EROSION PREVENTION DURING HIGHWAY CONSTRUCTION BY THE USE OF SPRAYED ON CHEMICALS

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(The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agencies.)

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SUMMARY

The purpose of this study was to evaluate the erosion inhibiting potential of nine commercial spray on plastic chemicals. All chemicals were also compared with the conventional method of straw tacked with an asphalt emulsion, and with untreated soil. In each case costs of the chemicals were obtained to determine if the most effective chemicals were economically feasible.

In Virginia there are three principal physiographic provinces. The soils in each province are significantly different in composition and erodibility. In each area two highway slopes with a vertical height of 15 to 20 feet and a slope of approximately 2:1 were selected to be tested. It was found that the same chemicals were not the most effective in the different areas. Also, no chemical performed better than the conventional method in any of the three areas. Some of the chemicals in certain soils even promoted erosion since soil treated with these showed greater erosion than the untreated soil.

In the westernmost area, or the Ridge and Valley physiographic province, Petroset SB and Soil Gard were the most effective erosion inhibitors. Petroset SB is relatively expensive compared to Soil Gard and the conventional method. Petroset SB costs between $501 and $803 per acre, while Soil Gard is $195 per acre and the conventional method $130 per acre.

For the soils in the Piedmont physiographic province, none of the chemicals performed well. Aerospray 70 and Curasol AE were the most effective, but performed only slightly better than the untreated soil. Aerospray 70 ranges in cost from $265 to $335 per acre, while Curasol AE costs from $132 to $174 per acre.

In the sandy soils of the Coastal Plain physiographic province, Petroset SB and straight asphalt emulsion were very effective. As mentioned earlier Petroset SB is expensive at $501 to $803 per acre, and asphalt emulsion is $252 per acre. Both are more expensive than, but about equal in effectiveness to, the conventional straw-asphalt method.

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INTRODUCTION

Each year more than a million acres of land in the United States are converted from agricultural use to some type of urban use(1)*. This conversion more often than not entails some type of building or highway construction. During construction, large areas of disturbed soil are exposed to the weather and provide a source of erosion. Much of the material found suspended in rivers and streams, and eventually deposited in lakes and reservoirs, is derived from this source. Studies have shown that sediment yield from construction sites is 10 times greater than from cultivated land in row crops, 200 times greater than from pasture land, and 2,000 times greater than from land in timber(2).

Damage due to erosion on construction sites involves many phases of construction. The damage may be in the form of rilled and gullied slopes, washed-out roads, undercut structures and pipelines, or in many other forms. Repairing of this damage causes increases in construction costs as well as delays in the scheduled work.

It is estimated that because of the sediment problem at least 1.5 billion cubic yards, or 1 million acre-feet, of reservoir capacity is lost in the United States each year(3). The uncontrolled erosion in the US each year is estimated to produce more than 4 billion tons of sediment(3). If one considers all aspects of the sediment problem, the estimated damage exceeds $500 million annually(2). More important to the farmer and the highway department are the soil resources lost by erosion.

Sediment is the greatest single pollutant of streams, ponds, lakes, and reservoirs. When it is carried into watercourses, it often takes with it harmful chemicals and minerals. Salts and nutrients, especially phosphorous, are absorbed into the soil or sediment particles

* Numbers in parentheses refer to entries in the list of references.

and are redissolved into the water when sediment is agitated. The sediment lowers the quality of the water and increases the cost of cleaning the water for municipal and industrial uses. Eventually, most suspended material settles out of the water into a reservoir, lake, or sediment basin. If the material settles in a sediment basin, large quantities of it will necessitate frequent cleaning. If a sediment basin or trap is not constructed, sedimentation will be apt to occur in a reservoir or lake. With additional sediment added to the reservoir or lake each year, the water storage available is reduced. The sediment is injurious to game fish, shell fish, and other small aquatic life on the bottom of the lakes and reservoirs.

Highway construction can be a large contributor to the sediment problem if erosion control measures are not provided. In the US approximately 14% of all roads are in municipalities and contribute very little to the sediment problem. Of the remaining roads, 24% are primary roads and 62% are secondary or rural roads(2). The majority of the sediment is derived from the secondary and rural roads. As mentioned earlier, urban or highway construction causes 10 times more sediment than cultivated land in row crops. A rough idea of the annual amount of the former is given by the fact that it has been estimated that the soil loss from the latter ranges from 10,000 to 70,000 tons per square mile per year, depending upon the soil characteristics, the crops, the topography, and the climatic factors(2).

In order to reduce the sedimentation resulting from the construction of highways, erosion control measures should be provided. It is estimated that it will cost approximately $1,000 per mile on each new construction job to reduce the erosion problem now and in the future(2). However, this initial cost of $1,000 per mile is less than the cost of providing the erosion control measures needed after construction is finished on some troublesome secondary and rural roads. It is estimated that the first investment to reduce the problem on these roads after construction could be between $275 to $15,000 per mile(2). Also, an additional cost of approximately $50 per mile per year for maintenance would be required to keep the erosion control measures in operation(2).

MECHANISM OF SOIL EROSION

Soil erosion is a process in which runoff water, mainly from rainfall, detaches and transports soil particles. Many factors determine the amount of erosion that occurs. Several of the important ones are the rainfall, the vegetative cover, the slope of the land, and the soil type. The amount of erosion occurring depends upon the runoff, which is related to the intensity and the length of time of the rainfall. Also, the soil type, the vegetative cover, and the slope greatly affect the amount of runoff from a particular area. As the slope length and/or angle increases, the runoff from the slope increases and becomes more erosive. On short, steep slopes the water has very little time to be absorbed into the soil, thus there is a rapid runoff and high erosion. Differences in the slope angle have a larger affect on runoff than differences in the slope length. Slope length has less effect on soil erosion when vegetation is present. Since the slope angle is very critical, slopes should never exceed 2:1. With slopes steeper than 2:1, plants are difficult to establish and large volumes of soil may accumulate at the bottom of the slope.

Two other factors directly related to the quantity of runoff are the intensity and the length of time of the rainfall. Long, hard rains place a great amount of water on a slope. The soil becomes saturated, and the excess water causes a heavy runoff. The amount of erosion from a particular slope of a particular soil will naturally increase if either of the two rainfall factors, intensity or duration, increase.

Another important factor affecting the amount of runoff is the soil type. As the granularity of soils increases so does the permeability. The more permeable soils or sands absorb water and thus decrease runoff, until they become highly saturated. For non-cohesive soils like sands the most important factors in determining erodibility are the weight and size of the individual soil particles. For fine-grained or cohesive soils these two factors are not as important as the electrochemical bond between the individual soil particles. The erodibility of these soils depends upon the strength of the electrochemical bonds. After considering the different factors that affect cohesive and non-cohesive soils, one can reason that erodibility increases as the silt content increases. Silt particles are smaller and lighter than sand particles and are not greatly influenced by electrochemical bonds. Conversely, as the sand, clay, or organic matter contents increase the erodibility decreases[5].

CONTROL MEASURES

Soil can be greatly susceptible to erosion even when significant cohesion of the particles is present, if vegetative cover is not provided. Vegetation plays a greater role in retarding erosion than it does in reducing the amount of runoff. Therefore, vegetative cover should be provided as soon as possible on bare areas to prevent fast rates of runoff and erosion. Certain types of plants or grass act as temporary erosion checks, while others are more permanent. Usually employed for temporary cover are rapidly growing plants and grasses, such as annual ryegrass and millet. Another erosion control measure used when seeds are sown is straw mulching. The mulch acts as an erosion control until the grass and plants are adequately established. Besides being a good erosion check, the mulch holds the moisture in the soil to stimulate germination of the seeds.

There are two other general erosion and sediment control measures besides vegetative cover. One of the measures, widely used by highway departments, is mechanical controls. These controls are used to reshape the land to intercept, divert, convey, or retard runoff. Several examples of these measures are basins to catch sediment from upstream erosion, diversion channels to prevent runoff from going over critical slopes, paved ditches to prevent erosion along pavements and beside hills, and berms to divert runoff from certain areas.

The other erosion and sediment control measure, the one evaluated in the study reported here, involves the use of chemicals. This type of erosion control has evolved relatively recently and has not been used widely. Several state highway departments have accepted and are using some of the plastic type chemicals on the market. Research is being conducted on these chemicals by several organizations other than the Virginia Highway Research Council. If the chemicals do as well as advertised, they will be very helpful in controlling erosion on a temporary basis. They could be used when seeding is not favorable or when a contractor has only a small exposed area and would rather wait until a larger area is ready for seeding. The chemicals, usually in liquid form, are applied to the slope by spraying. After drying, they act as a slightly permeable plastic coating. The coating holds the soil particles together while shedding most of the runoff. However, some of the runoff is allowed to absorb into the soil to provide moisture for germination of the seeds. The coating holds the moisture in the soil during warm weather and thus accelerates seed germination.

SITE SELECTION

In a study of this nature there are many variables to consider. In order to accurately evaluate a product, one must reduce the number of variables to a minimum; ideally to just one. In this study several of the variables considered were: 1) soil type, 2) slope height, 3) slope angle, 4) rainfall, which is uncontrollable, and 5) types of chemicals.

Prior to selecting the sites, it was decided that only earth fills with a vertical height of approximately 15 to 20 feet would be included. The experiments were limited to fills for several reasons. First, there would likely be different results obtained from cuts than from fills. In fills the natural soil structure has been destroyed, thus creating a more erosive condition than would occur on cuts,where the slopes may be tightly consolidated. It was decided to limit the vertical height of the fill so that experiments in one locality could be compared with those in other localities.

Besides limiting the vertical height of the fills, the slope angle was kept approximately 2:1. As mentioned earlier, plants are difficult to establish on steeper slopes and soil tends to migrate downslope easily. With most fill slopes in Virginia being close to 2:1, this was the most practical angle to use.

Another very important variable is the type soil on which the chemicals are applied. In Virginia there are three major geological areas. In the Valley and Ridge province (see Figure 1), there are many limestone soils. The soils contain a little organic matter and are plastic. Their erosion and sediment potential is medium, with a normal soil loss ranging from approximately 0.6 to 1.0 ton per acre per year [(4)].

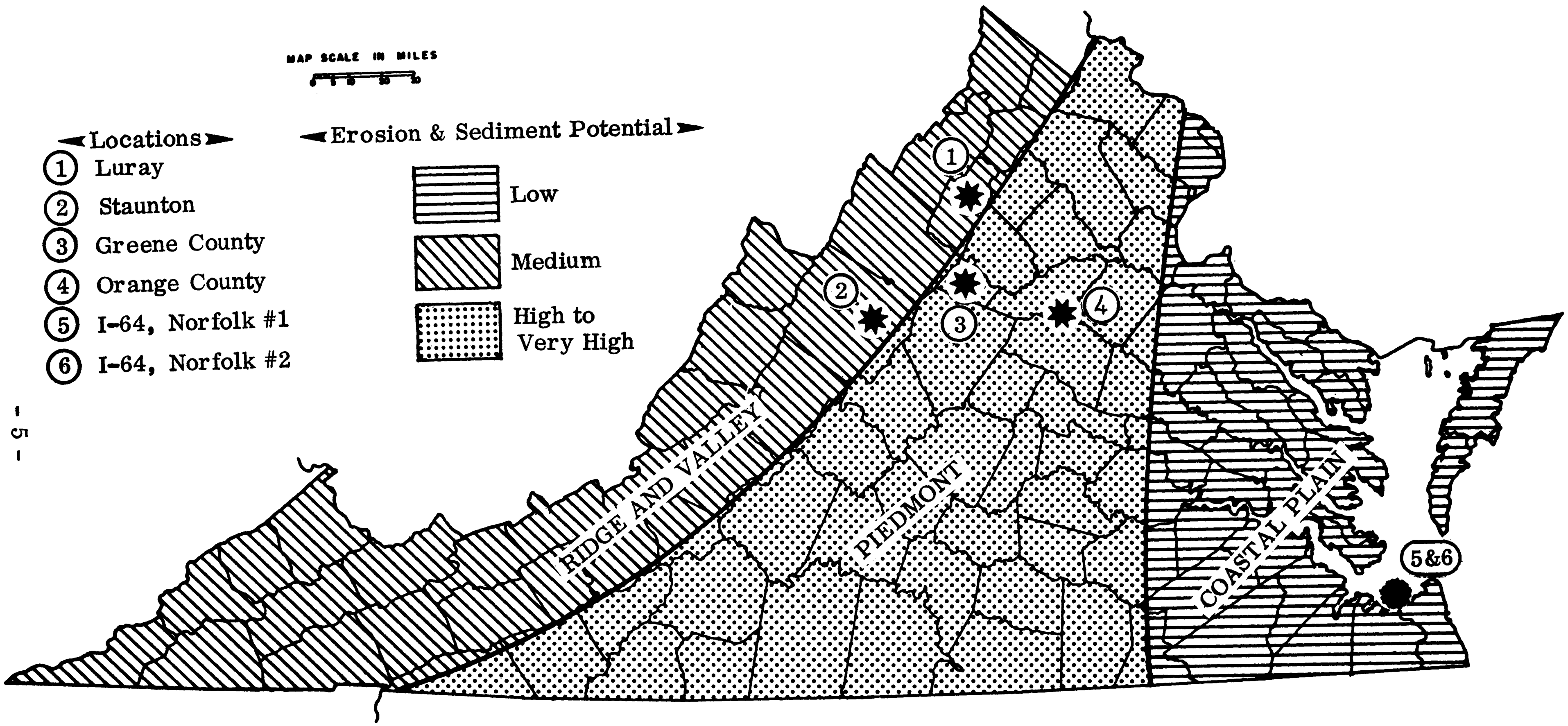

Figure 1. Erosion and Sediment Potential.

The next area to the east of the Ridge and Valley is the Piedmont. The soils in this area are generally residual micaceous silts with a high to very high erosion and sediment potential. The normal soil loss from the land in this area ranges from 1.2 to 4.3 tons per acre per year[4].

The easternmost area is the Coastal Plain, where the soils are predominantly sandy and have a low erosion and sediment potential. The normal soil loss is approximately 0.5 ton per acre per year[4].

It was decided that two experiments would be located in each of the three geological areas, as shown in Figure 1. As was pointed out earlier, only earth fill slopes were used and they were limited to approximately 15 to 20 feet vertical heights and a slope angle of 2:1.

SITE PREPARATION AND APPLICATION PROCEDURES

On each of the six sites the contractor or the highway forces were asked to prepare the slope by normal procedures up to the point where seed, fertilizer, and lime would be applied. At this point the Research Council personnel began their preparation of the slope for application of the chemicals.

At each site, two sections were laid off so as to have each of the seven chemicals applied in duplicate. In each section there were individual plots for the different chemicals. Each plot was 12 feet wide by the length of the slope, which varied between 35 and 45 feet. Between each plot a walkway the length of the slope and two feet in width was provided to allow a place to stand when working on the plots or applying the chemicals. Also, the walkway area prevented overlapping of the chemicals sprayed onto adjacent plots. Two larger areas were left at the ends of the two sections to provide a buffer between the two chemical sections and the area the contractor or the highway forces would spray with a hydro-seeder. These areas were approximately 12 feet wide and the length of the slope (Figure 2).

In addition to the plots for the different chemicals, one plot was left in each section as a control. This plot was not disturbed and had no chemicals applied.

The first experimental installations in each of the three geological areas included a "conventional method" plot. In Virginia, the conventional method is to place a layer of straw tacked with an asphalt emulsion as an erosion check and mulch. These plots were added to gain a comparison between the chemicals and the presently used method. After the first experimental applications in each geological area these plots were discontinued for a reason to be explained later in this section.

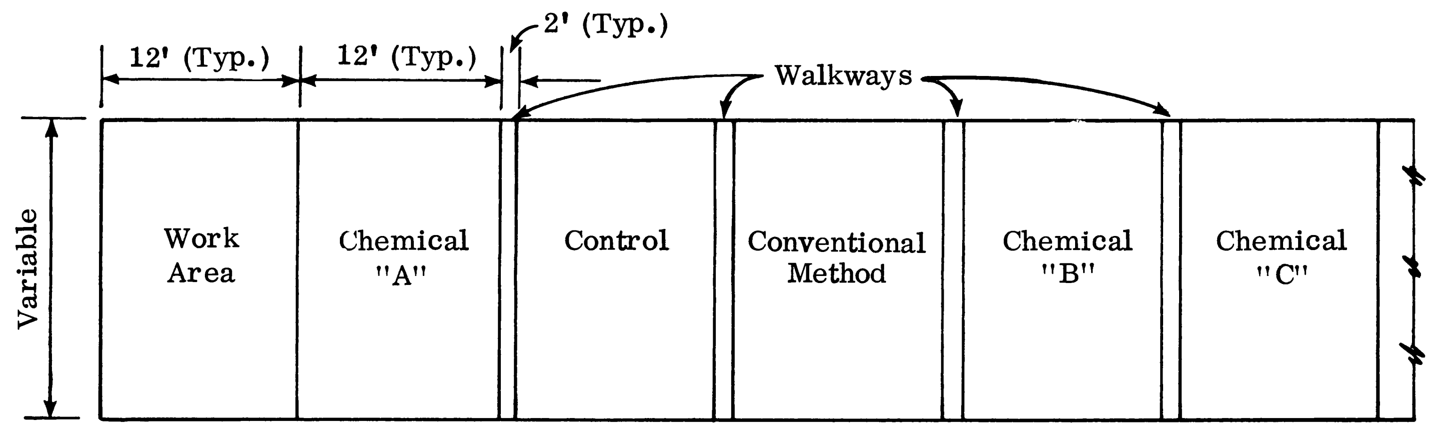

Figure 2. Layout of a section.

In the first experiment in the Coastal Plain area still another plot was added to each section. In the sandy soils of this area asphalt emulsions have been used to stabilize slopes. It was felt that this study provided a good opportunity to compare this method of erosion inhibition with the conventional method as well as the different chemicals. However, when asphalt emulsions are used, whether as a tack for straw or by themselves on the slope, they have one significant drawback in residential areas. Children and pets often play on the slopes and eventually track the asphalt into nearby homes. Also, sprayed asphalt has been wind carried onto houses and automobiles. A possible solution to these problems through the use of chemicals will be discussed in the section on FUTURE WORK.

After the two experimental sections were staked out, ten 1/4 inch round iron rods 12 inches long were driven flush to the surface of the slope at random locations in each plot. These rods were to be used as indicators of the amount of future erosion. However, it was found that they were only good indicators in the sandy soils of the Coastal Plain where sheet-type erosion dominates and very few rills occur. In non-sandy soils the rods usually were not visible for one of two reasons. First, the rills occur over a small area of the plot and there is a good possibility that most of the ten pins would not turn out to be placed in a rill. Secondly, most of the pins that were in the rills were not in place at the end of the study; the erosive force of the runoff tore them out of the slope. Therefore, no rods were used in the second experiment in both the Piedmont and the Ridge and Valley sections.

Prior to the applications, all the chemicals but one were mixed with water at the ratios shown in Table I. One chemical, Dow NC-1556.2L, was supplied to the Research Council in the diluted, ready to apply form. The chemicals were applied to the slopes with a commercial 20-gallon, 3-hp. sprayer (Figure 3). This sprayer was small enough that one person could move it around on the top of the slope. The spray nozzle was adjustable and enabled the user to apply the chemicals evenly over the plots by using a fine spray.

The conventional method plots were installed by spreading the recommended rate of straw on the plots and tacking it with an asphalt emulsion. The emulsion was applied by sprinkling from a watering can.

Since the asphalt plots in the first Coastal Plain installation required a large amount of emulsion applied at an even rate, it was decided that some type of asphalt spreader was needed. The local highway shop provided an asphalt tank with a spray bar, which was used to apply the emulsion to the two plots.

TABLE I

DILUTION RATIOS

Chemical	(Chemical: Water) 1st Experiment in Each Geological Area	Second Experiment In Each Geological Area
Aerospray 52	1:19	1:15
Aerospray 70	1:19	1:15
Curasol AE	1:20	1:15
Dow NC-1556.2L	2000 gal. per acre	
Norlig 41	1:4	—
Soil Gard	1:4	1:4
Terra Tack	0.025 lbs.: 1 gal.	0.025 lbs.: 1 gal.
Erode - X	1:10	1:10
Petroset SB	1:7	1:4

Figure 3. 3 hp., 20-gallon sprayer used.

After treatment of the plots by the different methods, no further work was done. Seed, fertilizer, and lime were not applied in order to allow an evaluation of the different methods with a minimum of additional variables.

The final procedure in the Ridge and Valley and the Piedmont experiments was to place straw bales at the toe of the slopes. The initial reason for using the straw bales was to prevent any soil lost from the slopes from washing onto adjacent properties. However, they also acted as traps that turned out to be good indicators of the amount of soil loss from each plot (Figure 4).

In the Coastal Plain area straw bales were not used because the majority of the soil loss there is due to wind erosion and not water runoff down the slope. Also, in this area, the iron rods in the plots were the best indicators of the amount of erosion.

Figure 4. Straw bales below plots.

The best chemicals from the first experiments in each geological area and the two new chemicals added to the study were the only chemicals applied on the second set of experiments. It was felt that the most severe seasonal conditions and the time when these products are needed the most is during the winter months. Therefore, if the chemicals did not do very well in the summer months, they were dropped from the second study because it was felt they could not withstand the more severe conditions in the winter months. Also, it was found from the first study that the conventional method using straw tacked with asphalt emulsion gave the greatest protection against erosion at all locations of the first set of experiments. Therefore, it was omitted in the second group of sites because the main interest of the study was to determine the relative protection afforded by the various chemicals under test.

CHEMICALS

Initially, many different chemicals were investigated for possible use. After some interviews with chemical distributors and a literature review, it was decided that the seven chemicals listed below appeared to be the most promising of those considered.

Aerospray 52 — by American Cyanamid Company

A heavy duty, water dispersible, alkyd emulsion resin.

Aerospray 70 — by American Cyanamid Company

This binder, the latest development of the American Cyanamid Company, is a polyvinyl acetate emulsion resin.

Curasol AE — by American Hoechst Corporation

A milky-white, polymer synthetic resin dispersion.

Dow NC-1556.2L — by Dow Chemical Company

An experimental erosion control product, not available on the market. It was supplied in a solution ready to be applied. Since the installation of the plots, Dow Chemical Company has discontinued research on this product and does not plan to market it.

Norlig 41 — by American Can Company

A by-product of the wood pulp industry containing resins, sugars, and lignosulphonic acids. After the first group of installations, the American Can Company removed this product from the market.

Soil Gard — by Alco Chemical Corporation

An inert polymer elastomeric emulsion supplied in liquid form for easy dilution and application.

Terra Tack — by Grass Growers Inc.

The only product used that is supplied in powder form. The natural vegetable powder is mixed with water before application.

While some of the first experimental sites were being installed several other companies contacted the Research Council about products that possibly could be used as erosion control measures. After consideration of some of the newer products, it was decided to add only the following two chemicals to the initial list.

Erode - X — by Malter International Corporation

A liquid erosion preventative and mulch that is diluted with water before being applied.

Petroset SB — by Phillips Petroleum Company

A rubberized emulsion mixed with water and used as a stabilizer for soils of very fine particles through small gravels.

METHOD OF EVALUATION

After the chemicals were applied, pictures were taken of each plot to record the initial appearance. Also, any important observations made of each plot were recorded.

Each site was observed at approximately one month intervals during the time of the study. Notes were recorded for each plot, and sometimes photographs were made. Notes were recorded on the following items:

1. occurrence of erosion;
2. type of erosion, whether sheet or rill;
3. approximate amount of erosion;
4. amount of material accumulated behind the straw bales or blown away;
5. number of iron rods visible;
6. amount of material washed from around the visible rods; and
7. amount and hardness of crust remaining on each plot.

When the detailed final evaluation was made of each site, information on all the items listed above was carefully recorded and detailed pictures were taken of each plot. Also, pictures were made of the material accumulated behind the straw bales.

RESULTS

Ridge and Valley

Page County

The first installation in the Ridge and Valley area was made on the newly constructed Luray bypass on June 29 and 30,1971 and terminated approximately 3 months later on October 7, 1971. It was estimated that 43 percent of the annual precipitation in the area of this site occurs during this period. Table II shows the precipitation recorded at a weather station near Luray. With the months of July through October all being above normal, the plots received more precipitation than the norms indicate. The total amount of precipitation that fell on the site is about 50 percent more than the normal expected.

TABLE II

PRECIPITATION AT PAGE COUNTY PLOTS

Month	Normal Precipitation (In.)	Actual Precipitation (In.)	Greatest Daily Amount on Plots (In.)
June (29 and 30)	.26*	0.01	0.01
July	3.80	4.04	0.85
August	4.26	5.24	1.51
September	2.83	6.26	1.72
October (1-7)	.66**	2.03	1.62
	11.81	17.58	

*Normal precipitation for June is 3.83 inches. The amount shown is the proportion of the normal that could be expected for the days shown.

**Normal precipitation for October is 2.90 inches. The amount shown is the proportion of the normal that could be expected for the days shown.

From the final evaluation of these plots, the three best chemicals were chosen and incorporated in the second experiment in Augusta County. These three were Aerospray 52, Curasol AE, and Soil Gard. However, as mentioned earlier none of these chemicals did as well as the conventional method. (Plates 1-3 in the Appendix.) Table III shows the rating and remarks about each chemical in this experiment.

TABLE III

RATING AND REMARKS ABOUT CHEMICALS APPLIED ON PAGE COUNTY SITE

Rating	Treatment	Remarks
1.	Conventional Method	No erosion visible; 1-2 inches of sediment behind straw bales
2.	Aerospray 52	Some erosion visible; 2-4 inches of sediment behind straw bales
3.	Soil Gard	Erosion visible; 3-5 inches of sediment behind straw bales
4.	Curasol AE	Several small rills (1 inch deep); 5-6 inches of sediment behind straw bales
5.	Aerospray 70	Several large areas of sheet erosion as well as some rills (1 inch deep); 5-6 inches of sediment behind straw bales
6.	Dow NC-1556.2L Norlig 41 Terra Tack Control	Sheet erosion with some large rills (2-4 inches deep); 6-9 inches of sediment behind straw bales

Augusta County

This was the second experiment in the Ridge and Valley. It was initiated on December 10, 1971 and terminated on March 28, 1972. It is estimated that during this period 26 percent of the yearly precipitation for this area falls. Table IV shows that only one month, February, had more than the normal rate of precipitation.

TABLE IV

PRECIPITATION AT AUGUSTA COUNTY PLOTS

Month	Normal Precipitation (In.)	Actual Precipitation (In.)	Greatest Daily Amount on Plots (In.)
December (10-31)	.87*	0.16	.16
January	2.67	1.35	.29
February	2.11	4.07	1.29
March (1-28)	2.86**	1.09	.46
	8.51	6.67	

*Normal precipitation for December is 2.70 inches. The amount shown is the proportion of the normal that could be expected for the days shown.

**Normal precipitation for March is 3.17 inches. The amount shown is the proportion of the normal that could be expected for the days shown.

Besides the three chemicals from the Page County experiment, the two new chemicals were used. After 3 1/2 months the plots were evaluated and the two most effective chemicals of the five were found to be Petroset SB and Soil Gard. (Plates 4 and 5 in the Appendix.) Table V shows the rating and remarks about each chemical at this site.

Piedmont

Orange County

This experiment constituted the initial work in the Piedmont soils. The chemicals were applied to an embankment on Rt. 651 in Orange County on July 27, 1971. Within a week after the application of the chemicals an extremely hard rain occurred over a short period of time. As shown in Table VI over half of the precipitation falling on the plots during the month of August occurred in one day. All of the plots except the conventional ones contained several gullies after this rain. However, the slope was not damaged to an extent that the experiment was a complete loss. The experiment was continued until October 6, 1971, which covered a period of approximately 2 1/2 months. It was estimated that 40 percent of the yearly precipitation in this area fell during this period. The total amount of precipitation that actually fell on the plots was above the normal. This is shown in Table VI, where the actual monthly precipitation for every month except July and October fell below the norms.

TABLE V

RATING AND REMARKS ABOUT CHEMICALS APPLIED
ON AUGUSTA COUNTY SITE

Rating	Treatment	Remarks
1.	Petroset SB Soil Gard	No erosion visible; no sediment behind straw bales
2.	Control	Several small rills (1 inch deep); no sediment behind straw bales
3.	Erode - X	Several medium size rills (2-3 inches deep); 1-2 inches sediment behind straw bales
4.	Aerospray 52 Curasol AE	Several medium size rills (2-3 inches deep) and a few large rills (3-4 inches deep); 3-4 inches sediment behind straw bales

TABLE VI

PRECIPITATION AT ORANGE COUNTY PLOTS

Month	Normal Precipitation (In.)	Actual Precipitation (In.)	Greatest Daily Amount on Plots (In.)
July (27-31)	.71*	1.59	1.42
August	4.71	4.15	2.30
September	3.60	2.82	1.76
October (1-6)	.51**	1.84	1.02
	9.53	10.40	

*Normal precipitation for July is 5.53 inches. The amount shown is the proportion of the normal that could be expected for the days shown.

**Normal precipitation for October is 2.62 inches. The amount shown is the proportion of the normal that could be expected for the days shown.

The best plots at this site were the conventional ones. Even with the heavy rains, the straw tacked with asphalt held the soil in place. The chemical plots were very badly eroded while the conventional plots were not. In order to be sure that these results were accurate, it was decided to drop only two chemicals from the original list of seven. The remaining five were retained for the second site in the Piedmont area, which was in Greene County. (Plates 6 and 7 in the Appendix.) Table VII shows the rating and remarks about each chemical at the Orange site.

TABLE VII

RATING AND REMARKS ABOUT CHEMICALS APPLIED ON ORANGE COUNTY SITE

Rating	Treatment	Remarks
1.	Conventional Method	Small amount of erosion at bottom of slope.
2.	Aerospray 70 Terra Tack	Small rills (2-3 inches deep) over plots
3.	Aerospray 52[a] Dow NC-1556.2L Soil Gard	Several large rills (3-6 inches deep) in the plots
4.	Norlig 41 Curasol AE Control	Large rills (3-6 inches deep) throughout entire plot

[a]Aerospray 52 was dropped from the Greene County study, because the other American Cyanamid product, Aerospray 70, is more effective and cost less under the conditions tested.

Greene County

With the additon of the two new chemicals a total of seven chemicals were applied to a slope on Rt. 630 in Greene County. The chemicals were applied on November 11, 1971 and the study was terminated about 5 1/2 months later on May 22, 1972. During this period, an estimated 58 percent of the yearly precipitation usually falls. The actual precipitation that did occur is shown in Table VIII. Also, one can see that the actual precipitation that fell on the plots during this period is about equal to the average precipitation.

TABLE VIII

PRECIPITATION AT GREENE COUNTY PLOTS

Month	Normal Precipitation (In.)	Actual Precipitation (In.)	Greatest Daily Amount on Plots (In.)
November (11-30)	2.01*	1.50	1.30
December	3.43	1.30	.83
January	3.30	2.61	.80
February	2.78	6.37	2.70
March	3.90	1.85	.80
April	3.69	3.14	1.14
May (1-22)	2.76**	5.13	1.65
	21.87	21.90	

*Normal precipitation for November is 3.01 inches. The amount shown is the proportion of the normal that could be expected for the days shown.

**Normal precipitation for May is 3.89 inches. The amount shown is the proportion of the normal that could be expected for the days shown.

In the final evaluation, Aerospray 70 and Curasol AE were found to be the best chemicals used in Greene County. However, these two did not inhibit erosion any better than the untreated soil or the control plot. Under the severe conditions experienced in Orange County, Aerospray 70 is the better chemical of the two; Curasol AE did not perform as well as it did in Greene County. (Plates 8 and 9 in the Appendix.) Table IX shows the rating and remarks on the chemicals applied in Greene County.

Coastal Plain

I-64, Norfolk #1

These plots were installed on August 30, 1971. The final evaluation took place approximately 7 months later on March 28, 1972. During this time, the nine chemicals and other plots were evaluated a total of 6 times. It is estimated that over this period approximately 65 percent of the yearly precipitation falls. Table X shows that the precipitation for the month of October was almost three times greater than the norm, but the overall precipitation on the site was a little below the normal rate.

TABLE IX

RATING AND REMARKS ABOUT CHEMICALS APPLIED ON GREENE COUNTY SITE

Rating	Treatment	Remarks
1.	Control Aerospray 70 Curasol AE	Several small rills (1-2 inches deep) in plots; 4-6 inches sediment behind straw bales
2.	Dow NC-1556.2L	Small rills (1-2 inches deep) throughout plots; 5-7 inches sediment behind straw bales
3.	Petroset SB	Several small to medium size rills (2-3 inches deep) in plots; 8-12 inches sediment behind straw bales
4.	Soil Gard Terra Tack	Small rills (1-2 inches deep) with several large rills (4-5 inches deep) in plots; 10-12 inches sediment behind straw bales
5.	Erode - X	Medium to large rills (4-8 inches deep) in plots; 12-14 inches sediment behind straw bales

Of the nine chemicals used on this site, four were selected for use on the second experiment in the Coastal Plain. The conventional plot did as well as the best chemicals except for the fact that it had no crust as the chemical plots did. In addition to the conventional method, the asphalt emulsion worked well. The surface had a flexible crust and showed no erosion. However, water had started pitting or eroding away the asphalt at the bottom of the slope where the crust ended. This type of erosion control causes two problems. First, as mentioned earlier asphalt may be tracked or windblown into residential or business areas. The second problem is getting some type of vegetation to grow through the asphalt. With the continuous flexible crust, no seeds can germinate and break through. Table XI shows the rating and remarks on the chemicals applied at this site.

TABLE X

PRECIPITATION AT I-64, NORFOLK #1 PLOTS

Month	Normal Precipitation (In.)	Actual Precipitation (In.)	Greatest Daily Amount on Plots (In.)
August (30 and 31)	.37*	0	0
September	4.08	5.46	3.49
October	2.75	10.12	2.99
November	2.97	0.97	.44
December	2.73	1.44	.45
January	3.19	2.94	1.06
February	3.12	3.50	1.03
March (1-28)	3.13**	2.46	.78
	22.34	26.89	

*Normal precipitation for August is 5.79 inches. The amount shown is the proportion of the normal that could be expected for the days shown.

**Normal precipitation for March is 3.46 inches. The amount shown is the proportion of the normal that could be expected for the days shown.

TABLE XI

RATING AND REMARKS ABOUT CHEMICALS APPLIED ON I-64, NORFOLK #1 SITE

Rating	Treatment	Remarks
1.	Petroset SB Asphalt Emulsion Conventional Method	Tough flexible crust present; no pins and no erosion visible
2.	Aerospray 52 Aerospray 70 Curasol AE	Thin soft crust present; a few erosion rills (1/2 inch deep) present; 1 to 2 pins visible in each plot by approximately 1 inch
3.	Control Norlig 41 Soil Gard Terra Tack Dow NC-1556.2L	No crust or scattered pieces of crust present; sheet and rill erosion (2-6 inches deep) present on plots; 3 to 8 pins visible for 1-4 inches in each plot

I-64, Norfolk #2

Five chemicals were applied in this experiment on December 1, 1971. From this time until termination of this study on March 28, 1972, it is estimated that 29 percent of the yearly precipitation falls. In Table XII one can see that a total of 10.34 inches of precipitation fell during this study. This is about 2 inches less than the normal rate.

TABLE XII

PRECIPITATION AT I-64, NORFOLK #2 PLOTS

Month	Normal Precipitation (In.)	Actual Precipitation (In.)	Greatest Daily Amount on Plots (In.)
December	2.73	1.44	.45
January	3.19	2.94	1.06
February	3.12	3.50	1.03
March (1-28)	3.13*	2.46	.78
	12.17	10.34	

*Normal precipitation for March is 3.46 inches. The amount shown is the proportion of the normal that could be expected for the days shown.

In this experiment Petroset SB was the best chemical of the five. In these plots, a crust was present over the soil, whereas the other chemical plots resembled the control section where no crust had formed. Therefore, for soils in the Coastal Plain area the conventional method, Petroset SB chemical, and asphalt emulsion were the best methods of inhibiting erosion on slopes. (Plates 10 and 11 in the Appendix.) Table XIII shows the rating and remarks on the chemicals applied at this site.

TABLE XIII

RATING AND REMARKS ABOUT CHEMICALS APPLIED ON I-64, NORFOLK #2 SITE

Rating	Treatment	Remarks
1.	Petroset SB	Tough flexible crust (approximately 1/2 inch thick) over most of the plot; no pins visible
2.	Control Aerospray 70 Curasol AE Dow NC-1556.2L Erode - X	Thin soft crust scattered over parts of the plots; 1-4 pins visible for 1-4 inches on the plots

COSTS AND RATES OF APPLICATION

It was felt that the cost of each chemical may have an effect on whether or not it would be used. Even if a chemical is very effective, it may cost too much to use on typical highway construction jobs. In obtaining the cost of the chemicals it was felt that the price of a large quantity would be desirable. Therefore, the chemical companies were asked to supply the cost of 10,000 gallons of their chemical or chemicals delivered to Charlottesville, Virginia. In the case of Terra Tack the cost of 2,500 pounds of the powder was requested. This amount will cover about the same area as 10,000 gallons of the other chemicals. Because of the large quantities involved the companies quoted their lowest prices. Also, in the requests for prices, it was stated that a contractor would be purchasing the product and not the Highway Department.

Table XIV shows the ratio of chemical to water, the rate of application, and the cost of each chemical for both experiments in each geological area. The dilution ratios and rates of application were recommended by the chemical companies.

TABLE XIV

DILUTION RATIO, RATE OF APPLICATION, AND COST OF EACH CHEMICAL

Chemical	1st Experiment in Each Geological Area			2nd Experiment in Each Geological Area		
	Dilution Ratio (Chemical: Water)	Rate of Application (Gal. Per Acre)	Cost Per Acre at this Rate	Dilution Ratio (Chemical: Water)	Rate of Application (Gal. per Acre)	Cost Per Acre at this Rate
Aerospray 52	1:19	120	$320	1:15	150	$404
Aerospray 70	1:19	120	$265	1.15	150	$335
Curasol AE	1:20	60	$132	1:15	80	$174
Dow NC-1556.2L	Pre-Mixed	2,000	N/A*	Pre-Mixed	2,000	N/A
Norlig 41	1:4	400	N/A	—	—	—
Soil Gard	1:4	150	$195	1:4	150	$195
Terra Tack	50 lbs.:2000 gal.	50 lbs. per acre	$ 85	50 lbs.:2000 gal.	50 lbs. per acre	$ 85
Erode - X	—	—	—	1:10	115	$990
Petroset SB	1:7	300	$501	1:4	480	$803
Asphalt & Straw	2 tons of straw per acre 250 gallons of asphalt emulsion per acre		$130			
Asphalt	1400 gallons per acre		$252			

* Not available.

CONCLUSIONS

The conventional method, straw tacked with asphalt, was found to be the best method for erosion prevention in all three geological areas of the state. The conventional method (at $130 per acre) has the second lowest cost of the methods tried. Only Terra Tack (at $85 per acre), which did not perform very well, costs less.

Different chemicals seem to work better in each geological area of the state. In the highly erosive soils in the Piedmont, Aerospray 70 and Curasol AE are the best of the nine chemicals tested. However, they are not nearly as efficient as the conventional method nor significantly better than the untreated soil. Aerospray 70 can cost as much as twice to two and a half times the cost of straw tacked with asphalt, depending upon the rate of application. Curasol AE is not as expensive as Aerospray 70 and can cost about the same as the conventional method at the lower application rates.

In the moderately erosive soils of the Ridge and Valley, Petroset SB and Soil Gard tested as the best chemicals. Soil Gard costs about one and one-half times as much as straw and asphalt at the rate used in this study, while Petroset SB is considerably more expensive, even at a low rate of application. The conventional method is as good an erosion inhibitor as these two chemicals except that the straw and asphalt does not provide a crust for the soil.

In the slightly erodible soils of the Coastal Plain area, Petroset SB is again the best chemical, while asphalt emulsion is equally as good. Asphalt emulsions (at $252 per acre) are more expensive than the conventional method because of the higher rate of application used. The conventional method (at $130 per acre) is an erosion inhibitor equal to any chemical or asphalt emulsion. However, it does not provide a crust as some of the chemicals and the asphalt emulsions do. But, one problem with the asphalt emulsion crust is that it is too tough to allow the growth of vegetation.

Table XV shows the most effective chemicals for each geological area.

TABLE XV

MOST EFFECTIVE CHEMICALS FOR EACH GEOLOGICAL AREA

	Ridge and Valley	Piedmont	Costal Plain
1.	Conventional	Conventional	Conventional
2.	Petroset SB Soil Gard	Aerospray 70 Curasol AE	Petroset SB Asphalt

FUTURE WORK

Due to the fact that the chemicals used in this study did not provide erosion prevention to match that obtained with conventional straw and asphalt mulch, no further work with chemicals sprayed directly onto the soil is anticipated at the Virginia Highway Research Council at this time. However, consideration is being given to investigating the effectiveness of selected chemicals as a tack for straw.

For any agency planning further research into the effectiveness of erosion inhibiting chemicals, the following discussion and suggestions are offered.

The present study was limited to earth fills of an approximate vertical height of 15 to 20 feet and a slope of 2:1. As discussed in the results and conclusions, different chemicals were found to perform better in each of the three different geological areas. Although the chemicals were not superior to the conventional method as an erosion inhibitor, they are of benefit in some instances. For example, they can be used in certain situations when straw and asphalt are unavailable or undesirable. It is for these reasons that the following work with chemicals would be recommended, if other agencies feel the need for further research.

1. Evaluate the different chemicals in the different geological areas on steeper slopes (1:1);
2. Evaluate the chemicals on higher slopes (more than 20 feet); and
3. Make the evaluation in (1) and (2) on both cuts and fills.

As mentioned earlier, asphalt emulsions are used as a tack for straw in normal construction procedures. However, in residential areas the asphalt emulsions are creating some problems. Several chemical companies claim that their chemical can be used as a tack for straw . Therefore, one phase of future work would be to evaluate those chemicals claimed to be tacks for straw mulch. The tacks should be evaluated under different soil conditions and on cuts and fills with different slope angles, heights, and lengths.

Another phase of future work would be to check the effect on seed germination of the best chemicals under various soil conditions. The first part of this phase would be to place both the chemicals and the seed at the same time on a slope. The rate and the amount of germination will determine whether or not the chemical retards germination. The second part of this phase would be to determine what will happen in the spring when the chemicals are applied at the beginning of the winter. In this part, the chemical would be applied and allowed to dry for several days. Then the seed would be sown to see if a stand of vegetation could be established through the chemical coating.

RECOMMENDATIONS

Based on the research presented here the following recommendations are offered: (1) The conventional method, straw tacked with an asphalt emulsion, should be retained by the Highway Department as the principal method of mulch and erosion prevention on bare slopes. In this study a chemical or chemicals were being sought that would be more effective and cost less than the conventional method. However, none of the nine chemicals tested were more effective and cost less than straw tacked with asphalt. There were several chemicals that were as effective as the conventional method in the Coastal Plain and the Ridge and Valley areas, but they cost more. Based on this finding a second recommendation is made. (2) If straw and/or asphalt is unavailable or undesirable for any reason, then the following chemicals would be recommended for use in the areas designated.

Most Effective Chemicals by Region

	Chemical or Chemicals
Coastal Plain	Petroset SB
Piedmont	No chemical recommended
Ridge and Valley	Petroset SB and Soil Gard

(3) The third recommendation resulting from this study involves other possible uses and future research for erosion prevention chemicals. For example, some of the chemicals may serve as a tack for straw mulch, and other similar uses may hold promise. Details of some suggested future uses are included in the section on Future Work.

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APPENDIX

Photographs of selected plots at each site

Plate 1. Conventional method used at all sites. 7 months — rating No. 1. This plot was treated at the rate of 2 tons of straw per acre tacked with 250 gallons of asphalt emulsion per acre.

Plate 2. Aerospray 52 — 3 months. Page County — Rating No. 2. Three quarters inch round iron rods used to hold straw bales in place are in the foreground.

Plate 3. Dow NC-1556.2L — 3 months.Page County — Rating No. 6. Sheet erosion in middle of plot.

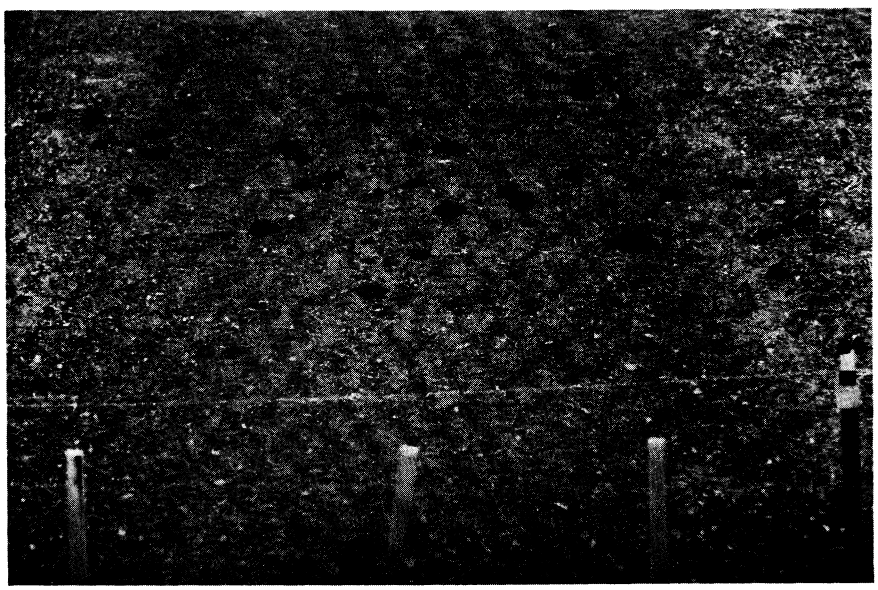

Plate 4. Soil Gard — 3 1/2 months. Augusta County — Rating No. 1. Dark areas are spots of grass. White posts in foreground are 2" x 2".

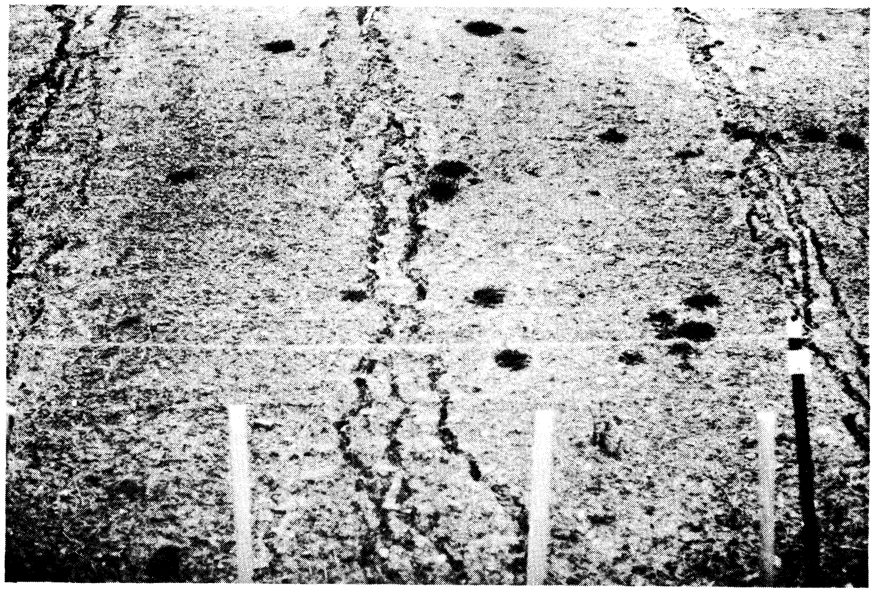

Plate 5. Aerospray 52 — 3 1/2 months. Augusta County — Rating No. 4. Dark areas are spots of grass. White posts in the foreground are 2" x 2". The rills in the middle of the plot are 2" to 3" deep.

Plate 6. Terra Tack — 2 1/2 months. Orange County — Rating No. 2. Even the best chemical treatment at the Orange County site appeared to be largely ineffective.

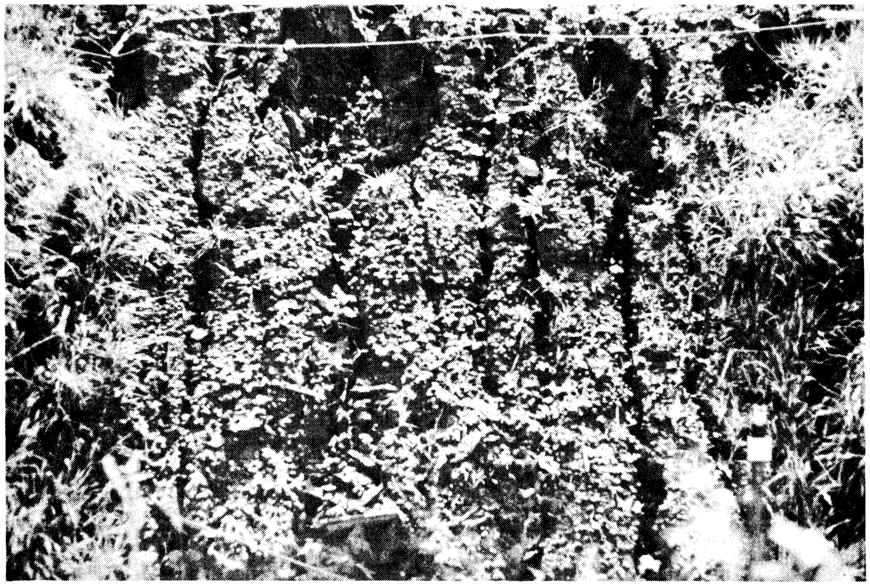

Plate 7. Control — 2 1/2 months. Orange County — Rating No. 4. Rills are 3" to 6" deep. The hole at the top of the plot is approximately 2 feet wide and 6" to 8" deep.

Plate 8. Aerospray 70 — 5 1/2 months. Greene County — Rating No. 1. Rills on right side are approximately 1" deep.

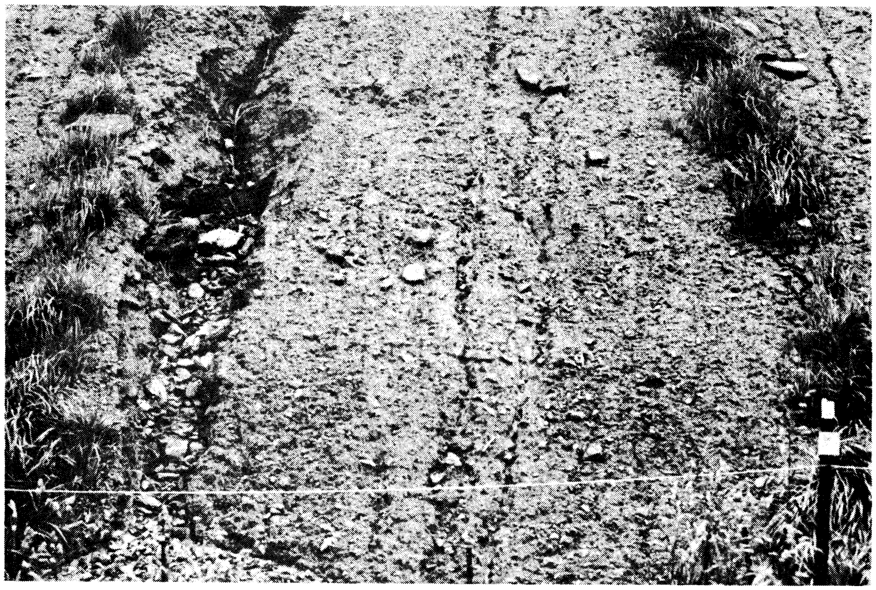

Plate 9. Erode - X — 5 1/2 months. Greene County — Rating No. 5. Gully on left side is 6" to 8" deep and about 2 feet wide. Rills in middle of plot are 1" to 3" deep.

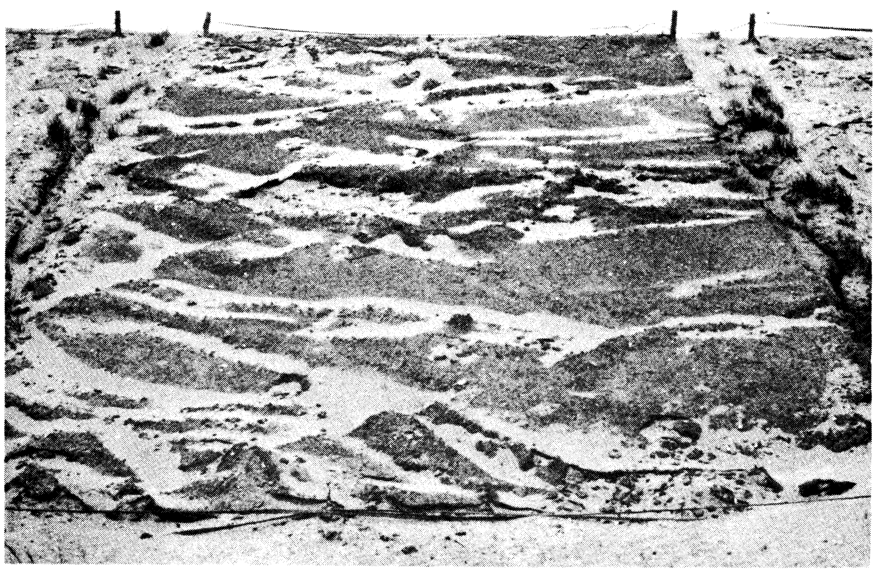

Plate 10. Petroset SB — 7 months. I-64, Norfolk — Rating No. 1. Sand on plot was blown onto it.

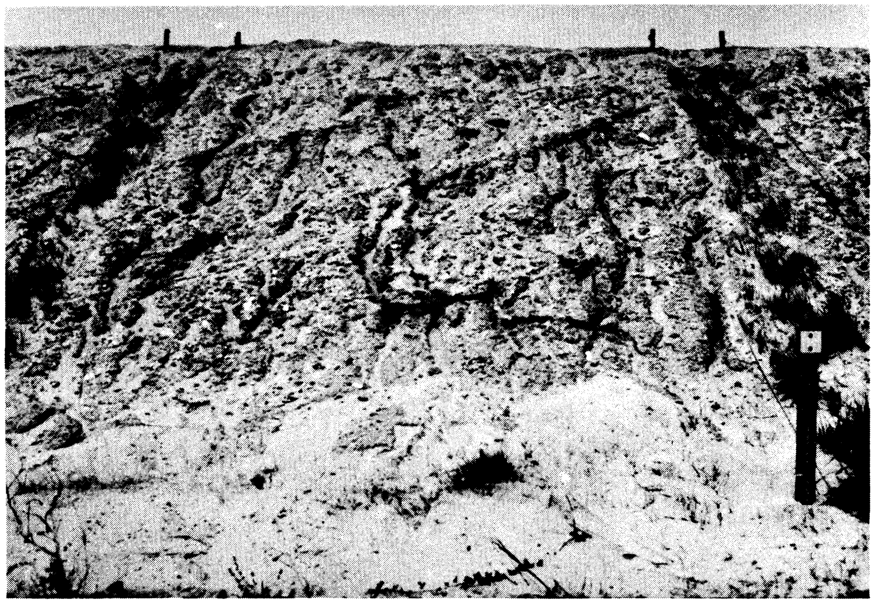

Plate 11. Control — 7 months. I-64, Norfolk — Rating No. 3. Rills in plot vary from 1" to 4" deep.