Final Report

HR-171

Evaluation of Crushed Limestone Rock as a Mulch Material

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The Effectiveness of a Limestone Aggregate Covering on Highway Back Slopes in Controlling Erosion and in Establishing Plant Cover

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Introduction

Earthen fills and back slopes resulting from highway building and other construction projects pose problems with respect to erosion stabilization and establishing vegetation cover. Sediments from such slopes create stream pollution while the erosion itself results in maintenance problems. Furthermore, adverse conditions aggravated by erosion prevent satisfactory establishing of vegetative cover.

Any unvegetated steep slope of soil material is subject to severe erosion damage at any time that rainfall exceeds the infiltration rate of the soil. Erosion rates of 339 tons per acre per year were measured on bare road cuts in Georgia (4). In a rainfall simulator study on a 20 percent 35-foot-long slope a soil loss of 40 tons resulted from a 5 inch rain applied over a 2 hour period (15). In another test on a 12 percent, 35-foot-long slope, a 5 inch rain applied over a 2 hour period resulted in a 54 ton per acre loss.

A dense vegetative cover is very effective in controlling erosion but even with optimum weather and soil conditions there is a delay of about 10 weeks between seeding and the establishment of a vegetative cover. Under actual field conditions, 3 months to a year may elapse between completion of construction and establishment of a vegetative cover.

Various types of mulches are used to protect the soil from erosion during this seedling establishment period and many more mulching materials have been studied. Vegetative mulches include straw (1)(3)(11)(13)(15)(16) and prairie hay (2)(4)(6)(16)(18). Other organic mulching materials include wood chips, excelsior, corn cobs, oat hulls, and wood cellulose (2)(3)(6)(8)(16)(17)(18).

Asphalt, fiber glass, various chemical compounds, and Kraft paper have been used alone and in conjunction with other materials with varying degrees of success (3)(10)(17).

Most of the more effective mulching materials are costly and many are difficult and expensive to apply.

Stones have long been known to be effective as protection against erosion losses. In 1943, in a study in Ohio, removal of surface stones above 2 inches diameter from field plots caused runoff to double and erosion to increase six fold. A 65% stone cover, compared to the normal 18% cover reduced soil water loss by evaporation, decreased soil loss and increased root absorption (9).

On potatoe fields in Maine where 31 percent of the surface was covered with ¼ and ½ inch diameter rock, water runoff and soil erosion was accelerated when the rocks were removed (7). In Mississippe, a gravel mulch was effective in controlling channel erosion (12). In a rainfall simulator study, Meyer et al., 1972 (15) found rock mulch more effective than 2 ton of straw per acre in controlling erosion.

The senior author has observed highway backslope erosion and slumping effectively controlled in New York with a thick layer of large boulders.

Objectives of Study and Location of Test Sites

A research project was initiated early in 1974 to determine the effectiveness of a rock mulch of crushed limestone aggregates in controlling soil losses on highway construction back slopes in Iowa and to find the influence of such treatments on stand establishment of grasses and legumes.

Limestone applications were made and test plots establihsed on two construction sites. The first was located on Highway 141 in Section 20, Township 80 north, Range 25 west in Polk County, Iowa near bridges over Beaver Creek approximately two miles north of the town of Grimes. This location is referred to herein as the Grimes site. The second test was located on Highway 17 in Sections 18 and 19, Township 88 north, Range 26 west in Hamilton County, Iowa approximately three miles south of Webster City. This location is referred to herein as the Webster City site.

Methods

Rock Application

The limestone aggregate was applied using a "Big A" high flotation spreader. This machine was run up and down the slopes at the Grimes site while at the Webster City site it was run along the top and at right angles to the slope. In the latter case spreading was effected by removing the spreader spinner opposite the slope and fashioning a baffle that fed all of the stone to the operating spinner. The spread of the stone thrown down from the top of the slope resulted in a reasonably uniform thickness.

The stone used at the Grimes site was both 1" and 1½" top size commercial concrete stone. The spread rate was varied from 100 to 135 tons per acre. The application varied from slightly less than one stone thick to slightly more than that.

The stone used at the Webster City site was an unwashed commercial stone with a top size of 1" and relatively few fines. This stone was applied slightly more than one stone thick or at a rate of approximately 135 ton per acre.

The stone was applied on prepared slopes at the Grimes site on August 15, 1974 and at the Webster City site on October 17, 1974 in strips approximately 50 feet wide beginning at the top of the slopes and extending down approximately 100 feet. Comparable areas alongside the strips were used as controls. Test plots were established in comparable positions on each of these strips. A description of the test plots is given in Table 1.

Table 1. Description of Test Plots.

No.	Treatment	Facing slope	Soil material	Percent	Back slope length to stake line
Grimes site established August 15, 1974					
IA	Limestone	South	Dickinson loam (clay loam subsoil)	2½:1 (37%)	35 feet
IB	No limestone				
IIA	Limestone	North	Dickinson loam (clay loam subsoil)	2½:1 (37%)	35 feet
IIB	No limestone				
IIIA	No limestone	East	Dickinson loam (clay loam subsoil)	3:1 (32%)	55 feet
IIIB	Limestone	East		3:1 (32%)	60 feet
IIIC	Limestone	Southeast		3:1 (32%)	60 feet
Webster City site, established October 18, 1974					
IA	Limestone	North	Cary till (clay loam subsoil)	4:1 (24%)	15 feet
IB	No limestone				
IC	Limestone	North	Cary till (clay loam subsoil)	4:1 (24%)	15 feet
ID	No limestone				
IIA	Limestone	South	Cary till (silty clay loam subsoil)	2¼:1 (37%)	16 feet
IIB	No limestone				
IIC	Limestone	North	Cary till (sandy clay loam subsoil)	2¼:1 (37%)	17 feet
IID	No limestone				
IIIA	No limestone	West	Cary till (clay loam subsoil)	2¼:1 (37%)	16 feet
IIIB	Limestone				

Evaluations

In order to determine the value of limestone aggregates in back slope control, soil losses were determined, plant populations were estimated and moisture retention caculated. Accurate records of rainfall were kept at each site using Tru-check plastic rain gauges.

Rainfall Records

A Tru-check rain gauge was placed within one mile of each of the two test sites. Co-operating persons read the gauges at specified times daily and took notes to characterize the rainfall. Tables 2 and 3.

Precipitation during the months of September and October was sufficient to characterize the fall season as moderately wet. Heavy rainfall at each site on October 31, 1974 caused some erosion on the test plots.

Rainfall during April, May, and June 1975 was moderate to excessive in amounts and well above normal, creating saturated soil conditions on the test sites. Heavy showers of short duration, however, were apparently not frequent. Heavier rainfall intensified as the season progressed. The saturated soil conditions coupled with comparatively frequent rainfall created more erosion pressure than normal on all plots at each test site.

Soil Loss

The "stake method" was used to determine the surface soil loss as influenced by the application of limestone aggregates. Fourteen twelve-inch garden stakes were driven firmly into the soil eighteen inches apart in rows across the slopes in comparable locations on each test plot. The length of slope to stake line as given in Table 1 and Appendix B is from the top line of the slope. The amount of surface soil loss was measured from marks on the stakes drawn at the original surface line. These measurements were made at the Grimes site on November 6, 1974, May 15, 1975, and July 18, 1975. They were made at the Webster City site on May 5 and July 16, 1975. The accumulated soil losses as of the final reading in July 1975, measured in inches, were averaged for each set of fourteen stakes and calculated to tons per acre. The results are shown in Table 3.

In addition to the surface soil loss, rill or small gully erosion soon became evident as part of the total erosion pattern and increased as the season progressed. In order to attempt to obtain a quantitative figure, even though possibly somewhat subjective, width and depth measurements in inches of these channels were taken along the stake lines.

Table 2. Rainfall.[1/]

Year	Start of record - August 20, 1974 Month	Rainfall in inches
a. Grimes site		
1974	August 27 to 31	.21
	September	1.97
	October	3.70
	November 1 to 10	.60
1975	April 8 to 30	3.57
	May	3.15
	June	6.66
	July	.20
b. Webster City site		
1974	October 25 to 31	1.60
	November 1 to 15	2.29
1975	April 8 to 30	3.85
	May	3.16
	June	9.04
	July	1.78

[1/] For a more complete record see Appendix A.

Table 3. Soil loss sheet erosion as influenced by application of limestone aggregates.[a]

Location	Erosion in tons per acre	
	No rock mulch	Rock mulch
Grimes[1]	176	59**
Webster City[2]	93	8**

[a] For a complete record see Appendix B.

[1] Average of 3 replications.

[2] Average of 5 replications.

Table 4. Rill erosion not reflected in stake measurements.[a]

Location	Erosion in tons per acre	
	No rock mulch	Rock mulch
Grimes[1]	81	22**
Webster City[2]	27	8**

[a] For a complete record see Appendix C.

[1] Average of 3 replications.

[2] Average of 5 replications.

Table 5. Summary of sheet and rill erosion.[a]

Location	Erosion in tons per acre					
	No rock mulch			Rock mulch		
	Sheet	Rill	Total	Sheet	Rill	Total
Grimes[1]	176	81	257	59	22	81
Webster City[2]	93	27	120	8	8	16

[a] For a more detailed record see Appendix C.

[1] Average of 3 replications.

[2] Average of 5 replications.

Erosion was greater at the Grimes site than at Webster City both on treated and untreated plots. Greater erosion probably resulted from longer slopes at Grimes as compared to Webster City and also from somewhat less uniform rock application.

As is shown in tables 3, 4 and 5 the rock mulch was effective in controlling erosion at both sites. The bench-mark stakes gave at least an indication of the magnitude of sheet erosion. As shown in table 3 there was a total of some 176 tons per acre of erosion at Grimes on the untreated plots. The rock mulch reduced sheet erosion to a total of about 59 tons per acre. While this amount of erosion was excessive it is only about 1/3 the quantity on the untreated plots. At Webster City sheet erosion totaled about 90 tons on the untreated plots and this was reduced to 8 tons by the rock mulch.

Some water appeared to run on the Grimes plots from higher ground. Under these conditions the rock mulch could not control soil movement. Essentially all erosion on the rock treated plots at Webster City occurred in one such run-on area.

The stake method of measuring erosion was not adequate for evaluating rill erosion, because most rills formed between the stakes. Width and depth measurements of rills were taken across the stake lines in July 1975. These measurements were converted into average surface deflation estimates and are reported in tables 4 and 5. Rill erosion was reduced by the rock mulch treatment at both sites. Rill erosion was more severe on both treated and untreated plots at Grimes as compared to Webster City. At Grimes rill erosion was reduced from 81 tons per acre to 22 tons per acre by the use of a rock mulch. At Webster City the untreated plots lost 27 tons per acre of soil and the treated plots 8 tons per acre.

The summary as in table 5 may slightly overstate erosion losses as there may be some duplication of reporting under sheet and rill erosion losses. The table was prepared to show the magnitude of erosion losses to which roadsides are subjected during the period of seedling establishment and also to show the effectiveness of the rock mulch.

Plant Stand Estimates

A temporary seeding of winter rye and hairy vetch was made at the Grimes site in August, 1974. A permanent seeding of alfalfa, brome grass, tall fescue, crown vetch and birdsfoot trefoil was made on April 9, 1975.

The back slopes at Webster City were seeded to rye in September 1974 and were seeded by plane in May 1975 to a mixture of alsike clover, birdsfoot trefoil, switch grass and meadow fescue.

Plant stands were estimated by counting the number of plants within a 50 cm square frame. Two random locations above and two below the stake line (erosion bench marks) were measured.

On the temporary seeding at the Grimes site stands of both rye and vetch were thin on all sites but there was a better stand on the untreated plots. As shown in table 6, there were about 4 times the number of plants on the untreated as compared to the mulched plots.

In the permanent seedings at both Grimes and Webster City stands of both legumes and grasses were much better on the mulched plots than on the untreated plots.

In mid July at the time these stand counts were taken, the vegetative cover on the mulched plots at both locations was sufficient to furnish erosion protection against all but the most extreme rainfall.

Note in table 6 that on the unmulched plots at Grimes the grass was a complete failure and there were only 2 alfalfa plants per square foot. Stands in the untreated Webster City plots were better but plant growth in mid July was still inadequate for erosion control.

Table 6. Stands of temporary and permanent seedings as affected by limestone rock mulch

a. Grimes site

1. Temporary seeding as of October 9, 1974

	Plants per square foot	
	No rock mulch	Rock mulch
Winter rye	5.2	1.2
Hairy vetch	4.0	1.3

2. Permanent seeding as of July 18, 1975

	No rock mulch	Rock mulch
Alfalfa	2.1	43.4
Grass	0.0	18.1

b. Webster City site

1. Permanent seeding as of July 16, 1975

	No rock mulch	Rock mulch
Clover	6.4	21.8
Grass	3.2	9.0

Soil moisture

Tensiometers were installed at 6 and 12 inch depths at the Grimes site. When tensiometer readings indicated that a soil moisture deficiency might be limiting plant growth, soil moisture samples were collected and soil moisture determined gravimetrically.

The results at two sampling dates are given in table 7.

Table 7. Soil moisture in upper 8 inches of soil as influenced by a limestone mulch at Grimes, Iowa

	Oct. 1, 1974	Oct. 21, 1974
	Soil moisture as percent by weight	
Grimes site:		
No mulch	7.9	12.2
Rock mulch	12.64	13.2

On October 1 the moisture content of the soil was higher under rock than on the check plot. On October 21 there was no difference in soil moisture on the mulched as compared to the unmulched plots.

During April, May and June 1975 rainfall was high and moisture did not limit plant growth at either site.

Summary and Conclusions

Limestone rock designated as commercial stone, sized 1" to $1\frac{1}{4}$" when applied uniformly at a rate of about 100 to 135 tons per acre is effective in controlling erosion under average Iowa weather conditions on 3:1 highway backslopes in late Wisconsin till that are protected from accumulations of water spilling across the backslope from higher positions.

Plant growth of permanent seeding was better under the rock mulch than on the unmulched ground and by mid July plant growth at both study sites was sufficient under the mulch to be effective in controlling soil erosion.

During the one period of moisture stress during the course of this study, soil moisture percentage was higher under the rock mulch than on the unmulched ground.

Literature Cited

1. Barnett, A. P., E. G. Diseker, and E. C. Richardson. 1967. Evaluation of mulching methods for erosion control on newly prepared and seeded highway backslopes. Agron. J. 59:83-85.

2. Chepil, W. S., N. P. Woodruff, F. H. Siddoway, D. W. Fryrear and D. V. Armbrust. 1963. Vegetative and non-vegetative materials to control wind and water erosion. Soil Sci. Am. Proc. 27(1):86-89.

3. Crabtree, R. J. Effectiveness of different types of mulches in controlling erosion on highway backslopes. Masters Thesis, Iowa State Univ. 1964.

4. Diseker, E. G. and E. C. Richardson. 1961. Roadside sediment production and control. Trans ASAE 4:62-68.

5. Dudeck, A. E., N. P. Swanson, A. R. Dedrick. 1967. Mulches for grass establishment on steep construction slopes. Hiway Rsch. Rec. 206:53-59.

6. Dudeck, A. E., N. P. Swanson, L. N. Mielke and A. R. Dedrick. 1970. Mulches for grass establishment on fill slopes. Agron. J. 62:810-812.

7. Epstein, E., and W. J. Grant. 1966. Rock and crop management effects on runoff and erosion in a potato-producing area. Trans. ASAE 9(6):832-833.

8. Haynie, R. M. and S. S. Karaki. 1963. The earth embankment erosion control study. Report No. CER63SSK26. Colorado State University. Fort Collins. 12 pp.

9. Lamb, J. Jr. and J. E. Chapman. 1943. Effect of surface stones on erosion, evaporation, soil temperature and soil moisture. Jour. ASA. Vol. 35(7): 567-571.

10. Mausbach, M. J., W. D. Shrader and Harold D. Dolling. Roadside erosion research in selected Iowa counties. Twenty-first Short Course on Roadside Development. Ohio Dept. of Trans., Columbus, Ohio 1972. pp. 90-103.

11. McKee, W. H., R. E. Blaser and D. G. Barkley. 1963. Mulches for steep cut slopes. Highway Res. Record 53:35-42.

12. McWhorter, J. C., T. B. Carpenter and R. N. Clark. 1969. Gravel mulch for bermudagrass-lined channels. Info. Sheet 1070. Miss. State Univ., State College, Miss. 2 pp.

13. Meyer, L. D., W. H. Wischmeier and G. R. Foster. 1970. Mulch rates required for erosion control on steep slopes. Soil Sci. Soc. Am. Proc. 34(6):921-931.

14. Meyer, L. D., W. H. Wischmeier and W. H. Daniel. 1971. Erosion, runoff and re-vegetation on denuded construction sites. Trans ASAE 14(1):138-141.

15. Meyer, L. D., C. B. Johnson and G. R. Foster. 1972. Stone and wood-chip mulches for erosion control on construction sites. Jour. Soil and Water Con. 27(6):264-269.

16. N. P. Swanson, A. R. Dedrick, H. E. Weakly, and A. H. R. Haise. 1965. Evaluation of mulches for water-erosion control. Trans. ASAE 8:438-440.

17. Schmidt, Bertie L. Methods of controlling erosion on newly-seeded highway backslopes in Iowa. Iowa State Highway Commission Research Bulletin. 1959.

18. Swanson, N. P., A. R. Dedrick and A. E. Vasleck. 1967. Protecting steep construction slopes against water erosion. Highway Res. Rec. 206:46-52.

APPENDIX A

Rainfall Records
Grimes site

Date	Amount in inches	Type and duration
1974		
August 27	.21	Intermittent
Sept. 2	.52	Intermittent
Sept. 6	.15	Two hours duration
Sept. 12	1.30	Extended
Oct. 6	.36	Showers over 2 hours
Oct 11	.24	Extended showers
Oct 13	.15	Drizzle over 14 hours
Oct 30	.70	Drizzle
Oct. 31	2.25	Medium over 12 hours period
Nov. 3	.10	Intermittent drizzel 12 hours
Nov. 5	.10	Snow and drizzle, 2 hours
Nov. 10	.40	Drizzle and light rain
	6.48	
End of fall records		
1975		
April 8	Light rain, not recorded	
April 13	trace	
April 19	.15	All-day drizzle
April 21	.34	Light showers
April 23	.76	Showers
April 25	.02	Light drizzle
April 27	2.30	Over 8-hour period, heavy at times.
	3.57	
May 2	.16	Light showers
May 6	.50	Thunder showers, heavy at times, 3 hours
May 7	.40	Heavy rain, 3 hours
May 11	.20	Light showers
May 20	.30	Light showers, 4 hours
May 25	.10	Shower
May 28	.51	Light showers
May 29	.57	Scattered showers
May 30	.41	Showers, drizzle 24 hours
	3.15	

June 4	.20	Thunder showers 2 hours
June 9	1.25	Gentle showers over 8-hr pd.
June 11	.66	Drizzle and light showers
June 14	1.50	Two very heavy showers, 15 to 20 minutes
June 16	.38	Medium showers lasting 45 minutes
June 18	1.45	Heavy rain for about 7 hrs.
June 21	.75	Heavy shower for 1 hr.
June 23	.10	Light rain and drizzle
June 24	.08	Light rain and drizzle
June 26	.22	Two light showers 15 min. each
June 28	.07	Light 45 min. shower
	6.66	
July 5	.08	Light shower, 15 min.
July 12	.01	Light shower
July 22	.04	Drizzle, 3 hours
July 23	.07	Light shower
	.20	

Rainfall Records
Webster City Site

1974

Oct. 29	.11	Drizzle, 10 to 12 hours
Oct. 30	.09	Drizzle
Oct. 31	1.40	Heavy rain, 2 hours drizzle 9 hours
Nov. 1	.28	Drizzle
Nov. 5	.03	Light snow, 5 hours
Nov. 10	.23	Light rain
Nov. 11	.05	Light rain
Nov. 14	.10	
	2.29	

End of fall records

1975

Mar. 26	.34	Light rain
Mar. 27	1.07	Snow, sleet and rain
April 8	.50	Drizzle and snow 24 hrs
April 10	.30	Drizzle and snow
April 13	.30	Light rain, 16 hours
April 18	.50	Light rain, 16 hours
April 20	.25	Light rain, 8 hours

April 22	.40	Light rain, 15 hours
April 26	.40	Light rain, 12 hours
April 27	1.20	Showers, 12 hours
	3.85	
May 2	.50	Light to heavy rain, 12 hours
May 3	Trace	
May 4	Trace	
May 6	.30	Light rain, 6 hours
May 7	.15	Light rain, 6 hours
May 11	.50	Light rain
May 22	.13	Heavy rain, 15 min.
May 26	Trace	
May 27	.13	Light rain, 4 hours
May 28	1.25	Light rain, 24 hours
May 29	.05	Light drizzle, 1 hour
May 30	.15	Light drizzle, 6 hours
May 31	Trace	
	3.16	
June 2	.10	Shower, 2 hours
June 3	.40	Shower, heavy at times, 2 hours
June 9	.75	Shower, heavy at times, 10 hours
June 10	.07	Light rain, 4 hours
June 11	.72	Light rain, 24 hours
June 12	.50	Light rain, 12 hours
June 15	1.10	Showers, 24 hours
June 16	1.20	Showers, 24 hours
June 17	.08	Light rain, 10 hours
June 18	1.25	Showers, 12 hours
June 20	1.20	Heavy rain at times
June 23	.20	Light rain, 2 hours
June 24	.17	Light rain, 2 hours
June 26	1.25	Heavy, one inch in 20 min. 3 hours
June 27	.05	Light rain
	9.04	
July 5	.75	
July 20	.25	Light rain, 1 hour
July 21	.40	Light to medium rain, 2 hours
July 22	.20	Light rain, 2 hours
July 31	.18	Light rain, 2 hours
	1.78	

APPENDIX B

Soil Loss As Influenced by Applications of Limestone Aggregates

Grimes Site

Number	Treatment	Length of slope in	Average depth of soil removed in inches	Soil loss in tons per acre
IA	Limestone	35	.43	71.7
IB	No limestone	35	1.11	185.1
IIA	Limestone	35	.34	56.7
IIB	No limestone	35	.52	86.7
IIIA	No limestone	55	1.57	261.7
IIIB	Limestone	60	.36	60.0
IIIC	Limestone	60	.23	38.3

Webster City Site

Number	Treatment	Length of slope in	Average depth of soil removed in inches	Soil loss in tons per acre
IA	Limestone	15	.09	15.0
IB	No limestone	15	.61	101.7
IC	Limestone	15	.09	15.0
ID	No limestone	15	.63	105.0
IIA	Limestone	16	0	0
IIB	No limestone	16	.57	95.0
IIC	No limestone	17	.50	83.3
IID	Limestone	17	0	0
IIIA	No limestone	16	.48	80.0
IIIB	Limestone	16	.05	8.3

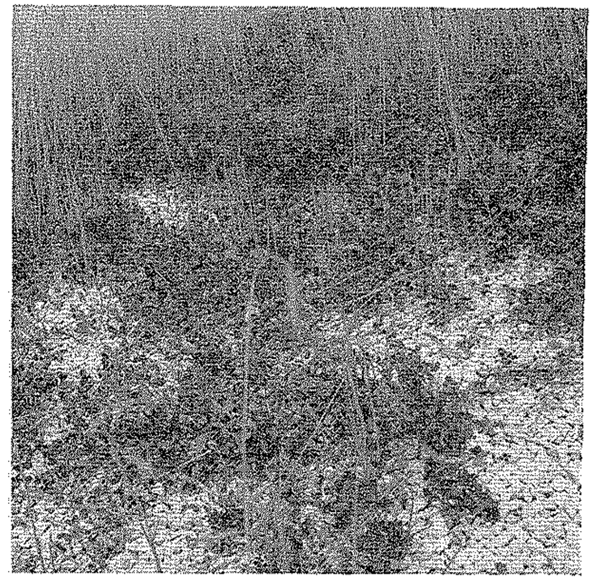
APPENDIX C

Small Gully Erosion as Influenced by Limestone Aggregate Application -- Grimes site

Number	Treatment	Width and depth in inches
		November 6, 1975
IA	Limestone	None
IB	No limestone	1x1, 1x2, 2x2, 2x4, 1x1, 2x3, 1x2, 2x2
IIA	Limestone	1x3, 1x2, 1x4
IIB	No Limestone	2x5, 3x4, 1x1, 1x3, 1x2
IIIA	No Limestone	2x2, 1x1, 1x2, 1x1, 2x2
IIIB	Limestone	None
IIIC	Limestone	None
		May 15, 1975
IA	Limestone	None
IB	No Limestone	2x2, 6x9, 1x1, 1x4, 8x8, 3x2, 4x2, 4x3, 3x3, 2x1, 4x2
IIA	Limestone	1x5, 7x9, 3x5, 6x4, 6x12
IIB	No limestone	2x3, 3x3, 2x2, 3x2, 6x2, 4x1
IIIA	No limestone	6x6, 2x2, 1x2, 1x2, 1x2, 2x2, 1x1, 2x4, 2x3, 2x1
IIIB	Limestone	None
IIIC	Limestone	None
		July 18, 1975
IA	Limestone	None
IB	No limestone	4x12, 8x10, 2x6, 2x3, 4x2, 2x4, 1x1, 1x4, 2x2, 2x1, 1x1, 1x2
IIA	Limestone	8x10, 10x6, 1x4, 5x2, 8x2
IIB	No limestone	10x3, 6x2, 5x3, 8x4, 2x3, 2x2, 2x2, 3x2, 3x2
IIIA	No limestone	8x2, 4x4, 2x2, 1x2, 1x2, 2x2, 1x1, 2x1, 1x2, 2x4, 1x1, 1x1, 2x2
IIIB	Limestone	None
IIIC	Limestone	None
		Webster City Site July 16, 1975
IA	Limestone	None
IB	No limestone	6x2, 2x2, 3x2, 2x2, 1x1, 1x1
IC	Limestone	None
ID	No limestone	6x2, 2x2, 4x1, 4x2, 6x3, 4x2, 6x1, 3x1, 6x2, 7x2, 2x1
IIA	Limestone	None
IIB	No limestone	4x3
IID	Limestone	12x8, 4x4
IIC	No limestone	1x2, 1x2, 3x1, 2x2, 6x4, 3x1, 4x2
IIIA	No limestone	12x1, 3x2, 2x1, 4x2, 3x1
IIIB	Limestone	None

PICTURES

1. Good growth of alsike clover and complete erosion control under a limestone rock mulch at Webster City, August 1, 1975



2. Limestone rock mulch in place with no erosion and fair growth of alsike clover and thin stand of rye at Webster City, August 1, 1975

3. Failure of rock mulch at Grimes site because of run-on of water from higher area. August 1, 1975

4. Severely eroded slope at Grimes site and poor plant stand on unmulched plot. August 1, 1975

5. Average erosion (250 ton/A) on an unmulched plot at Grimes, August 1, 1975

6. Close-up of rill erosion at Grimes site