EROSION CONTROL STUDY

Final Report

Part II

ROADSIDE CHANNELS

by

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PREFACE

In August of 1963, the Louisiana State University Agricultural Experiment Station initiated a roadside erosion control study under the sponsorship of the Louisiana Department of Highways and the Federal Highway Administration, U. S. Department of Transportation.

The objectives of the study were:

1. To evaluate present methods and develop new methods for establishing a permanent vegetative cover.

2. To develop erosion control practices for existing highway drains and ditches.

3. To develop highway bank stabilization methods that do not require top soil from adjacent agricultural lands.

The study was assigned to the University's Departments of Agricultural Engineering and Agronomy since the objectives overlapped the two fields. In August of 1966, the writer transferred from the position of Assistant Professor of Agricultural Engineering, Louisiana State University to the position of Assistant Research Engineer (Drainage), Louisiana Department of Highways. Concurrently the Department's Research and Development Section assumed the responsibility for the engineering phase (Part II) of the project.

The agronomic phase (Part I) of the research was presented in a previous report "Erosion Control Study" by John Beavers in cooperation with Allen L. Cox, M. D. Swanner, H. T. Barr and C. L. Mondart, Jr., all present or former members of the Louisiana State University Agricultural Experiment Station. Recommended procedures for establishing and maintaining grass covers for roadsides were presented in the report.

Part II of the study, reported herein, was an investigation of erosion of roadside drainage channels and an evaluation of methods and materials for its control. The primary information gained from the study was that temporary liners of jute mesh or fiber glass roving with asphalt cement can be used to establish permanent grass liners from seeding operations. The cost of establishing grass liners by this method is 1/5 to 1/3 the cost of slab sodding operations. The reduced cost allows the designer to use these materials for controlling erosion in areas not previously considered as being critical. Also the assurance that a durable living grass liner can be established with the aid of temporary liner materials allows the designer to use this method rather than paved liners for some channels. Design limitations are presented in the report.

The Louisiana Department of Highways has effectively implemented the more important recommendation presented in the two reports. By June 1971, road contracts involving over 50,000 lbs. of fiber glass roving covering over

200, 000 square yards of channels and steep slopes had been let by the Department. In addition maintenance forces have used over 10, 000 lbs. of fiber glass roving to cover an estimated 35, 000 square yards of seeded channels and slopes. In-place costs including tillage, fertilizer, seed and 0. 25 lbs. fiber glass roving with 0. 25 gal. of asphalt are less than 40 cents per square yard.

In-place costs for 10, 000 square yards of jute mesh on bids let in the first quarter of 1971 were approximately 60 cents per square yard including tillage, fertilizer, seed and jute mesh. By contrast, the in-place costs for 42, 730 square yards of slab sod on bids let in the first quarter of 1971 were $1. 77 per square yard.

Slab sod costs have increased from $1. 38 per square yard to $1. 77 per square yard in the past year. Also, contractors report difficulty in obtaining quality slab sod. Therefore, it is anticipated that fiber glass roving with asphalt and jute mesh will be used with seeding operations to replace most of the slab sod on future jobs.

Due to the workload in the Road Design Section the channel design procedures presented in the Appendix have not been fully implemented yet. As time permits, Department personnel will adapt these design procedures for computer solution.

At this time the writers wish to acknowledge the cooperation and assistance furnished by Associate Professors John Beavers and C. L. Mondart, Jr. of the Louisiana State University Agronomy Department; Professor H. T. Barr, former head of the Louisiana State University Agricultural Engineering Department and his staff.

The cooperation and assistance of O. M. Pourciau, Roadside Development Supervisor, Louisiana Department of Highways and his assistants, Dennis Berry and Norman Kinsella, is especially appreciated by the researchers.

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CONTENTS

CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF TABLES

SYNOPSIS

Several eroded roadside channels were observed for an 18-month period to determine erosion losses and the peak flow rates causing these losses. Monument stakes and flow measuring flumes were used.

These eroded channels were reworked, fertilized, seeded and lined with temporary liner materials. The liners tested were jute mesh, excelsior mat and fiber glass roving with asphaltic cement. In each test runoff rates sufficient to cause severe erosion in unlined sections of the channels occurred. Depths of flow were determined for the lined and unlined portions of the test channels. This information was used to develop or verify equations expressing the permissible depth of flow versus channel slope for newly seeded channels with bare soil, jute mesh and fiber glass roving with asphaltic cement.

This information was used with permissible depth of flow curves for grass-lined channels modified from a study by McWhorter, et al., (1968) to develop a design procedure for roadside drainage channels.

The conclusions of the study are as follows:

1. Roadside erosion is a serious problem because hazardous conditions often develop.

2. Mature grass will withstand the flow rates anticipated for most roadside channels.

3. Temporary channel liners are required to protect newly seeded channels from erosive flows during the critical period between seeding and establishment of protective growth.

Implementation of the following recommendations will provide for the establishment and maintenance of mature grass liners in most roadside drainage channels in Louisiana.

1. The channel bed should be properly tilled, limed, fertilized and seeded.

2. Approved temporary channel liners should be used to protect the newly seeded channel bed from erosion during the critical period required for establishment of protective growth.

3. The continued use of jute mesh and an approved temporary channel liner is recommended.

4. The use of fiber glass roving and asphalt cement as an approved temporary channel liner is recommended.

5. The Design Procedures presented in the Appendix of this report should be used to determine the stability and capacity of roadside channels.

6. Compacted soil check dams (fertilized, seeded and lined with two layers of fiber glass roving and asphalt cement) are recommended for use as erosion retards in eroded channels. These check dams should be designed with roadside safety in mind.

INTRODUCTION

The primary function of the roadside drainage channel is to convey runoff waters from the roadway. These channels should be designed to provide efficient conveyance of runoff water consistent with initial cost, importance of the road, maintenance cost, safety and legal requirements.

Once the highway location has been determined, the topography of the area and other factors fix the channel location, alignment, and grade and govern the quantity of surface runoff entering the channel. Design of the roadside channel then consists of determining the design discharge, selecting a suitable channel section which will convey the design discharge and meet the safety requirements and specifying the type of lining required to protect the channel from erosion.

While all of these design considerations are interrelated and the selection or determination of one affects each of the others, this study is primarily concerned with the selection of suitable temporary channel liners and development of design procedures. The determination of design discharges and suitable channel sections has been aptly discussed by others (AASHO, 1954; Izzard, 1942; Stonex, 1960; and Searcy, 1965).*

The problem of selecting a suitable channel liner is complex. The choice is limited to linings which can withstand the anticipated velocities. Hydraulic characteristics of liners must be considered so that cost comparisons are of channels of equal capacity rather than equal size. These linings generally consist of one of the following: bare soil, grass, stone, asphaltic concrete and concrete.

Permissible velocities for continuously wet, aged channels with bare soil are shown in Table 1. Since most roadside channels flow intermittently, they cannot withstand the velocities shown in this table. Therefore some type of lining is required.

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* Refers to selected bibliography at end of report. The references used in this report are indicated by the author's name and the year of the publication in parentheses.

TABLE 1. MAXIMUM PERMISSIBLE VELOCITIES RECOMMENDED BY FORTIER AND SCOBEY AND THE CORRESPONDING UNIT-TRACTIVE-FORCE VALUES CONVERTED BY THE U.S. BUREAU OF RECLAMATION*
(For straight channels of small slope, after aging)

Material	n	Clear water		Water transporting colloidal silts	
		V, fps	τ_0, lb/ft²	V, fps	τ_0, lb/ft²
Fine sand, colloidal	0.020	1.50	0.027	2.50	0.075
Sandy loam, noncolloidal	0.020	1.75	0.037	2.50	0.075
Silt loam, noncolloidal	0.020	2.00	0.048	3.00	0.11
Alluvial silts, noncolloidal	0.020	2.00	0.048	3.50	0.15
Ordinary firm loam	0.020	2.50	0.075	3.50	0.15
Volcanic ash	0.020	2.50	0.075	3.50	0.15
Stiff clay, very colloidal	0.025	3.75	0.26	5.00	0.46
Alluvial silts, colloidal	0.025	3.75	0.26	5.00	0.46
Shales and hardpans	0.025	6.00	0.67	6.00	0.67
Fine gravel	0.020	2.50	0.075	5.00	0.32
Graded loam to cobbles when noncolloidal	0.030	3.75	0.38	5.00	0.66
Graded silts to cobbles when colloidal	0.030	4.00	0.43	5.50	0.80
Coarse gravel, noncolloidal	0.025	4.00	0.30	6.00	0.67
Cobbles and shingles	0.035	5.00	0.91	5.50	1.10

* The Fortier and Scobey values were recommended for use in 1926 by the Special Committee on Irrigation Research of the American Society of Civil Engineers.

TABLE 2. PERMISSIBLE VELOCITIES FOR CHANNELS LINED WITH GRASS*

Cover	Slope range, %	Permissible velocity, fps	
		Erosion-resistant soils	Easily eroded soils
Bermuda grass	0–5	8	6
	5–10	7	5
	>10	6	4
Buffalo grass, Kentucky bluegrass, smooth brome, blue grama	0–5	7	5
	5–10	6	4
	>10	5	3
Grass mixture	0–5	5	4
	5–10	4	3
	Do not use on slopes steeper than 10%		
Lespedeza sericea, weeping love grass, ischaemum (yellow bluestem), kudzu, alfalfa, crabgrass	0–5	3.5	2.5
	Do not use on slopes steeper than 5%, except for side slopes in a combination channel		
Annuals—used on mild slopes or as temporary protection until permanent covers are established, common lespedeza, Sudan grass	0–5	3.5	2.5
	Use on slopes steeper than 5% is not recommended		

REMARKS. The values apply to average, uniform stands of each type of cover. Use velocities exceeding 5 fps only where good covers and proper maintenance can be obtained.

* U.S. Soil Conservation Service, (1954)

Experience has proved that mature grass is an economical liner for roadside channels in areas where grass grows readily. If the proper nutrients are available in the soil, a grass liner will stabilize the channel section and prevent erosion. Minor erosion damage to grass liners often heals itself, whereas it may lead to general undermining of rigid linings.

Extensive tests reported by Cox and Palmer (1948), Ree and Palmer (1949) and Smith (1946) have been conducted at Stillwater, Oklahoma; Spartenburg, South Carolina; and McCredie, Missouri to determine the hydraulic characteristics and protective ability of various types of vegetation. Results from these tests have been used to develop design criteria for grass-lined channels (U. S. D. A., 1949, 1954). Table 2 shows the maximum permissible velocities for channels lined with uniform stands of various grass covers. This table indicates that a mature stand of bermuda grass can be used to protect channels for velocities much greater than those anticipated in most roadside ditches (This is especially so in view of the relatively wide and shallow channel sections required for safety). However the grass must have time to develop and form a good root system before it can carry water at these velocities.

The possibility of failure from excessive runoff velocities during the critical period required for establishment of protective growth often causes designers to use paved ditches when a grass liner would serve as well and much more economically. Therefore studies of various methods and materials for aiding in the establishment of grass liners for roadside channels were in order.

Some of the methods being used or considered for such use are reviewed in the following paragraphs.

Ditch Checks

Ditch checks were once used extensively in roadside ditches to reduce steep channel grades to a series of parallel grades flat enough for the establishment of a grass cover. In recent years these structures have become increasingly unpopular for safety reasons. Also, many failed because of inadequate design. Searcy (1965) discusses the design of ditch checks but recommends that their use be limited to ditches inaccessible to vehicles accidentally leaving the roadway.

Although ditch checks are a safety hazard, maintenance forces will continue to use them in severely eroded roadside ditches which are also safety hazards until funds become available for extensive reconstruction. There appears to be a need for a relatively safe and economical ditch check design to serve this temporary purpose.

Temporary Liners

Ree (1960) studied the use of protective liners which cover the channel during the vegetative establishment phase. Ree's experimental procedure consisted of the installation of various channel linings in a 100-foot test section of a V-shaped channel and subjecting the channel to a fixed flow for a standard time period. Table 3 gives Ree's findings. Successive tests were conducted with increasing flows until failure occurred. All tests were conducted on a six percent slope.

TABLE 3

MAXIMUM PERMISSIBLE VELOCITY FOR VARIOUS LINER MATERIALS AS SUGGESTED BY REE

Liner	Discharge c. f. s.	Velocity f. p. s.
1. Glass fiber mat with complete transverse pinning.	3. 7	4. 0
2. Jute cloth - fine	0. 8	3. 4
3. Paper mesh - fine	0. 4	2. 0
3. Glass fiber mat with partial pinning.	0. 3	*
3. Hay mulch and asphalt	0. 3	*
3. Hay mulch and paper net	0. 3	1. 0
3. Jute cloth - coarse mesh	0. 3	1. 0
4. Asphalt emulsion and paper fiber.	- -	*

* No velocity indicated

At the time this project began (1963), several researchers were just beginning to experiment with these materials (Dolling, 1964; Gilbert and Davis 1967; McWhorter, etal. , 1968). The materials considered included jute mesh, twisted paper yarn mesh, twisted paper yarn mesh over straw, twisted paper yarn mesh over excelsior mat and fiber glass filter. These materials were pinned to the newly seeded channel bed with wire staples. Another experimental material considered was fiber glass roving pneumatically applied over the newly seeded channel bed and anchored to the channel bed with emulsified asphalt.

As the study progressed, experience with these materials and correspondence with other researchers indicated that the most economical method of establishing vegetated channel liners would require the utilization of some of these temporary porous liners over newly seeded channel beds. Therefore greater emphasis was placed on these materials.

Soil Amendments

Several chemical amendments for controlling soil erosion were discussed in a report by the U. S. D. A. (1962). These materials included a resin-in-water emulsion, a latex emulsion and water dispersible starch compounds. All were used primarily for controlling rill erosion however these did not prove very successful. Therefore it is unlikely that their use under the flow conditions existing in roadside ditches would produce beneficial results.

Bare Soils

The ability of cohesive soils (those with high clay contents) to resist erosion is generally recognized. This is indicated in Table 1. Smerdon (1959) conducted research showing that a direct relationship exists between the critical tractive force and the plasticity index of various soils. The critical tractive force is that shear force that exists at the channel bed when excessive erosion begins. The research was conducted in a hydraulic flume with several uncompacted soils under several flow conditions. Smerdon expressed this relationship in the form

$$T_c = 0.0034 \, (P.I.)^{0.84}$$

where: T_c is the critical tractive force in pounds per square foot and P. I. is the plasticity index.

The plasticity index of a soil can be increased by adding clay. This practice is recommended for channels; however the cost may be prohibitive for large scale operations. The addition of relatively small amounts of bentonite will increase the plasticity index considerably. A search of the literature revealed that bentonite has been used to line irrigation canals in the West for prevention of water losses. No information was found concerning the use of bentonite for controlling erosion in channels.

OBJECTIVE

The objective of this study was to investigate methods and materials for controlling erosion in roadside drainage channels. Primary emphasis was placed on evaluating various ways and means of establishing and maintaining permanent grass liners.

The information gathered was to be analyzed and used to develop design and maintenance procedures for controlling erosion in roadside drainage channels.

SCOPE

The proposal for this study stated that the objectives were to be accomplished by studying the amounts of soil eroding from channels with varying soil conditions, slopes, lengths, and runoff rates. Sod, chemical amendments, mats and other devices were to be installed in roadside channels and evaluated for their erosion prevention abilities.

After conducting a preliminary study, which included a literature review, discussion of the objectives with other researchers and an inspection tour of Louisiana's roadsides, the researchers concluded that the study would be conducted in the following manner:

1. Type H flow-measuring flumes would be installed in several typical eroding channels to obtain an indication of the flow rates causing the erosion.

2. Monument stakes would be driven in these channels at selected stations and existing cross sections recorded. These cross sections would be checked at six-month intervals to determine the erosion resulting from the runoff.

3. Temporary channel liners would be installed in a test channel and tested under controlled flow conditions. Information gained during these controlled flow tests would be used to determine field test procedures.

4. Temporary channel liners would be installed over newly seeded roadside channels to evaluate their effectiveness in preventing erosion and aiding in the establishment of a permanent grass liner.

5. Limited testing of amendments for stabilizing soil would be conducted.

6. Limited testing of compacted soil check dams, seeded and lined with the materials used in the temporary channel liner experiments, would be conducted to determine their effectiveness as relatively safe grade control structures.

7. The information gained in these experiments would be used to develop design and maintenance procedures for controlling erosion in roadside ditches.

FIELD OBSERVATIONS

Introduction

The first objective of this study was to observe typical roadside channels in order to obtain an indication of normal runoff rates and the resulting erosion. The observations covered four stable grass-lined channels and 11 severely eroded channels. The grass-lined channels were observed to see if they had the same flow conditions as the eroded channels and to see if any measurable erosion was occurring. The observations were conducted over an 18-month period.

Flow-measuring flumes were placed in nine of the channels. High water marks at culverts were used to estimate peak discharges at three of the channels. Monument stakes were driven at selected cross sections of the channels to reference erosion losses and flow depths.

The observation channels were selected primarily for their location and suitability for future test sites and not necessarily for variable soil conditions.

Eight of the channels were reworked at the end of the observation period and used for ditch liner tests.

Grass Lined Channels

Observation channels 67-1L and 67-1R were located on opposite sides of State Highway 67, approximately $8\frac{1}{2}$ miles north of Clinton, Louisiana, in East Feliciana Parish. These two channels had well established mixed grass covers averaging six inches in length. They were on a six percent slope and each drained one acre watersheds of similar characteristics. Their cross sections consisted of 3:1 foreslopes, 4:1 backslopes and four foot bottoms. Monument stakes were driven at four cross sections in each channel. A precalibrated type H measuring flume was installed in channel 67-1L. During the first six months, peak flows of 2.25, 3.7 and 5 cubic feet per second were recorded. The estimated velocities in these channels based on watermarks on stakes and the discharge measurements above were 1.2, 1.9 and 3.1 feet per second. The maximum depth of flow was 0.35 feet. No large storms occurred; therefore, these appeared to be minor runoff rates for these two channels. Any erosion or deposition occurring during the first six months was too small to measure at the reference stakes.

Shortly after the beginning of the second six-month observation period, the flume in channel 67-1L was destroyed by a vehicle accidently leaving the road. Two storms occurred producing maximum flow depths of 0.35 and 0.4 feet. The estimated velocities were in excess of 5 feet per second. Any erosion or deposition occurring during the second six-month observation period was not measurable.

These channels were observed again in 1968, four years after the initial observations. The mixed grass cover was in good condition and no erosion was evident. Observations of these channels indicate that they can withstand velocities in excess of 5 feet per second several times each year without any erosion.

Observation channels 67-2L and 67-2R were located on opposite sides of State Highway 67, approximately eight miles south of Clinton, Louisiana. Observation of these channels began upon the completion of their carpet grass slab sod linings in 1964. The channels were on three percent slopes and had cross sections with 4:1 sides slopes and four-foot bottom widths. Watermarks in 18 inch culverts indicated a peak discharge of 3.5 cubic feet per second five days after the slab sod was installed. The corresponding velocity was 2.7 feet per second with a flow depth of 0.26 feet. Several smaller runoff events occurred with no damage to the slab sod. These events were not considered as severe tests.

Bare Eroded Channels

Observation channels 441-1L and 441-1R were located in St. Helena Parish on State Highway 441. These two 450-foot long eroded channels (See Figures 1 and 2) were on five percent slopes and each drained 3/4 acre watersheds of similar characteristics. The soil was a silty clay loam with a P. I. (plasticity index) of 12 to 14. The characteristics of these channels are summarized in Table 4 on Page 19. The maximum flow rates observed in these two channels were 5.0 c.f.s. in channel 441-1L and 4.3 c.f.s. in channel 441-1R. Several discharges in the range of 4 c.f.s. were recorded. The discharge rates in the two channels were nearly equal for storms producing runoffs of 4 c.f.s. or less. These discharges produced velocities in excess of 4 f.p.s. in the eroded channels. The increases in cross-sectional area caused by erosion at the end of six months and 12 months were 0.5 square feet and 0.7 square feet for a total increase of 1.2 square feet for channel 441-1L. The corresponding increases were 0.6 square feet and 0.8 square feet for a total increase of 1.4 square feet for channel 441-1R. The total weight of soil lost for the 450-foot length of each of these channels was 22.9 tons and 26.9 tons for the observation period.

The channel section at the time this road was reconstructed five years before, appeared to be a V-ditch with a 1:3 backslope and 3:1 foreslope with bare soil exposed. The cross sections of October 1964 were compared with the assumed original cross sections. This indicated the cross-sectional area of each channel had increased approximately nine square feet over the previous five years due to erosion. This would be an average increase of 1.8 square feet per year or an average loss of 34.5 tons per year for the 450-foot long channels. These channels probably eroded at a much faster rate during the period immediately after initial

Figure 1 Observation Channel 441-1L

Figure 2 Observation Channel 441-1R

construction and tapered off to the rate indicated in 1965.

These ditches were reworked for other experiments in the fall of 1965.

Observation channels 37-1L and 37-1R were located on State Highway 37, nine miles west of Greensburg, Louisiana, in St. Helena Parish. Each of these channels had slopes varying from 0 to 1.5 percent for the first 450 feet and then a three percent slope for the next 550 feet. These two channels are shown in Figures 3 and 4. The soil was a silty clay loam with a P.I. of 19 to 20. Channel 37-1L drained a watershed of approximately 19 acres of which approximately 16 acres was covered with dense bahia grass. A two-foot type HL flume installed in this channel indicated several peak discharges in the range of 16 c.f.s. Channel 37-1R drained a watershed of 1.73 acres. A two-foot Type H flume installed in this channel indicated a peak discharge of six c.f.s. and several peaks in the range of four c.f.s. during the 18-month observation period. Erosion increased the channel cross sections of channel 37-1R by 0.8 square feet and channel 37-1L by 1.3 square feet during the 18 month observation period. The difference in erosion rates in these two parallel channels can be attributed to the watershed sizes.

Channel 37-1L was reworked in June 1966, and used for channel liner experiments.

Observation channels 37-2L and 37-2R were located on opposite sides of State Highway 37, ten miles west of Greensburg, Louisiana, in St. Helena Parish. These two 500-feet long channels had severely eroded cross sections on three percent slopes. Refer to Figures 5 and 6 for a view of these channels. The soil was a silty clay loam with a P.I. of 9 to 10.

Each of these two channels drained 0.69 acre watersheds with similar characteristics. The observations began in October 1964. The increases in channel cross section due to erosion at the end of 6-, 12-, and 18-month periods were 0.9, 0.7, and 0.7 square feet for a total increase of 2.3 square feet for channel 37-2L and 0.8, 0.7, and 0.6 square feet for a total increase of 2.1 square feet for channel 37-2R.

Two-foot type H measuring flumes installed in these channels in the last 6-month observation period indicated peak runoff rates of 3.6 c.f.s. in each channel. The water marks left by this event were at approximately the same level as the high water marks of the previous spring.

The two channels were reworked in June 1966 for ditch liner tests of jute mesh and fiber glass mat.

Observations channels 37-3L and 37-3R were located on opposite sides of State Highway 37, five miles west of Greensburg, Louisiana. These channels had

Figure 3 Observation Channel 37-1L

Figure 4 Observation Channel 37-1R

Figure 5 Observation Channel 37-2L

Figure 6 Observation Channel 37-2R

severely eroded cross sections on five percent slopes. The channels were approximately 550 feet long with 0.5 acre watersheds. The soil was a silty clay loam with a P.I. of 14 to 16. No discharge measurements were made. Erosion measured at the end of 6-, 12-, and 18-month observation periods was 0.5, 0.5, 0.4 square feet for channel 37-3L and 0.5, 0.4, and 0.3 square feet for channel 37-3R.

These channels were reworked and used for a series of ditch liner tests in August 1966.

Observation channels 37-4L and 37-4R were located 3.8 miles southwest of Greensburg, Louisiana on State Highway 37. The channels were 750 feet long with five percent slopes and severely eroded cross sections (see Figures 7 and 8). Each of the channels had watersheds of approximately one acre. These watersheds were rectangular shaped and included the pavement and backslopes along the channels. The soil was a sandy clay loam with plasticity indices ranging from 11 to 14. Each channel cut through several strata. The plasticity index of the bed soil of channel 37-4L was approximately 11 while that of channel 37-4R was approximately 14.

Two-foot type H flow measuring flumes were installed in each channel. The flow lines of the flumes were three feet above the thalwegs of the channels. This created a 400 cubic foot sediment basin above each flume. These basins were filled in less than two months. The sediment basin storage area was increased 200 cubic feet by placing a 2"x 12" board across the entrance to the flume (see Figure 9). This additional storage was filled by one storm which had a peak discharge of 3.2 c.f.s. This was the highest flow rate that occurred during the 18-month observation period.

Erosion increased the cross-sectional area of channel 37-4L by 3.6 square feet during the observation period while channel 37-4R increased 2.8 square feet. These channels had been graded to a V-shaped ditch with 2:1 backslopes and 3:1 foreslopes in 1954. The assumed cross sections of 1954 were compared with cross sections taken in 1969. This comparison indicated an average increase in cross-sectional area of 36 square feet for the 400 foot section of the channel immediately above the flume. This was an average of 2.4 square feet per year. Channel 37-4R had increase of 24 square feet for the same period for an average of 1.6 square feet per year. This difference in erosion rates can be attributed to the differences in the plasticity indices of the soils.

Observation channel 61-1L was located along U. S. 61, approximately 12 miles north of Baton Rouge (see Figure 10). The channel was 850 feet long with an average slope of one percent. The soil forming the bed was a mottled brown and yellow silty clay with a plasticity index ranging from 8 to 12. During the previous six years, the cross-sectional area of this channel had increased an average of

Figure 7 Observation Channel 37-4L

Figure 8 Observation Channel 37-4R

Figure 9 Two-foot Type H Flow-Measuring Flume in Channel 37-4L. Approximately 600 cubic feet of sediment was trapped in the basin upstream of this flume in a three month period. This sediment is four feet deep immediately upstream of the flume. Peak flow rate was 3.2 c.f.s.

Figure 10 Observation Channel 61-1L

43 square feet due to erosion. The cross-sectional area increased six square feet during the 18-month observation period. During this time several peak flows in the range of 30 to 40 c. f. s. occurred. The discharge rates were determined from high water marks at a 42-inch R. C. pipe crossdrain and an 18-inch pipe sidedrain at the upstream end of the channel. A resident of the area indicated that the upstream end of the 42-inch culvert had been submerged at least two times since the road had been reconstructed six years before. This indicated peak discharges in excess of 55 c. f. s. The tractive forces resulting from these flows were in the order of 10 times greater than the recommended permissible tractive forces for wet aged channels in this type of soil. Therefore it is understandable that erosion such as that shown in Figure 10 could occur in a period of six years.

Summary

Several roadside channels in southeastern Louisiana were observed for an 18-month period in order to obtain an indication of the normal runoff flow rates and the resulting erosion. The observation channels were typical of those secondary roads in all rolling to hilly areas of the state.

These observations, which are summarized in Table 4, indicate that channels conveying runoff flows of five c. f. s. or less are losing up to one cubic foot of soil per linear foot of channel per year. Channels conveying larger flow rates are losing larger quantities of soil. This erosion is occurring in channels which have acid soils low in essential plant nutrients.

In general, this erosion can be attributed to lack of vegative cover. Channels lined with mature stands of sod-forming grasses will convey the flow rates occurring in most roadside channels with little or no erosion.

TABLE 4
SUMMARY OF
OBSERVATION CHANNEL CHARACTERISTICS*

Channel	Soils Name	Soils Type	P.I	pH	Channel Slope Percent	Channel Length Feet	Observed Peak Discharge c.f.s.	Increase in Cross sectional Area of Channel by Erosion Sq. Ft.
441-1L	Lexington	Silty Clay Loam	14	4.8	5	450	5.0	1.2
441-1R	Lexington	Silty Clay Loam	12	4.8	5	450	4.3	1.4
37-1L	Providence	Silty Clay Loam	19	5.0	3	550	16.0	1.3
37-1R	Providence	Silty Clay Loam	20	5.1	3	550	6.0	0.8
37-2L	Providence	Silty Clay Loam	10	4.8	3	500	3.6	2.3
37-2R	Providence	Silty Clay Loam	9	4.7	3	500	3.6	2.1
37-3L	Providence	Silty Clay Loam	14	4.5	5	550	-	1.4
37-3R	Providence	Silty Clay Loam	16	4.6	5	550	-	1.2
37-4L	Ruston	Sandy Clay Loam	11	4.2	5	750	3.2	3.6
37-4R	Ruston	Sandy Clay Loam	14	4.3	5	750	3.2	2.8
61-1L	Oliver	Silty Clay Loam	10	5.0	1	850	40.0	6.0

* Observations conducted over 18-month period beginning in winter of 1964-65 and ending in the spring of 1966.

P.I. - Plasticity Index
pH - Soil Acidity

STABILITY OF NEWLY SEEDED CHANNELS

Field Observations

Several newly seeded channels were observed during and after runoff flows from short duration rains in order to determine at what point temporary liners would be required. These channels were usually prepared in conjunction with other tests in the area, fertilized, seeded and left unlined. Softwood stakes were placed at several points in the channel for reference of soil losses and to obtain a rough estimate of the depth of water.

Observation of these channels under flow conditions indicated the water level reached some critical depth at which excessive erosion began. This erosion was usually in the form of a rill or small channel cut in or near the center or deepest part of the channel. As soon as the rill erosion began, the water became deeper at this point as the bottom eroded. This deeper flow caused the erosion rate to increase to such an extent that the rill or eroded channel carried most of the flow. Usually the rill cut completely through the prepared layer of soil (see Figure 11).

Critical Tractive Force

These observations can be explained by the tractive force theory. The tractive force is the shear force exerted on the bottom of the channel by the flowing water. The tractive force for uniform flow conditions is

$$T = w\ y\ S$$

where T is the tractive force, w is the unit weight of water, y is the depth of flow and S is the channel slope.

Where the tractive force becomes greater than the shear resistance of the bed material, excessive erosion begins. The tractive force existing at the instant at which bed failure begins is called the critical tractive force.

According to the preceding equation, the tractive force for a flow in a channel of a set slope is directly proportional to the depth of flow. Thus, if the depth of flow existing at the time excessive erosion begins can be determined for a channel with a given slope and soil conditions, the critical tractive force can be comptued. This critical or maximum permissible tractive force is considered to remain constant for given soil conditions. Once the maximum permissible tractive force has been determined for given soil conditions, the designers can use the tractive force formula to compute maximum permissible depths of flow for channels of different slopes.

Figure 11. Typical Erosion Damage to Newly Seeded Channel

The maximum permissible tractive forces for channels excavated in non-cohesive soils have been defined in Table 1. The maximum permissible tractive forces for cohesive soils have not been fully determined. Research by Smerdon and Beasley (1959), Laflen and Beasley (1960) and Lyle and Smerdon (1964) has shown that the critical tractive forces for cohesive soils are significantly related to the plasticity index, the dispersion ratio and the voids ratio. The plasticity index appears to have more effect on the shear resistance than other soil properties.

Recently, Glass (1968) presented a design procedure for drainage and irrigation channels excavated in cohesive soils. The following equation, showing the relationship between permissible tractive force and soil plasticity index, was derived from his design curve

$$Tc = 0.0053\ (P.I.)^{1.28}$$

where Tc = critical tractive force, and P. I. = plasticity index of soil in which channel is excavated. Glass stated that this design information is subject to revision as additional data is collected.

The permissible tractive forces shown in Table 1 and those computed from the above equation are for channels excavated in firm, wet, aged soil and cannot be applied to newly seeded roadside channels. These values are recommended for use in unlined highway drainage channels that remain wet most of the time.

Smerdon and Beasley (1959) worked with uncompacted soils in a hydraulic flume 2.5 feet wide by 60 feet long. Their study indicated that the critical tractive force was significantly related to the plasticity index of uncompacted soils. This relationship is represented by the following equation

$$Tc = 0.0034\ (P.I.)^{0.84}$$

where Tc is the critical tractive force and P. I. is the soil plasticity index.

Comparison of Results

In this researcher's opinion, the results of the foregoing study should be applicable for the soil conditions encountered in newly seeded roadside ditches. Therefore an attempt was made to determine the depth of flow existing at the time excessive erosion began in the newly seeded roadside channels previously discussed.

Watermarks on the softwood stakes in the channel were used to estimate the depth of flow. Only those stakes near the upstream end of the rills and at the sides of rills (which had caused the water level to recede as erosion increased the conveyance) were used in estimating the flow depth existing at the time excessive erosion began. These observations were used to compute the critical tractive force of the soil at the site. The computed tractive force ($T = w\ y\ S$) and the soil plasticity index were plotted on log log paper with a line representing the equation developed by Smerdon and Beasley (Figure 12).

Estimation of the exact depth that critical tractive force occurs is difficult for flume studies and even more so for field observations. Therefore it is understandable that these field measurements would produce considerable scatter. After studying Figure 12, the researcher concluded that the equation developed by Smerdon and Beasley defines the critical or maximum permissible tractive force for newly seeded roadside channels accurately enough for design purposes.

Permissible Depth

The concept of a permissible depth of the flow is probably more easily understood by most designers of roadside channels; therefore, the critical tractive force equation developed by Smerdon and Beasley

$$Tc = 0.0034\ (P.I.)^{0.84}$$

can be expressed as

$$(w)(Y_p)(S) = 0.0034\ (P.I.)^{0.84}$$

Dividing the equation by wS yields

$$Yp = \frac{5.45 \times 10^{-5}\ (P.I.)^{0.84}}{S}$$

where Yp is the permissible depth of flow for newly seeded channels, P.I. is the plasticity index, S is the channel slope and w is the unit weight of water.

As a further point concerning the utilization of this concept, the above equation was used to plot permissible depths of flow versus channel slopes for soils with P.I. = 10, 20, 30, 40, and 50. These curves were then compared with design information developed from flume studies at Mississippi State University (McWhorter, et al., 1968). This comparison indicates that the design curves developed from the above equation coincide with the upper and lower limits for the Mississippi State study (see Figure 13). The soil types used in the Mississippi State Study had plasticity indices ranging from non-plastic to 47. The objective of the Mississippi State study was to develop upper and lower limits for permissible depth of flow over bare soils. The study did not attempt to correlate permissible depth of flow with plasticity index.

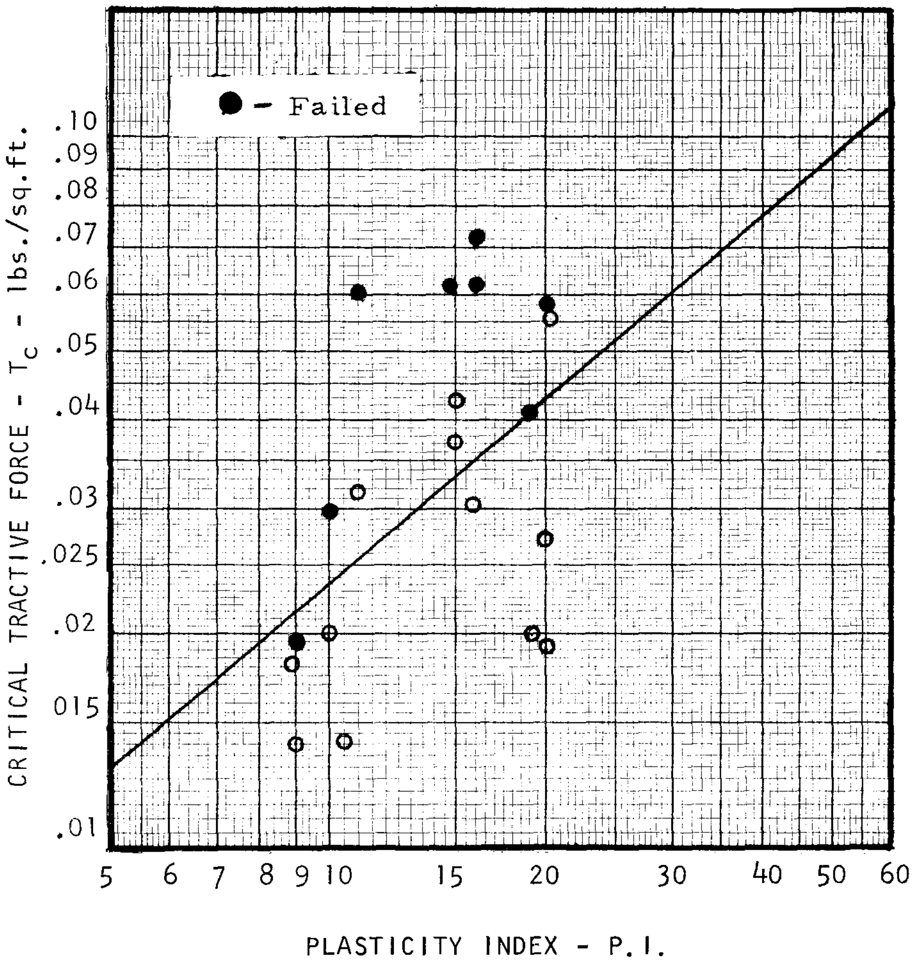

Figure 12. Critical tractive shear force versus plasticity index for uncompacted soils. The points represent data obtained from field observations. The line represents the equation developed from flume studies of uncompacted soils by Smerdon and Beasley (1959).

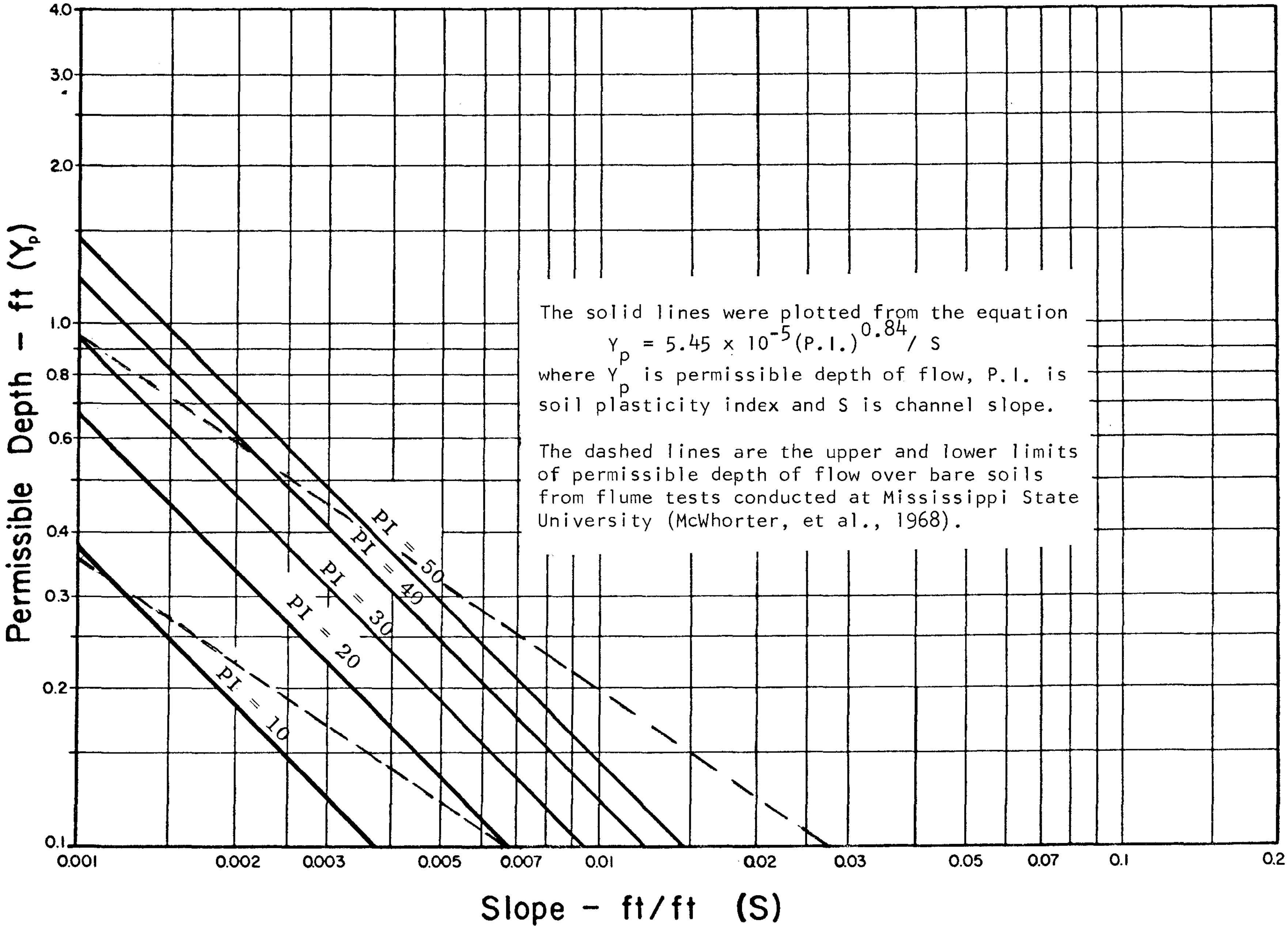

Figure 13. Permissible depth of flow versus slope for channels lined with bare soil in seed bed condition.

TEMPORARY DITCH LINERS

Introduction

The preliminary work plan for this investigation outlined methods for evaluating several types of temporary channel liners to be used as aids in establishing permanent grass liners. This plan included an evaluation of the hydraulic characteristics, the temporary protection afforded to the channel section and the permanent effects of temporary liners on channel sections. The first part of this work was to be accomplished under controlled flow conditions while the second part was to be accomplished in the field.

The controlled flow tests on four temporary liners were described in the second annual report on this investigation (Beavers and Cox, 1965). The liners tested are listed below:

1. Fine mesh jute net
2. Fiber glass mat - 3/16" thick
3. Wood excelsior mat under paper net
4. Fiber glass roving tacked with asphalt emulsion

Tests on two other materials were abandoned because their costs were not competitive.

The fine mesh jute net consists of one-quarter inch diameter jute yarn woven into a net approximately four feet wide, of varying lengths. The net has about 250 openings per square foot and is pinned to the ground with staples, six to eight inches long (see Figure 14). The material can be purchased in rolls up to 225 feet and costs from 18 to 22 cents per square yard. The inplace cost of this material is approximately 75 cents per square yard.

The fiber glass mat was 3/16 inch thick and eight feet wide. The material can be purchased in rolls from 80 to 255 feet long. The purchase price is about 22 cents per square yard. Installation costs have not been determined for the Louisiana area. The manufacturer recommended pinning the material to the ground with wide staples or "T" pins.

The wood excelsior mat under paper net consists of long wooden fibers covered with a paper string net. The material is similar to the excelsior used in packing materials. The mat is three feet wide and approximately 150 feet long. The material is pinned to the ground with staples with the net ontop of the excelsior (see Figure 15). This material also costs 18 to 22 cents per square yard.

The fiber glass roving comes in a 32-pound spool. The roving has sixty 204-fiber strands with a slight twist. The material is applied by pulling the strand from

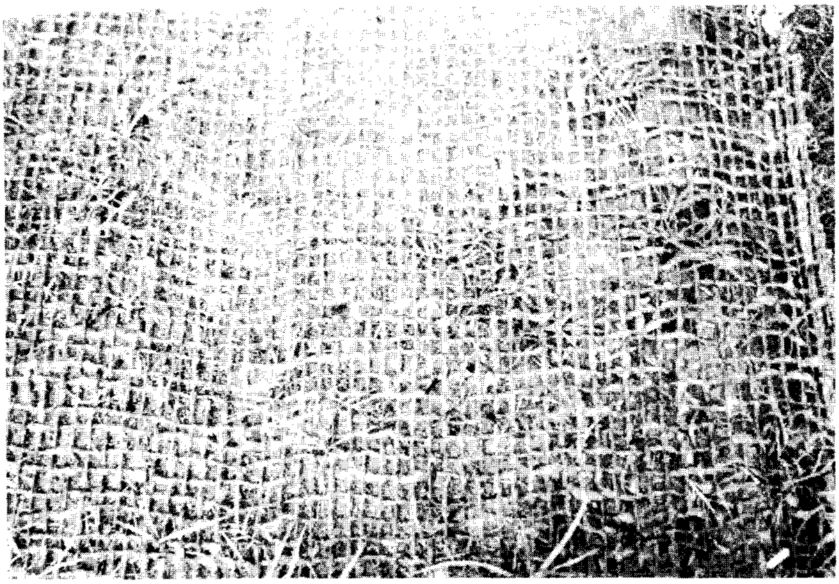

Figure 14. Jute Mesh Pinned to Soil

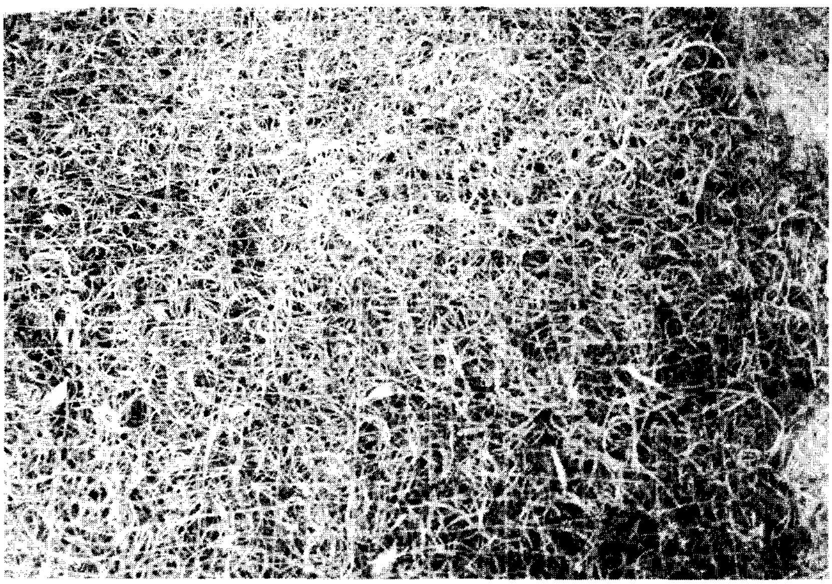

Figure 15. Excelsior Mat Pinned to Soil

the center of the spool and feeding it through an ejector driven by an air compressor. The material is blown out over the ground in a continuous strand to form a fluffy mat. The air compressors used by maintenance crews to drive jack hammers can be used to drive two to three of these ejectors. After the material has been applied to the ground, it is tacked with asphalt emulsion or asphalt cement (see Figures 16 and 17). The recommended application rate for most channels is 0.25 to 0.3 pounds of fiber glass per square yard. The rate of fiber glass and asphalt can be varied as needed. One ejector can apply the roving at a rate of 2 to 3 pounds per minute or 8 to 12 square yards per minute. The fiber glass costs about 40 cents per pound and the emulsion costs about 11 cents per gallon. At these prices, the cost of the liner material is 10 to 13 cents per square yard. The inplace cost of this material is approximately 40 cents per square yard.

Controlled Flow Tests

These materials were tested under controlled flow conditions in a test channel with a triangular cross section with a top width of eight feet and a depth of 0.5 feet. The channel was 150 feet long with a 4.8 percent slope. The actual test section was 50 feet long. The results of these tests were described in the second annual report for this study (Beavers and Cox, 1965). A summary of these results is shown in the Appendix.

The controlled flow tests indicated that each of the materials had possibilities and should be tested in the field with some changes in installation methods.

Germination and Growth Tests

Germination and growth tests indicated that good stands of grass could be developed with the fiber glass roving tacked with asphalt emulsion and with jute net liners. The excelsior mat retarded growth. The 3/16 inch thick fiber glass mat did not allow the growing grass to penetrate and was pushed away from the ground. The grass under this mat was severely damaged. This indicated the mat needed to be anchored to the ground by some other means in order for the grass to grow through the mat. A combination of partial pinning and asphalt tack was recommended for the field tests.

Field Test Procedures

The preliminary work plan provided for field testing the temporary ditch liners. The liners were to be tested under similar conditions. The liners were to be placed in test channels below a common watershed so that the flows could be equally divided among all channels. After observing field conditions, this did not appear to be very practical or necessary. The liners were not necessarily being compared with one another but each was being evaluated to determine the

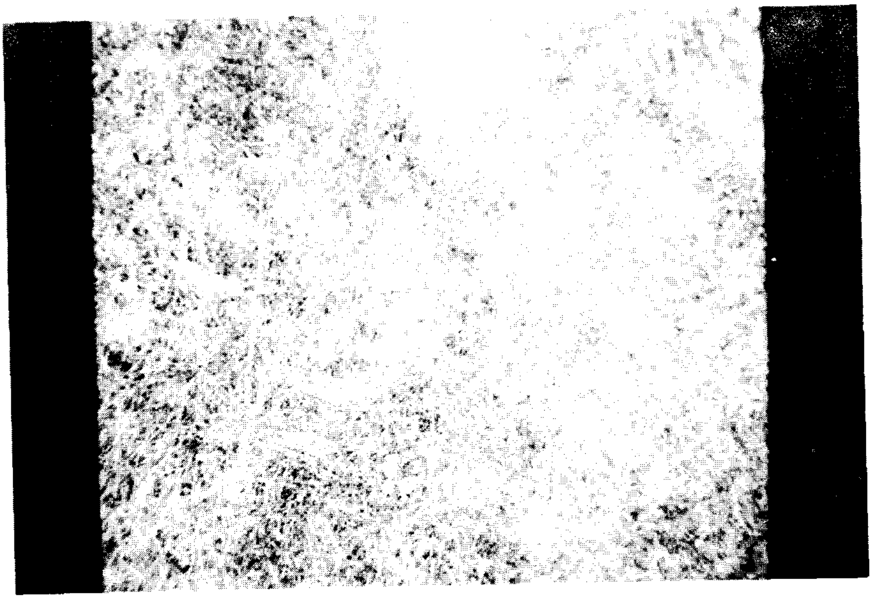

Figure 16. Fiber Glass Roving and Asphalt Cement
One Application

Figure 17. Fiber Glass Roving and Asphalt Cement
Two Applications

protection it would afford a typical roadside ditch during the critical period required to establish a mature grass liner. Therefore it was necessary to conduct the test in full size roadside ditches.

In order to provide a severe test, some knowledge of the erodibility of the soils and the flow characteristics of the test sites was necessary. The first series of test sites chosen were eight severely eroded ditches which had been under observation since 1964. These test sites were described in the previous section. These sites were located in an area with an average annual rainfall of 60 inches. This series of tests was previously described in the third annual report for this study (Beavers and Cox, 1966).

Type H flow-measuring flumes had been previously installed in four of the ditches selected for the test. Type H flow-measuring flumes were installed in two other ditches before the liners were installed. These measuring flumes were used to determine the peak flows (Figure 18).

The eroded areas were reworked with a tractor with a rotary tiller and rear-mounted blade. This equipment was not capable of reshaping the severely eroded ditches to current design standards. The eroded backslopes were cut down and the soil removed was used to fill the eroded ditch bottoms. Each ditch had a five-foot wide flat bottom. Some of the new ditch bottoms were two to three feet above the eroded bottoms. Generally construction of drainage ditches over fill material is not a recommended practice but was necessary in these tests. No top soil other than that existing at the top of the backslope was used. Most of the soil exposed in the ditch section was erodible subsoil. This provided a severe test for the liners.

After the test channels were reshaped, lime and fertilizer were incorporated with a rotary tiller. The area was packed, seeded and packed again. The liners were then installed over the test section of the channel.

A description of each of the field tests conducted in this series is included in the Appendix. Before and after pictures and appropriate comments are also included. The results and conclusions drawn from the temporary ditch liner tests conducted in 1965 and 1966 are discussed in the following section.

Discussion of Results of First Series of Tests of Temporary Channel Liners

Jute Mesh - Only two tests of jute mesh liners were conducted. In each case the liner performed satisfactorily. This material has been in the Louisiana Department of Highway's specifications for several years. Several projects have been observed since the beginning of this project. Therefore further field testing was not necessary.

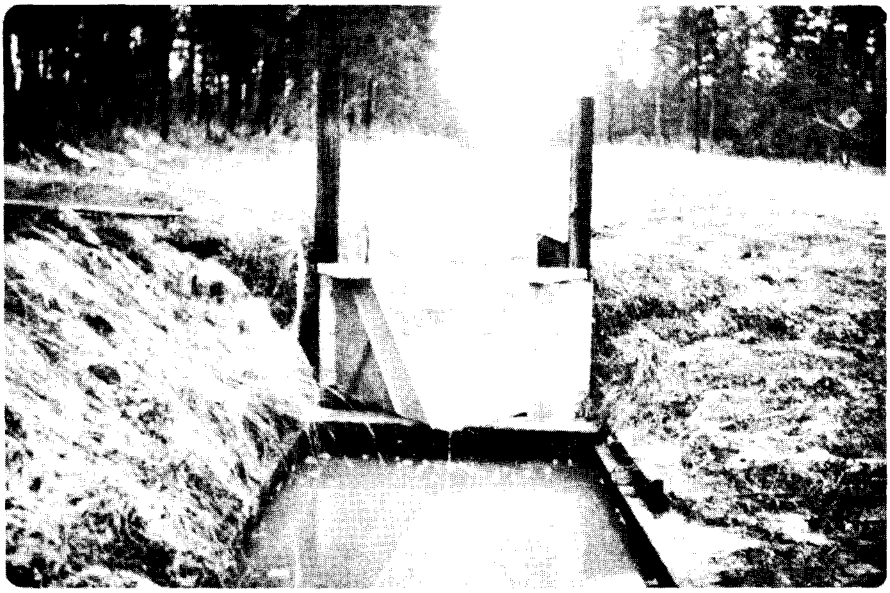

Figure 18. Type H Flow-Measuring Flume

This material will aid in establishing permanent grass liners in ditches with watersheds up to one acre and with slopes up to four percent. It is not recommended for non-plastic soils.

Experiments by McWhorter, et al., (1968) were used in conjunction with these tests to develop design information for jute mesh.

Fiber Glass Mat - The fiber glass mat performed satisfactorily when installed with pins and tacked to the soil with asphalt. This material tears easily and must be in firm contact with the soil to prevent erosion. Unless it is tacked to the soil with asphalt, the growing grass pushes the mat away from the soil.

The glass fibers are brittle and are apt to become embedded in the installer's skin unless protective clothing is worn. Due to this problem, this material is not recommended for inclusion in the Department's specifications.

Excelsior Mat - The results of the excelsior mat tests indicate that the erosion prevention capabilities of this material were very good. The material trapped sediment and the fibers became embedded in the channel bottom. However, a satisfactory stand of grass did not develop in either the germination and growth test plots or in the four channel sections covered in the test.

Since these tests were conducted, the manufacturer has changed the specifications. The material is much thinner than that tested in this study and should allow the grass to penetrate. The manufacturer sent several rolls of the new mats to be tested. The mats were installed and performed satisfactorily. Germination was retarded but satisfactory stands of grass were established.

Fiber Glass Roving - The tests of the fiber glass roving anchored with asphalt demonstrated its ability to protect the channel bottom during the period required to develop a permanent grass liner from seed. Bed samples indicate that the glass fibers become entwined with the root mass of the grass and continue to strengthen and protect the channel long after the grass has developed. This is an additional benefit not found with some liners which deteriorate with age.

This material is unique as a ditch liner in that the application rate for the roving and asphalt binder can be varied to form a very light temporary liner or a permanent fiber glass reinforced asphalt liner. These tests indicated that fiber glass roving applied at the rate of 0.25 pounds per square yard and anchored with 0.25 gallon of emulsified asphalt per square yard will provide adequate protection for typical roadside drainage channels with slopes up to five percent and discharges of 5 c.f.s. or under. As a result of this first series of field tests, this material was recommended for use in the Department's maintenance operations.

The test channels with heavier application rates could have carried much greater rates than this; however, no such flows occurred during the test period. Therefore additional tests of fiber glass roving and asphalt were conducted under more extreme flow conditions. These tests are described in the following section.

Laminated Fiber Glass Roving and Asphalt Cement Liners:

Field Tests - Observation of the field tests of fiber glass roving and asphalt applied at the heavier rates indicated that the liners would withstand more extreme flow conditions than those encountered during the test period. Therefore additional tests were conducted.

Observation channel 61-1L, shown in Figure 19, was reshaped and graded to form a trapezoidal channel with 4:1 sideslopes and a five-foot bottom. The channel had a one percent slope. During the previous year, several discharges in the range of 35 c. f. s. had been observed. These flows during the observation period had increased the channel cross-section by six square feet by erosion. During the previous six years the average cross-sectional area of this channel had increased 43 square feet by erosion.

After reworking the channel section, the area was fertilized, seeded and lined with two layers of fiber glass roving and asphalt. Each layer consisted of fiber glass roving at 0. 25 pounds per square yard and 0. 25 gallon of AC-8 asphalt cement per square yard. Approximately two weeks after the liner was installed, a storm with a 12-hour duration produced a peak discharge of 45 c. f. s. The flow exceeded 30 c. f. s. for six hours. This liner withstood this event satisfactorily (see Figure 20).

Four channels with smaller watersheds but steeper slopes were selected for additional tests of fiber glass roving. These channels were located along U. S. Highway 165 in control section 15-6. These channels had relatively small watersheds ranging from one to three acres. The slope of each channel ranged up to ten percent (see Figure 21). These channels were shaped with a parabolic blade pulled by a tractor with a three point hitch. The channel section was approximately five feet wide and one foot deep.

The area was fertilized, seeded and lined with two layers of fiber glass roving and AC-8 asphalt cement. Each layer consisted of fiber glass roving of 0. 25 pounds per square yard and asphalt cement at 0. 25 gallon per square yard.

No flow measurements were made during the growth establishment period, however, depths of flow were determined at several points along each channel.

These liners performed satisfactorily during the critical period of establishment and a good grass cover has been established.

Figure 19. Eroded Channel 61-1L
Before Reconstruction

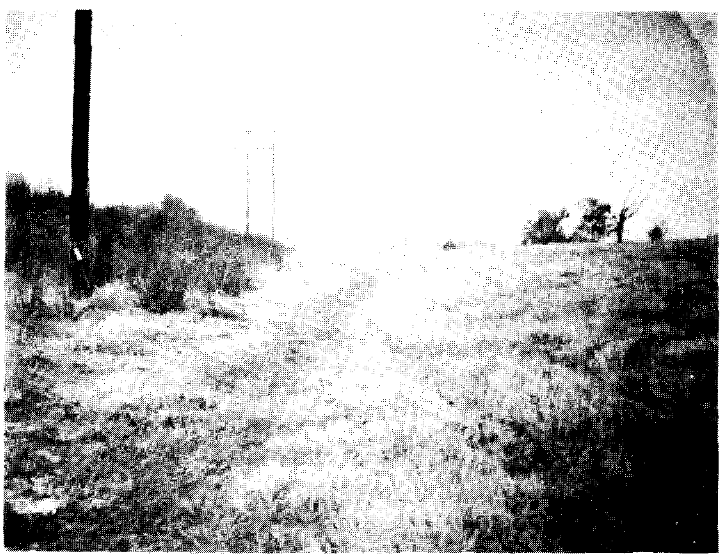

Figure 20. Channel 61-1L Two Years After
Reconstruction and Lining with Two
Applications of Fiber Glass Roving
and Asphalt Cement

Figure 21. Roadside Drainage Channel Lined with Two Applications of Fiber Glass Roving and Asphalt Cement

Figure 22. Same Channel Two Years Later

Field Tests - Laminated Liners Over Sterilized Soils - Another series of tests utilizing this material as a permanent exposed liner over bare soil treated with soil sterilants was conducted. The primary purpose of a liner such as this would be the increased hydraulic efficiency.

A single channel approximately 900 feet long treated with soil sterilant and lined with fiber glass roving and AC-8 asphalt (see Figure 23). These channels were on a very flat slope and carried some sewage effluent in the runnoff. These liners performed satisfactorily for approximately two years. After this the asphalt began to show signs of deterioration. Also, the soil sterilant is apparently leaching out of the soil because a few weeds were beginning to grow in the channel after two years.

This type of liner would have to be treated with soil sterilant and asphalt cement every two to three years to maintain hydraulic efficiency. The economics of each installation would have to be determined.

Controlled Flow Tests - The laminated fiber glass roving and asphalt liners were tested under controlled flow conditions in a flume. The objectives of these tests were to determine the roughness coefficient of the liner and its durability under repeated flows. These tests simulated the liner as a permanent protective liner with no grass cover as well as a temporary protective liner prior to the establishment of a grass lining.

The test channel was trapezoidal in cross section with a one and one-half foot bottom and side slopes of one to one. The slope of the channel bottom was three percent. The flume was 72 feet long with a 16-foot test section.

The test section was sprayed with a coat of asphalt tack. Then the laminated channel was applied in layers. This consisted of a layer of fiber glass roving applied at the rate of 0.25 pounds per square yard followed by a layer of asphalt cement applied at the rate of 0.25 gallon per square yard, then by another layer of fiber glass roving at the same rate as above and another layer of asphalt cement at the above rate. The final result was a tough flexible asphalt membrane reinforced with glass fibers.

Two series of tests were conducted in this channel. The first series of tests was conducted in early December 1967. A second series of tests was run two months later to see if the same roughness conditions would exist after the membrane had aged for two months.

These two series of tests were conducted by varying the discharge from 0.25 cfs to 2.60 cfs for a total of 10 observations for each test. The discharge was controlled by a large gate valve in the supply line.

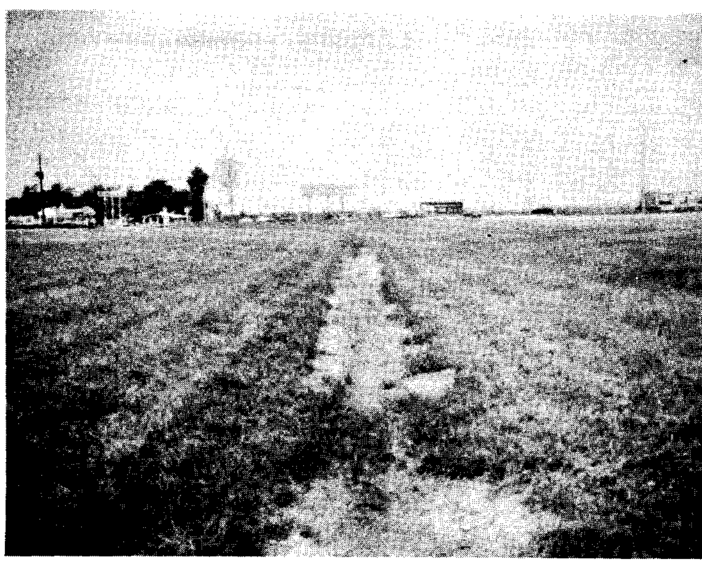

Figure 23. Asphalt Cement and Fiber Glass Roving Liner Over Sterilized Soil After Two Years

The discharge was measured by a depth-recording device attached to the two-foot H-flume. The depth of flow in the flume, for known flume flow characteristics, was used to obtain the discharge rate.

Figure 24 shows a graph of the hydraulic roughness coefficient, n, versus the discharge, Q. The equation for the data plotted is $Y = a + bX$. For the values of the data obtained, this becomes $Y = 0.019 + 0.0001X$, where the slope of the line is 0.0001. Since the line through the plotted points has such a small slope, this shows that the roughness coefficient, n, does not vary appreciably with the discharge, Q.

An average of 0.0197 was obtained for the roughness coefficient. This value was somewhat lower than expected. It is assumed that this value may be used with confidence since the results varied only slightly in both series of tests. It appears that the two-month aging period had no effect on the roughness coefficient. As a result of these tests, a value of $n = 0.020$ is recommended for laminated asphalt-fiber glass channel liners over smooth rolled channel beds. This value would be slightly higher for channel beds having numerous clods and tracks on the soil surface.

Discussion

Correspondence from Dolling* indicated that fiber glass roving and asphalt emulsion has been used extensively by the Iowa Department of Highways for lining roadside ditches. The application rates were 2.5 pounds of glass and 1.0 gallons of asphalt emulsion per 100 square feet.

McCool and Ree (1965) indicated that fiber glass roving at the rate of 35 pounds per 150 square yards with asphalt sprayed over it may have some usefulness for light duty protection of newly established earth waterways, but that a cost-benefit comparison analysis should be conducted for each situation. Gilbert and Davis (1967) reported that ditches treated with a spray of RC-2 asphalt emulsion, 0.24 pounds of fiber glass roving and another spray of RC-2 asphalt emulsion was the best of all materials tested in their study when both economics and effectiveness in preventing erosion were considered.

Since the third annual report on this study (Beavers and Cox, 1966) was presented, maintenance forces of the Louisiana Department of Highways have used over 6,000 pounds of fiber glass roving for lining an estimated 15,000 square yards of road-side ditches. All installations have performed satisfactorily.

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* Personal correspondence from Harold Dolling, Landscape Architect, Iowa Department of Highways, 1968.

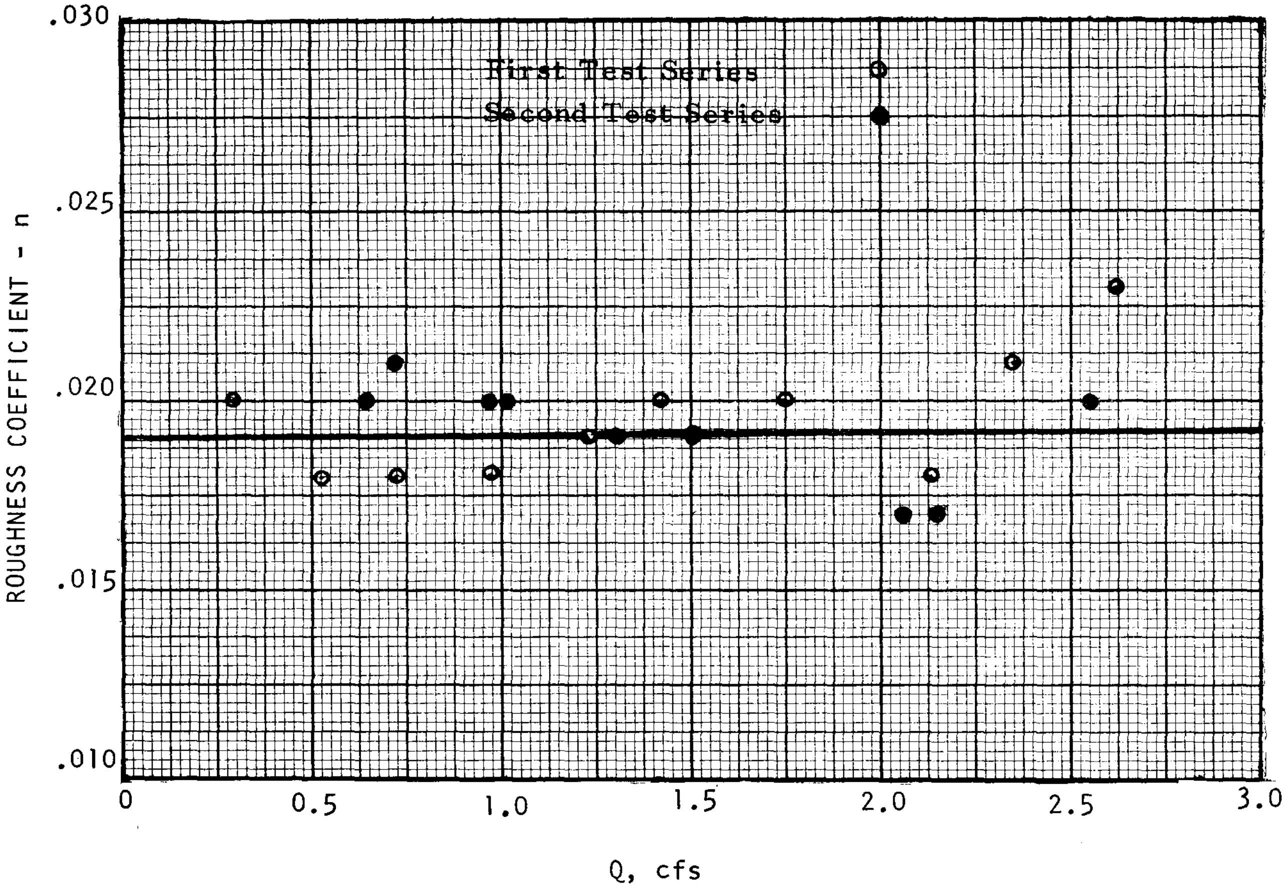

Figure 24. Graph of n versus Q for Laminated Fiber Glass Roving and Asphalt Cement Liner

Analysis and Development of Design Limits

The equation developed in the section on stability of newly seeded channels expresses the permissible depth of flow as a function of the plasticity index of the soil forming the channel bed and the slope of the channel. This equation can be used by designers to determine the point at which some type of channel protection must be provided.

The temporary channel liner tests indicated some of the flow conditions under which these liners would perform satisfactorily. At the time these observations were being conducted, the method of analysis had not been determined. The permissible velocity concept of analysis was impractical because the discharge measurements were limited and only peak flow rates were determined. The permissible tractive force concept appeared to provide a more practical method of analysis since depths of flow had been determined at several points in each of the test channels.

Concurrently with this study, McWhorter, et al., (1968) conducted flume studies of temporary channel liners at Mississippi State University. These researchers used the maximum permissible depth of flow as a criterion for describing channel failure limits. In a review of the preliminary draft of the study conducted by McWhorter, et al., Normann* stated "the depth of flow at which failure was determined to have occurred for a given liner and slope is the limiting depth for a channel of any shape." This is essentially the same principle expressed in the section on stability of newly seeded channels. Therefore this method was used in the analysis of the field data for the temporary channel liners studied in this report.

McWhorter, et al., determined the depths of flow just preceding failure of the test liners in hydraulic flumes. These flume studies included several channel slopes and bed soils. Regression analysis was then used to fit this data to a log log plot of permissible depth of flow versus channel slope for each liner tested. Then the researchers used their judgment in determining upper and lower limits. Their design was presented in the form of two design curves for each liner tested, an upper limit and a lower limit. The designer selects the limits based on his knowledge of the erodibility of the soil.

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* Technical comments from J. M. Normann, Highway Research Engineer Bureau of Public Roads to J. C. McWhorter in 1967. This comment was stated in the final report (McWhorter, et al., 1968).

Jute Mesh Design Limits

The data collected during the previously discussed field observations for channels with the jute mesh liners were plotted on log log paper in the same form as the Mississippi State University study. Figure 25 shows a comparison of the upper and lower design curves developed by McWhorter, et al., for channels lined with jute mesh and the field data collected during this study. The solid line is the design curve being recommended for use by the Louisiana Department of Highways by the researcher. This design limit was set by the researcher after comparing the field observations of this study with the results of the Mississippi studies. This comparison also indicated that additional field tests were not necessary at this time.

In this researcher's opinion the single line with a 1:1 slope is suitable for design purposes. The jute mesh is not recommended for non-plastic soils. Erosion checks should be buried at 50-foot intervals to prevent localized scour from extending along the channel bed.

Fiber Glass Roving and Asphalt Cement Channel Liners - Design Limits

McWhorter, et al., (1968) reported that fiber glass roving tacked to the soil with asphalt would not stay in the flumes with vertical side walls under flow conditions. Therefore they used a net and pins to anchor the glass fibers to the flume bottom.

This problem did not occur in any of the test installations previously discussed or in any of the roadside channels lined by maintenance forces. All of the channels had either rounded sections or trapezoidal sections with 3:1 and 4:1 side slopes. Preliminary tests (Beavers and Cox, 1965) indicated that the glass and asphalt should be applied at least two feet beyond the anticipated highwater to prevent the tractive forces from pulling the liner from the sideslopes.

Since no failures occurred in the channels lined with fiber glass roving, the researcher used the observed maximum depths of flow with the channel slope and judgment based on the field observations to develop the design limits shown in Figure 26. These design limits are considered to be very conservative and may be revised after additional data has been collected. Roadside channels designed within these limits will convey the discharges anticipated for most roadside channels.

These design curves are for newly seeded channels with either rounded bottoms or triangular or trapezoidal sections with sideslopes of 3:1 or flatter. The liner must be applied at least two feet beyond the anticipated high water during the critical period while the grass is being established.

The lower curve is for liners of fiber glass roving pneumatically applied at the minimum rate of 0.25 pounds per square yard and tacked with asphalt cement at the minimum rate of 0.25 gallons per square yard. The recommended roughness coefficient (Mannings "n") for this liner is 0.03 for smooth rolled channels and 0.035 for channels with clods and tracks on the soil surface.

The upper curve is for liners consisting of two layers, each consisting of fiber glass roving pneumatically applied at 0.25 pounds per square yard and penetrated with 0.25 gallon of asphalt cement (AC-8 or equivalent). The recommended roughness coefficient (Manning's "n") for this laminated liner is 0.02 for smooth rolled channels and 0.025 for channels with clods and tracks on the soil surface.

The liners are temporary for aiding in the establishment of permanent grass liners. The laminated liner will last approximately two years without a grass cover. The fibers become entwined in the grass roots and give additional protection to the channels. The extent of this additional benefit needs to be determined in future research.

Design procedures for roadside channels are discussed later in this report. Sample problems and recommended material and construction specifications are provided in the Appendix.

Vegetative Liners - Design Criteria

The design of vegetated waterways is more complex than the design of channels lined with inert materials because the roughness coefficient varies with the depth of flow, hydraulic radius, velocity and stage of growth.

The U. S. D. A. Soil Conservation Service has conducted extensive flow tests with grass-lined channels. They found that a satisfactory index of channel retardance could be found by plotting the observed roughness coefficients versus the product of velocity and hydraulic radius. Later this information was used to develop graphical solutions for channels lined with various classes of vegetation. These graphical solutions are presented in the U. S. D. A. publication "Handbook of Channel Design for Soil and Water Conservation," SCS-TP 61, Rev. 1954. In general a solution for the flow in a channel is obtained in the following manner, or some variation thereof:

1. Assume the design discharge Q_d, slope S, and channel shape.
2. Estimate the depth of flow y and compute hydraulic radius R and cross-sectional area A.
3. Enter the appropriate chart with R and S and read velocity at the point of intersection.
4. Compute discharge $Q_c = AV$
5. Compare Q_c with Q_d

6. Vary the depth and repeat this procedure until $Q_c = Q_d$.

To check for stability of a channel, the procedure is varied slightly in that a permissible velocity (Table 2) is used with the slope to find the hydraulic radius. Then the area is computed and Q_c determined and compared with Q_d.

Recently McWhorter, et al., (1968) determined permissible depths of flow versus slope for channels lined with two to three inch bermuda grass. Then using this information and the recommended permissible velocities, the permissible depths of flow versus channel slope were determined for the various classes of vegetation. Thus the stability as well as the capacity of a channel can be determined by using the six steps listed above in conjunction with graphs or equations representing the permissible depth of flow versus slope.

DITCH CHECKS

Ten check dams were constructed in two severly eroded channels. These check dams were constructed with soil removed from the steep backslopes. The check dams were shaped with 3:1 slopes for the upstream face and 4:1 slopes for the downstream face. The top of the check dam was shaped so that each side was higher than the center in order to concentrate the flow. After each check dam was compacted and shaped, the surface area of the check dam and the immediate area were fertilized, seeded and lined with the temporary liner materials discussed in this report.

All check dams trapped enough sediment to completely fill their sediment basins after two storms. Continued runoff eroded the downstream face and caused failure of the check dams lined with excelsior mat, jute mat and one application of fiber glass roving and asphalt emulsion. No erosion occurred at the two check dams lined with two applications of fiber glass roving and asphaltic cement.

The eroded check dams were reshaped, fertilized, seeded and lined with two applications of fiber glass roving and asphaltic cement. All sediment basins filled and sediment was deposited with a small slope upstream from the check dams (see Figure 27). A good stand of grass developed at each check dam. Later fertilizer and seed were broadcast over the sediment. The result of this experiment was a channel consisting of a series of grassed steps with flat slopes.

The following procedure is recommend as an economical method of checking erosion in severly eroded roadside ditches until sufficient funds are available for reshaping the ditches to conform with current safety standards.

1. Determine the required spacing for the check dams from the formula

$$L = \frac{h}{S-S_a}$$

where L = the distance between checks in feet.
h = the height of the check in feet.
S = the channel slope in feet per feet.
S_a = the allowable channel slope for the anticipated depth of flow in feet per feet.

In general use $S_a = 0.01$ unless additional information is available. The drop at each check in a roadway channel should not exceed one foot (Searcy, 1965).

Figure 27 - A Series of Compacted Soil Check Dams in an Eroded Ditch with a 5% Slope. The check dams were seeded and lined with two applications of fiber glass roving and asphaltic cement. The check dams are 1.5 feet high with 50 foot spacings. Additional tillage and seeding was performed on the backslope of the ditch after the sediment basins filled.

This may be increased to two feet for severely eroded channels which are already safety hazards.

2. Use a grad-all or other equipment to construct the compacted soil check dam with soil from the eroded backslopes and ditch section. The slope of the downstream face should be 6:1 or flatter if possible to reduce the traffic hazard. The upstream face can be steeper because the sediment basin should soon be filled. The top and downstream face of the check dam should be higher at each side of the channel in order to concentrate the flow in the center.

3. Fertilize and seed the surface of the check dam and immediate area according to specifications.

4. Line the seeded area with two applications of fiber glass roving and asphalt cement. The material shall extend beyond the check dam on all sides. Bury the upstream end in the sediment basin. Additional pinning may be necessary where large flow rates are anticipated.

5. The sediment basins will eventually fill with sediment. This process will be accelerated if the steep backslope is pulled down into the eroded channel. This is desirable from a safety standpoint.

6. At some future date additional grading accompanied by seeding operations can be utilized with the grass covered check dams to establish a series of grass covered steps. This type of ditch check can be mowed and is safer than the eroded ditch.

SOIL AMENDMENTS

Bentonite

Observations conducted during the course of this study and other prior studies (Smerdon and Beasley, 1959; Lyle and Smerdon, 1964 and Glass, 1968) have shown that the critical tractive force of a soil is a direct function of the plasticity index. The plasticity index of a soil can be increased considerably by the addition of small amounts of bentonite (drilling mud).

Limited flow tests were conducted with soils amended with bentonite. The flow tests were conducted in a 72-foot long test flume with a three percent slope. The flume was rectangular and had a 2.5 foot bottom width. The soil samples were placed in a 16-foot test section with plexiglass sides (see Figure 28).

Clear water from a well was metered into the flume through a two foot type H flow measuring flume at the upper end. The maximum flow rate of the supply well was 2.7 c.f.s.

The tests were conducted with three soils with and without bentonite. The bentonite was mixed with the soil in the test section at the rate of one pound per square foot per four inches of depth. The bentonite cost at this rate was 21 cents per square yard.

Prior to each flow test, the sample was placed in the test section, dressed with no compaction, thoroughly wetted and allowed to drain for 24 hours. Then water was metered through the flume until uniform flow was established. The water was allowed to flow for 30 minutes or until failure occurred. The soil lost by erosion was measured and the process was repeated at a higher flow rate. The maximum flow rate was limited to 2.7 c.f.s. The results of the hydraulic flume tests are shown in Table 5.

These flume tests indicate that amending soil with bentonite will increase the permissible tractive force of the soil. Additional flume tests need to be conducted with higher discharges and other slopes in order to determine the actual increase in critical tractive force. Also additional tests need to be conducted with different rate of bentonite.

Two field tests were installed in two sandy clay roadside ditches. The soil mixture was not wetted prior to the initial runoff event. Some soil and seed were eroded from the center of the channel as successive layers of the dry mixture became wet and pealed off of the surface during the flow. This same type of erosion occurred in preliminary flume tests with dry mixtures. The soil mixture must be thoroughly wetted prior to the initial flow to prevent this.

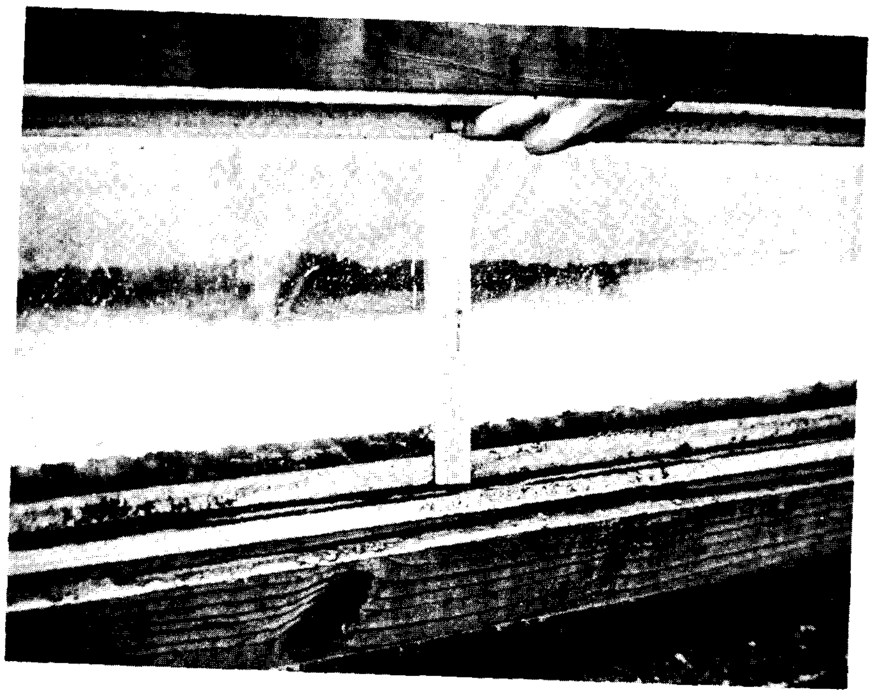

Figure 28 - View of Flow over Soil in Test Section of Hydraulic Flume. The soil is a silty loam (P. I. = 11) amended with one pound of bentonite per square foot per four inches of depth. The plasticity index of the mixture was 62. The maximum observed tractive force was 0.46 pounds per square foot. The flow data for this observation is Q = 1.1 c.f.s., V = 3.4 f.p.s. and tractive force = 0.24 lbs. per sq. ft.

TABLE 5

TRACTIVE FORCES OBSERVED IN FLUME TESTS
OF THREE SOILS WITHOUT AND WITH BENTONITE

Soil	Plasticity Index	Observed Discharge c. f. s.	Observed Tractive Force lbs. /sq. ft.	Failure?
Silty Loam	11	0.5	0	Yes - immediately
Silty Loam + Bentonite*	62	2.7	0.46	No
Sandy Clay	13	0.8	0.15	Yes - after 10 minutes
Sandy Clay + Bentonite*	44	2.7	0.48	No
Mortar Sand	NP	0.5	0	Yes - immediately
Mortar Sand + Bentonite*	**	2.7	0.49	No

Test conducted in 2.5 foot wide flume with three percent slope. The flume was 72 feet long with a test section 16 feet long (see Figure 28).

* Bentonite added to soil at one lb. per sq. ft. per four inches of soil depth.

** This sample appeared to be plastic and could be molded. The plastic limit could not be determined because the sample consisted primarily of uniform grains of sand bound together by extremely small particles of bentonite.

The remainder of the test sections were stabilized long enough for a mature stand of grass to develop. There is a need for basic research concerning the long term effects of soils amended with bentonite on grasses.

Chemical Amendments

The idea of increasing a soils erosion resistance with some chemical has interesting possibilities. The literature review conducted at the beginning of this study indicated that considerable research had been conducted with various chemicals for prevention of rill erosion. Various chemicals including salt compounds, acids, resin-in-water emulsions and water dispersible startch compounds. Very little success was reported with any of these materials for prevention of rill erosion; therefore, it was unlikely that they would withstand the tractive forces occurring in roadside channels.

As the study progressed several new chemicals appeared on the market. Limited tests were conducted with two chemical amendments consisting of dilute forms of sulfuric acid in water-soluble-petroleum derivatives. The materials were tested with a sandy clay soil in the flume described above and in short test sections in a roadside ditch.

There was no appreciable increase in the erosion resistance of the treated soils over the untreated soils in either case. Grass growth developed over the treated plots as well as the untreated plots.

Due to the time involved and the number of materials being promoted for use, further testing was deemed to be beyond the scope ofthis study. Recent advances in polymer and emulsion technology has produced several products which may increase the erosion resistance of soils at a reasonable cost. Further research in this field is recommended.

CONCLUSIONS

Erosion of roadside channels is a serious problem in Louisiana. The photographs of eroded ditches shown in this report are typical views which can be found in all of the rolling to hilly areas of the state. Some of these channels are serious safety hazards and, unless corrective measures are taken soon, the magnitude of the problem will increase. This is evidenced by the fact that most of these areas have acid soils which are low in essential plant nutrients. Observations indicate that eroded channels with discharges of 5 c. f. s. or less are losing up to one cubic foot of soil per linear foot of channel per year. These losses are greater in channels having larger discharges.

In general, most of this erosion can be attributed to the lack of vegetative cover. This lack of cover is the result of one or more of the following:

1. the occurrence of erosive velocities during the critical period between seeding and development of protective growth;
2. failure to provide sufficient fertilizer and lime for establishment and maintenance of protective growth; and sometimes
3. failure to provide for any vegetative cover.

Channels lined with sod-forming grasses, such as bermuda grass, will convey the design discharges of most roadside channels with little or no erosion after the grass has matured.

The possible occurrence of erosive flows during the critical period required for establishment of protective growth must be considered in the design of roadside channels.

Protective growth can be rapidly developed by lining the channel with solid slab sod, or by lining newly seeded or sprigged channels with approved temporary liners.

Jute mesh can be used to provide limited temporary protection of newly seeded channels during the critical establishment period. Mulch sod should be used where low grade or non-plastic soils are encountered.

Fiber glass roving pneumatically applied at the minimum rate of 0. 25 pounds per square yard and penetrated with asphalt cement (AC-8 or equivalent) at the minimum rate of 0. 25 gallons per square yard can be used for limited protection of newly seeded channels during the critical period. These fibers become entwined in the grass roots and increase the channel bed's resistance to erosion after the grass matures. Mulch sod should be used where low grade or non-plastic soils are encountered.

Two layers of fiber glass roving and asphalt cement, each layer applied at the above rates, will give good protection to newly seeded channels during the critical period. Germination is retarded but the increased protection more than offsets this.

Two chemical soil ammendments, consisting of dilute forms of sulfuric acid in water-soluble-petroleum derivatives, indicated no appreciable increase in erosion resistance over bare soil in either flume test or small test sections in roadside channels.

Flume studies of bentonite mixed with soil to a depth of four inches at the rate of one pound per square foot of channel bed increased the critical tractive force of the soil. This mixture had to be thoroughly wetted prior to the initial flow or layers peeled off during flow.

Field tests of nine compacted soil check dams (fertilized, seeded and lined with two layers of fiber glass and asphalt) demonstrated that these structures could be used to check erosion in roadside channels.

RECOMMENDATIONS

Implementation of the following recommendations will provide for the establishment and maintenance of mature grass liners in most roadside drainage channels in Louisiana.

1. The channel bed should be properly prepared before seeding, sprigging or slab sodding operations are conducted. This includes tillage to a minimum depth of four inches, incorporation of two tons of agricultural lime per acre and 500 pounds of 10-20-10 fertilizer or equivalent per acre and packing the soil with an approved roller.

2. Approved temporary channel liners should be used to protect the newly seeded or sprigged channel bed from erosion during the critical period required for establishment of protective growth.

3. The continued use of slab sod for lining channels is recommended. Design limitations set forth in the Design Procedures should not be exceeded.

4. The continued use of jute mesh as an approved temporary channel liner is recommended. Mulch sod may be required where low grade or non-plastic soils are encountered. Design limitations set forth in the Design Procedures (Appendix A) should not be exceeded.

5. The use of fiber glass roving and asphalt cement as an approved temporary channel liner is recommended. Mulch sod may be required where low grade or non-plastic soils are encountered. Design limitations set forth in the Design Procedures should not be exceeded.

6. The grass-lined channel section should be top-dressed with a supplemental application of fertilizer approximately six weeks after seeding and sodding operations. This application should consist of 200 pounds of ammonium nitrate for the period between February 15 and August 15 or 200 pounds of potassium nitrate for the period between August 15 and February 15.

7. The Design Procedures presented in Appendix A of this report should be used to determine the stability and capacity of roadside channels.

8. All of the liners tested in this study are suitable for use in repairing eroded ditches by maintenance forces.

9. Compacted soil check dams (fertilized, seeded and lined with two layers of fiber glass roving and asphlat cement) are recommended for use as erosion retards in eroded channels. These check dams should be designed with roadside safety in mind.

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APPENDIX

APPENDIX A

DESIGN PROCEDURE FOR ROADSIDE DRAINAGE CHANNELS

The objective of this project specified that the information gathered in this study would be analyzed and used to develop design and maintenance procedures for controlling erosion in roadside drainage channels.

This section concerns the development of procedures for designing grass-lined roadside drainage channels. The outline presented in this section indicates sequentially each step to be undertaken using the design equations and curves presented in this report.

The determination of design discharges was beyond the scope of this project. The rational formula $Q = CiA$ is recommended for predicting the design discharges to be used with this procedure in Louisiana. Any reliable method of predicting peak runoff rates from small watersheds is satisfactory. A two-year return interval storm should be used for computing the design discharge to be conveyed by a newly seeded channel. Admittedly, some failures would occur during the establishment period, but overall savings would be realized. A ten-year or greater return interval storm should be used for computing the discharge to be conveyed by the channel lined with mature grass in the unmowed condition.

In order to minimize construction costs, the designer should divide the channel reach into several stations (one station is sufficient for short channels.) Then the design discharge should be computed for the watershed area above each station. The designer should begin his design procedure by determining the required channel section at a station near the upstream end of the channel and progress downstream, determining the required channel section at each station in sequential order. The channel section for the reach above each station should be designed to convey the design discharge anticipated at that station. It is realized that geometrical design standards set for safety reasons and provisions for subgrade drainage may require channel sections which are more than adequate for conveying the anticipated surface runoff.

This design procedure begins with the assumption that a grass lined channel will convey the design discharge. In case the computations indicate that excessive channel widths are required, a continuous partially paved section should be specified for the reach. It is also assumed that the geometrics of the channel such as sideslopes and minimum bottom width will be governed by certain set design standards and that the channel slope will be governed by the topography of the area. For design purposes uniform flow conditions are assumed to exist between each station under consideration; that is, the water surface is assumed to be parallel with the channel bottom.

The Design Procedure, which consists of five parts, is self-explanatory. The five parts are:

A. Stability of Newly Seeded Channels (Bare Soil or Temporary Liners)

B. Stability of Channels Lined with Short Bermuda Grass

C. Stability and Capacity of Channels Lined with Retardance Class B Grass

D. Final Design Information

E. Construction and Material Requirements

For the designers convenience all terms are listed in Table A-1. This table also provides a tabular form for listing the design information as well as the results of the computation. All of the design curves and computational aids are shown in Figures A-1 through A-6, pages A-8 through A-13. Material and construction specifications are included.

Part A. Stability of Newly Seeded Channels

Step 1. Determine or set the values for the terms listed in rows 1-8 of Table A-1 and enter these values in column 1 of same table.

Step 2. Compute the required section factor $AR^{2/3}$ using the previously determined values of n, S, Q in the equation

$$AR^{2/3} = nQ/(1.49\ S^{1/2})$$

and enter this value in Row 9, Table A-1.

Step 3. Compute the value of the dimensionless parameter

$AR^{2/3}/b^{8/3}$ and enter the abscissa of Figure A-1 to find the ratio Y/b. Compute $Y=(Y/b) \times (b)$ and enter required depth of flow in row 11.

Step 4. Determine Y_p the permissible depth of flow for a newly seeded channel of given slope, roughness and plasticity index or temporary liner by using the appropriate curve in Figure A-2. Enter this value in row 12.

Step 5. Compare required depth of flow Y with permissible depth of flow Y_p. If $Y \leq Y_p$ proceed to Part B Stability of Channels Lined with Short Bermuda Grass. If $Y > Y_p$ either increase b by 0.5 foot or use a more durable temporary liner and repeat Steps 1, 2, 3, 4, and 5. If this procedure requires excessive channel widths, a partially paved channel is recommended.

Part B. Stability of Channels Lined with Short Bermuda Grass

Note: This same procedure may be used for slab sod liners.

Step 1. Determine the design discharge and enter the value in row 14 of Table A-1.

Step 2. Determine permissible depth of flow Y_p for channel of given slope lined with 2-3 inch bermuda grass by using the appropriate curve in Figure A-3. Enter this value in row 15.

Step 3. Use $Y = Y_p$ to compute a trial hydraulic radius R and cross-sectional area of flow A for a trapezodial channel with bottom width b and sideslopes z. Use the appropriate curves in Figure A. These computational aids are solved by entering the curve with the ratio Y/b to find the ratios R/b and A/b^2. Then multiply R/b by b to obtain

R and A/b^2 by b^2 to obtain A. Enter these values in rows 16 and 17, respectively.

Step 4. Determine the velocity for a channel lined with Retardance Class D vegetation and having a hydraulic radius R and slope S by using Figure A-5. Enter the bottom of the chart with R from Step 3 and move vertically to intersect the curve representing the channel slope. Then proceed horizontally to the left side of the chart to read the velocity. Enter this value in row 18.

Step 5. Compute the discharge conveyed through the trial cross section by multiplying the value of A from Step 3 by the value of V from Step 4, $Q_c = AV$. Enter this value in row 19.

Step 6. Compare the discharge conveyed by the trial channel section Q_c from Step 5 with the discharge anticipated at this section Q_D. If $Q_c \geq Q_D$, the channel section will convey the discharge safely at the trial depth. Proceed to Part C. If $Q_c < Q_D$, the channel section will not convey the design discharge. Either increase the bottom width b by increments of 0. 5 feet and repeat steps 3, 4, 5 and 6 or provide for a more durable liner, such as a continuous partially paved section.

Part C. Stability and Capacity of Channels Lined with Retardance Class B Grass

Note: Retardance Class B Vegetal Liners include the following:

Bermuda grass - good stand, 12 inches tall
Weeping Lovegrass - good stand, 13 to 24 inches tall
Native Grass Mixtures - good stand, unmowed.

Step 1. Determine or set the value of D = maximum depth allowed by road geometrics and topography of area.

Step 2. Determine the permissible depth of flow Y_p for channels lined with Retardance Class B vegetal linings by using the appropriate curves in Figure A-3. Enter the smaller value of D (Step 1) or Y_p in row 21 of Table A-1.

Step 3. Use Y_p or D to compute a trial hydraulic radious R and cross-sectional area of flow A for a trapezodial channel with bottom width b and sideslopes z. Use the appropriate curves in Figure A-4. Enter these values in rows 23 and 24, respectively.

Step 4. Determine the velocity for a channel lined with Retardance Class B Vegetation and having hydraulic radius R and slope S by using Figure A-6. Enter this value in row 24.

Step 5. Compute the discharge Q_c conveyed through this trial section by multiplying A from Step 3 by V from Step 4, $Q_c = AV$. Enter this value in row 25.

Step 6. Compare the discharge Q_c from Step 5 with the design discharge anticipated at this station Q_D. If $Q_c \geq Q_D$, the channel section will convey the design discharge safely. If $Q_c < Q_D$, the channel will not convey the design discharge. Increase the bottom width b by 0.5 feet and repeat steps 3, 4, 5 and 6. If excessive widths are required, specify a partially paved section.

Part D Final Design Information

Step 1. Add freeboard to the final value assumed for the depth of flow Y for the long grass condition in Part D to obtain the design depth Y_d.

Step 2. Compute the channel cross-sectional area A_d and hydraulic radius R_d corresponding to the design depth Y_d. Use the same procedure as Part C-Step 3.

Step 3. Compute an average volume of soil to be excavated by multiplying the cross-sectional area A_d by the length of the reach L.

Step 4. Compute the surface area of the channel reach to be tilled, limed fertilized and seeded by using the formula

$$S.A. = L\,(A_d/R_d)$$

where S. A. is surface area and the other terms are defined above.

Step 5. Compute the quantity of temporary liner material or slab sod required for protection for the two-year storm from the equation

$$M = L\,(A/R + 4)/9$$

where M is the quantity of liner material in square yards required to line the channel, L is the length of the channel reach in feet and A and R are the cross-sectional area of flow and hydraulic radius for the two-year storm flow over the liner material.

Step 6. Summarize the design information for this reach of channel in Table A-2.

Step 7. Proceed to next downstream station and repeat Parts A, B, C, and D. If this is the last station, specify construction and material requirements (Part E).

Part E Construction and Material Requirements

1. Excavation for roadside channels shall conform to the construction requirements for drainage excavation Sec 203 (L. D. H., 1971*). All cross sections and grades shall be determined from the information as summarized in Part D of this manual. Smooth transitions will be provided at each change in channel section.

2. Seeding of roadside channels shall conform to the construction and material requirements of Section 717 (L. D. H., 1971*). Copy attached.

3. Newly seeded channel sections shall be lined with an approved liner for protection against erosion. The areas to be lined shall be designated by the plans or by the engineer when field conditions dictate. Approved liners shall consist of jute matting Section 719 (L. D. H., 1971*) and fiber glass roving and asphalt cement Section 720 (L. D. H., 1971*). Construction and material requirements are attached. All other areas shall be protected from erosion by the placement of vegetative mulch (Section 716, L. D. H., 1971*) or alternate.

4. Slab sod channel linings shall conform to the construction and material requirements of Section 714 (L. D. H., 1971*). Copy attached.

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*Proposed Revisions of Standard Specification for Roads and Bridges, State of Louisiana Department of Highways, 1971.

TABLE A-1

Tabular Form for Listing of Design Information and Results of Computations for Stability and Capacity of Grass-Lined Channels

	Row		Trial Results
Stability of Newly Seeded Channels (Bare soil and Temporary Liners)	1	Channel Reach No.	
	2	Length of Reach, L feet	
	3	Channel Slope, S ft. /ft.	
	4	Soil P.I. or Liner Type	
	5	Roughness Coefficient, n	
	6	Bottom Width, b feet	
	7	Sideslopes, z ft. /ft.	
	8	Design Discharge, Q_2 c. f. s.	
	9	Req'd Section Factor, $AR^{2/3} = (nQ)/(1.49S^{\frac{1}{2}})$	
	10	Dimensionless Parameter, $AR^{2/3}/b^{8/3}$	
	11	Req'd Depth of Flow, Y ft.	
	12	Permissible Depth of Flow, Y_p ft.	
	13	Is $Y_p \geq Y$? If yes, proceed to Row 14. If no, increase b (Row 6) and repeat the above procedure.	
Channel Stability (Short Grass)	14	Design Discharge, Q_d c. f. s.	
	15	Permissible Depth of Flow, Y_p ft.	
	16	Trial Hydraulic Radius, R ft.	
	17	Trial Cross-sectional Area, A sq. ft.	
	18	Velocity, f. p. s. in Trial Channel, V f. p. s.	
	19	Capacity of Trial channel, Q_c c. f. s.	
	20	Is $Q_c \geq Q_d$? If yes, proceed to Row 21. If no, increase b (Row 6) and repeat the above procedure.	
Maximum Channel Capacity (Long Grass)	21	Allowable depth of flow Y_p or D.	
	22	Trial Hydraulic Radius, R ft.	
	23	Trial Cross-sectional Area, A sq. ft.	
	24	Velocity in Trial Channel, V f. p. s.	
	25	Capacity of Trial Channel, Q_c c. f. s.	
	26	Is $Q_c \geq Q_d$? If yes, channel will convey design discharge safety. If no, increase bottom width and repeat above procedure or use partially paved section.	

b	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
$b^{8/3}$	1.00	2.95	6.35	11.5	18.7	28.2	40.3	55.2	73.1	94.3	119	147	179	216	256	301	350	405	461

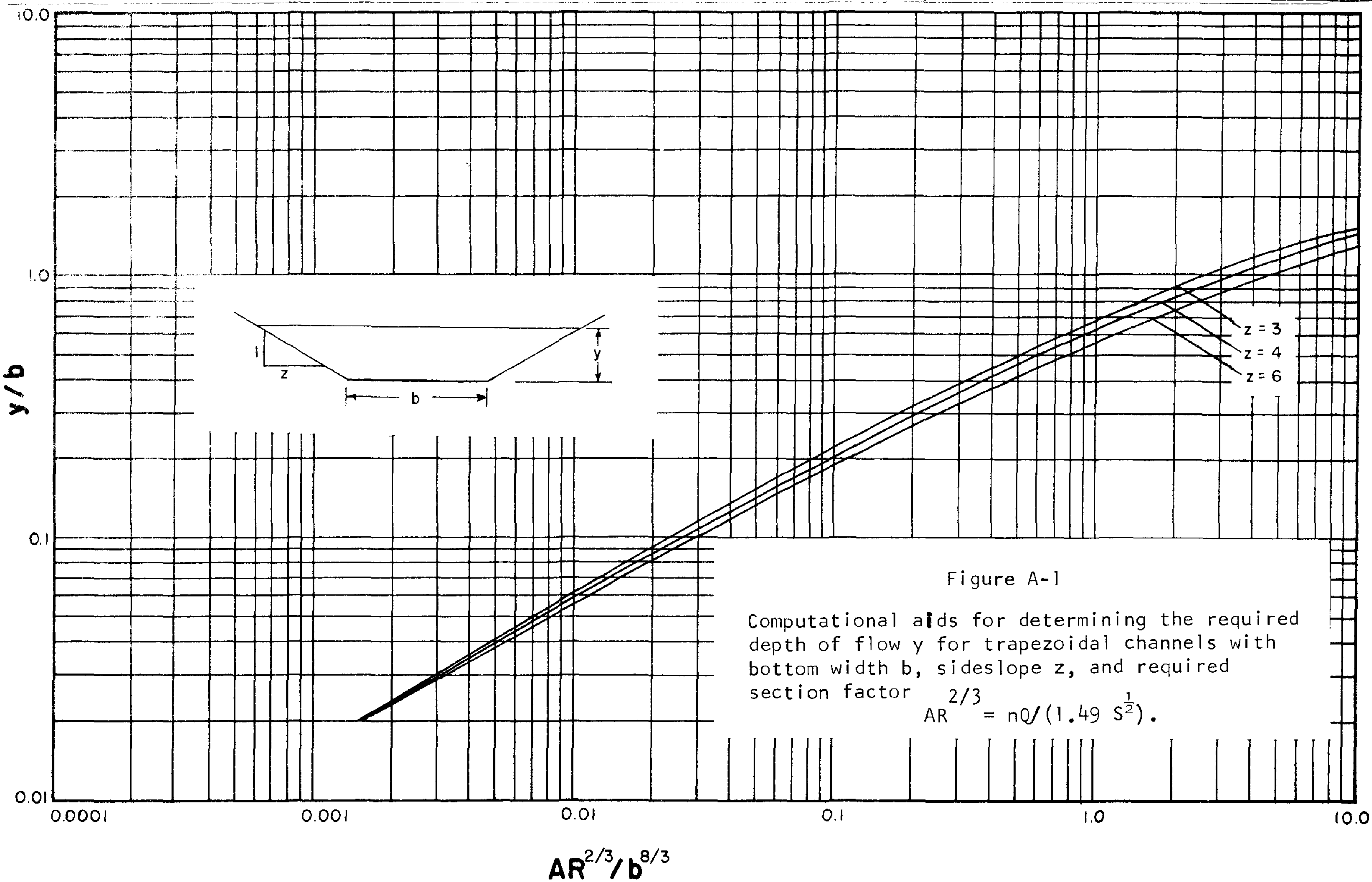

Figure A-1

Computational aids for determining the required depth of flow y for trapezoidal channels with bottom width b, sideslope z, and required section factor $AR^{2/3} = nQ/(1.49\ S^{\frac{1}{2}})$.

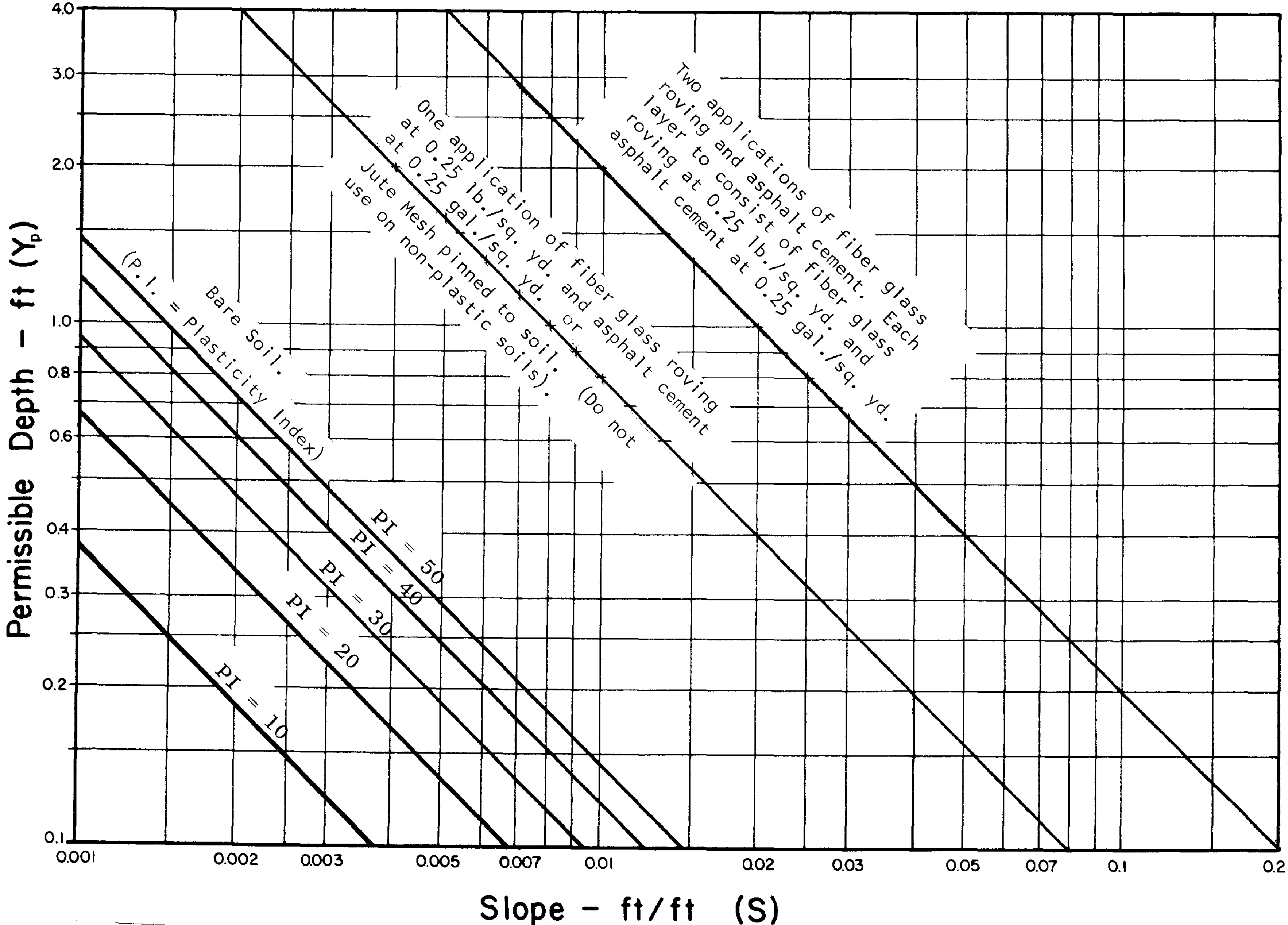

Figure A-2. Permissible Depth of Flow versus Channel Slope for Newly Seeded Channels.

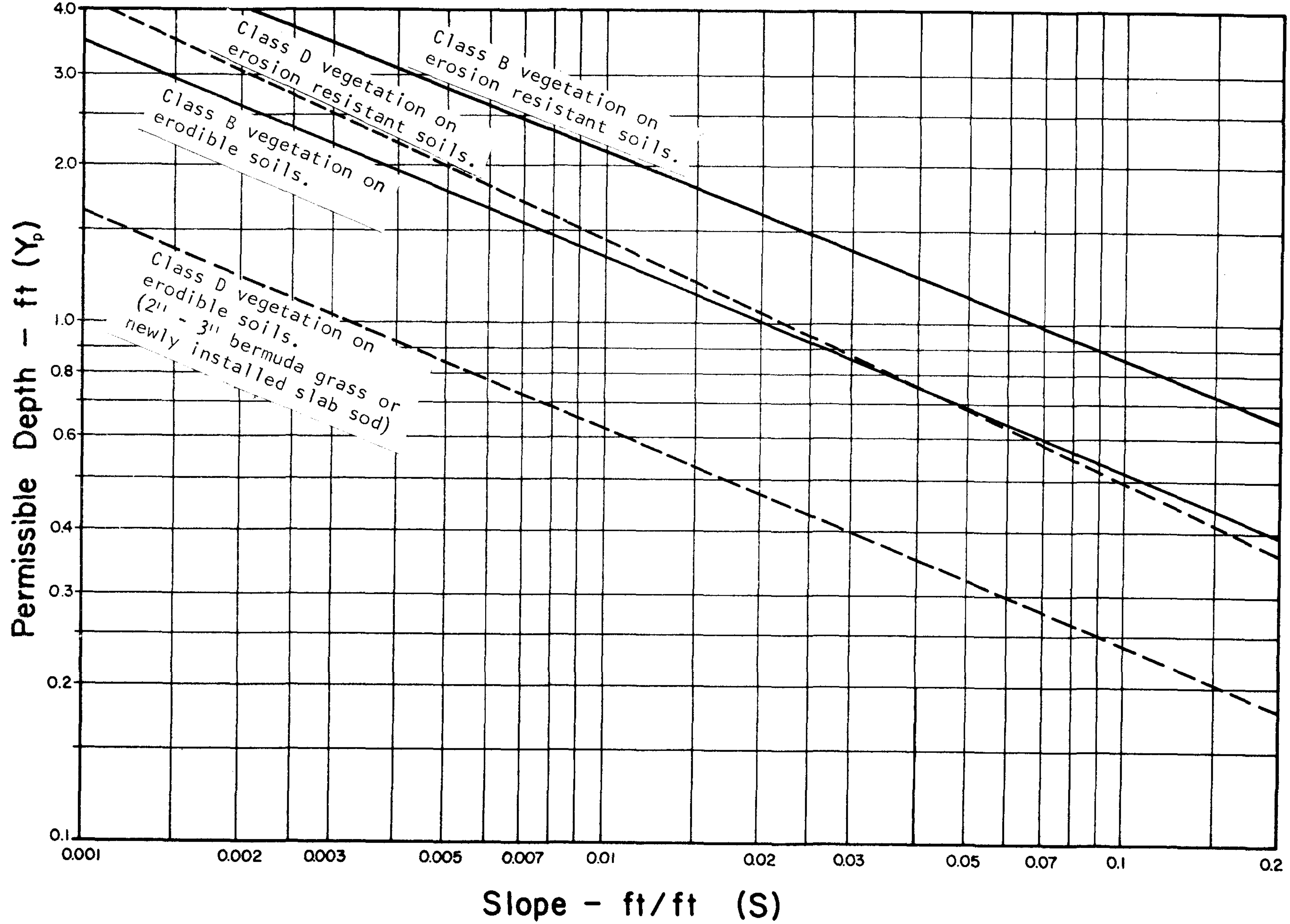

Figure A-3. Permissible Depth of Flow versus Channel Slope for Vegetal Retardance Class B and D Grasses. These curves modified from McWhorter, et al., (1968).

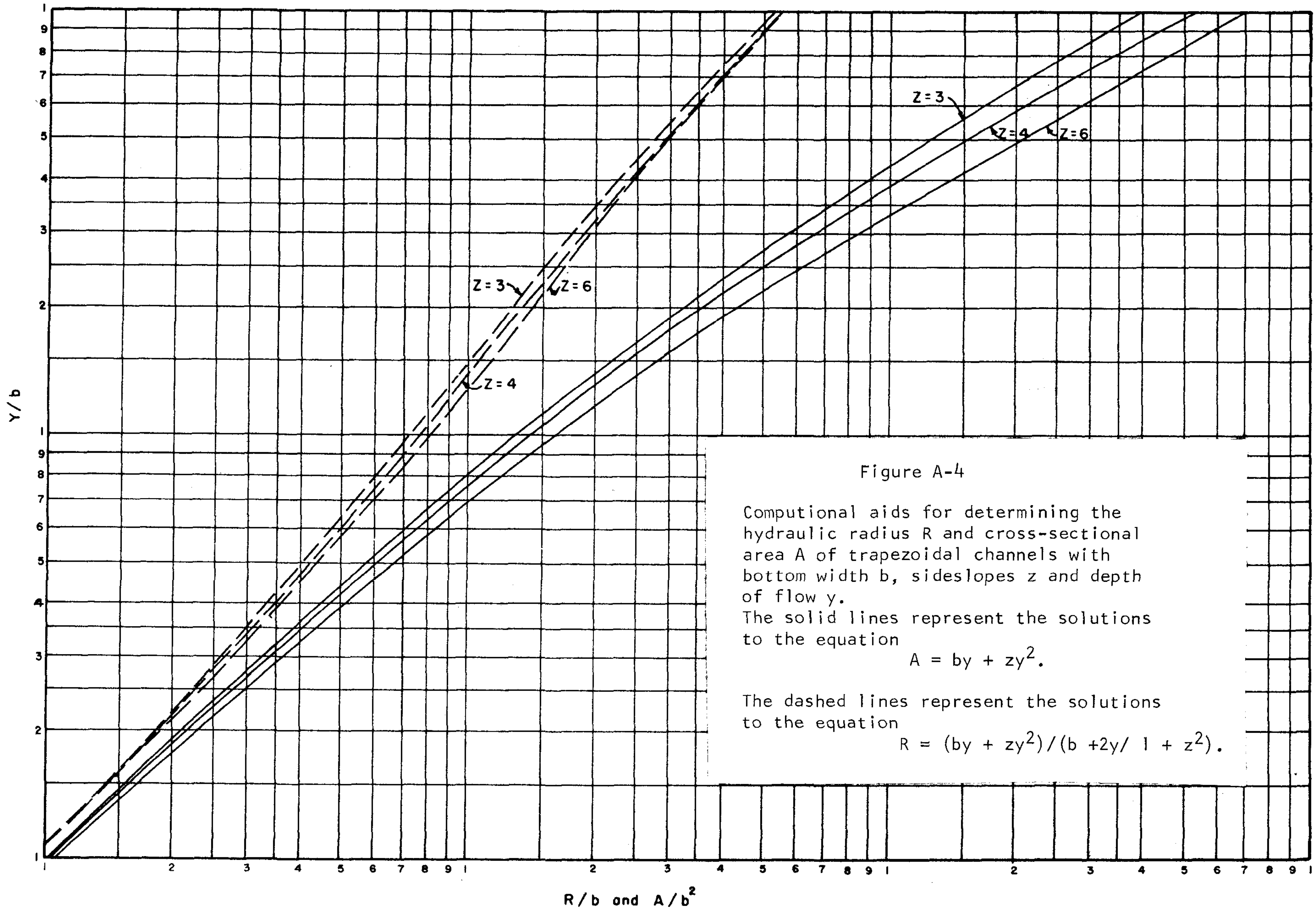

Figure A-4

Computional aids for determining the hydraulic radius R and cross-sectional area A of trapezoidal channels with bottom width b, sideslopes z and depth of flow y.
The solid lines represent the solutions to the equation

$$A = by + zy^2.$$

The dashed lines represent the solutions to the equation

$$R = (by + zy^2)/(b + 2y/\ 1 + z^2).$$

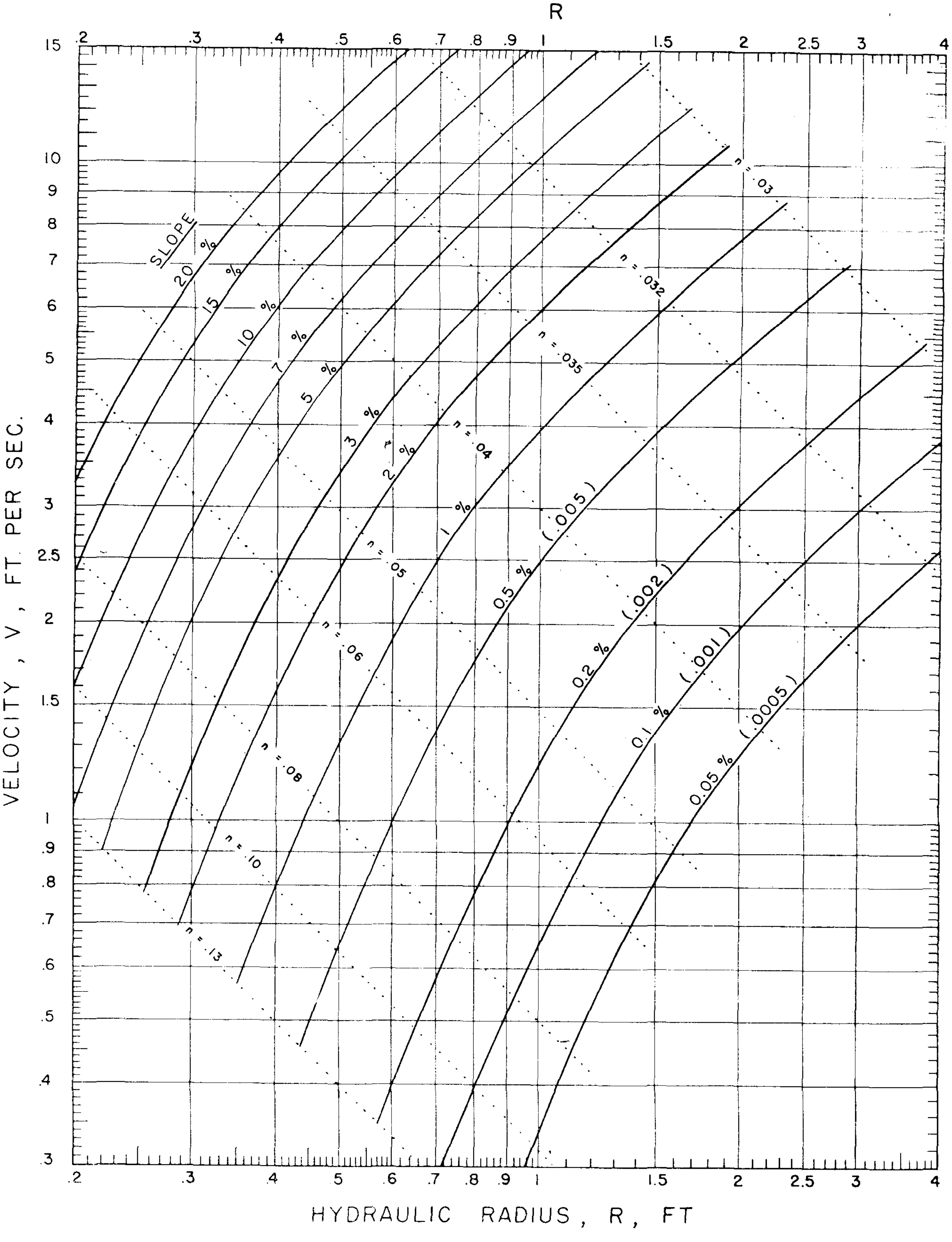

Figure A-5

Solution of the Manning Formula for Retardance Class D Vegetation. (Reproduced from "Handbook of Channel Design for Soil and Water Conservation", SCS-TP-61, Revised 1954.)

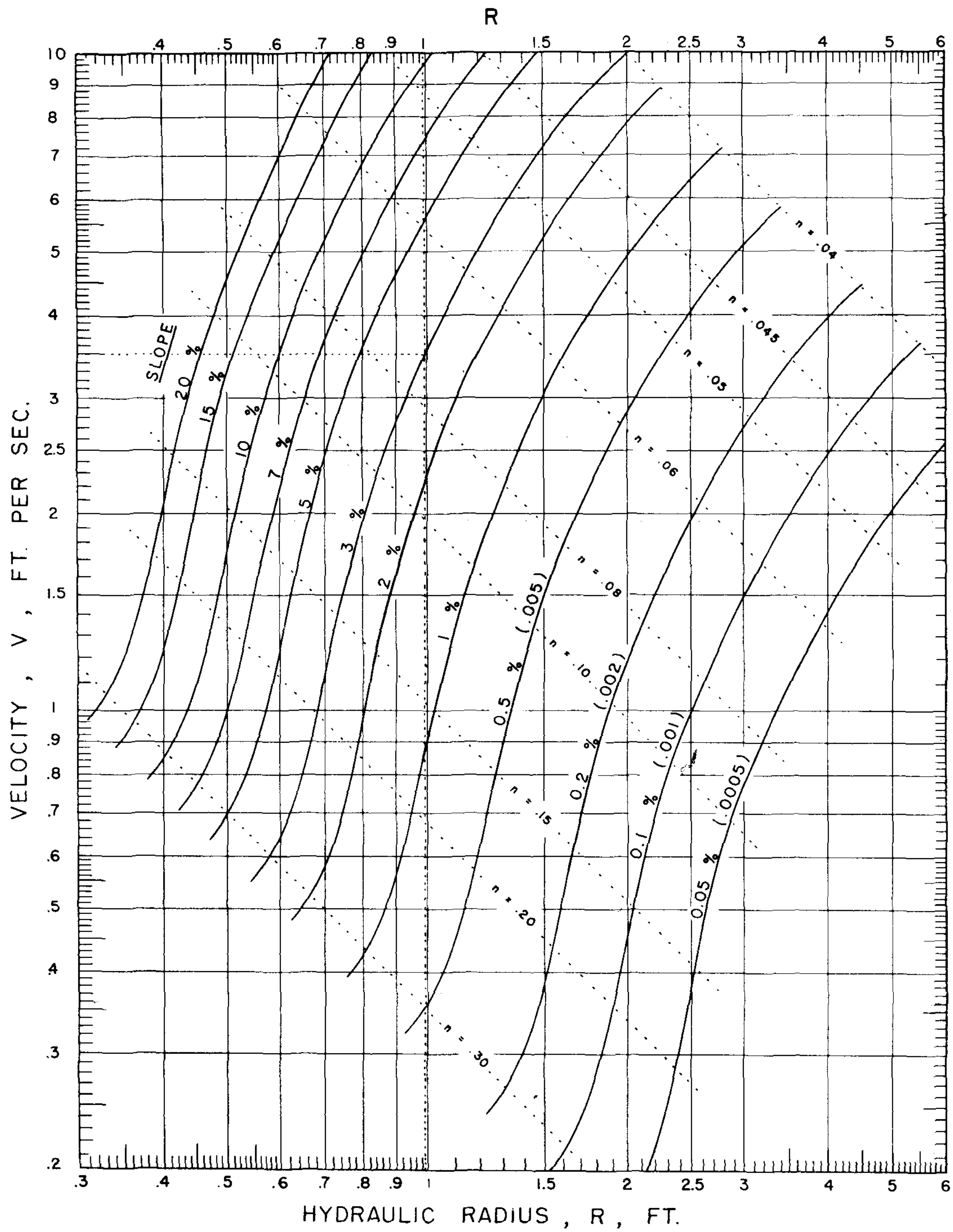

Figure A-6

Solution of the Manning Formula for Retardance Class B Vegetation. (Reproduced from "Handbook of Channel Design for Soil and Water Conservation", SCS-TP-61, Revised 1954.)

TABLE A-2

Tabular Form for Final Design Information
for Roadside Channels

Channel Reach No.	1	2	3	4
Length of Reach, L ft.				
Channel Slope, S ft./ft.				
Bottom Width, b ft.				
Sideslopes, z ft./ft.				
Design Depth, Y_d ft.				
Design Discharge, Q_{10} c.f.s.				
Cross-Sectional Area, A_d sq. ft.				
Hydraulic Radius, R_d ft.				
Volume (Avg.) Excavated, $(A_d)(L)/27$ cu. yds.				
Surface Area of Channel, S.A. sq. ft.				
Quantity of Liner Material, M sq. yds.				

SECTION 714

SLAB SODDING

714.01 DESCRIPTION. This work shall consist of furnishing, hauling, planting; fertilizing and liming if required, rolling, watering and maintaining live bermuda grass sod, live carpet grass sod or any other approved grass sod which is native to the area, at locations shown on the plans or designated by the engineer.

714.02 MATERIALS. Slab sod shall be composed of bermuda grass, carpet grass or other approved grass which is native to the locality of the work.

Sod furnished shall be free from noxious weeds and other vegetation and shall be planted as provided in these specifications.

Commercial fertilizer, and agricultural lime, shall meet the requirements of Subsection 915.08.

Water may be obtained from any available source, except brackish or oily water shall not be used.

CONSTRUCTION REQUIREMENTS

714.03 GENERAL. Slab sod shall be cut with approved mechanical or manual sod cutters. The designated area shall be mowed when necessary, and the sod shall be cut to a minimum depth of 2 1/2 inches, and to a uniform width and in convenient lengths for handling. Care shall be exercised at all times to retain the native soil on the roots of the sod during the process of excavating, hauling and planting.

Sod which has been cut more than 48 hours before placing shall not be used.

Sod taken from bare areas that may produce inferior growth will not be accepted.

Any watering required in connection with digging, storing or hauling sod will not be paid for.

714.04 DIGGING AND HANDLING SOD. The contractor may use either a (1) hand method or (2) machine method for digging and handling sod.

(a) Hand Method: When sod is cut in the field, it shall be placed flat, grass side up on boards of convenient lengths and hauled to the planting site with soil still intact. Only one layer of sod shall be placed on each board and such boards shall be of sufficient thickness to prevent unreasonable bending and of sufficient width so that the slabs of sod shall not hang over the edges. The slabs shall be placed closely without leaving unreasonable spaces between them. In no case shall slab sod be loaded in bulk on vehicles or dumped in bulk on the plating site.

(b) Machine Method: The contractor may use mechanical devices to cut, load, haul and plant sod. Care should be exercised at all times to retain the native soil on the roots of the sod. All sod stacked shall be kept moist and protected from the elements in a manner satisfactory to the engineer. When the machine method is used, final acceptance will not be made until satisfactory growth of sodding has been obtained. Satisfactory growth shall be understood to mean a healthy, living and growing grass turf which has been planted in accordance with the requirements of these specifications.

714.05 PLANTING. All areas to receive slab sod shall be thoroughly scarified and pulverized to a depth of approximately 3 inches and dressed to a reasonable grade. If an item for agricultural lime is included in the contract, the liming shall be done when area is being pulverized. If an item for fertilizer is included in the contract, approximately 90 percent shall be broadcast over the entire area to receive the slab sodding, the remaining 10 percent shall be broadcast over the sod after placing and rolling. Upon delivery to the planting site, the slab sod shall be transferred onto the surface of the soil. The area to be sodded shall be watered as directed. The slabs of sod shall be placed closely, leaving a minimum amount of space between slabs. Slabs which do not fit closely shall be pulled together with suitable tools.

714.06 ROLLING. All slab sod shall be rolled as soon after planting as practicable with plain rollers or cultipackers. Where rolling is impracticable, the sod shall be tamped by approved hand methods.

714.07 WATERING. All slab sodding shall be watered as necessary.

714.08 EQUIPMENT. All equipment necessary for the satisfactory performance of this work shall be on the project and approved before work will be permitted to begin.

714.09 METHOD OF MEASUREMENT. Slab sodding will be measured by the square yard, and the area to be included in the measurement shall be the actual area sodded as authorized. Water will be measured by the 1000 gallons in tanks used by contractor. Fertilizer and agricultural lime, when required, will be measured and paid for as provided in Subsections 718.05 and 718.06.

714.10 BASIS OF PAYMENT. Sodding planted and accepted, measured as provided above, shall be paid for at the contract unit price.

Water will be paid for at contract unit price.

Payment will be made under:

ITEM NO.	PAY ITEM	PAY UNIT
714(1)	Slab Sodding	Square Yard
714(2)	Water	M Gallons

SECTION 715

MULCH SODDING

715.01 DESCRIPTION. This work shall consist of furnishing, hauling, spreading, fertilizing and liming if required, rolling watering and maintaining live bermuda or bahia grass roots and topsoil.

715.02 MATERIALS. Mulch sod shall consist of a natural combination of grass roots and topsoil or approved artificial combination as described elsewhere in this section. Mulch sod shall predominate in bermuda grass or bahia grass roots and be reasonably free of weeds and debris. Topsoil shall consist of good loamy topsoil from fields, creek banks, woods or other approved sources and shall be reasonably free of roots, rocks, weeds, trash and other debris.

Commercial fertilizer and agricultural lime shall meet the requirements of Subsection 915.08.

Water shall conform to the applicable requirements of Subsection 714.02.

Seed for approved artifical combination shall conform to the requirements of Subsection 915.09.

CONSTRUCTION REQUIREMENTS

Natural Combination

715.03 DIGGING. The approved source of mulch sod shall be mowed, raked and disked if necessary. The mulch sod shall then be plowed up into rows, the depth of removal not to exceed 6 inches unless otherwise directed. It will then be bladed into windrows or otherwise stockpiled for convenience in loading. The contractor shall not be allowed to disk, plow, windrow or otherwise stockpile the mulch sod on any source area too large for early removal. Mulch sod stockpiled over 48 hours shall not be used.

Mulch sod shall not be contaminated with tree roots, tops, branches or other debris. Such foreign material shall be dug up, cleared and removed before sod is loaded or stockpiled.

Any watering required to facilitate digging the sod or for other reasons in connection with digging, storing or hauling, shall not be paid for.

715.04 HAULING. Mulch sod shall be loaded with suitable equipment, hauled and dumped on the areas as designated by the plans.

715.05 SPREADING. After dumping, the mulch sod shall be uniformly spread to a depth of approximately 6 inches. The mulch sod shall be spread in such a manner that a minimum amount of roots will be exposed. In no case shall spike tooth harrows or drags be used to spread mulch sod.

All areas to receive mulch sod shall be thoroughly scarified and pulverized to a depth of approximately 3 inches and dressed to grade.

If an item for agricultural lime is included in the contract, the liming shall be done when area is being pulverized. If an item for fertilizer is included in the contract, fertilizer shall be broadcast over the entire area to be mulch sodded before sod is placed.

715.06 ROLLING. After spreading, the mulch sod shall be rolled with a culti-packer or soil pulverizer until the surface presents a level appearance. In inaccessible places and locations where rolling with the above equipment is impracticable, the soil shall be tamped by suitable hand methods.

CONSTRUCTION REQUIREMENTS

Artificial Combination

715.07 GENERAL. Where a natural combination of suitable grass roots and topsoil is unavailable, the contractor may substitute, (a) a combination of approved grass roots and topsoil, or (b) bermuda grass seed and topsoil, in lieu of mulch sodding.

When bermuda grass seed and topsoil is used, the grass seed shall be sown at the rate of 30 pounds per acre and shall be cultivated until a satisfactory growth of grass is produced prior to the final acceptance of the project. The seeding shall be done in accordance with the applicable requirements of Section 717, Seeding, and no seeding will be permitted between the dates of September 30 and February 15.

715.08 SPREADING. All areas to receive topsoil shall be thoroughly scarified, pulverized and uniformly dressed. Topsoil shall be uniformly spread to the depth specified in the proposal or on the plans over the areas to be sodded. Where no depth is specified, the depth will be approximately 6 inches.

Topsoil shall be thoroughly disked and all stiff clods, lumps, stones, roots, litter or other foreign matter shall be removed.

Bermuda roots and tops shall be broadcast over all areas where topsoil has been spread. The roots and tops shall be placed closely together on the surface so as to completely cover the ground. All bermuda roots and tops shall be kept moist from the time of digging to that of spreading at the expense of the contractor. All dried out roots will be rejected.

Immediately after spreading, the roots and tops shall be thoroughly disked into the surface so they will be chopped and covered without disturbing the uniform distribution.

After disking, the area thus sodded shall be rolled with a cultipacker or soil pulverizer until the surface presents a level appearance. In inaccessible places and locations where rolling in impracticable, the contractor shall hand tamp such areas in a satisfactory manner. Toothed harrows, rakes, drags with spikes, and other implements which would tend to tear out the grass roots and tops shall not be used.

The contractor shall have the right to strip suitable topsoil from surface areas within the limits of construction. The topsoil shall be stockpiled in windrows, or otherwise, for ultimate respreading on areas to be sodded. No topsoil shall be stripped from any areas within the limits of the right of way outside the limits of actual construction. All topsoil stripped as described above shall be replaced with acceptable material from sources beyond the project limits at the contractor's expense.

It an item for agricultural lime is included in the contract, the liming shall be done when the area is being pulverized. If an item for fertilizer is included in the contract, fertilizer shall be broadcast over the entire area of topsoil prior to placing bermuda roots and tops or bermuda grass seed.

715.09 WATERING. All mulch sod, whether natural or artificial mix, shall be watered and kept moist as long as necessary to establish a satisfactory growth.

715.10 EQUIPMENT. All equipment shall be on the project and in working condition before starting the mulch sodding operations.

Equipment shall consist of the following:

(a) A soil roller or cultipacker weighing not less than 500 pounds and not more than 1500 pounds, either a single or double type.

(b) Necessary plows, disks, scarifiers, rollers and harrows.

(c) Required bulldozers, blades, drags and other tools to complete the work.

(d) Approved water wagons or tanks of sufficient capacity or other sprinkling devices.

715.11 METHOD OF MEASUREMENT. Mulch sod will be measured by the cubic yard in vehicles at the point of delivery on the project.

When an artificial mixture of grass roots and topsoil is used, only the topsoil will be measured.

For natural combination and artificial combination of grass roots and topsoil, water will be measured and paid for as provided in Subsections 714.09 and 714.10. Fertilizer and agricultural lime, if required, will be measured and paid for as provided in Subsections 718.05 and 718.06.

When an artificial mixture of bermuda grass seed and topsoil is used, only the topsoil will be measured. The topsoil will be measured by the cubic yard in vehicles at the point of delivery. All cost for furnishing, planting, watering and otherwise cultivating the seed will be considered incidental and shall be included in the price bid on this item.

715.12 BASIS OF PAYMENT. Mulch sod, placed and accepted as provided above, shall be paid for at the contract unit price.

Payment will be made under:

ITEM NO.	PAY ITEM	PAY UNIT
715(1)	Mulch Sodding	Cubic Yard

SECTION 716

VEGETATIVE MULCH

716.01 DESCRIPTION. This work shall consist of furnishing and placing an asphalt tacked mulch of straw or hay on areas that have been seeded or mulch sodded.

The intent of these specifications is to insure that all seeding, mulch sodding, or a combination thereof, is protected against erosion.

716.02 MATERIALS.

(a) Types of Mulches: Mulch shall be vegetative in character and shall consist of either stalks or stems of oats, rye, rice, wheat or other approved straw, or hay obtained from various legumes or grasses, such as lespedeza, clover, vetch, soybeans, bermuda, carpet sedge, bahia, fescue or other approved legumes or grasses, or a combination thereof.

Straw of hay shall be dry and reasonably free from Johnson grass or obnoxious weeds. Contractor shall notify the engineer at least 7 days in advance of operations as to the source of the mulch supply, so that the straw or hay can be inspected. The mulch shall be approved before being used.

(b) Storage of Materials: Mulching material shall be delivered to the project in bales of uniform size. If stockpiling of the bales is necessary, they may be stored on the right-of-way. Stockpiling will not be permitted in close proximity to any residence or other building occupying private lands adjacent to the right-of-way. If the contractor desires to stockpile mulching materials on private property and/or in buildings off the right-of-way, he shall furnish the engineer with a copy of agreement signed by property owner. Stockpiles shall be suitably protected from the weather.

(c) Asphalt: Asphalt used as a part of the mulching process shall be an approved emulsified asphalt meeting the requirements of Section 902.

CONSTRUCTION REQUIREMENTS

716.03 GENERAL. Mulching shall closely follow ground preparation, fertilizing, liming, seeding or mulch sodding, or a combination thereof. All mulch shall be placed with mechanical equipment of a conventional type which will distribute the mulch uniformly by blowing it onto the area. The equipment shall be provided with jet nozzles spaced in the muzzle of the blower, through which the asphalt is ejected simultaneously with the mulch, thus coating the mulch uniformly with a spray of asphalt as the mulch is blown through the nozzle.

Spreading the mulch manually and after-spraying with asphalt will be permitted only in areas which are inaccessible to the equipment or where the asphalt may deface a structure.

716.04 SPREADING RATES. Mulch shall be applied at an approximate rate of 1 1/2 to 2 tons per acre simultaneously with the emulsified asphalt at an approximate rate of 75 to 150 gallons per ton of mulch.

When required, the emulsified asphalt shall be diluted with water in such proportions as is designated, however, measurement and payment will be made only for the emulsified asphalt.

The specific rates of application of mulch and asphalt may vary within the job limits and be contingent on the type areas to be covered and the character of the mulching materials furnished. The rates for these areas shall be specified by the engineer.

716.05 MANUAL SPREADING. Where manual spreading is permitted, the mulch shall be placed in such a manner that a loose, shredded and fluffy condition will prevail, after which the emulsified asphalt shall be sprayed over the surface of the mulch. The rates shall be the same as described in the mechanical operation.

716.06 MULCHING OPERATIONS. Mulching operations shall begin within 24 to 36 hours after completion of seeding and/or mulch sodding, even for the smallest areas, in order to protect such areas from erosion.

In its final position, the asphalt-tacked mulch shall be loose enough to allow air to circulate, but compact enough to partially shade the ground and to reduce the impact of rainfall on the surface of the soil. Mulching shall begin at the top of slopes and extend downward. Particular attention shall be given to the top of slopes so that such areas will be covered at the junction with the natural ground. Extensions to the blower pipe shall be supplied where high slopes are encountered that cannot be reached by the blower under normal conditions. Windy conditions will have an effect on the uniformity of final mulch placement, and the contractor will be required to make adjustments in his operations to obtain uniform spreading.

Care shall be taken not to get asphalt on structures that are within the mulching area. Any asphalt stains that are unsightly shall be removed and the surface left in a condition acceptable to the engineer.

716.07 EQUIPMENT. Equipment shall consist of the following:

(a) Mulch blowing machine equipped as provided above.

(b) Asphalt tank attached to or accompanying blowing machine.

(c) All rakes, pitchforks and other tools necessary to perform the work.

716.08 METHOD OF MEASUREMENT. Vegetative mulch will be measured by the ton, complete in place and accepted. The weight for measurement will be the product of the number of bales used and the average weight per bale as determined on certified scales provided by the contractor.

Emulsified asphalt placed and accepted will be measured by the gallon at a temperature of 60°F in accordance with Temperature Volume Correction, Table III, given in Subsection 505.11. No measurement or payment will be made for water used in the emulsion.

716.09 BASIS OF PAYMENT. The number of tons of vegetative mulch and the number of gallons of emulsified asphalt, measured as provided above, shall be paid for at the contract unit prices for the items complete in place and accepted.

Payment will be made under:

ITEM NO.	PAY ITEM	PAY UNIT
716(1)	Vegetative Mulch	Ton
716(2)	Emulsified Asphalt	Gallon

SECTION 717

SEEDING

717.01 DESCRIPTION. This work shall consist of preparing seed bed, fertilizing, liming and watering if required, furnishing and sowing grass seed on the areas designated on the plans or as directed.

717.02 MATERIALS. All seed furnished shall conform to the requirements of Subsection 915.09.

Commercial fertilizer and agricultural lime shall meet the requirements of Subsection 915.08.

Water shall conform to the applicable requirements of Subsection 714.02.

CONSTRUCTION REQUIREMENTS

717.03 SELECTION OF SEED. Prior to planting time, the engineer shall contact the Roadside Development Section in order to select the variety or varieties of seed to be used on the project as shown in Table I. The contractor shall abide strictly to this selection and furnish seed in accordance therewith.

717.04 SOIL AREAS. The seed shall be selected for planting on the basis of 5 general soil areas shown as follows:

(1) Alluvial soils of the Mississippi and Red River bottoms.

(2) Mississippi terraces and loessial hill soils.

(3) Coastal plain soils (rolling, hilly and flatwoods areas in central, northern and eastern part of the State).

(4) Coastal prairie soils.

(5) Ouachita valley cone (lying between the Ouachita River bottom on the west and Boeuf River bottom on the east).

TABLE I

Mixture	Seed To Mix	Approx. Pounds Per Acre	Preferable Soil Areas	Preferable Planting Dates
A	Hulled Bermuda Carpet Grass	10 20 30	(2)(3)(4)(5)	Feb. 15. thru Sept.
B	Hulled Bermuda Pensacola Bahia	15 15 30	(1)(2)(3)(5)	Feb. 15 thru Sept.

TABLE I (Continued)

Mixture	Seed To Mix	Approx. Pounds Per Acre	Preferable Soil Areas	Preferable Planting Dates
C	Hulled Bermuda	10	(1)(2)(3)(5)	Feb. 15 thru April
	Common or Kobe Lespedeza*	20		
		30		
D	Hulled Bermuda	6	(2)(3)(4)(5)	Feb. 15 thru April
	Carpet Grass	10		
	Common or Kobe Lespedeza*	14		
		30		
E	Hulled Bermuda	10	(1)(2)(5)	Feb. 15 thru April
	La. White Dutch Clover*	20		
		30		
F	Hulled Bermuda	10	(1)(2)(3)(5)	Feb. 15 thru March
	Dixie Crimson Clover*	20		
		30		
G	Alta or Kentucky 31 Fescue	30	(1)(2)(3)(4)(5)	Sept. thru January
	Dixie Crimson Clover*	10		
		40		
H	Alta or Kentucky 31 Fescue	30	(1)(2)(3)(5)	Sept. thru January
	Pensacola Bahia	10		
		40		
I	Alta or Kentucky 31 Fescue	20	(1)(2)(3)(5)	Sept. thru January
	Dixie Crimson Clover*	10		
	Pensacola Bahia	10		
		40		

When only one variety of grass is to be planted in connection with mulch sod, the following will apply.

J	Hulled Bermuda	15	(1)(2)(3)(4)(5)	Feb. 15 thru Sept.
K	Dixie Crimson Clover*	30	(1)(2)(3)(5)	Sept. thru January

TABLE I (Continued)

Mixture	Seed To Mix	Approx. Pounds Per Acre	Preferable Soil Areas	Preferable Planting Dates
L	Alta or Kentucky 31 Fescue	30	(1)(2)(3)(4)(5)	Sept. thru Jan.
M	La. White Dutch Clover*	15	(1)(2)(3)(5)	Feb. 15 thru April Sept. thru November

*All clovers and lespedezas shall be inoculated with the proper culture before planting.

717.05 PREPARATION OF SEED BED (Bare Areas). The seed bed shall be prepared by breaking, disking, harrowing, blading, dragging or other approved methods. The soil shall be thoroughly pulverized to a minimum depth of approximately 3 inches and leveled as directed. The surface soil shall be firmed by lightly rolling the area with a cultipacker. If natural firming by rain has occurred, the rolling may be eliminated. All sticks, debris, and other foreign matter must be removed and the soil left in a suitable horticultural condition to receive the seed. If mulch sod, fertilizer, agricultural lime or other materials are required by the specific terms of the contract, such material shall be spread over the areas and incorporated into the soil during the preparation of the seed bed. When required by the plans, newly seeded areas shall be protected against erosion by the placement of vegetative mulch as provided in Section 716.

717.06 PREPARATION OF SEED BED (Grassy Areas). Where seed is to be sown on areas partly covered by grass which has grown during construction, such areas shall be lightly disked or scarified and rolled with a cultipacker as directed.

717.07 SEEDING. Immediately prior to planting, all clovers and lespedezas shall be inoculated with the proper culture for each variety of seed. The inoculated clovers or lespedezas shall then be mixed with other seed in the proportion designated for the various mixtures. If the seed is not planted on the date of inoculation, the inoculation shall be repeated.

All seed shall be planted in the proper season and in the amounts shown in Table I unless written permission is granted for earlier or later plantings. Seed shall be sown with rotary or other mechanical seeders. All seeded areas shall be lightly rolled immediately after seeding so as to press the seed firmly into the soil to prevent drifting.

The application of seed and fertilizer at the same time in a slurry will be permitted provided the correct ratio of seed and fertilizer is used and the operation is satisfactory to the engineer.

717.08 WATERING. After the seed has been planted, the area shall be watered immediately with approved watering tanks unless, in the opinion of the engineer, there is sufficient moisture to eliminate watering. After the first watering operation, other waterings will follow as directed. These watering operations will continue as necessary until the project is finally accepted. The water for seeding purposes shall be obtained from an approved source.

717.09 EQUIPMENT. Equipment shall be the same as required in Subsection 714.08.

717.10 METHOD OF MEASUREMENT. Seed will be measured by the pound, and the quantity to be measured shall be that actually used on the project. For the purposes of measurement, no differentiation will be made for different types or combinations of types of seed furnished. Water will be measured and paid for as provided in Subsection 714.09 and 714.10. Fertilizer and agricultural lime, if required, will be measured and paid for as provided in Subsections 718.05 and 718.06.

717.11 BASIS OF PAYMENT. The number of pounds of seed sown and accepted shall be paid for at the contract unit price.

Payment will be made under:

ITEM NO.	PAY ITEM	PAY UNIT
717(1)	Seeding	Pound

SECTION 718

FERTILIZER AND AGRICUTURAL LIME

718.01 DESCRIPTION. This work shall consist of furnishing and applying commercial fertilizer and agricultural lime at the locations shown on the plans in accordance with these specifications and as directed.

718.02 MATERIALS.

(a) Commercial Fertilizer: Fertilizer shall be an approved brand conforming to the requirements of the Louisiana Department of Agriculture, Fertilizer Division. Fertilizer furnished may be either 8-8-8, 9-9-9, 10-10-10, 12-12-12, 13-13-13, 14-14-14, 15-15-15 or 16-16-16 at the option of the contractor in accordance with Subsection 915.08.

(b) Agricultural Lime: Lime shall consist of ground limestone or seashells conforming to the requirements of Subsection 915.08. The material shall be free of foreign matter and large lumps. The material may be delivered to the job site either in sacks or bulk quantity.

CONSTRUCTION REQUIREMENTS

718.03 APPLICATION.

(a) Commercial Fertilizer Application: Fertilizer shall be uniformly broadcast over the area to be fertilized either by hand or machine methods. Unless otherwise provided, the approximate rate of broadcast fertilizer per acre shall be as follows.

Type	Pounds Per Acre
8-8-8	1,000
9-9-9	889
10-10-10	800
12-12-12	667
13-13-13	615
14-14-14	571
15-15-15	533
16-16-16	500

The rate per acre may be increased or decreased as directed.

Fertilizer shall be applied as indicated in Subsections 714.05, 715.08 or 717.05, or as directed.

When fertilizer is applied following surface dressing, it shall be thoroughly incorporated in the soil by light disking or harrowing. Fertilizer may be applied just before final disking or harrowing during the process of surface dressing or, if dressed by hand, it may be applied just before final raking and leveling.

(b) Agricultural Lime Application: Liming, when required, shall be applied to correct the acid conditions encountered in several soil areas to aid in the establishment of a satisfactory grass cover. Soil Areas 2, 3, 4 and 5 as described in Subsection 717.04 are the areas that will normally be specified for liming.

Agricultural lime shall be spread uniformly over the area to be limed at the rate of two tons per acre with an approved spreader. The lime must be applied prior to seeding and may be applied in conjunction with the fertilizer. Several passes may be required to obtain the desired application rate. Soon after application, the entire area must be disked, harrowed, or rototilled in order to incorporate the lime or lime-fertilizer into the top 3 to 6 inches of the soil.

718.04 EQUIPMENT. Required mechanical and hand spreaders, and tillage equipment.

718.05 METHOD OF MEASUREMENT.

(a) Commercial Fertilizer: Fertilizer will be measured by the pound, and the quantity to be measured shall be that actually used on the project. The estimated quantity shown on the plans and in the proposal is based on the use of type 8-8-8 fertilizer.

Should the contractor elect to use any of the other types shown herein, the quantity actually used shall be measured and such quantity multiplied by the factor given below for the type used to obtain the quantity for payment.

Type	Factor
9-9-9	1.125
10-10-10	1.25
12-12-12	1.5
13-13-13	1.625
14-14-14	1.75
15-15-15	1.875
16-16-16	2.0

(b) Agricultural Lime: Agricultural lime shall be measured by the ton, and the quantity to be measured will be that actually used on the project.

718.06 BASIS OF PAYMENT.

(a) Commercial Fertilizer: The number of pounds of fertilizer placed and accepted, measured as provided above, shall be paid for at the contract unit price.

(b) Agricultural Lime: The number of tons of lime placed and accepted, measured as provided above, shall be paid for at the contract unit price.

Payment will be made under:

ITEM NO.	PAY ITEM	PAY UNIT
718(1)	Fertilizer	Pound
718(2)	Agricultural Lime	Ton

SECTION 719

JUTE MATTING

719.01 DESCRIPTION. This work shall consist of furnishing and installing jute matting for stabilization of soils on slopes and ditches where shown on the plans.

719.02 MATERIALS. Materials shall meet the requirements of the following Subsections of Part IX, Materials.

Jute Matting	915.15
Staples	915.16

CONSTRUCTION REQUIREMENTS

719.03 GENERAL. The jute matting shall be placed immediately after seeding and mulch sodding operations have been completed except for final rolling.

Beginning at the upgrade end, the matting shall be laid out flat, parallel to, and in the direction of the flow of water. When more than one strip is required to cover the area, they shall overlap on the sides at least 4 inches and the ends shall overlap at least 12 inches, with the upslope sections on top.

The matting shall be spread evenly and smoothly and shall be in contact with the soil or mulch sod at all points.

The upgrade end of each strip shall be buried to a depth of not less than 6 inches in a slot perpendicular to the ground, with the soil tamped firmly against it.

In ditches and on slopes, check slots or junction slots shall occur at 50 foot intervals as shown on the plans or as otherwise directed. Edges of jute matting shall be buried around the edges of catch basins and other structures by placing a tight fold of the matting at least 6 inches vertically into the soil.

719.04 STAPLING. Matting shall be tightly held to the ground by vertically driven staples. Furnishing and installing staples shall be included in price bid on jute matting. Staples shall be spaced not more than 3 feet apart in 3 rows for each strip, with 1 row along each edge and 1 row alternately spaced in the center. On the overlapping edges of parallel strips, staples shall be spaced not more than 2 feet apart. At all anchor slots, junction slots, and check slots, staples shall be spaced not more than 6 inches apart.

719.05 ROLLING. After installation is complete, the jute matting shall be firmly embedded in the soil or mulch sod surface by tamping or rolling with an approved roller. Rolling shall be accomplished without damage to the matting and the established grades. Matting shall be pressed firmly into the soil or mulch sod and be nearly flush with the ground surface over the entire area.

719.06 MAINTENANCE AND REPAIRS. Jute matting shall be repaired immediately if damaged. Soil in any damaged area shall be restored to original grade and shall be re-fertilized or re-sodded or re-seeded as originally specified. No payment shall be made for such areas repaired.

719.07 EQUIPMENT. Equipment shall include the following:

(a) Approved smooth wheel hand sod roller.

(b) Necessary hammers, rakes and other hand tools.

719.08 METHOD OF MEASUREMENT. The quantity of jute matting shall be measured by the square yard complete in place.

719.09 BASIS OF PAYMENT. Jute matting placed and accepted shall be paid for at the contract unit price.

Payment will be made under:

ITEM NO.	PAY ITEM	PAY UNIT
719(1)	Jute Matting	Square Yard

SECTION 720

FIBER GLASS ROVING

720.01 DESCRIPTION. This work shall consist of furnishing and installing fiber glass roving and asphalt for stabilization of soils on slopes and in ditches where shown on the plans or as directed by the engineer.

720.02 MATERIALS.

(a) Fiber Glass Roving: This material shall meet the requirements of Subsection 915.20.

(b) Asphalt Material: The asphalt furnished shall be either asphalt cement grade AC-8 or an approved emulsified asphalt, all meeting the requirements of Section 902.

CONSTRUCTION REQUIREMENTS

720.03 GENERAL. The fiber glass roving shall be applied over the designated area within 24 hours after the normal seeding operations have been completed.

The fiber glass roving shall be spread uniformly over the designated area to form a random mat of continuous glass fibers at the rate of from 0.25 to 0.35 pounds per square yard. This rate may be varied as directed by the engineer.

The fiber glass roving shall be anchored to the ground with the asphaltic material applied uniformly over the glass fibers at the rate of from 0.25 to 0.35 gallons per square yard. This rate may be varied as directed by the engineer.

The upgrade end of the lining shall be buried to a depth of one foot to prevent undermining. The above instructions for slope and ditch protection may be varied by the engineer to fit the field conditions encountered.

720.04 MAINTENANCE AND REPAIRS. The lining shall be repaired immediately, if damaged due to the contractor's operations. Soil in any damaged areas shall be restored to original grade, refertilized and reseeded if originally specified, all at no additional cost to the Department.

720.05 EQUIPMENT. Equipment shall include the following:

(a) Pneumatic ejector capable of applying fiber glass roving at the rate of 2 pounds per minute (approximately 8 square yards per minute).

(b) Air compressor capable of supplying 40 cfm at 80 to 100 psi. Acceptable air hoses necessary for supplying air to areas not accessible to the compressor.

(c) Approved asphaltic material distributor with necessary hoses and hand spray bar for working on slopes and other areas not accessible to the distributor.

720.06 METHOD OF MEASUREMENT. Fiber glass roving will be measured by the pound, and the quantity to be measured will be that actually used on the project.

The asphalt cement (AC-8) or emulsified asphalt will be measured by the gallon at the temperature of 60°F in accordance with temperature volume correction, Tables II and III given in Subsection 505.11. The quantity of asphalt to be measured will be that actually used on the project.

720.07 BASIS OF PAYMENT. The accepted quantities of fiber glass roving and asphalt material will be paid for at the respective contract unit prices.

If the asphalt material does not conform to the specifications, the final test results for the material taken at the point of delivery will be applied to the appropriate acceptance schedule for price adjustment, and any adjustment in unit price will be made as specified.

Payment will be made under:

ITEM NO.	PAY ITEM	PAY UNIT
720(1)	Fiber Glass Roving	Pound
720(2)	Asphaltic Material	Gallon

SECTION 721

ASPHALT MULCH

721.01 DESCRIPTION. *This work shall consist of furnishing* and placing asphalt on areas that have been seeded or mulch sodded as shown on plans or directed by engineer.

721.02 MATERIALS. The asphalt mulch used shall be an approved emulsified asphalt meeting the requirements of Section 902.

CONSTRUCTION REQUIREMENTS

721.03 GENERAL. Asphalt mulching shall follow seeding or mulch sodding operations as soon as possible in order to protect such areas from erosion. If the areas to receive asphalt mulch have not been sufficiently moistened by rainfall, these areas should be watered to the satisfaction of the engineer. Asphalt shall be spread with a mechanical spreader equipped with approved boon or hand spray nozzles.

721.04 SPREADING RATES. Asphalt shall be spread over the surface of the newly seeded or mulch sodded areas at the rate of 0.2 to 0.3 gallons per square yard. When required, the asphalt shall be diluted with water in such proportions as designated by the engineer; however, payment will be made only for the asphalt used.

721.05 METHOD OF MEASUREMENT. The asphalt mulch will be measured by the gallon at a temperature of 60°F in accordance with Temperature Volume Correction, Table III given in Subsection 505.11. The quantity of emulsified asphalt to be measured will be that actually used on the project. No measurement or payment will be made for water used in the emulsion.

721.06 BASIS OF PAYMENT. The asphalt mulch placed and accepted will be paid for at the contract unit price.

If the emulsified asphalt material does not conform to the specifications, the final test results for the material taken at the point of delivery will be applied to the appropriate acceptance schedule for price adjustment, and any adjustment in unit price will be made as specified.

Payment will be made under:

ITEM NO.	PAY ITEM	PAY UNIT
721(1)	Asphalt Mulch	Gallon

SAMPLE SPECIFICATIONS

915.20 FIBER GLASS ROVING.

(a) Description: This specification covers a continuous fiber glass roving used in combination with asphalt or other cementitous materials to control erosion on newly seeded slopes and drainage channels.

(b) General Requirements: The material shall be formed from continuous fibers drawn from molten glass, coated with a chrome-complex sizing compound, collected into strands and lightly bound together into roving without the use of clay, startch or like deleterious substances. The roving shall be wound into a cylindrical package approximately 1 foot high in such a manner that the roving can be continuously fed from the center of the package through an ejector driven by compressed air and expanded into a mat of glass fibers on the soil surface. The material shall contain no petroleum solvents or other agents known to be toxic to plant or animal life.

(c) Detailed Requirements: The fiber glass roving shall conform to these detailed requirements:

Property	Limits	Test Method
Strands/Rove	56-64	End Count
Fibers/Strand	184-234	
Fiber Diameter, in. (Trade Designation-G)	0.00035-0.0004	ASTM D 578
Yards/lb. of Strand	13,000-14,000	ASTM D 578
Yards/lb. of Rove	210-230	ASTM D 578
Organic Content, percent max.	0.75	ASTM D 578
Package Weight, lbs.	30-35	ASTM D 578

SECTION 902

BITUMINOUS MATERIALS

902.01 GENERAL. The asphalt shall be prepared by the refining of petroleum. It shall be uniform in character and shall not foam when heated to 350°F.

All storage tanks, piping, retorts, booster tanks, distributors and other equipment used in delivering, storing or handling bituminous materials shall be kept clean and in good operating condition at all times and shall be operated in such manner as to avoid any possible contamination of the contents with foreign materials.

All final test results for the bituminous materials shall be applied to the proper schedule for conformance to the specifications. Any deviation from the specifications will result in an adjustment in unit price, and any adjustment in unit price shall be made as specified.

Schedules No. 1, 2, 3, 4, 5, 6, 7 and 8 shall be used for the purpose of adjusting the appropriate unit prices of bituminous materials. The adjustment in pay for bituminous materials shall be applied only to samples taken at the point of delivery. All samples taken at the refinery shall be in accordance with the specification requirements. Should the sample fail to meet these requirements, the material will be rejected.

The intent of adjustments in pay for point of delivery samples is to allow partial payment for bituminous materials which, in the judgement of the engineer, are satisfactory for use in the work and will serve the purpose intended, but which do not conform to the specifications in every detail.

In the event the engineer finds the bituminous materials not conforming to the requirements listed under 100 percent pay have resulted in an inferior or unsatisfactory product, the materials shall be removed and replaced or otherwise corrected by and at the expense of the contractor.

If the test results are such that a penalty would result from more than 1 of the test values, only the price adjustment for the greatest reduction shall apply.

902.02 ASPHALT CEMENT. Whenever samples of AC-3 and AC-5 taken at the point of delivery or from the hot mix plant storage tanks do not meet the specification requirements as shown in Schedule No. 1, then an adjustment in unit price shall be made according to Schedule No. 1 provided the material is performing satisfactorily.

Whenever samples of AC-8 taken at the point of delivery do not meet the specification requirements as shown in Schedule No. 2, then an adjustment in unit price shall be made according to Schedule No. 2 provided the material is performing satisfactorily. All testing of asphalt cement, unless otherwise directed, shall be in accordance with the test methods given in Schedules No. 1 and 2.

902.03 EMULSIFIED ASPHALT. Whenever samples of anionic emulsified asphalts RS-1 and RS-2 taken at the point of delivery do not meet the specification requirements as shown in Schedule No. 3, then an adjustment in unit price shall be made according to Schedule No. 3 provided the material is performing satisfactorily.

Whenever samples of SS-1 and SS-1h anionic emulsified asphalts taken at the point of delivery do not meet the specification requirements as shown in Schedule No. 4, then an adjustment in unit price shall be made according to Schedule No. 4 provided the material is performing satisfactorily.

Whenever samples of MS-2 (EA-4) anionic emulsified asphalts taken at the point of delivery do not meet the specification requirements as shown in Schedule No. 5, then an adjustment in unit price shall be made according to Schedule No. 5 provided the material is performing satisfactorily.

Whenever samples of cationic asphalt RS-3K and quick-set emulsion for Slurry Seals taken at the point of delivery do not meet the specification requirements as shown in Schedule No. 6, then an adjustment in unit price shall be made according to Schedule No. 6 provided the material is performing satisfactorily.

All testing of emulsified asphalts, unless otherwise specified shall be in accordance with the test methods given in Schedules No. 3, 4, 5 and 6.

902.04 CUTBACK ASPHALT. Whenever samples of cutback asphalts taken at the point of delivery do not meet the specification requirements as shown in Schedule No. 7 for medium curing or Schedule No. 8 for rapid curing, then an adjustment in unit price shall be made according to Schedules No. 7 or 8 for medium curing or rapid curing cutback asphalts respectively provided the material is performing satisfactorily.

All testing of cutback asphalts, unless otherwise specified, shall be in accordance with the test methods given in Schedules No. 7 and 8.

902.05 UNDERSEALING ASPHALT. Whenever samples of the undersealing asphalt taken at the point of delivery do not meet the specification requirements as shown in Schedule No. 9, then an adjustment in unit price shall be made according to Schedule No. 9 provided the material is performing satisfactorily.

All testing of undersealing asphalt shall be in accordance with the test methods given in Schedule No. 9.

APPENDIX B

Field Tests of Temporary Ditch Liners

Ditch Liner Test
Fiber Glass Roving

Test No. 1-FGR Test Installation Date: Oct. 25, 1965

Location: District 62 La. St. Hwy. 441 Control Section 260-10

Orientation: Watershed located on west side of north-south highway

Watershed Area (see dimensions in Fig. 2): 0.75 acres

Length of Channel Test Section: 450 feet

Width of Channel Test Section: 18 feet

Slope of Channel Test Section: approximately 5%

Increase in Cross sectional Area of Ditch by Erosion since 1964: 1.2 square feet

Type of Soil: Lexington Silty Clay Loam

Rate of Lime Applied: 2 tons/acre

Rate of Fertilizer Applied: N-120 #/acre P-80 #/acre K-60 #/acre

Seed Rate: Channel - 9¼ #/acre KY - 31 Fescue, 9¼ #/acre NK - 37 bermudagrass 9¼ #/acre Common bermudagrass. Backslope--10#/acre Weeping lovegrass 16 #/acre NK - 37 bermudagrass 16 #/acre Common bermudagrass

Application Rate of Fiber Glass Roving: Channel 0.25 #/sq. yd.

Backslope 0.20 #/sq. yd.

Application Rate of Asphalt: Channel and backslope 0.1 gal./sq.yd.

Peak Discharge During Critical Period: 2.25 c.f.s.

Comments: Due to the late planting date, the Ky-31 fescue was the only grass that germinated and grew. The liner successfully prevented erosion during the critical period while the fescue was maturing.

The fiber glass roving prevented erosion on the backslope until the entire area was overseeded with a combination of 6 #/acre of NK - 37 bermudagrass and 6 #/acre of Common bermudagrass in April, 1966.

Figure B-2 shows the channel before the test. This roadside was reworked in 1959. The extent of the erosion that has occurred since that time is evident.

Figure B-3 shows the liner in place just after a light rain on November 5, 1966. Figure B-4 shows the channel in September, 1966 after the permanent grass liner had matured.

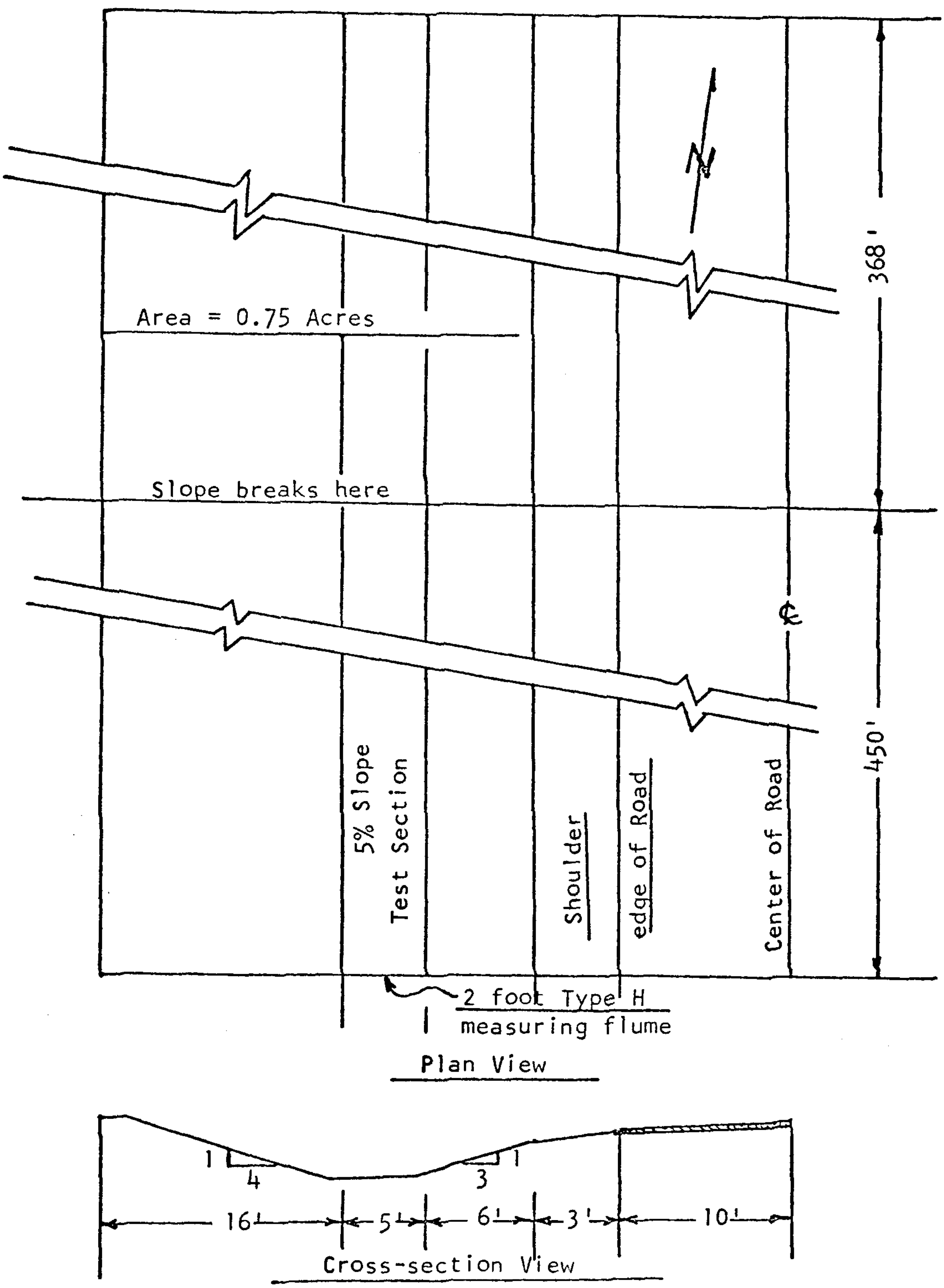

Figure B-1 Watershed No. 1-FGR
Louisiana State Highway 441
Control Section 260-10

Figure B-2 Test Channel No. 1-FGR before reworking.

Figure B-3 Test Channel No. 1-FGR lined with fiber glass roving and asphalt tack. A light rain had just stopped.

Figure B-4 Test Channel No. 1-FGR with permanent grass liner established with aid of fiber glass roving.

Ditch Liner Test
Fiber Glass Roving

Test No. 2-FGR Test Installation Date: April 5, 1966

Location: District 62 La. St. Hwy. 441 Control Section 260-10

Orientation: Channel located on east side of north-south highway

Watershed Area (see dimensions on Fig. 6): 0.75 acres

Length of Channel Test Section: 450 feet

Width of Channel Test Section: 9 feet

Slope of Channel Test Section: approximately 5 %

Increase in Cross sectional Area of Ditch by Erosion since 1964: 1.4 square feet

Type of Soil: Lexington Silty Clay Loam

Rate of Lime Applied: 2 ton/acre

Rate of Fertilizer Applied: N-120 #/acre P-80 #/acre K-70 #/acre

Seed Rate: Channel 9 #/acre NK-37 bermudagrass 9#/acre Common bermuda. Backslope 9#/acre Common bermudagrass 5#/acre Weeping lovegrass

Application Rate of Fiber Glass Roving: 0.5 #/sq. yd.

Application Rate of Asphalt: 0.25 gal./sq. yd. AC-8

Peak Discharge During Critical Period: 4.8 c.f.s.

Comments: This channel was lined with a heavier lining than the previous channel because higher discharges were expected during the critical period of establishment.

Two days after the liner was installed, an intense spring storm caused a discharge of 4.8 c.f.s. to occur. The liner was damaged along the backslope side because it did not extend as far up the backslope as it should have.

Seed were broadcast over the damaged areas and a light application of fiber glass roving and EA-4 asphalt were applied over the damaged area and further up to backslope.

Since that time no further erosion has occurred. The channel has a permanent grass liner at this date.

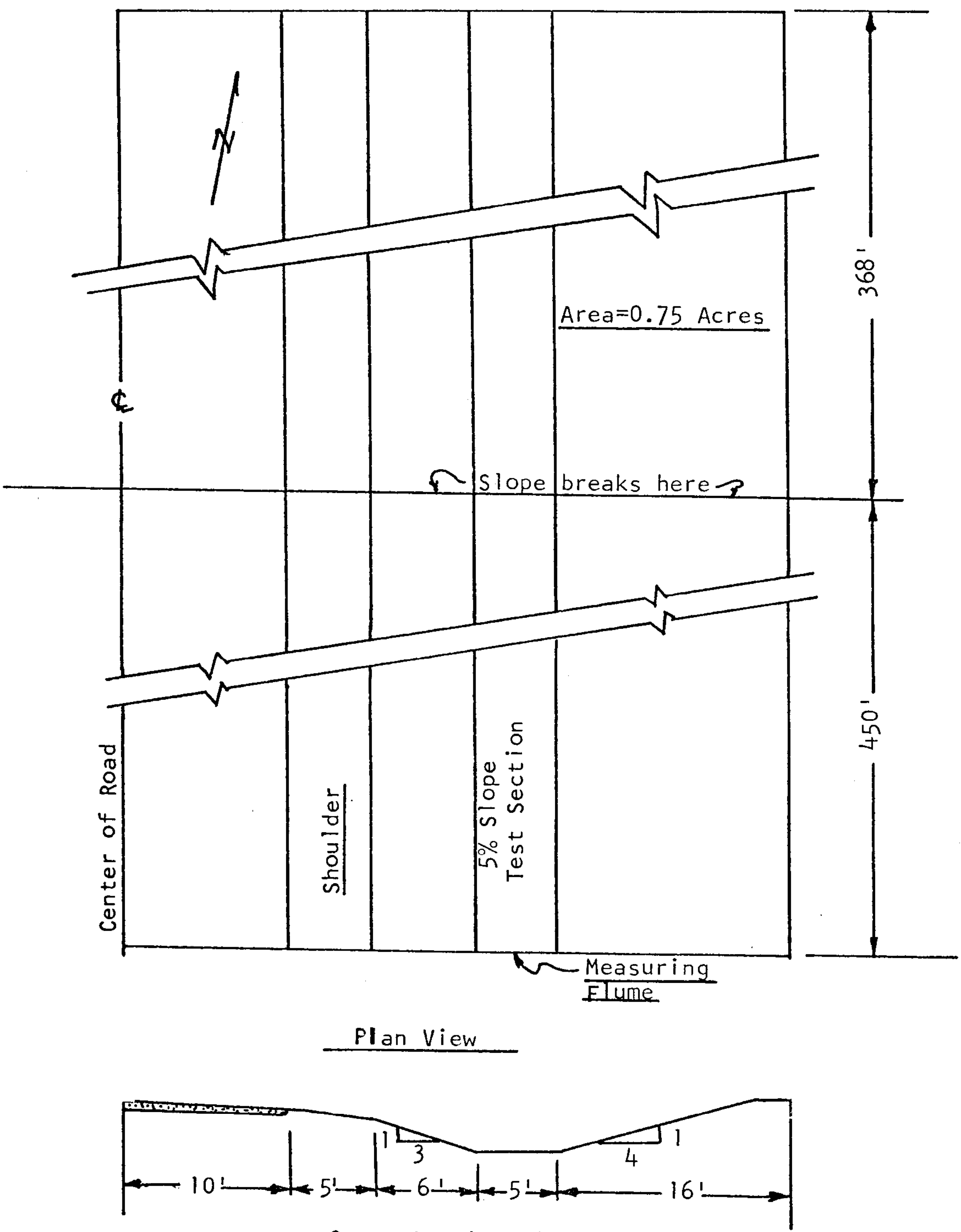

Figure B-5 Watershed No. 2-FGR
Louisiana State Highway 441
Control Section 260-10

Ditch Liner Test
Fiber Glass Roving

Test No. 3-FGR   Test Installation Date: June 23, 1966

Location: District 62 La. St. Hwy. 37 Control Section 254-5

Orientation: Watershed located on south side of east-west highway

Watershed Area (see dimensions on Fig.B-6) 1.72 acres

Length of Channel Test Section: 550 feet

Width of Channel Test Section: 12 feet

Slope of Channel Test Section: approximately 3%

Increase in Cross Sectional Area of Ditch by Erosion since 1964: 0.8 square feet

Type of Soil: Providence Silty Clay Loam

Rate of Lime Applied: 3 tons per acre

Rate of Fertilizer Applied: N-120 #/acre P-100 #/acre K-50 #/acre

Seed Rate: 10 #/acre Common bermudagrass 5 #/acre NK-37 bermudagrass 25 #/acre Pensacola bahiagrass

Application Rate of Fiber Glass Roving: Center section 0.75 #/sq. yd. channel sides and lower backslope 0.25 #/sq. yd.

Application Rate of Asphalt: Center section 0.5 gal./sq. yd. AC-8 channel sides and lower backslope 0.1 gal./sq.yd.

Peak Discharge During Critical Period: 5.0 c.f.s.

Comments: This channel was used for another test of four types of ditch liners which were pinned to the soil. This previous test was washed out by a discharge of 5.65 c.f.s. which occurred on June 16, 1966, just after the test had been installed. Most of the erosion occurred in the center section of the 5-foot bottom.

This eroded area was reshaped to form a small U-shaped channel 0.5 feet deep by 2.0 feet wide in the center of the large channel. This center section was lined with the heavier rate of fiber glass roving and asphalt in order to form a permanent liner in the center of a grassed channel.

The lighter application of fiber glass roving and EA-4 asphalt allowed the grass to grow up to the edge of the permanent liner. Some grass has encroached over the permanent liner. This is desirable for this type of liner.

This test section is located in open range and cattle have used the center section of channel continuously without damaging it.

Figure B-7 shows the channel before it was reworked. Figure B-8 shows the liner just after a 5 c.f.s. discharge occurred. Figure B-9 shows the channel after the grasslined portions had been established. This last picture was made two months after the test was installed.

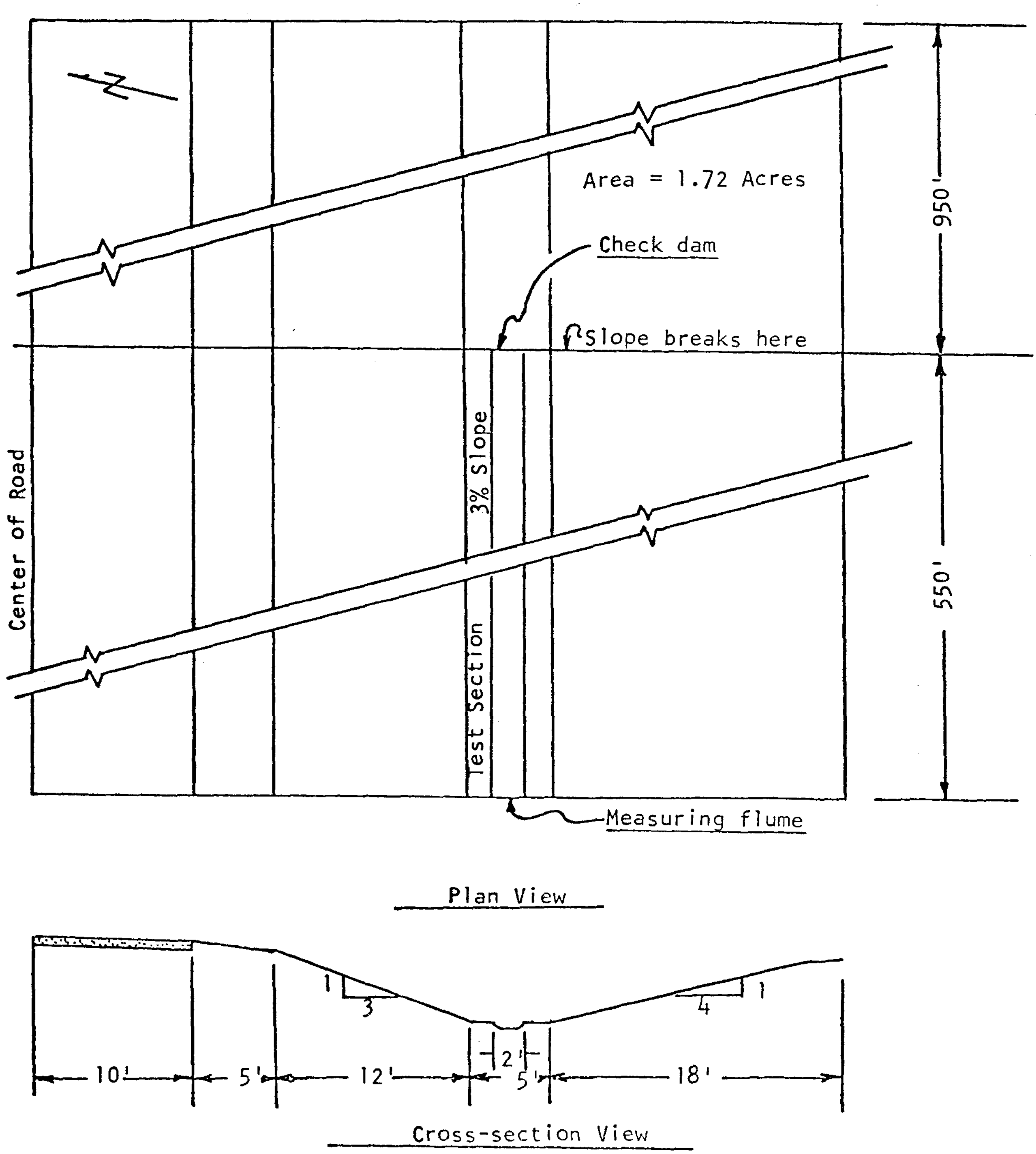

Fig B-6 Watershed No. 3-FGR La. St. Hwy. 37 Control Section 254-5

Figure B-7 Test Channel No. 3-FGR before reworking.

Figure B-8 Test Channel No. 3-FGR lined with fiber glass roving. This liner carried a discharge of 5 c.f.s. the previous day.

Figure B-9 Test Channel No. 3-FGR after permanent grass liner had been established. This picture was made two months after Figure 9.

Ditch Liner Test
Fiber Glass Roving

Test No. 4-FGR   Test Installation Date: August 1, 1966

Location: District 62 La. St. Hwy. 37 Control Section 254-5

Orientation: North and south sides of east-west highway

Length of Channel Test Section: Two 50 foot sections on each side

Width of Channel Test Section: Each section 11 feet wide

Slope of Channel Test Section: approximately 5%

Increase in Cross Sectional Area of Ditch by Erosion since 1964: 1.4 and 1.2 square feet

Type of Soil: Providence Silty Clay Loam

Rate of Lime Applied: 2 tons per acre

Rate of Fertilizer Applied: 117 #-N/acre 100# - P/acre 50# K/acre

Seed Rate: 25# Pensacola bahiagrass/acre and 5# Weeping lovegrass per acre on back slope

Application Rate of Fiber Glass Roving: 0.25 #/sq. yd.

Application Rate of Asphalt: 0.2 gal. EA-4 per sq. yd.

Peak Discharge During Critical Period: No record of discharge

Comments: Three other materials were tested in these channels at the same time. A heavy rain fell the day the ditch was lined and several heavy rains fell during the critical period of establishment. A good stand of Pensacola bahiagrass developed in the section lined with fiber glass roving. No erosion occurred in any of the test sections. Some sediment accumulated from the unprotected backslopes. The test section was in an open range area and was heavily grazed.

Ditch Liner Test
Jute Net

Test No. 2-JN Test Installation Date: August 1, 1966

Location: District 62 La. St. Hwy. 37 Control Section 254-5

Orientation: North and south sides of east-west highway

Length of Channel Test Section: Two 50 foot sections on each side

Width of Channel Test Section: Each section 11 feet wide

Slope of Channel Test Section: approximately 5%

Increase in Cross Sectional Area of Ditch by Erosion since 1964: 1.4 and 1.2 square feet

Type of Soil: Providence Silty Clay Loam

Rate of Lime Applied: 2 tons per acre

Rate of Fertilizer Applied: 117# N/acre 100# P/acre 50# K/acre

Seed Rate: 25 #/acre Pensacola bahiagrass and 5 #/acre Weeping lovegrass on backslope

Installation Data: Jute net installed according to specifications

Peak Discharge During Critical Period: No record of discharge

Comments: Three other liners were tested in these channels at the same time.

Several heavy rains fell during the critical period. A good stand of Pensacola bahiagrass developed in the test section. No erosion occurred. Some sediment was accumulated from the backslopes which were not mulched.

The test sections are in an open range area which is heavily grazed.

Ditch Liner Test
Fiber Glass Mat

Test No. 1-FGM Test Installation Date: July 8, 1965

Location: District 62 La. St. Hwy. 37 Control Section 254-5

Orientation: South side of east-west highway

Watershed Area: 0.69 acre

Length of Channel Test Section: 255 feet

Width of Channel Test Section: 14 feet

Slope of Channel Test Section: Approximately 3%

Increase in Cross Sectional Area of Ditch by Erosion since 1964: 2.1 square feet

Type of Soil: Providence Silty Clay Loam

Rate of Lime Applied: 2000# hydrated lime per acre (ditch bottom only)

Rate of Fertilizer Applied: 117# N/acre 100# P/acre 50# K/acre

Seed Rate: 12# Common bermudagrass and 6# NK-37 bermudagrass/acre

Installation Data: Fiber glass mat rolled out, pinned and tacked with large drops of EA 4 Asphalt Emulsion (approx. 0.2 gal./sq. yd.)

Peak Discharge During Critical Period: 4.3 c.f.s.

Comments: No erosion occurred in the test section. The asphalt held the mat firmly against the ground and allowed the grass to grow through the mat. This area was open range and there was some minor damage caused by cattle walking over the test section. The ditch bottom has a well developed permanent liner. There are some bare eroded spots on the backslope where there was no lime or mulch applied.

Ditch Liner Test
Fiber Glass Mat

Test No. 2-FGM Test Installation Date: August 1, 1966

Location: District 62 La. St. Hwy. 37 Control Section 254-5

Orientation: North and south sides of east-west highway

Length of Channel Test Section: Two 50 feet sections on each side

Width of Channel Test Section: Each section 11 feet wide

Slope of Channel Test Section: Approximately 5%

Increase in Cross Sectional Area of Ditch by Erosion since 1964: 1.4 and 1.2 square feet

Type of Soil: Providence Silty Clay Loam

Rate of Lime Applied: 2 tons/acre

Rate of Fertilizer Applied: 117# N/acre 100# P/acre 50# K/acre

Seed Rate: 25# Pensacola bahiagrass/acre and 5# Weeping lovegrass/acre on backslope

Installation Data: Fiber glass mat rolled out, partially pinned and tacked with large drops of EA-4 (0.2 gal./sq. yd.)

Peak Discharge During Critical Period: No record of discharge

Comments: Three other materials were tested in these channels at the same time. Several heavy rains fell during the critical period. The liner prevented erosion while a good stand of Pensacola bahiagrass developed. The test section was in an open range area which was heavily grazed.

Ditch Liner Test
Excelsior Mat

Test No. 1 EM   Test Installation Date: August 1, 1966

Location: District 62 La. St. Hwy. 37 Control Section 254-5

Orientation: North and south sides of an east-west highway

Length of Channel Test Section: Two 50 feet sections on each side

Width of Channel Test Section: Each side 11 feet wide

Slope of Channel Test Section: Approximately 5%

Increase in Cross Sectional Area
of Ditch by Erosion since 1964: 1.4 and 1.2 square feet

Type of Soil: Providence Silty Clay Loam

Rate of Lime Applied: 2 tons per acre

Rate of Fertilizer Applied: 117 # N/acre 100 # P/acre 50 # K/acre

Seed Rate: 25# Pensacola bahiagrass/acre 5# Weeping lovegrass/acre on backslope.

Installation Data: Material rolled out and pinned according to manufacturer's specifications

Peak Discharge During Critical Period: Not recorded

Comments: Three other materials were tested in these channels at the same time.

Several heavy rains fell during the critical period. The liner prevented erosion and accumulated sediment from the backslopes. A very poor stand of grass developed in the sections covered by this liner.