.4	31.0	33.0	10.0	9.0	11.0
5D	0.5	28.0	39.0	23.0	16.0	23.0

Referring to both Table 7 and Figure 16, one can see that the grass cover began developing at the 2 week period and reached the maximum at 3 weeks, dropped off and began leveling off. This was probably caused by the grass dying in these small boxes. Product Numbers 3, 5A, 5B, 5D and partially 2B showed more grass cover generally than was exhibited by plot No. 1A, the control plot. Product No. 5C started off well with more grass cover but ended up with less grass cover than the control plot, while Product Nos. 2A and 1B both showed less grass cover than the control plot. Product No. 1B, both in the field and in these seed germination plots, exhibited considerably less grass cover than any any of the other products or the control plot. Of course, grass cover is an important part of erosion control and products that will help the grass grow are very important, but there are also products that are best suited for immediate erosion control. The ideal product would be one that helped give immediate erosion control, help establish grass cover and also worked for an extended period of time. These are hard to find. Figure 28-30 in the Appendix show the seed germination boxes at 7 weeks.

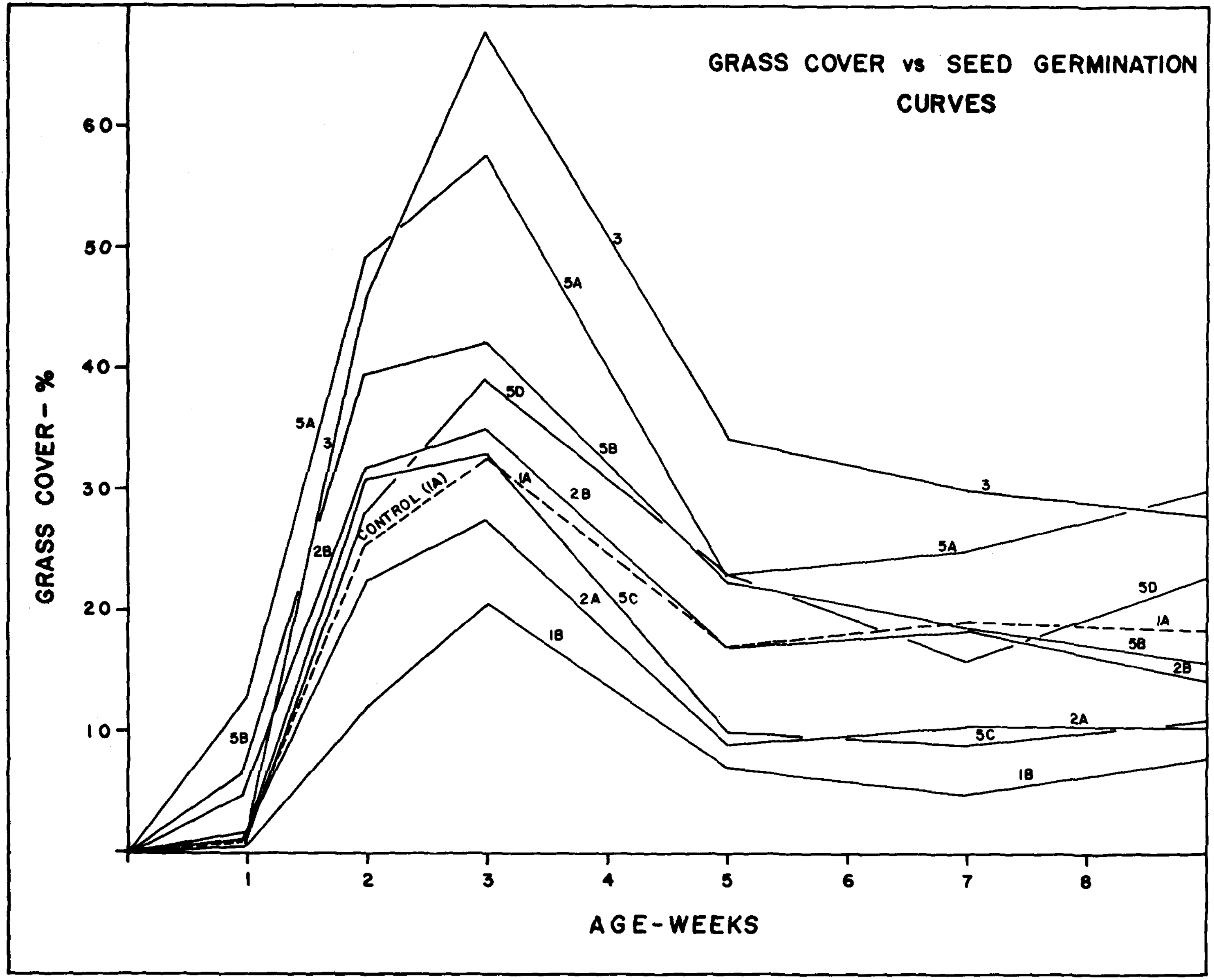

Figure 16
Grass Cover-Seed Germination
Curves

D. Discussion of Laboratory Testing

Once the rainfall-simulator was checked out and operational, the testing schedules and procedures were established and the first steps in the test procedure were commenced. As stated before, the conditions present for these laboratory tests were less than perfect, however emphasis was made on consistency.

For the laboratory tests, the researchers had to make do with what was available, then conduct the laboratory tests under these conditions, evaluate the results, take into account the problem areas, and make recommendations for a tentative test procedure. This hopefully would give an adequate test procedure which could be improved as time, experience and more evaluated results or additional information and facts are acquired.

The biggest potential problem that could be encountered in these laboratory tests was that of the weather. Since the rainfall-simulator was placed outside, test times could have been altered by delays due to rain or bad weather. Luckily this was not the case, there was always good weather at the scheduled test times. The wind factor affecting the water spray to the test pan was cut down by placing a tarpaulin around the rainfall-simulator in such a way as to minimize the effect. If a tentative test procedure is adopted from recommendations made in this report, these problems should be eliminated by placing the rainfall-simulator in an inside location.

By also placing the soil stockpile in an inside location or in a covered condition, moisture problems could also be minimized. A problem that was encountered in these laboratory tests was that of taking moisture content samples, making the appropriate calculations and converting the wet weight of soil in the test pan to that of the dry weight of the soil in that test pan. Any bad sample would throw the resulting dry weight value off and might result in considerable variations in soil loss data.

Another possible place where errors could be made is in obtaining the drop-off sample of material in solution and then coverting the solid runoff material in the sample to the total runoff value or soil loss value. Some of these conditions are discussed later in the section, Discussion of Tentative Test Procedures, found on page 41. Here in this section we will only discuss the results as obtained from the laboratory testing. Table 8 found on the following page gives the laboratory soil loss data as acquired from all of the laboratory testing and Figures 17 through 22 in the Appendix give graphic representations of these results and also possible recommendations on allowables for soil loss values under the recommended test procedure discussed later.

Two sizes of test pans were used in the laboratory testing phase of the study, one a small test pan which measured 1/6000 acre in area and another a large test pan which measured 1/3000 acre in area. It became readily apparent that the small pan was more ideally suited for the laboratory testing since it was easier to handle, it could be placed in an oven for the soil to dry out and the resulting data was more suitable to be analyzed.

The lack of a good range of data on the large test pans and the handling problems associated with the large pans led the researchers to reject use of these in the recommended test procedure. This decision was made early in the testing phase, however the testing with the large pans was continued and completed so that a more complete block of test data would be available for presentation in table form with the other data. Large test pan data will generally not be discussed here in this report and any further discussion of the laboratory test results will be strictly on the small test pans.

Referring to Table 8, one can see that by using the Drop-off Method of sampling runoff (discribed in Methods of Procedure), the values are generally less than by the Oven Method (also described in Methods of Procedure). This is due to the fact that only a small sample of runoff is obtained and converted proportionately to the total runoff value. Obviously an error is possible if the sample is not taken correctly or the determination procedure for solid material is not performed correctly. The error could then be expanded because of the conversion factor being so large. The Oven Method will give a more correct value since total dry weights are used. The biggest drawback to the Oven Method is the possibility of an error in the moisture content sample throwing off the conversion of wet weight of soil to dry weight of soil. This could

TABLE 8

LABORATORY SOIL LOSS DATA

Product	Test Period	1/6000 acre SMALL PAN - Soil Loss, Tons/Acre				1/3000 acre LARGE PAN - Soil Loss, Tons/Acre	
		Original Oven	Re-run Oven	Original Drop-off	Re-run by Drop-off	Original Drop-Off	Re-run by Drop-off
Control Plot, 1A	Immed.	13.41	-	10.20	-	4.99	-
	3 Wks	12.12	-	9.21	-	2.31	-
1B	Immed.	9.48	8.34	7.13	7.80	15.87	4.71
	3 Wks	3.87	1.02	2.98	1.44	0.13	1.52
2A	Immed.	4.56	-	1.54	-	0.94	-
	3 Wks.	1.20	-	0.73	-	0.53	-
2B	Immed.	8.55	6.00	3.66	8.83	2.46	-
	3 Wks.	3.15	-	2.16	-	0.79	-
3	Immed.	4.56	16.14	3.44	7.66	5.27	14.09
	3 Wks.	12.36	xxx	14.97	xxx	0.85	20.55
5A	Immed.	2.01	-	2.21	-	*	-
	3 Wks.	*	-	*	-	*	-
5B	Immed.	1.44	-	3.04	-	*	-
	3 Wks.	2.67	-	1.57	-	*	-
5C	Immed.	7.44	-	2.30	-	3.84	-
	3 Wks.	14.43	-	2.59	-	0.73	-
5D	Immed	8.10	-	4.16	-	3.64	-
	3 Wks.	7.41	-	5.28	-	1.92	-

* - Not enough material for all tests

xxx - Not available due to a mishap

possibly lead to a negative end result if a substantial error is present or one is not careful in sampling. In the Drop-off Method, a positive value is always obtained because a solid runoff weight is converted to the total runoff value. Each method has its advantages and disadvantages.

In reviewing the results of the laboratory testing for soil loss, it became readily apparent that there were some erratic results. Some reruns of tests had to be made because of results that appeared out-of-line with the field results or because of a lack of sufficient curing time for the soil stabilizers. However there still appears to be some erratic results even on the reruns.

In the report by Peters, Rastler and Vallerga (12), one of the soil stablizing products tested had an effective curing time of approximately six days. Since soil stabilizers do need some curing time and each varies anywhere from 3-7 days depending on soil moisture and air temperatures, then a recommended initial curing period needs to be set up for soil stabilizers when tested in the laboratory. The researchers recommend a seven day curing period to be included in the Recommended Tentative Test Procedure for Soil Loss Data. One can then compare the effect of a seven day curing period for stabilization to be extended curing period of 21 days for stabilization.

Soil stabilizing Product Numbers 1B and 3 were tested at the three day period (immediate test). Since this was an insufficient curing time for these soil stabilizers, these results did not reflect the conditions sought in these products. However these results did show that the soil stablizing materials have some effect on resulting erosion just with their presence before setting up. This information can also be very helpful.

Since mulches, when put down, are ready to do their job immediately and are primarily used for helping the germination of the grass seed, they will help resist soil erosion during the critical time before the grass is established. Since this is the case, a rainfall-simulator test can be made anytime after the material is applied. Such a test would still probably be satisfactory up to seven days, since the grass would probably not be established by then to affect the results.

Usually a good protective ground cover in the field will be established in 8 to 10 weeks under the right conditions, and the study results bear this out. The researchers feel that after three weeks in the laboratory, enough grass is present to give an indication of erosion resisting capabilities of the remaining product on the surface of the pan, if any, and the effect of the available grass present on resisting erosion. One does not want to extend this time too far when good indications can be obtained earlier at a realistic time interval. The so-called immediate test (from 0-7 days after preparation) is to provide information on the immediate erosion resisting capabilities of the product before the grass is established.

Product Numbers 2A, 2B, 5A and 5B were wood fiber mulches that were tested. with Numbers 2A and 2B being similar but supplied by different companies while 5A and 5B were nearly the same, but supplied by one company. Product Number 5C was a combination of 2A and 3, a wood fiber mulch with a soil stabilizer or slurry product. Product Number 5D was also a combination, that of 2B and 3, a wood fiber mulch with a soil stabilizer or slurry product. The results from combinations are shown for comparative information mainly to show what these will do.

One difference in the method of application of the materials on the slopes in the field and in the soil pans in the laboratory was that the field application was by hydroseeder with the grass seed, fertilizer, product material and water all being distributed over the slope together in one application while in the laboratory all of the materials had to be applied separately for the most part. One had to be careful to do the application the same way everytime in the laboratory so comparative results could be obtained. Variation in application from the field to the laboratory could make a difference in the results, however if one just compares the laboratory results among themselves then good comparative results are obtained.

One would expect that the soil loss values for test samples of products should be less than the appropriate tests with the control sample (soil, seed and fertilizer) and generally this was the case, yet there were some obvious exceptions. Looking at Figures 17 to 22 in the Appendix, one can see that Product 5C by the Oven Method, small pan at three weeks showed a high soil loss value; also, the original test on Product 1B by the Drop-off Method, large pan on the immediate test showed a high soil loss value, but the rerun of this test gave a much lower value. Product No. 3 showed high values for a number of the cases. Figures 31 and 32 in the Appendix show soil test pans for Products 1B and 5C during the three week waiting period.

Even with some shortcomings the researchers feel that the test procedure to be recommended will be a good tool to use, along with visual observations and judgment, in narrowing down the list of products put on the market to help resist erosion by eliminating the less promising ones. Action can than proceed in the field to check the more promising ones. This test procedure will give comparative results to use for this purpose.

Of course, the key to acceptance or rejection of materials when using soil loss data is the allowable value that is established. In setting so-called allowables (values above which the material may be considered poor in performance and values below which the material may be considered adequate or good in performance) there are no precedents (data, reports or formulas) specifically for laboratory conditions. As far as is known, this is the first laboratory test procedure using the rainfall-simulator to test new products for their performance under laboratory conditions, for this particular use anywhere.

The universal soil loss equation, as developed by the Agricultural Research Service and described in a report by Wischmeier and Meyer (17), was the closest thing to a formula which could be used; however, this formula was set up for an estimation of soil loss on slopes in the field when using particular type products. This universal value is an estimation of soil loss expected to result from a particular product and not an allowable value.

For the laboratory tests, an allowable value has to be set up for the particular conditions, rainfall-simulator and test procedure being used. The field results from the study could be used to help as a guide or correlation to setting up the allowable values in the laboratory.

The researchers are establishing a maximum percentage value of the control plot soil loss data as an allowable for the appropriate set condition used.

Setting the allowable values was the main problem confronting the researchers and still is, because it is difficult to adequately justify the actual allowables set. Of course if the product does not perform in the laboratory under known and set conditions, then it should not be tried in the field. In our case, once the values or allowables are set, then these values will govern, tempered by observation and judgment to see if they are workable and adequate. Through future results, both in the laboratory and in the field, revisions can be made to obtain better values to be used as the allowables. Time will tell in process of revision as to the adequacy.

Since under the recommended test procedure (found in the Appendix) several sets of conditions were specified, then a different allowable was established for each set of conditions. The two sets of conditions and allowables established were as follows: (1) small pan, 7 day test by the Oven Method - 50% of the control sample soil loss value and (2) small pan, 21 day (3 weeks) test by the Oven Method - 50% of the control sample soil loss value. The two sets of conditions by the Drop-off Method were not recommended for use in the tentative test procedure because the laboratory results did not bear out the field results or the Oven Method results in the laboratory.

Primarily the starting point for the first set of allowables was a matter of judgment by the researchers, being guided by the field results and having comparative data in the laboratory weigh heavily along with observation of performance under the rainfall-simulator. As stated before, since this is the first time this has been done, revisions will probably have to be made later. The recommended tentative test procedure for determination of soil loss data and the rainfall-simulator are tools to be used to compare new products in the erosion field for adequacy and acceptable use. These tools should be used with consistency of tests and realistic allowable values for acceptance of products.

E. Discussion of Tentative Test Procedures

The recommended tentative test procedure found in the Appendix has been developed from results obtained on this research project and from other sources, and includes the literature review for this study plus a common knowledge of what is needed and how it can be obtained.

As stated in the preceding article on the rainfall-simulator, the primary aim is to have a consistency of operation with the rainfall-simulator. The tentative test procedure will also have the requirements of the realistic test constants, a minimum of changing variables and a test procedure that is easy to apply, easy to analyze results and yet provide results which will in the end help to eliminate some materials that are less than promising or not satisfactory from further checking in the field.

A test procedure is only as good as the personnel who will perform it, and in addition analyze and report on the results of the tests. The interpretation of data is very important. Even though many constants have been established in this procedure, there are still some areas where sampling errors may be made which will materially affect the results and also there are some weaknesses in the procedure.

An attempt will be made here to outline these areas of weakness or places where errors could possibly be made, discuss them and tell why it was decided to go with the present recommendation. Hopefully with time and effort these weaknesses can be eliminated or reduced to a bare mimimum to provide a better test procedure.

At this time, the present conditions outlined in the recommended tentative test procedure will have to be used because of simplicity and ease of operation and because the procedure does provide adequate test results which can be for comparison purposes. Changing this test procedure would involve some expense and would necessarily complicate parts of the procedure, yet not meaningfully change any results. Of course, the operating personnel should still be careful in performing their tasks and calculations.

The rainfall-simulator itself along with the test constants established for it should be quite adequate for its purpose. However, an element which is necessary for a correct operation of the procedure is the type and consistency of the soil to be used with the erosion control materials to be checked.

Again, consistency is the key work here. Obtaining a good supply of soil is a necessity along with specifying the same type every time, however, sometimes this creates a problem in stockpiling. It is not practical to keep a large supply of soil stockpiled, therefore specifying the same source, taking a sample of that soil and running the appropriate identification tests to check the soil are important.

For our purposes on this study, a local commercial source was used and six cubic yards (0.46 cubic meters) of top soil was ordered. Soil tests indicated this was an A-4 soil, a silty clay loam with a P.I. of 6, 11% sand 200, 69% silt and 20% clay. In our case six cubic yards of soil was sufficient to be stockpiled in order to carry out all the rainfall-simulator tests.

Another area which could cause problems is that of filling the test pans with the soil in a loosely compacted state, them leveling the surface off to obtain a smooth even surface. It was felt this condition would be more realistic of actual field conditions, yet be fairly easy to accomplish.

The area most subject to error is that of obtaining moisture contents of the soil placed on the pans, then calculating the dry weights of the soil in each pan. Since small moisture samples represent so much more soil, a small error here can be magnified and the true moisture content and especially the actual dry weight of the soil can be quite a bit off. These calculations are probably the key ones in the whole procedure. Again, consistency is the key word plus being careful in obtaining the moisture content, running it and making the calculations.

There may be other areas which could create problems, such as interpretation of data, handling of the materials or curing and germination of grass seed, but these are relatively minor and can be corrected as a good working knowledge of the procedure is acquired outside of what has already transpired on the study itself.

The recommended test procedure "Tentative Method of Test for Simulated Rainfall Soil Loss Data" is found in the Appendix.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions reached on this study were achieved from several different phases of the study and combinations of these phases. These conclusions concern what happened in the field phase of the study and also in the laboratory phase of the study, including seed germination, grass stand growth plots and product testing with the rainfall-simulator. Recommendations were made for possible future construction and use of the rainfall-simulator. A tentative laboratory test procedure for the testing of erosion control products for soil loss data was then evolved and recommended.

Conclusions reached on the field phase of the study were limited to the degree of effectiveness of the various additives, either mulch or chemical. for erosion retardation and grass stand growth. Definitive conclusions were complicated somewhat by the many variables present at the field site and by the weather. Conclusions on the performance of the products during the field phase of the study may not be synonomous with normal capabilities of these products; therefore, the conclusions will be limited to the actual performance results as observed during the field phase of the study.

A summary of field results is as follows:

1. On Slope No. 2, the erosion was about average, but not excessive as it was on Slope No. 5 in particular.
2. Erosion was most prevalent on Slope No, 5: however, this fact may have been caused by the shape and size of the slope rather than the type and quality of the products installed.
3. For erosion retardation capabilities the soil binder or chemical product (Number 1B) performed very well, as it formed a crust on top of the soil thus hindering immediate erosion.
4. The chemical product (Number 1B) although doing a good job of preventing erosion, somewhat hindered grass growth because of the crust present on the top of the soil.
5. Slopes No. 1 and 3 had the least amount of erosion, however they also had the lease amount of grass coverage.

6. Grass stand growth was slow in beginning on all field slopes and grass coverage was limited on all slopes even after a period of time except for Slope No. 5, where a combination of grass and weeds enveloped the entire slope with the exception of a narrow strip along the top of the ridge where no seeding was done.

7. The slurry product used on Slope No. 3 seemed to do the least constructive job of helping grass growth although erosion was not prevalent at the beginning.

Some general conclusions reached from the field were as follows:

1. All of the products were fairly easy to handle and easy to install except for the chemical product, which was hard to handle and to load into the hydroseeder and required a good cleanup after its use.

2. All of the products were within normal competitive price range as shown in Table 6 on page 32, except for the chemical product (emulsion), which is much more costly than any of the other products.

A conclusion reached from the laboratory seed germination plots was that these plots tended to corroborate the field results of the study in regard to grass coverage with the possible exception of Product Number 3. Erratic results were observed in both the field and laboratory Number 3 plots.

Conclusions reached from the laboratory testing phase of the study were as follows:

1. A rainfall-simulator is constructible, practical and low cost (approximately $600) for providing a good consistent tool to test erosion control products. Some construction details are shown in the Appendix and operational details are described in this report.

2. There is only an observed general relationship between the field phase test results and the laboratory test results; however, the laboratory results bear out the field observations, thus, the laboratory test procedure should work to provide comparative results.

3. A tentative laboratory testing procedure for determination of soil loss data was developed in the laboratory phase of the study and recommended for use. Although the procedure is not perfect, through future revisions the procedure will come closer to that goal and provide an excellent tool for testing these

new erosion control products to determine the most promising ones to later check in the field and to eliminate the less promising ones.

4. The biggest drawback to the laboratory test procedure is not the use of the rainfall-simulator, but the sample preparation along with the sample size and measurement of weight loss.

5. After it has set up, Product Number 1B showed excellent results on erosion retardation. However in the period before the product had set up, the capabilities were greatly reduced and although showing some erosion retarding capabilities, it was still felt that the product did not do a good enough job during the first six days.

6. The overall results from Product No. 3 were less than satisfactory. Results were very erratic.

7. Product Numbers 2A, 2B, 5A and 5B, generally speaking, performed well.

8. The combination of products (Numbers 5C and 5D) showed erratic results and therefore may need further checking in the future to determine if use of combinations of products, such as soil stabilizers and mulches, is practical and effective.

Recommendations are as follows:

1. A laboratory test procedure entitled "Tentative Method of Test for Simulated Rainfall Soil Loss Values," found in the Appendix, is recommended for use in testing new erosion control products placed on the market to determine whether these products are promising enough to be field checked.

2. The construction of a Rainfall-Simulator, as shown in construction details found in the Appendix, is recommended as a necessary tool in performing the aforementioned test procedure.

3. Implementation of recommendations 1 and 2 above is recommended if the number of new erosion control products on the market now and in the future warrants such action.

4. The practicability of implementing the laboratory test procedure and the construction of the rainfall-simulator will depend on administrative decisions, especially considering the cost of implementation, along with the physical space

needed and the ease of implementing these items. The future flow of new erosion control products introduced on the market and the need for new products evaluation will be a consideration in the implementation.

5. The authors recommend that work should be continued in this effort to check for repeatability of soil loss results using the rainfall-simulator and the tentative test procedure.

BIBLIOGRAPHY

1. Barnett, A. P., Diseker, E. G., and Richardson. E. C. "Evaluation of Mulching Methods for Erosion Control on Newly Prepared and Seeded Highway Backslopes," Agronomy Jour., pp. 83-85, Vol. 50, 1967.

2. Bertrand, A. R. and Parr, J. F. Design and Operation of the Purdue Sprinkling Infiltrometer. Research Bulletin No. 723, Purdue Univ. Agricultural Experiment Station, August 1961.

3. Briggs, W. M. "Inventory of Roadside Erosion in Wisconsin," HRB Special Report 135, pp. 77-81, Washington: Highway Research Board, 1973.

4. Bubenzer, G. D. and Meyers, L. D. "Simulation of Rainfall and Soils for Laboratory Research," Trans. ASAE, pp. 73 and 75, Vol. 8, No. 1, 1965.

5. Mech, S. J. "Limitations of Simulated Rainfall as a Research Tool," Trans. ASAE, pp. 66 and 75, Vol. 8, No. 1, 1965.

6. Meyer, L. D. An Investigation of Methods for Simulating Rainfall on Standard Runoff Plots and a Study of the Drop Size, Velocity and Kinetic Energy of Selected Spray Nozzles. Special Report No. 81, Purdue University Agricultural Experiment Station, May 1958.

7. Meyer, L. D., Johnson, C. B., and Foster, E. R. Stone and Woodchip Mulches for Erosion Control on Construction Sites. Jour. Soils and Water Cons., 1972.

8. Meyer, L. D. and Kramer, L. A. "Relation Between Land-Slope Shape and Erosion," Agr. Eg., pp. 522-523, Vol. 50, 1965.

9. Meyer, L. D. and McCune, D. L. "Rainfall Simulator for Runoff Plots," Agr. Eng., pp. 644-648, Vol. 39, 1958.

10. Mutchler, C. K. and Hermsmeier, L. F. "A Review of Rainfall Simulators," Trans. ASAE, pp. 67-68, Vol 8, No 1, 1965.

11. Mutchler, C. K. and Moldenhauer, W. C. "Applicator for Laboratory Rainfall Simulator," Trans. ASAE, pp. 220-222, Vol. 6, No. 3, 1963.

12. Peters, J. D., Rostler, F. S. and Vallerga, B. A. "Promising Materials and Methods for Erosion Control," HRB Special Report 135, pp. 105-117, Washington: Highway Research Board, 1973.

13. Plass, W. T. "Chemical Soil Stabilizers for Surface Mine Reclamation," HRB Special Report 135, pp. 118-122, Washington: Highway Research Board, 1973.

14. Swanson, N. P., Dedrick, A. R., and Weakly, H. E. "Soil Particles and Aggregates Transported in Runoff from Simulated Rainfall, "Trans. ASAE, pp. 437 and 440, Vol. 8, No. 1, 1965.

15. Swanson, N. P., Dedrick, A. R., Weakly, H. E. and Haise, H. R. "Evaluation of Mulches for Water-Erosion Control," Trans. ASAE, pp. 438-440, Vol. 8, No. 1, 1965.

16. Turelle, J. W. "Factors Involved in the Use of Herbaceous Plants for Erosion Control on Roadways," HRB Special Report 135, pp. 99-104, Washington: Highway Research Board, 1973.

17. Wischmeier, W. H. and Meyer, L. D. "Soil Erodibility on Construction Areas," HRB Special Report 135, pp. 20-29, Washington: Highway Research Board, 1973.

APPENDIX

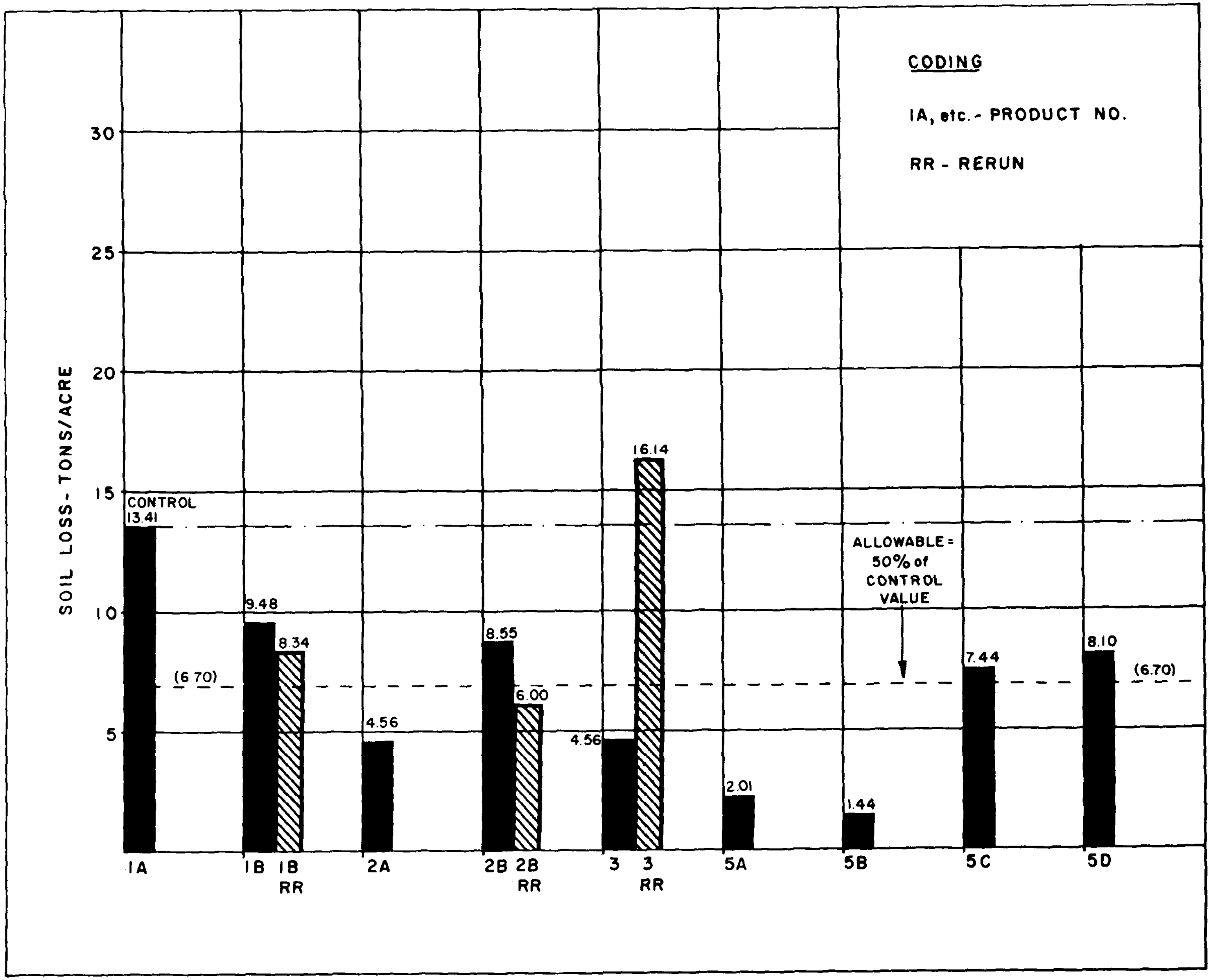

Figure 17

Soil Loss Data Graph for Small Pans,
Immediate Test by Oven Method

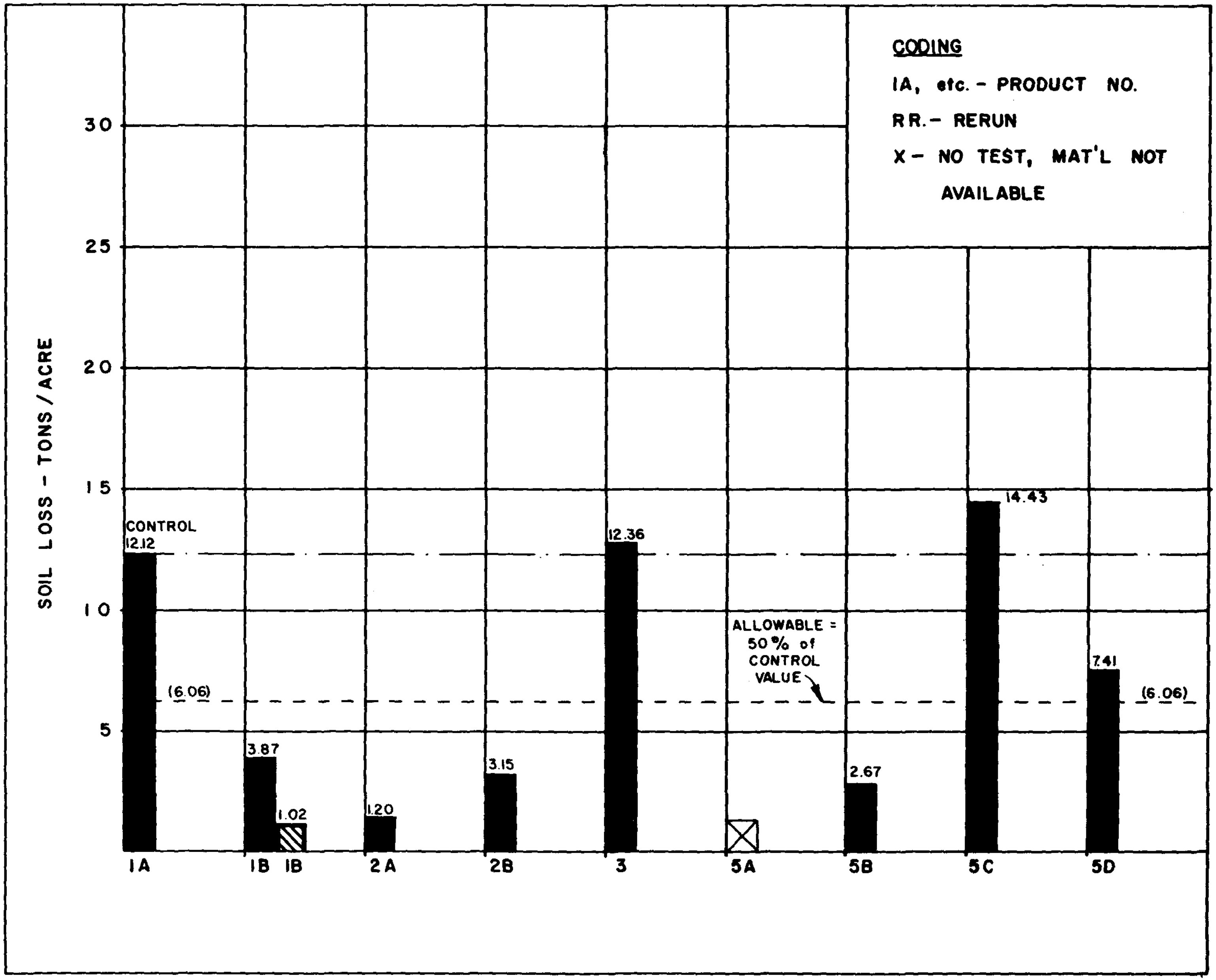

Figure 18
Soil Loss Data Graph for Small Pans,
3 Week Test by Oven Method

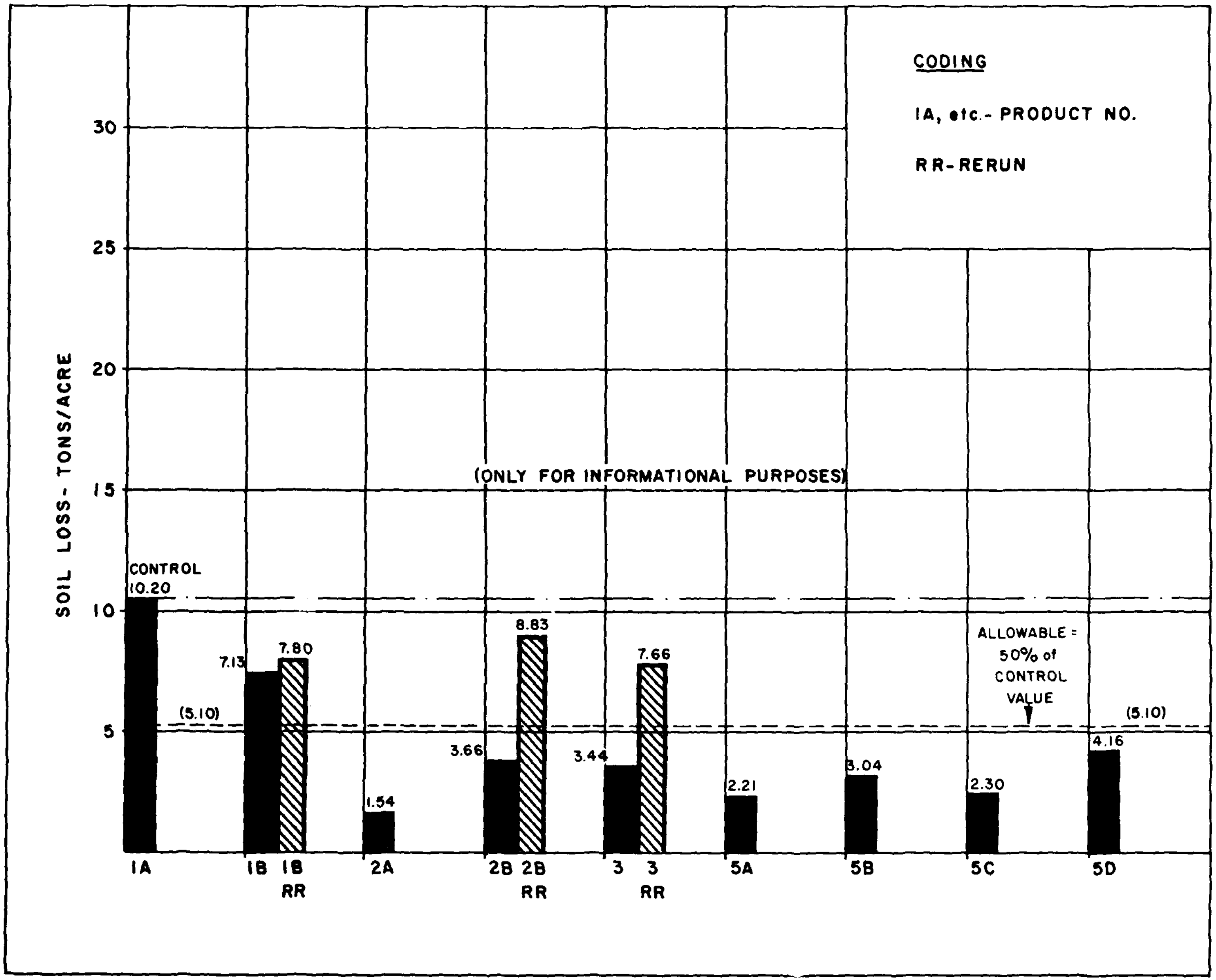

Figure 19

Soil Loss Data Graph for Small Pans, Immediate Test by Drop-Off Method

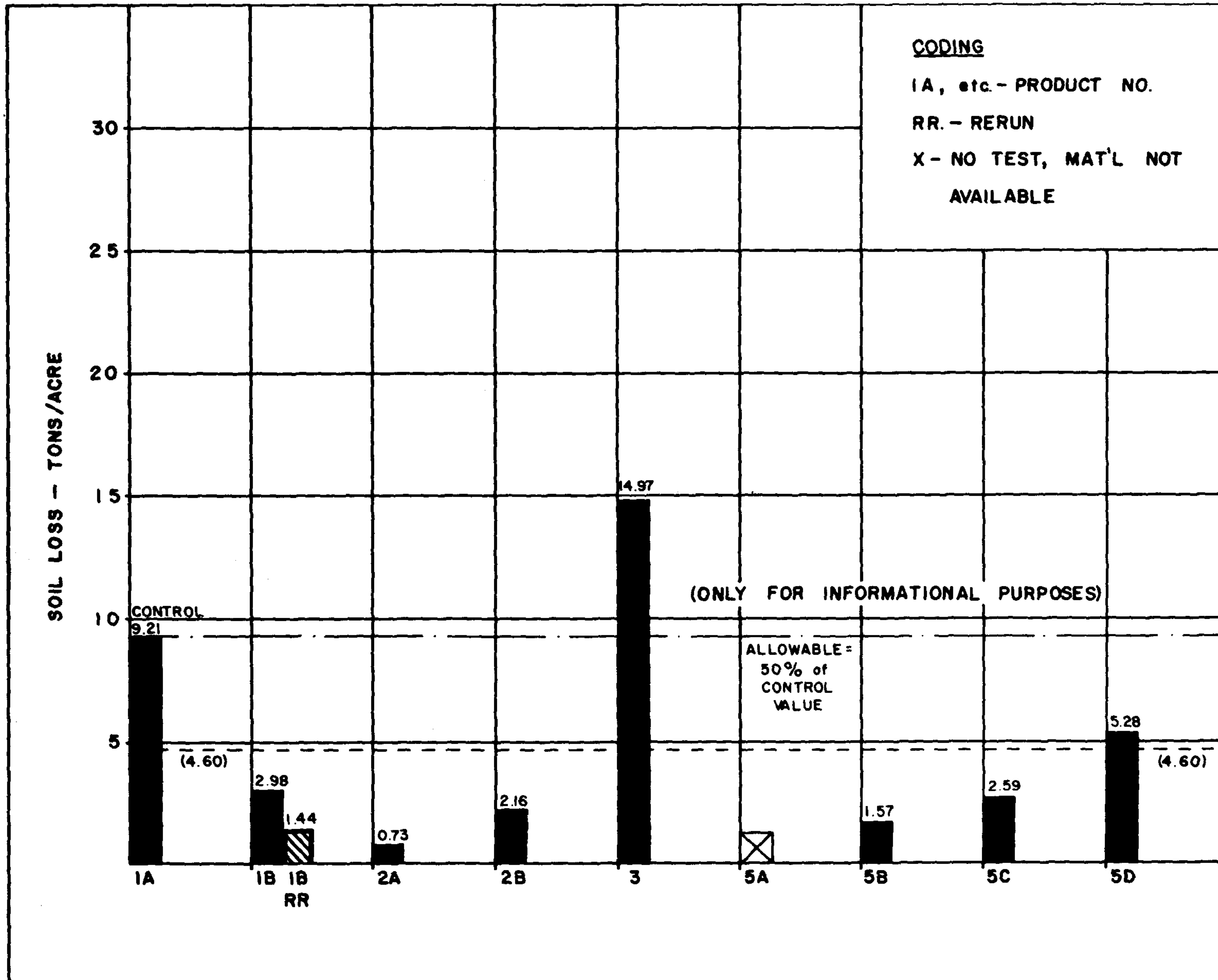

Figure 20

Soil Loss Data Graph for Small Pans,
3 Week Test by Drop-Off Method

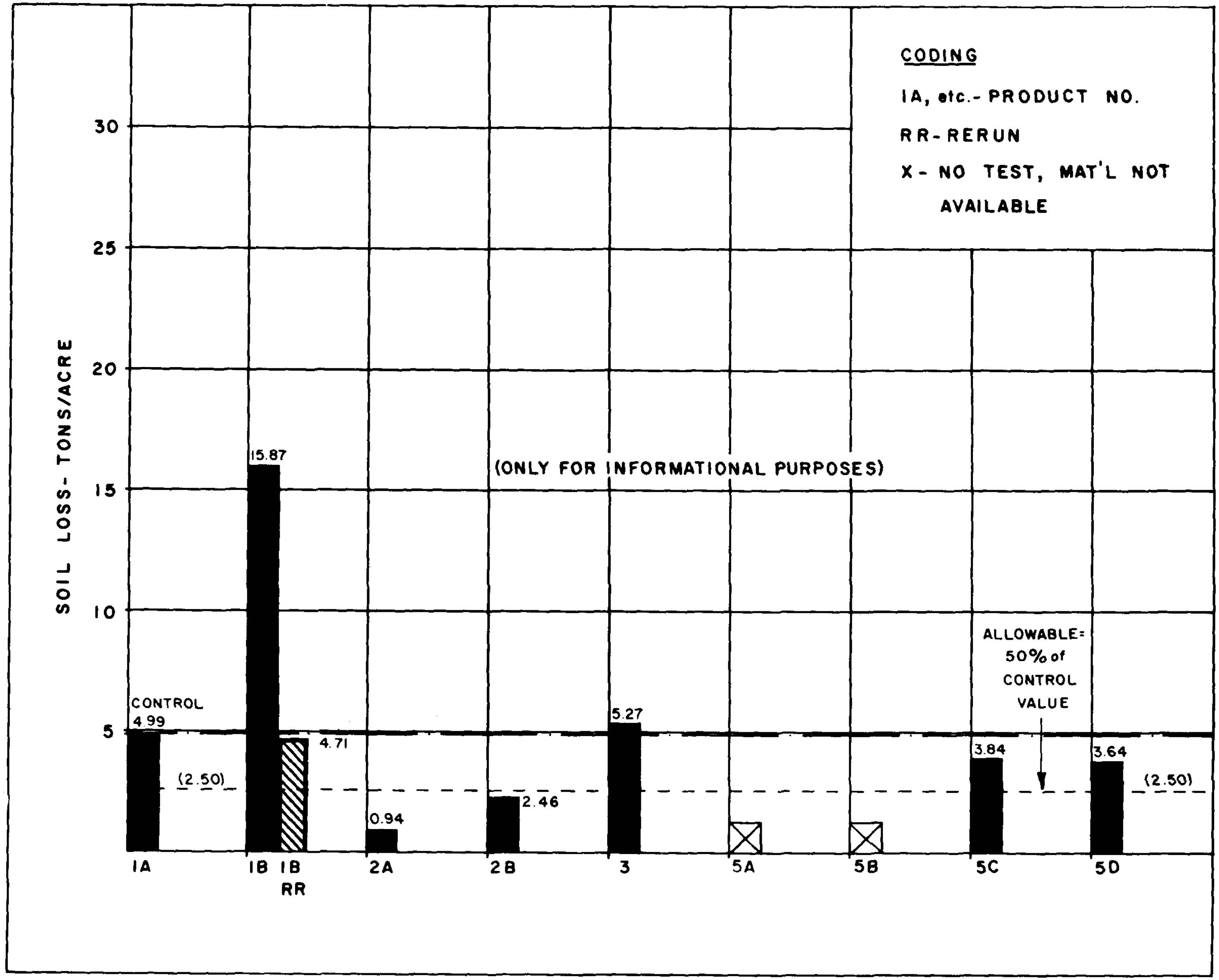

Figure 21

Soil Loss Data Graph for Large Pans,
Immediate Test by Drop-Off Method

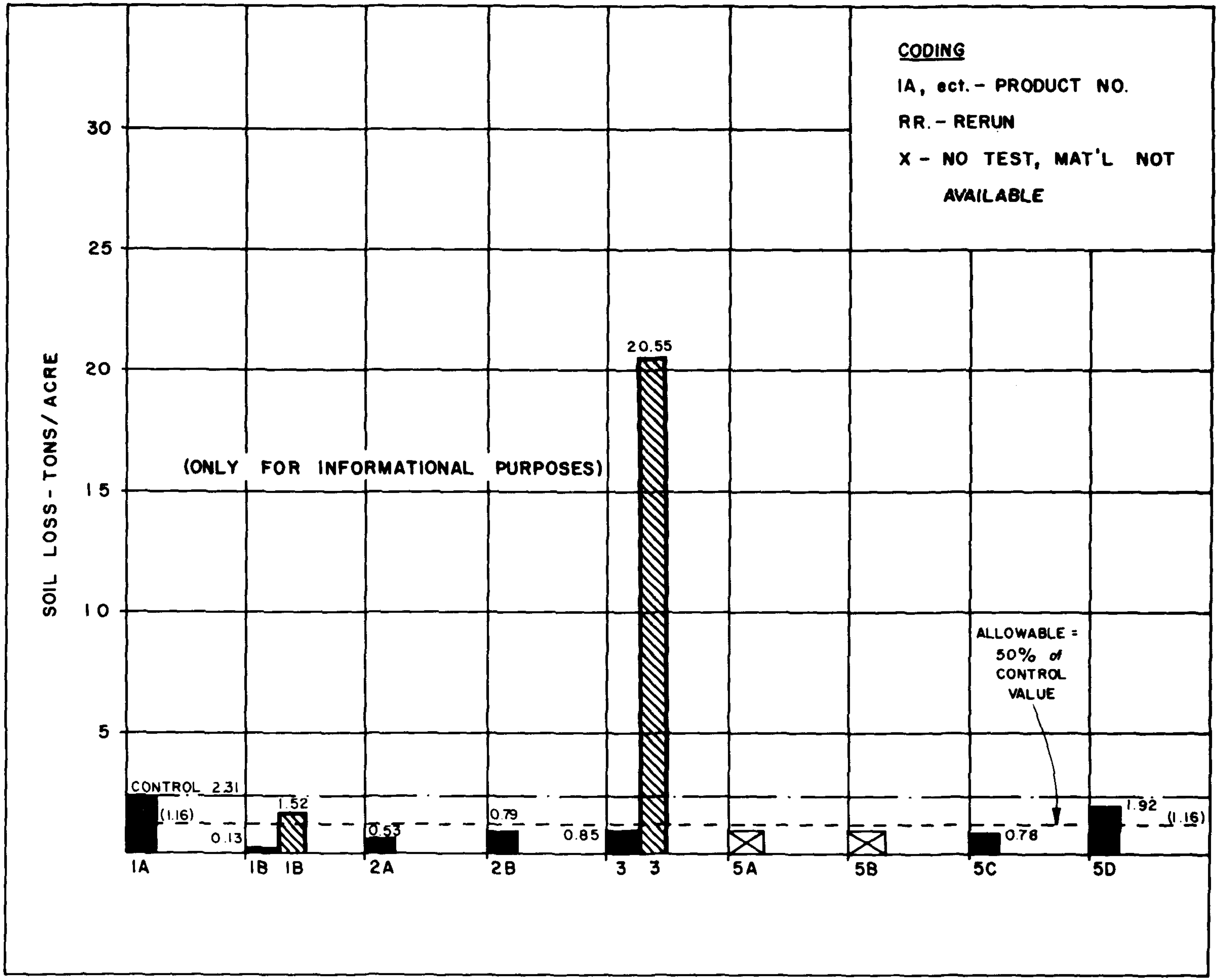

Figure 22

Soil Loss Data Graph for Large Pans,

3 Week Test by Drop-Off Method

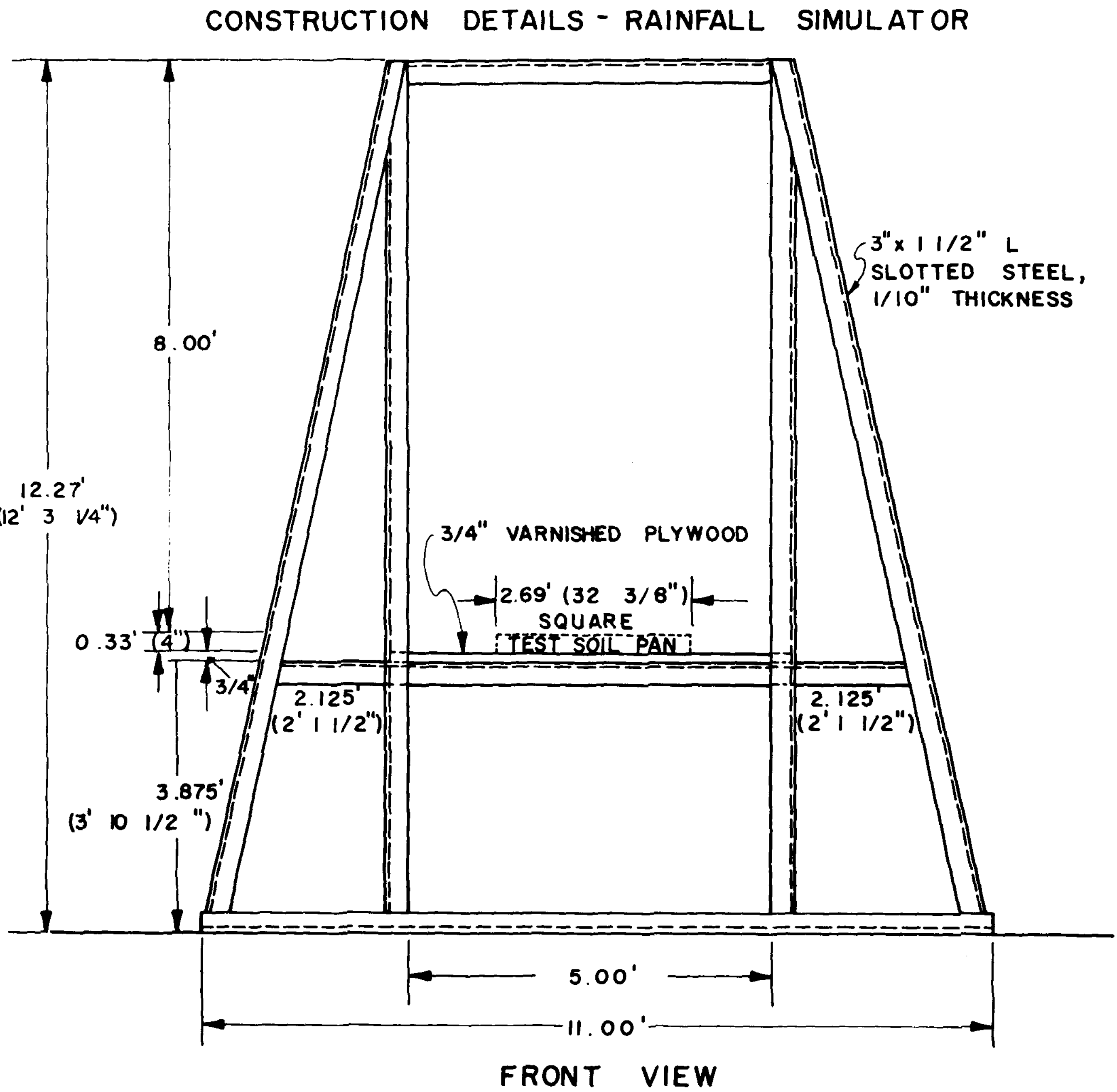

Figure 23
Front View, Rainfall-Simulator

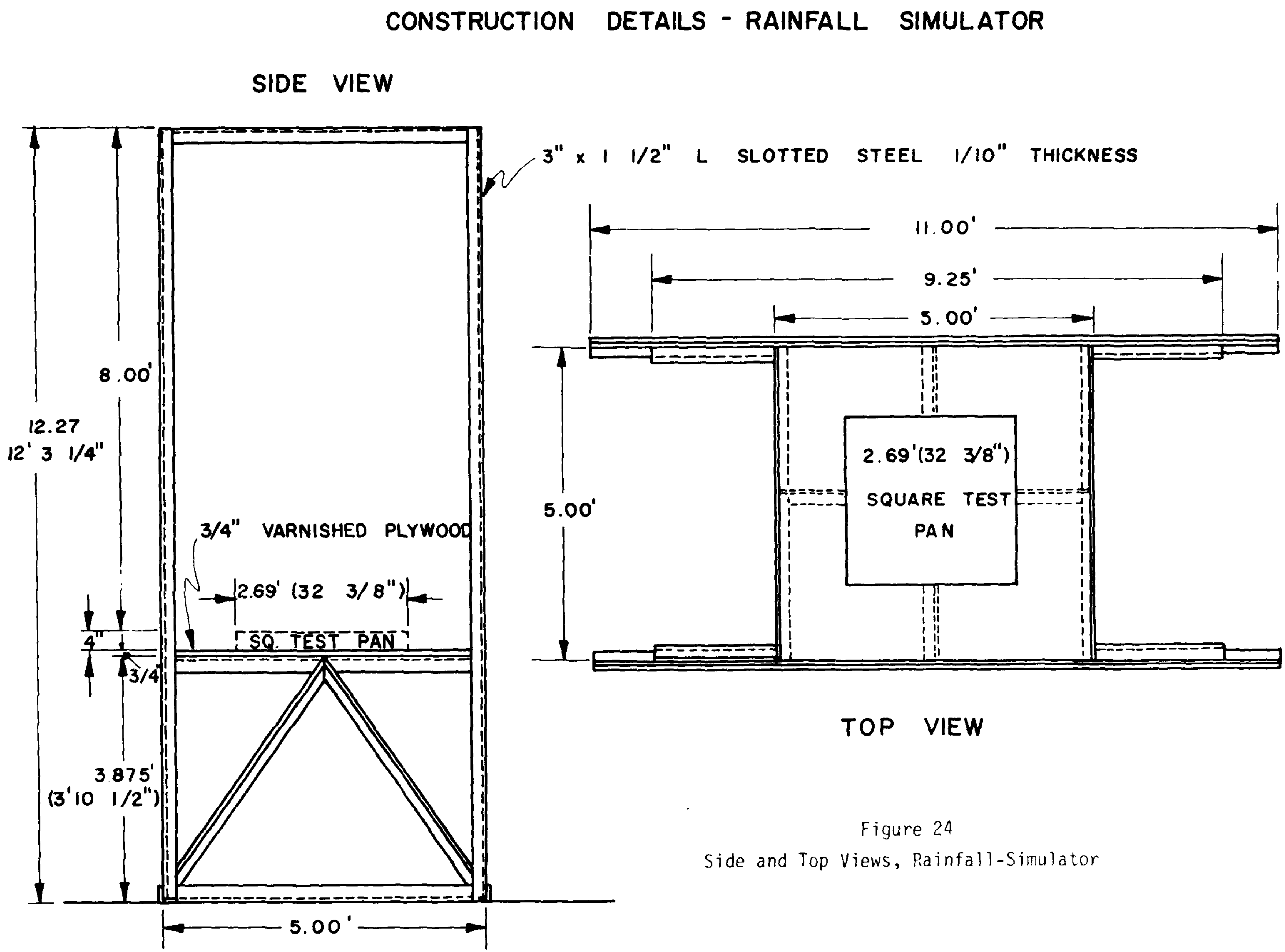

Figure 24

Side and Top Views, Rainfall-Simulator

CONSTRUCTION DETAILS - SOIL TEST PANS

(FOR USE WITH RAINFALL- SIMULATOR)

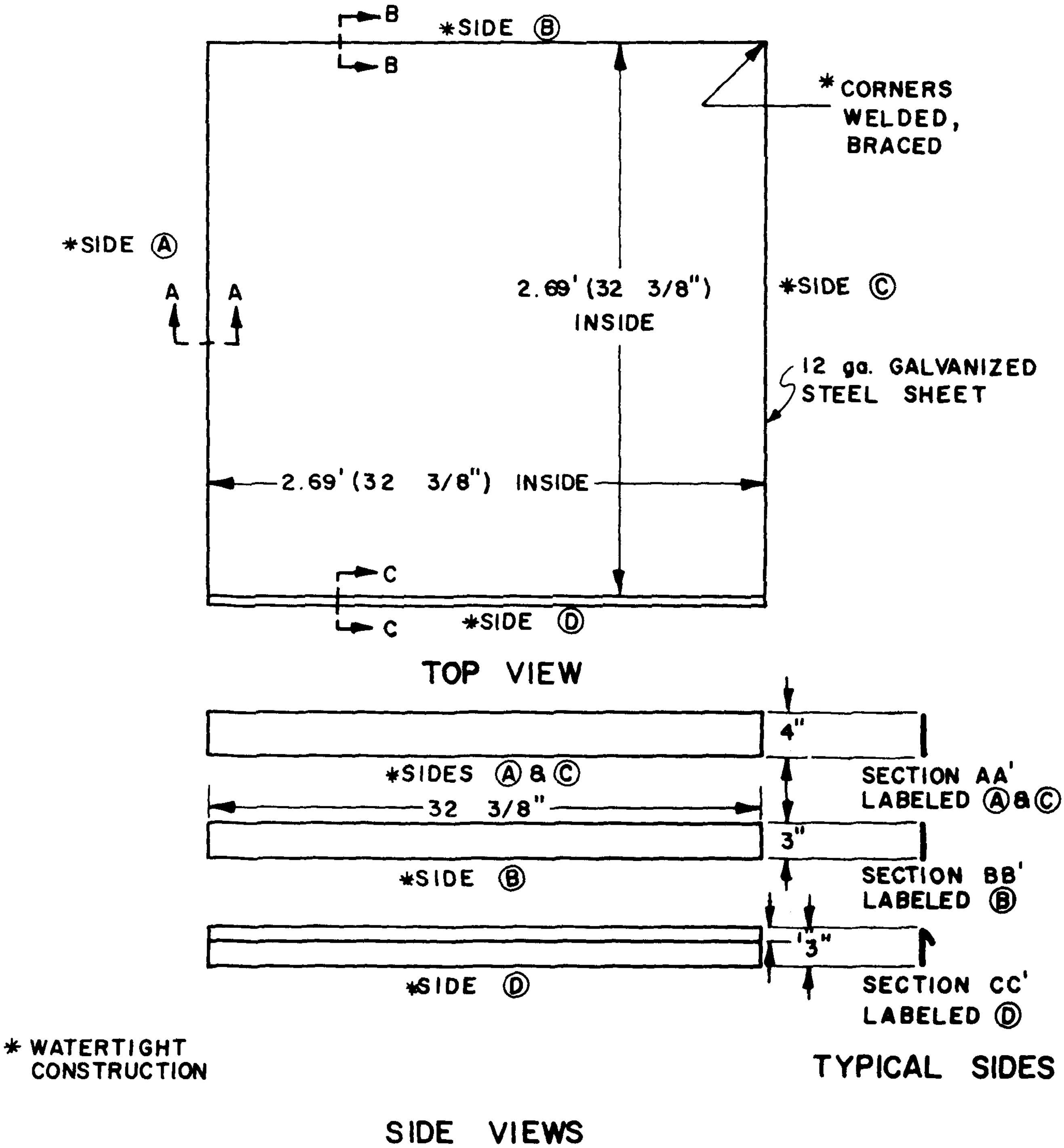

Figure 25

Soil Test Pans

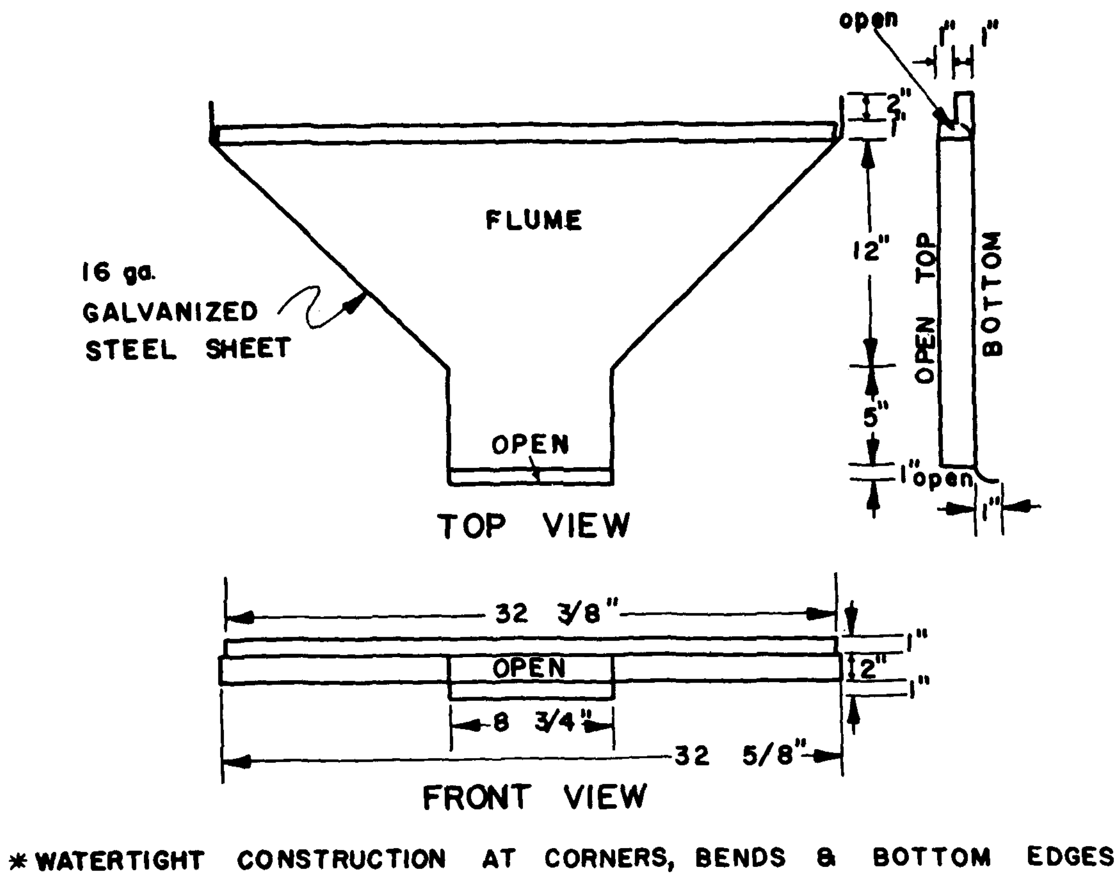

Figure 26
Flume or Channel

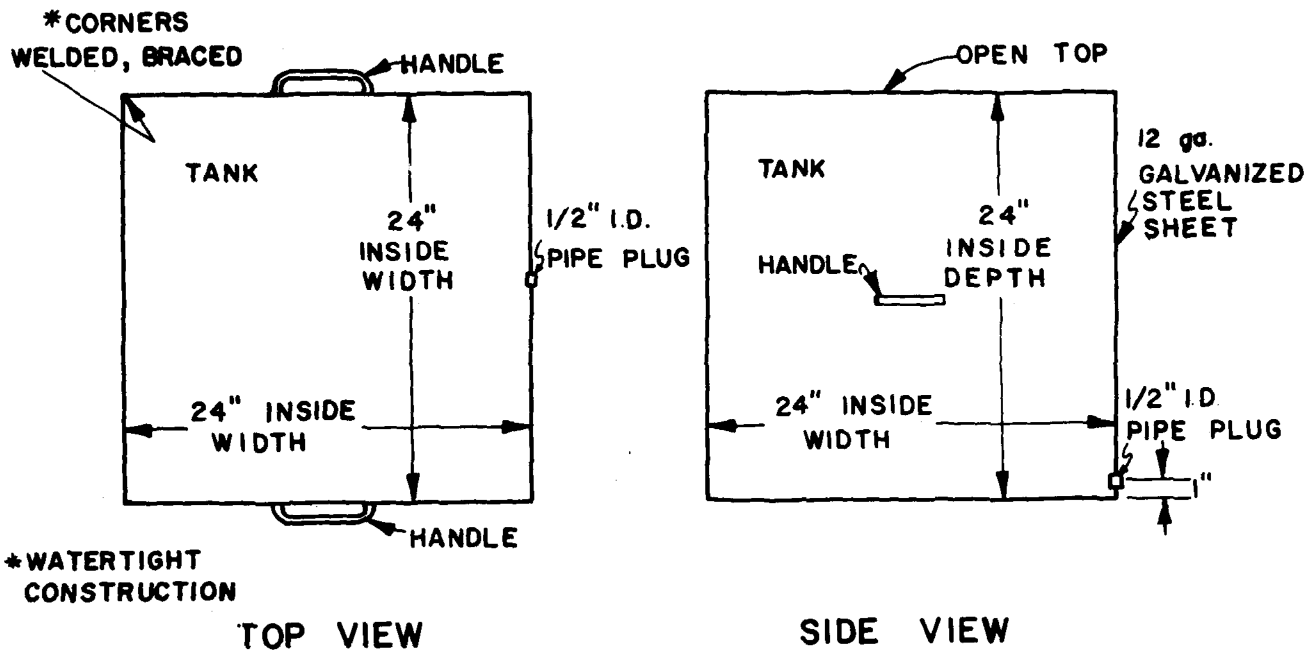

Figure 27
Holding Tank

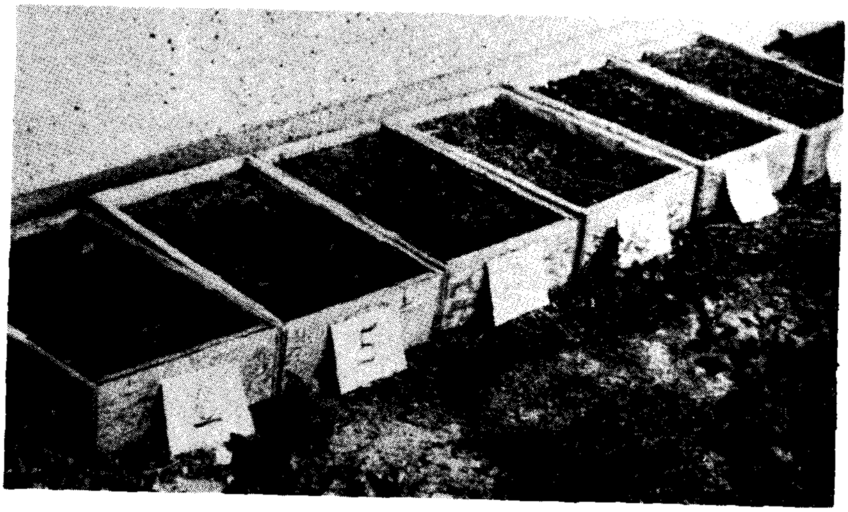

Figure 28

Seed Germination Boxes
1-7 at 7 Weeks

Figure 29

Seed Germination Boxes
7-11 at 7 Weeks

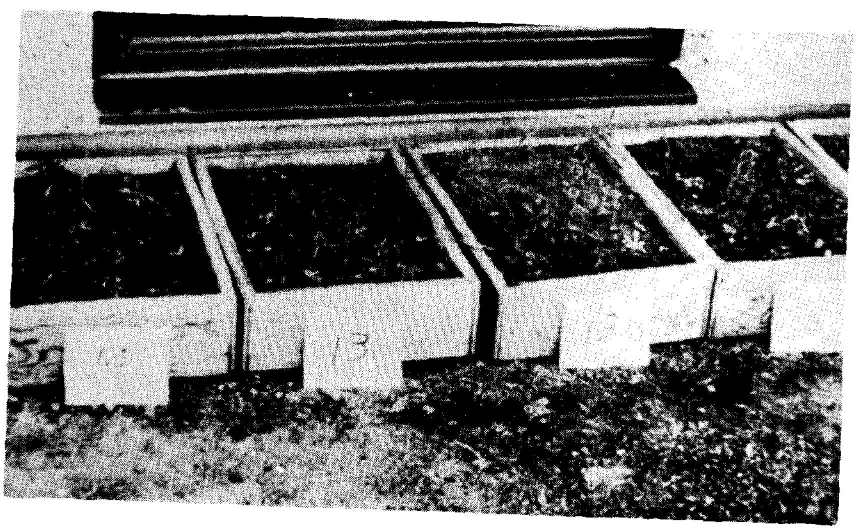

Figure 30

Seed Germination Boxes
11-14 at 7 Weeks

Figure 31
Soil Test Pan for Product 1B

Figure 32
Soil Test Pan for Product 5C

TENTATIVE METHOD OF TEST FOR

SIMULATED RAINFALL SOIL-LOSS VALUES

LDH DESIGNATION: TR -74

Scope

1. This method is intended to describe a tentative test procedure for the determination of soil loss under simulated rainfall as a comparative value when testing mulches, erosion retardant materials or soil stabilizers placed on a standard typical top soil. New products coming out on the market, those designed to help resist or retard erosion of the soil or to help germinate grass seed to do this work. will be tested by this method and procedure for determination of which products are to be further field tested for approval.

Apparatus

2. (a) Rainfall-simulator (as shown in Figure 1).
   (b) Water spray nozzle (Fulljet 3/4 HH50SQ) (Figure 2).
   (c) Water pressure gages (0-15 psi or 0-1.05 kg. per sq.cm range) (Figure 2).
   (d) Water pressure regulator (5-28 psi or 0.35-1.97 kg. per sq. cm range, set at 6 psi or 0.422 kgs. per sq. cm) (Figure 3).
   (e) Plastic water pipe and other necessary appurtenances, clamps, etc.
   (f) Water runoff apparatus (matal flumes or channels and metal tank calibrated) (Figures 4).
   (g) Stopwatch.
   (h) Metal test pans (as shown in Figure 5).
   (i) Metal cans for obtaining soil moisture samples.
   (j) Graduated cylinder (250 cc.) for measuring amounts of water or liquid to be added to each soil sample.
   (k) Small calibrated scale (range 0-1000 grams, sensitivity 0.01 grams).
   (l) Handling amd mixing tools, small tools. ect.
   (m) Platform scales (1500 lbs. or 680 kg. capacity).
   (n) Drying oven, capable of maintaining a temperature of 110°C (230°F.).
   (o) Electronic calculator.

(p) One gallon sample cans (with top rim removed fro smooth flow).

(q) Small pans for material weighing and handling.

Preparation of Soil Pan Samples

3. (a) For each material tested, fill two metal test pans (Figures 6) with loose soil secured from a stockpile of standard typical top soil (consistent for each test).

(b) Two small moisture can samples will be taken from each pan and the moisture content for that pan will be determined. From that moisture content, the dry weight of soil in each pan will be calculated.

(c) Break up any clods or balls or soil, smooth soil surface to where the soil in each pan is loosely compacted but the surface is level.

(d) Spread 76 grams of 8:8:8 fertilizer over the soil surface in each pan.

(e) Distrubute 2-1/2 grams of Bermuda grass seed over the soil surface in each pan.

(f) Lightly brush the soil to spread, imbed or seat the fertilizer or grass seed.

(g) Place or pour material to be tested (either mulch, erosion retardant material or soil stabilizer) evenly over the soil surface in each pan using the manufacturer's recommended amount for that pan area, which is 1/6000 acre.

(h) If the material to be tested is a liquid, such as a soil stabilizer, mix or combine with the recommended amount of water prior to placing on the soil surface in each pan.

(i) If the material is a muclh, then distribute the recommended amount of water for that pan area and material over the mulch and soil in each pan.

(j) The weight of each pan and the total weight of the pan plus the soil will be determined by weighting on the platform scales.

(k) One pan will be allowed to set f or a period of three weeks (to allow grass seed to germinate) under cover free from the effects of weather, but exposed to sunlight and watered at set intervals of time (every three days) with a standard amount of water (2000 ml.).

(l) The other pan will be allowed to set for a period of seven days (to allow soil stabilizer to set up, if this material is used) under cover free from the effects of the weather, but exposed to sunlight and watered (2000 ml.) at three days and again two hours before the actual test time on the 7th day. This pan will be tested under the rainfall-simulator at the seven day period.

(m) Control soil pan samples will be set up and tested just as the test material samples are, except only soil, grass seed. fertilizer and water will be placed in the pans.

Test Procedures

4 (a) The rainfall-simulator will be under cover or in a building and the water spray will be protected against the effects of wind or air movement.

(b) A check run of water spray will be made prior to the actual test run. The 6 psi (0.422 kgs. per sq. cm) water pressure will be checked on the two water pressure gages located immediately in front of the water nozzle.

(c) The water nozzle will be checked to make sure it is a vertical and perpendicular position to the floor or ground, centered over the pan.

(d) At the prescribed test period, the soil pan will be placed on the platform of the rainfall simulator, centered under the test nozzle and one end of the pan placed in a raised position (2-1/4" or 5.72 cm) to form a 4° (.07 radians) slope.

(e) The metal flume or channel will be attached to the soil pan and placed where any runoff will be emptied over the edge of the platform into the calibrated metal holding tank below. Set up is shown in Figure 4.

(f) When the soil test pan is in position to be tested and all other required conditions are met, the water is to be turned on and run for a period of 12 minutes as determined by a stopwatch.

(g) After the water has been turned off at the 12 minute period, the total volume of runoff solution in the holding tank will be determined and then recorded.

(h) The soil pan will then be taken and placed in a drying oven, dried out for a period of three days at a constant temperature of 110°C. (230°F) The dry weight of soil in this pan will then be determined and recorded

Soil Moisture and Soil Runoff Calculations:

5. (a) The moisture content of the soil sample shall be calculated as follows:

$$MC = \frac{(W_1 - W_2) \times 100}{W_2}$$

Where:

MC = Moisture content in percent based on weight of oven-dry soil

W_1 = Weight of wet soil (grams)

W_2 = Weight of oven-dry soil (grams)

(b) The dry weight of soil in test pan before test shall be calculated as follows:

$$DW_1 = \frac{WW_1 \times 100}{(100 + MC)}$$

Where:

MC = Moisture content in percent based on weight of oven-dry soil

DW_1 = Dry weight (lbs. or kgs.) of soil in test pan

WW_1 = Wet Weight (lbs. or kgs.) of soil in test pan

(c) The dry weight of soil in test pan after test (DW_2) shall be determined by weighing on platform scales after being oven dried as described in section 4, Test Procedures.

(d) *Soil loss by soil pan weights shall be calculated as follows:

$$SL = (DW_1 - DW_2) \times 3$$

Where:

SL = Soil loss in tons/acre

DW_1 = Dry weight (lbs.) of soil in test pan before test

DW_2 = Dry weight (lbs.) of soil in test pan after test

*Note: Soil loss in tons/acre can be converted later to the metric system

Reports

6. Report the following data:

(a) 7 day test, soil loss (ton/acre or kgs. per sq.meter) by pan weight method.

(b) 21 day (3 weeks) test, soil loss (ton/acre or kgs. per sq.meter) by pan weight method.

(c) Name of material, type of material and manufacturer of material tested.

(d) Any additional information pertaining to recommended installation weights of materials, volume of water application or miscellaneous information.

(e) Recommendations and remarks.

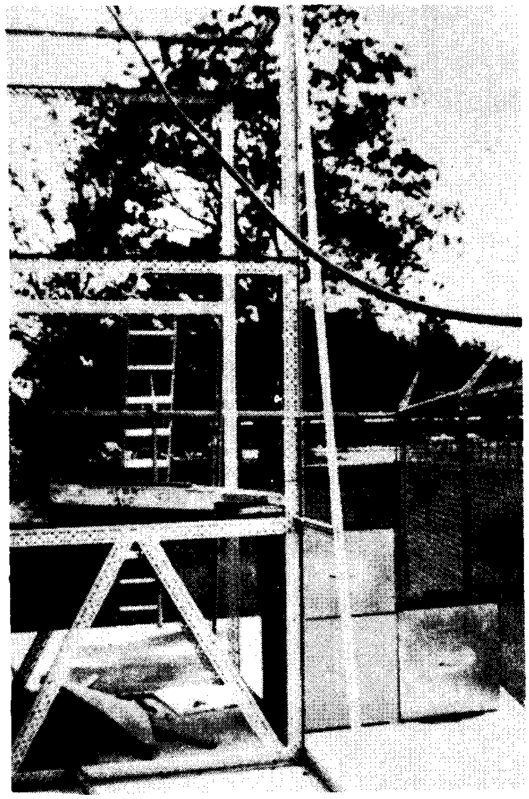

Figure 1
Rainfall-Simulator

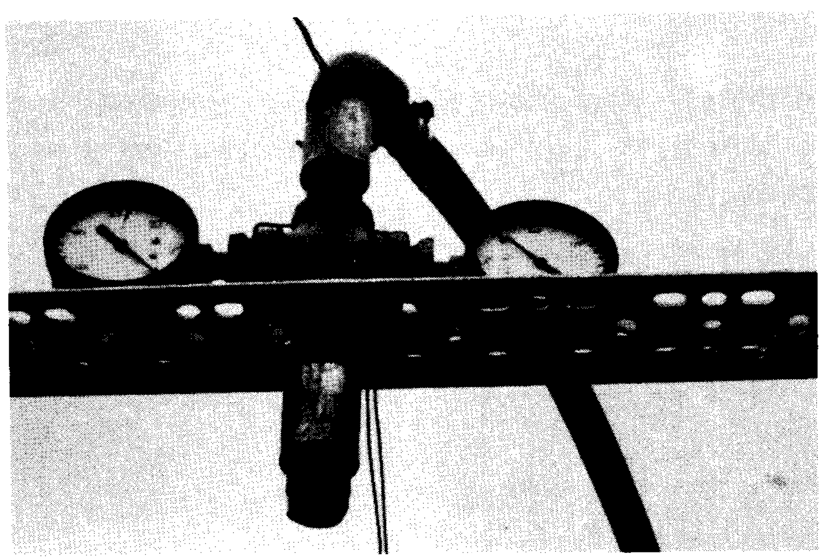

Figure 2
Water Spray Nozzle
and
Water Pressure Gages

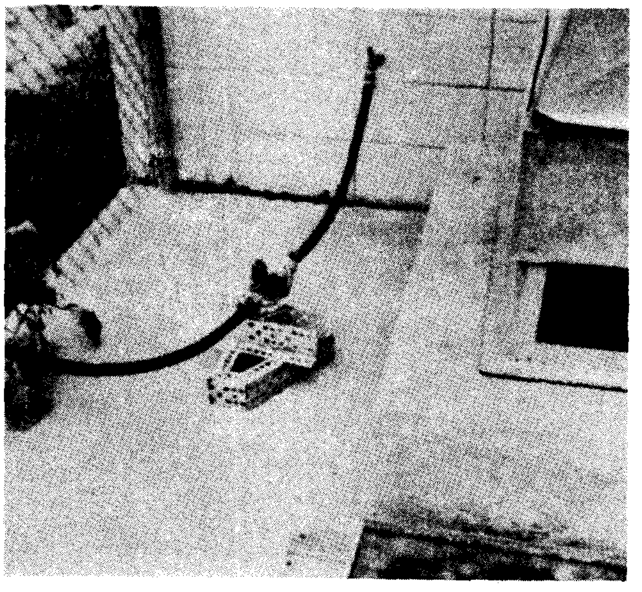

Figure 3
Water Pressure Regulator

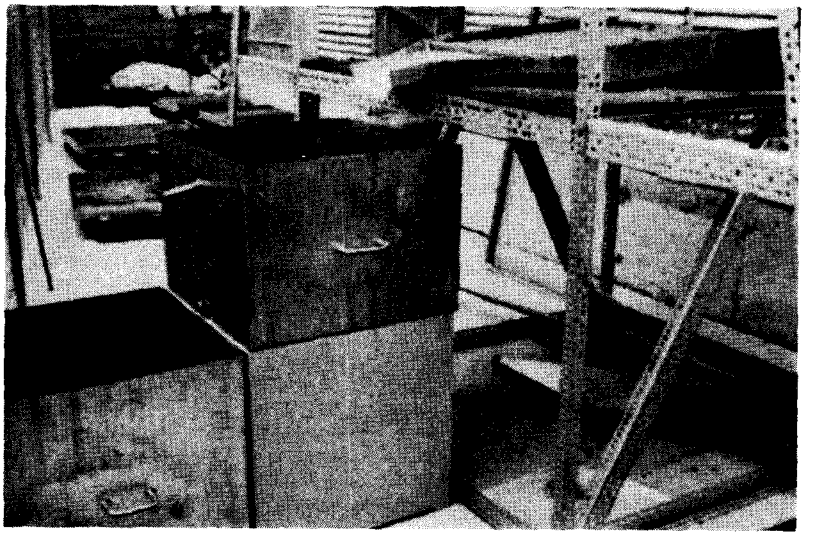

Figure 4
Water Runoff Apparatus

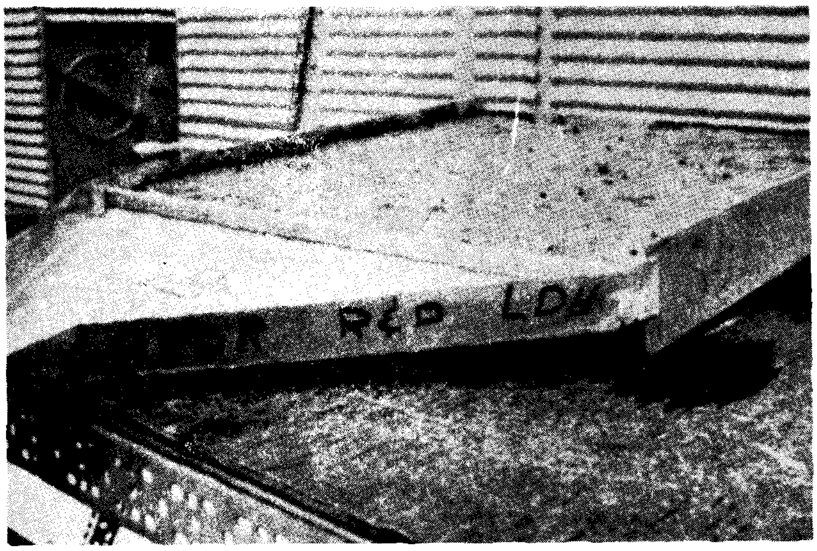

Figure 5
Metal Test Pan and Flume

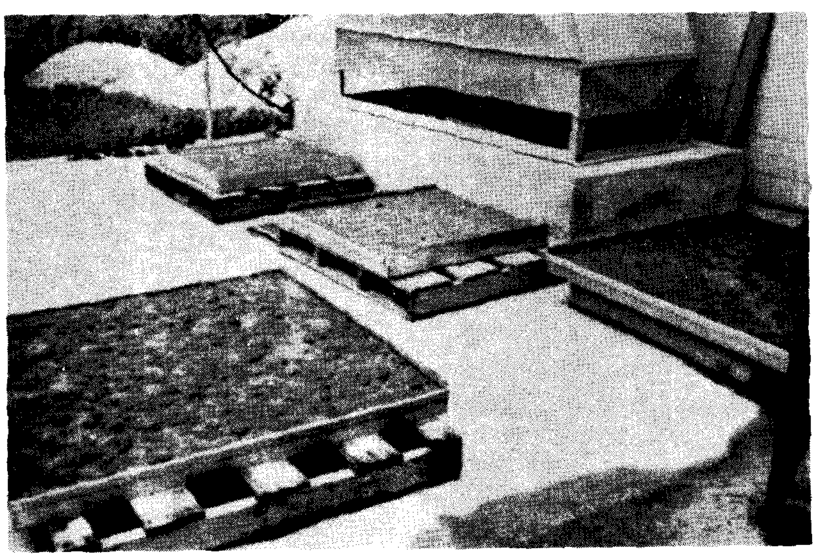

Figure 6
Soil in Metal Test Pans