APPENDIX III

ANALYSIS AND PROGRESS RECORD OF SLOPE PROTECTION METHODS USED ON THE PENNSYLVANIA TURNPIKE (1940 - 41 - 42)

INTRODUCTION. The basic problems of slope protection which face the highway engineer working on roadsides and the ways in which these problems are being handled should be helpful in solving similar questions in connection with post-war construction programs.

The following reports by Dr. Fred V. Grau covering the establishment of vegetation on steep slopes on the Pennsylvania Turnpike construction are a reference guide and example of record in the analysis of typical highway problems of this character. Each of the three reports contains explanatory information of conditions found and of the methods used on this important construction project which should be helpful to a better understanding by those who do not have an extensive background in the particular subject.

(1) The first report covers the preliminary inspection trip made over the Pennsylvania Turnpike in 1940 for the purpose of determining the possible uses of grasses in the protection of bare surfaces.

(2) The second report was made in 1941 on slope protection, seeding methods and mixtures, and includes a record study of natural cover along the Turnpike.

(3) The third report, made one year later (1942), is of slope protection methods used, giving details of results obtained relative to slope design, seeding methods, mixtures, time of seeding, climate, and other factors.

It is expected that these preliminary observations of results will be checked over two or three seasons of growth before a report on conclusive findings based on a longer period of field test will be possible.

PRELIMINARY REPORT - TO DETERMINE THE POSSIBLE USES OF GRASSES IN THE PROTECTION OF BARE SURFACES

(Inspection made Nov. 26 and 27, 1940, by C. N. Keyser, Turnpike Landscape Architect in Charge of Design, and Dr. Fred V. Grau, Extension Agronomist, Pennsylvania State College).

During the drive from the Carlisle Interchange to the Somerset Interchange and return, soil samples were collected from the median strip and from cut slopes. The native grasses and other vegetation were noted with relation to the predominating soil series and types. From these notes a preliminary list is given (Table 1) to indicate the predominating grasses which occur naturally in the areas through which the Turnpike has been built. The list is not necessarily complete.

TABLE 1 - PRELIMINARY CLASSIFICATION OF MOST SIGNIFICANT EXISTING GRASS POPULATION ADJACENT TO THE PENNSYLVANIA TURNPIKE/1

Grasses	Overlying Mantle			
	Rock	Shale	Sandstone	Limestone
Drought-tolerant Types				
Canada Bluegrass (Poa compressa)		x	x	x
Tall Oatgrass (Arrhenatherum elatius)		x	x	x
Povertygrass (Danthonia spicata)	x	x	x	x
Redtop (Agrostis alba)	x	x	x	
Colonial Bentgrass (Agrostis tenuis)	x	x	x	
Yellowsedge Bluestem (Broomsedge) - (Andropogon virginicus)	x	x	x	x
Intermediate Types				
Kentucky Bluegrass (Poa pratensis)		x	x	x
Orchardgrass (Dactylis glomerata)		x	x	x
Meadow Fescue (Festuca elatior)		x		x
Quackgrass (Agropyron repens) (noxious)		x	x	x
Timothy (Phleum pratense)		x	x	x
Nimblewill (Muhlenbergia schreberi)		x	x	x
Sweet Vernalgrass (Anthoxanthum odoratum)		x		x
Chess Brome (cheat) (Bromus secalinus)	x	x	x	x
Yellow Bristlegrass (Setaria glaucus) annual	x	x	x	x
Green Bristlegrass (Setaria viridis) weedy	x	x	x	x
Crabgrass (Digitaria spp.)	x	x	x	x
Panic grasses (Panicum spp.)	x	x	x	x
Yellow Indiangrass (Sorghastrum nutans)		x		x
Moisture-tolerant Types				
Roughstalk Bluegrass (Poa trivialis)	x	x	x	x
Common Velvetgrass (Holcus lanatus)	x	x	x	x
German Velvetgrass (Holcus mollis)	x	x	x	x
Reedgrass (Calamogrostis spp.)		x	x	x
Reed Canarygrass (Phalaris arundinacea)		x		x

/1 - Grasses arranged roughly according to their occurrence on major divisions of the overlying mantle.

SELECTION OF GRASS SEED MIXTURES. Engineering devices have so well removed water from the Turnpike and from the right-of-way that most of the surfaces to be protected or landscaped may be considered as dry surfaces which would support only drought-tolerant vegetation or the more drought-tolerant of the intermediate types. Only in a few isolated spots would the moisture-tolerant types be adapted. Since this condition seems to prevail throughout the length of the Turnpike, there seems to be a good possibility of developing only three, or at the most, four basic grass seed mixtures to adequately care for all existing conditions.

Grasses which are not included in the list of the existing grass population, but seeds of which may be obtained on the open market include species which have value for dry locations. Most important of these follow:' (Note: the fescues listed here are not presently available.)

Agrostis canina - Velvet Bentgrass	Festuca ovina duriscula - Hard Fescue
Festuca capillata - Hair Fescue	Festuca rubra - Red or Chewings Fescue
Festuca ovina - Sheep Fescue	Lolium multiflorum - Italian Ryegrass

Festuca capillata - Hair Fescue

The selection of a seed mixture for various locations throughout the length of the Turnpike will depend first upon the exposure. A slope which receives the direct rays of the sun will support a more drought-tolerant population than the opposite bank which rarely receives the direct rays. A second consideration is the type of parent material and its ability to support certain types of plants. The location with respect to the cross section of the road is a third factor. The median strip will require a certain type of mixture; the relatively level fills outside of the shoulders will need a different type.

SOIL MOISTURE-FERTILITY ANALYSIS. Soil samples taken at several locations indicate considerable variability in pH values, lime content, and active aluminum. They are all uniform in having a very low available plant food content and are low in organic matter content.

The low organic matter content of the soils indicates low water-holding capacity, and a tendency to puddle, bake and crack. Grass seed sown on raw soils without some type of covering or mulch to hold moisture cannot be expected to succeed. Mulch materials which may be investigated as to cost and availability are:

Native peat (humus)	Straw	Marsh hay
Manure (stable)	Old hay	Bluegrass hay
Manure (poultry)	Povertygrass hay	Sawdust (rotted)
Mushroom manure	Broomsedge hay	

It will be necessary to use liming materials in most locations to counteract the acidity of the soil and to provide more favorable conditions for the growth of legumes. Materials which should be investigated as to cost and availability include: (1) Agricultural limestone, (2) Limestone dust, (3) Agricultural slag, (4) Marl.

Grass-legume combinations invariably give more satisfactory growth than either alone. Nitrogen collected by the nitrogen-fixing bacteria on the legume roots feeds the grasses. Legumes which may be used to advantage in various locations on the Turnpike include:

Sweetclover (Melilotus spp.)
Alsike Clover (Trifolium hybridum)
White Clover (Trifolium repens)
    Kent Type
    White Dutch and associated types
    Ladino
Black Medic (Medicago lupulina)
Lespedeza (Lespedeza spp.)
    Korean
    Common
    Sericea
Hop Clover
Crownvetch Coronilla (Coronilla varia)
Hairy Vetch
Crimson Clover
Alfalfa (Medicago sativa)
    Northwestern common
    Grimm
    Cossack
    Ladak

FERTILIZERS. A certain amount of fertilizer will be necessary to establish and maintain a satisfactory growth of grasses and legumes. For all practical purposes a single combination of N-P-K may be used throughout the Turnpike, varying only the amount as required by the particular situation. Since phosphorus and potash are the two elements that are most deficient in Pennsylvania soils, the fertilizer should be rich in these ingredients. Nitrogen is necessary but in lesser amounts. A complete mixed fertilizer carrying an N-P-K ratio of approximately 1-3-1, 1-3-2, or 1-4-2 should be satisfactory. An inorganic mixture will be satisfactory and will be less expensive than a mixture of organic materials.

For the purpose of placing seed mixtures on steep slopes which are difficult to scale and which would require much hand labor, the possibility of using some type of a blower has been discussed. The seeds may be mixed with appropriate materials such as limestone, fertilizer, topsoil and humus in the proper proportions. The entire mixture could be blown on the difficult slopes where a portion of it will lodge in crevices and niches. The materials accompanying the seeds will furnish proper covering and nutrition to insure a fair percentage of germination and establishment. Such a plan could not be expected to yield 100 per cent returns but the low labor cost will offset the loss of part of the seeds. Some of the material will not stick but will fall down to the bottom of the slope where it may be picked up and used again.

SEED MIXTURES.

MEDIAN STRIP. It is not to be expected that a grass seeding in the median strip will be uniformly successful. The shallow soil at the road edges, the low organic matter and plant nutrient content, the hardpacked condition - all make it difficult to establish a satisfactory sod. The seed mixture suggested here is designed to offset some of the disadvantages by including grasses which are tolerant of acidity and poor soil conditions. It is considered wise to compound only one seed mixture for the entire length of the median strip, including species which are adaptable to all variations of soil and climatic conditions.

Species	Pounds per acre
Kentucky Bluegrass	15
Canada Bluegrass	15
Redtop	7
Perennial Ryegrass (U. S. grown)	15
Colonial Bentgrass (R. I. grown)	5
Sheep Fescue	10
Chewings Fescue	15
White Dutch Clover	5
Black Medic	3
TOTAL	90

This rate of seeding is equivalent to approximately 2 lbs. of seed for each 100 linear ft. of median strip.

STEEP SLOPES. It is entirely feasible to compound a single broad seed mixture to be used on slopes throughout the length of the Turnpike, regardless of differences in soil and climatic conditions. Species included in the mixture should care for all the different situations.

Species	Parts by weight in mixture
Kentucky Bluegrass	1
Canada Bluegrass	3
Orchardgrass	1
Redtop	3/4
Colonial Bentgrass	1/4
Sheep Fescue	2
Reed Canarygrass	1/2
Tall Oatgrass	1
Sweet Vernalgrass	1
Timothy	1
Perennial Ryegrass	1
Alsike Clover	1/2
Ladino (clover)	2
White (Dutch) Clover	1
Black Medic	1
Sweetclover	1
Hairy Vetch	1
Lespedeza: Common	1/3
Korean	1/3
Sericea	1/3
Alfalfa	2
TOTAL	22

Suggested rate of seeding - one lb. to 1,000 sq. ft. or 44 lb. to the acre.

FLAT SLOPES. This includes the areas outside the berms and areas that are to be filled with rocks and stone and covered with topsoil. These areas will most likely be quite dry because of no connection with the sub-soil. A few areas will be wet, hence the seed mixture must contain species which will be adapted to both conditions. Since the seed mixture for the steep slopes has

been made up to suit a number of conditions, it may be used on these Flat areas. With this "shotgun" type of mixture there is little need of preparing a special one for the flat slopes.

A leguminous plant, identified variously as Axseed, Crown vetch, and Coronilla varia, grows wild in Berks County on shale soil, seed of which is not obtainable. It grows in soil which apparently requires no lime amendment. Plants set out on roadsides in Western Pennsylvania on poor shale slopes have given an excellent account of themselves without further treatment. This plant should have good possibilities on limestone and shale slopes. They could be set out at any time after the slopes have been stabilized with the grass-legume mixture.

GENERAL-PURPOSE MIXTURE. At the present time only a general-purpose mixture of topsoil, seed, limestone and fertilizer is suggested for trial. The proportions of this mixture may be altered to meet unknown conditions.

	Amount for 1,000 square feet	
	Median strip	Slopes
Topsoil screened to exclude stones	½ cu. yd.	¼ cu. yd.
Limestone to neutralize acidity	50 lbs.	25 lbs.
Fertilizer (4-16-8 or 5-15-5)	20 lbs.	10 lbs.
Grass seed	2 lbs.	2 lbs.

To this general-purpose mixture may be added seeds of native shrubs and flowers which may be established on slopes, such as sumac, dogwood, crataegus, rose, aster, and others.

An advantage of the method of blowing the mixture into place, aside from low-cost operation, is that the seeds should find natural resting places and the effect would be one of natural beauty. Natural reseeding would tend to establish the surviving plants over more of the area.

TESTS OF SOIL SAMPLES.

Sample Number	NO_3	PO_4	K	Ca	Mg	Al	pH	Lime Requirement lb. per acre	Organic Matter Percent
7190	100	Tr	Tr	2000	120	5	7.1	0	2.31
7191	Tr	Tr	Tr	1000	160	30	5.35	3225	0.10
7192	100	Tr	Tr	2000	200	5	7.65	0	1.8
7193	50	Tr	Tr	1500	160	50	5.55	4000	0.24
7194	200	Tr	Tr	2000	160	5	6.8	2000	1.24
7195	50	Tr	Tr	2000	120	Tr	7.15	0	2.13

Analyses by Dr. F. G. Merkle, Instructor, Soils Department, The Pennsylvania State College.

Sample 7190 Median strip opposite Carlisle Service Station
Sample 7191 South slope, bank, ½ mile east of Willow Hill Interchange
Sample 7192 Median strip, 1 mile east of Willow Hill Interchange
Sample 7193 Median strip, 2½ miles east of Sideling Hill Tunnel
Sample 7194 Median strip, 14½ miles west of Newville
Sample 7195 Median strip west of Carlisle Interchange

The nitrates mean little where there is no vegetation. With phosphorus and potash uniformly low, we would expect to use fertilizers containing relatively large percentages of these elements. There seems to be a fair supply of available calcium and sufficient magnesium. High aluminum content (over 5) indicates that phosphorus is more likely to be rendered unavailable to plants. Soils with pH values over 6.5 are not badly in need of lime and for practical purposes lime need not be used. When the pH value drops below 6.0 it is usually helpful to apply lime before seeding, particularly where legumes are to be used.

The lime requirement figures are essentially accurate but for practical use it is not possible to vary the amount of lime used exactly in accordance with the tests. Slight excesses are not significant but may be quite helpful, especially when the organic matter content is so low, as indicated. The figures for soil samples containing organic matter above 2.0 per cent are only fair but good catches of grass may be expected. Figures below 1.0 per cent indicate an abnormally low organic matter content and a decided tendency for the soil to bake and crack and to dry out badly. The need for a mulch after seeding is indicated by the low organic matter.

MULCHING. A mulch of old hay, straw, or native grass hay is suggested to follow the seeding on the median strip and on slopes. Success in establishment will be more sure where a mulch is used. The mulch reduces surface evaporation, conserves moisture, reduces erosion, increases the rate of absorption of rainfall, and prevents a crust from forming on the surface of the soil. One-half inch to one inch of hay is sufficient to protect the surface during germination and establishment. There will be no need of removing the mulch after establishment.

SECOND REPORT - TO SURVEY PROBLEMS OF SLOPE PROTECTION, SEEDING METHODS AND MIXTURES, AND OF NATURAL COVER

Survey trips were made October 8 and 9 and October 21 and 22, 1941 by C. N. Keyser, Landscape Architect in charge of Design, Pennsylvania Turnpike Commission, and Dr. Fred V. Grau, Extension Agronomist, The Pennsylvania State College

MEDIAN STRIP. One of the difficult problems of the Turnpike is the median strip. During the winter it will be largely covered by cinders and other material that is used on the road to prevent slippage. Snow plows will scrape most of the vegetation off along with the snow. During the summer periods of heat and drought, together with hard-packed shallow soil, will limit the choice of cover plants to only a hardy few. These few will, of necessity, be chosen

for their drought tolerance, their ability to grow in poor soil, in acid soil, and for their ability to regenerate growth in the spring either from rhizomes or from seeds, or both. Low-growing plants are essential to minimize danger to fast-moving traffic. It is essential to choose plants which require the minimum of maintenance for obvious reasons. Any type of slow-moving equipment on the Turnpike is a hazard to traffic. Ultimate road safety demands the absolute minimum of such maintenance equipment.

One of the difficulties of selecting plants for use on the median strip is that there has been little or no research work done on plants adapted to conditions found on The Turnpike. At the present time it is necessary to delay action until practical test plantings can be established and observed over a sufficient period of time to be able to correctly interpret observations. Meanwhile Nature is establishing a cover in some sections from the seeds and rhizomes which were in the soil. Some of this natural vegetation is desirable, some is not. The survey disclosed the following plants which are occurring naturally in the median strip:

Grasses	Legumes	Weeds
*Quackgrass	*Native White Clover	Buckhorn
Redtop	Red Clover	Bristle grasses
Timothy	Alsike Clover	Knotweed
*Colonial Bentgrass	Sweetclover	Chickweeds
*Canada Bluegrass	*Black Medic	*Yarrow
*Kentucky Bluegrass		
Poverty Grass		
Orchardgrass		
Meadow Fescue		

The asterisk indicates those plants which are producing the most satisfactory growth and cover from the standpoint of low maintenance costs. On the basis of this survey and from our knowledge of the known plants which may grow under these conditions, the following plants are under consideration in addition to those found naturally-occurring: (1) Lotus corniculatus (Birdsfoot Deervetch) (Birdsfoot trefoil), (2) Coronilla varia (Crownvetch Coronilla), (3) Creeping Red Fescue, (4) Zigzag Clover, (5) Myrtle.

Lotus would be desirable because it is tap-rooted, tolerant of drought, acid soil and poor soil, and because of its seed-producing ability and its beauty during the blooming period. In association with low-growing plants it remains quite prostrate. It should be included in the seed mixture if tests indicate that it will do well.

Coronilla produces a deeper vegetative growth than lotus and, for that reason, it may not be so desirable. An advantage is that it spreads both by seeds and by underground rootstocks so that it could survive the rigors of the winter season better than Lotus. During the blooming period it presents a beautiful sight to the traveler. It is more likely to succeed than Lotus but it must be tested under Turnpike conditions before it can be recommended for use on the median strip. The seed is not available on the market but it can be collected from established plantings.

Creeping Red Fescue is an interesting possibility for use on the median strip because of its tolerance to drought, poor soil and acid soil. One clipping a year at seeding time usually suffices to keep it in presentable condition. Its tendency to spread makes it particularly desirable.

Zigzag Clover and Myrtle are interesting possibilities but they cannot be considered in direct comparison with those plants, the seeds of which are readily obtainable. The total area of the median strip is about 190 acres. With this acreage and the limited amount of labor available, it may not be practicable to attempt to set out rooted cuttings of plants. It is essential to establish a desirable cover as quickly and as economically as possible with seeds which are readily obtainable to prepare the areas for later plantings.

After due consideration of the existing conditions, the variable conditions over the entire length of the Turnpike, the availability of seed, the type of cover desired, and the maintenance factor, the following seed mixture was suggested for use on the median strip.

	APPROXIMATE PARTS BY WEIGHT
Canada Bluegrass	2
Kentucky Bluegrass	1
Creeping Red Fescue	1/2
Black Medic	1
Lotus	1
Rate of seeding per acre	5 pounds

It is suggested that this mixture be subjected to the same calculations as the interchange and the soil stabilization mixtures and adjusted so as to yield approximately 9 grass seeds to 1 legume seed. To avoid any possible extra maintenance costs, no quick-growing temporary nurse grasses are included in the mixture.

The method of seeding the median strip is complicated by the delineator posts which are set every 100 ft. and which preclude the use of machinery which can cover the entire 10 ft. strip at one operation. Since it did not appear to be necessary to cover the entire strip with vegetation at once and since time was a factor in establishing some cover, the following method was suggested:

To a mobile power unit such as a small garden tractor, attach various implements and equipment which, at one operation, will open a narrow furrow, sow the FLOSS[2] in the furrow, and firm the soil well to enhance rapid germination. The depth of the furrow need not be over 2 in. since the seeds in the mixture require only a shallow covering (not more than 1/4 in.). At least part of the soil removed from the furrow by the implement should be returned to it in a loosened condition through some arrangement of scrapers. Following this can be the seeder, or the seed spout from an attached seeding arrangement, which delivers the FLOSS to the furrow. Finally a heavy flat wheel should complete the operation to press the FLOSS firmly into place. Two furrows would be planted, each 2½ ft. in from the edge of the concrete.

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[2] - FLOSS - term applied for convenience to a mixture of fertilizer, lime, organic matter, seed, soil.

The proportions of the ingredients of the FLOSS for the median strip were suggested as follows (on an acre basis, or for each 4,356 linear ft. of the 10 ft. width of median strip):

Fertilizer	(4-16-8 Turnpike Formula)	100 lb.
Lime	(Pulverized Limestone)	160 lb.
Organic matter	(Best available material from stock piles)	
Soil		
Seed		5 lb.

INTERCHANGE SEEDINGS. Inspection of the interchange seedings revealed that the selection of seeds for the mixture was entirely justified first, from the standpoint of quick cover and stabilization and, second, from the standpoint of grass-legume combination. The Ryegrass and Redtop are holding the soil but are open enough to permit the permanent grasses to become established. There is a good stand of the five permanent grasses. Of the legumes, the Black Medic predominates. It is uniformly well established throughout the seedings and is contributing to the formation of a good turf by feeding the grasses with nitrogen. The seed mixture used was:

	Rate of Seeding Pounds per Acre
Kentucky Bluegrass	5
Canada Bluegrass	15
Chewings Fescue	5
Colonial Bentgrass	3
Redtop	11
Domestic Ryegrass	12
White Clover	5
Black Medic (yellow trefoil)	14
	70

This seed mixture cost about $16 an acre. The seedings were much more uniform where an even layer of mulch was spread. With no mulch the soil was hard and dry and the turf was thin. An improved method for cutting and blowing mulch on new seedings would be a great advance in insuring stands. Every place where the mulch was evenly applied the seeding was much better than without mulch, both on interchanges and on banks.

At Somerset the seeding was in fine shape. At Breezewood where it had been extremely dry the turf was very thin but is holding on. Rain was needed badly in October but if it came soon the seeding would be a success.

At the Eastern Terminus the legumes in the seeding were very much in evidence as compared to the grasses. Foxtail formed a good temporary natural ground cover. Grass seeds were still lying dry (October 21) but with good late fall rains there should be considerable permanent coverage before winter.

The interchange seeding at the Western Terminus was the best of any along the Turnpike. Favorable moisture contributed largely to the good results.

ESTABLISHMENT OF COVER ON STEEP SLOPES. (Protection) The use of the blowing equipment to seed the high slopes is working out even more satisfactorily than anticipated.[3] An even coating of FLOSS can be laid down on even the roughest steepest banks with little or no loss from "drift" into the ditch. The force of the gun blows the FLOSS into every crack and crevice where the seed awaits moisture favorable to germination.

Certain mechanical problems have not been solved with complete satisfaction but the principle of the gun for seeding banks has been demonstrated to be entirely practicable and feasible for large scale highway seeding operations. One feature which completely justifies its use is that seeds of any kind of shrub, tree, vine, or any other plant can be "spotted" on the banks simply by adding the seeds to the FLOSS as it is mixed for the gun. There has been no indication of any harm to germination by the seeds passing through the gun.

At milepost 33, 2 miles west of Kittatinny the easternmost point where the "Gun" was used to blow the FLOSS on the banks, there is a good catch of grass even with no mulch and with very little rainfall. Examination showed that much of the seed was still lying dormant but that it was viable and should germinate when moisture conditions were favorable.

At milepost 43 going west, the first slope that was blown shows an excellent stand of grass in the crevices of rocks. Bare rock surfaces protruding were softened by the surrounding covering of grasses and legumes. When one looks at such a steep rock slope this question is uppermost, "How else could you seed it?"

It is noteworthy that this method of seeding establishes a cover in the places where it is needed the most with no extra expense of preparing a seed bed. In this connection it should be pointed out that it is a waste of time and completely unnecessary to "sandpaper" the slopes with picks and shovels in preparation for seeding by the "blowing" method. After "sandpapering," the slopes are smooth and much less receptive to the FLOSS than before all this labor went into them. A slope left rough as the contractor leaves them, is the best possible medium for the FLOSS since there are innumerable cracks and crevices for the seed soil and fertilizer to lodge and establish an erosion-control cover.

The item of watering the slopes after they have been seeded is considered not only as a waste of time and labor but a distinct detriment to the seeding. If left to Nature, the seeds will lie dormant until conditions favorable to germination and establishment are presented. Artificial watering may result in quicker germination but if water is not continually supplied during a period of drought following germination, the seedlings will perish. We suggest the discontinuance of artifical watering and "sandpapering" and suggest further that the money and labor so used be devoted to further research on equipment for the blowing of a mulch material on the slopes.

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[3] - Description published in Journal of American Society of Agronomists, Vol. 34, No. 4, April, 1942. Vol. 34, No. 8, August, 1942. Green Keepers Reporter 10 (3) 39, May-June, 1942.

It was of interest to note that a section of the Turnpike slopes which was seeded by others using Turnpike seed and fertilizer, did not work out well in comparison to the blowing equipment. Several inches of topsoil were laid on the slope before seeding. Where the slopes were "laid back" to a 3:1 or flatter, the topsoil remained in place. At 2:1 or steeper, the topsoil and the sod slid off the slope into the ditch, leaving the raw soil exposed.

With the blowing equipment, the FLOSS sticks to the slopes with almost unbelievable tenacity. This is made possible by the use of water in conjunction with the FLOSS so that the material is laid down as a thin mud. It was thought that when the moisture evaporated much of the FLOSS would drop off and be lost. Contrary to our belief, it all stayed on the slopes even when heavy rains fell soon after seeding.

Where mulch has been spread on unseeded slopes, there is a surprisingly good cover being established from seeds which were in the soil and from seeds which were in the mulch. This lends support to the method suggested in the preliminary report, that of cutting mulch material in the seeding stage so that there would be natural seeding coincidental with mulching. In connection with this problem there is attached a preliminary list of common grasses and the times at which they normally mature seed in Pennsylvania, together with a note as to the relative shattering or persistence in the head. Along the Turnpike there are hundreds of acres of native grasses which could be cut as hay when the seed is ripe. This could be used as seed-mulch if labor is available for the preparation of the material.

Approximate dates of seed maturity of some common grasses which occur naturally in Pennsylvania

	Range of Maturity	Shatters Easily	Persistent
Bluegrasses			
Kentucky	June 10-20		Yes
Canada	June 15 - July 1		Yes
Roughstalk	May 20 - June 10	Yes	
Annual	April and October	Yes	
Fescues			
Meadow	July 1 - 15	Yes	
Chewings	July 1 - July 10	Yes	
Red	July 1 - July 10	Yes	
Sheep	June 10 - 20	Yes	
Agrostis			
Redtop	July 15 - Aug. 1	Yes	
Colonial Bentgrass	July 15 - Aug. 1	Yes	
Andropogon			
Bluestem (Broomsedge)/4	Aug 15 - Sept. 10		Yes
Little Bluestem (Prairie Beardgrass)	Aug 15 - Sept. 10		Yes
Big Bluestem (Bluejoint turkeyfoot)	Aug 15 - Sept. 10		Yes
Poverty Grass	June 20 - July 15	Yes	

/4 - Hitchcock.

Other Grasses	Range of Maturity	Shatters Easily	Persistent
Panicum			
Switchgrass (virgatum)	July	Yes	
Common Witchgrass (capillare)	July	Yes	
Sweet Vernalgrass	May 15 - June 1	Yes	
Timothy	July 15 - Aug. 1		Yes
Orchardgrass	June 10 - July 1		Yes

NATIVE VEGETATION. Specimens of the more desirable types and species of naturally-occurring vegetation (grasses and legumes) were collected and transferred to the Turnpike office in Harrisburg as the first step in establishing a "Living Plant Museum" of Turnpike plants. Some of the promising - appearing natural - cover plants include the following: (1) Trailing blackberry (one of the better plants for sterile areas, especially on shale slopes), (2) Yarrow, (3) Wild Aster, (4) Native White Clover (particularly on "spouty" spots), (5) Poverty oatgrass, (6) Field Speedwell, (7) Bluestem (Broomsedge), (9) Panicum Spp., (10) Carex Spp. (Sedges).

Many other plants were collected, some of which were used in the seed mixture for the slopes. This slope mixture was prepared as follows to yield 2387 seeds per sq. ft. in the proportions of 4 permanent grass seeds, 8 nurse grass seeds, and 1 legume seed. Calculations as to numbers of seeds were made by C. N. Keyser.

Kind	Pounds to the Acre
Kentucky Bluegrass	2
Canada Bluegrass	6
Orchardgrass	4
Chewings Fescue	2
Timothy	4
Colonial Bentgrass	1
Redtop	11
Domestic Ryegrass	10
Alsike Clover	6
White Clover	1
Black Medic	5
Sweetclover	6
	58 lbs. to the acre

In many sections of the Turnpike the slopes are beginning to be covered with much undesirable vegetation from the standpoint of maintenance. It is of great importance to quickly protect slopes with a reasonably good mixture of easily established plants. After initial covering of the soil by grasses, any type of vine, shrub, or tree planting may be superimposed. In Nature the grasses always precede vine, tree, and shrub climaxes since the grasses provide a favorable place for the seeds of the larger plants to come to rest and find favorable conditions for germination and establishment. Slope protection comes first, then Landscape Planting. Further simplification and improvement of the mixing, blowing, and mulching equipment is needed. With improved equipment the seeding of steep highway slopes may be readily and economically accomplished.

This incomplete report serves to indicate that while the problem of seeding large areas of steep slopes has been apparently satisfactorily solved, there remain to be solved many practical problems of desirable permanent cover on the slopes. There are many plants which appear to have unlimited possibilities for

slope protection and for lasting beautifying ground cover which have not been included in mixtures because of the practical difficulties of lack of available seed, insufficient parent material, uncertainty as to best locations, and insufficient knowledge of best methods of establishment. All of this indicates the need for a research program and extensive test plots in order to answer these and many other highway problems in the State.

THIRD REPORT TO DETERMINE RESULTS OBTAINED RELATIVE TO SLOPE DESIGNS, SEEDING METHODS, MIXTURES, TIME OF SEEDING, CLIMATE, AND OTHER FACTORS

Inspection made November 1, 1942 by C. N. Keyser, Landscape Architect in Charge of Design, Pennsylvania Turnpike Commission, Wilbur H. Simonson, Senior Landscape Architect, Public Roads Administration, Harold Webber, Maintenance Engineer, Pennsylvania Turnpike Commission, and Dr. Fred V. Grau, Extension Agronomist, The Pennsylvania State College.

One of the primary objectives of the third inspection trip was to study results and to ascertain the occurrence of the various species, which were included in the slope and interchange seed mixtures, in relation to time of seeding and other factors. Tables 1 and 2 list the species used in 1941 and the species found on November 1, 1942. Table 1 is supplemented with notes to partially explain the variations in the population.

Table 1

Slope Mixture	Lbs. Acre	Station Locations in terms of East-bound Milepost Numbers													
		148	125	118.2	118	116.7	116.5	116	35.5	19.8	18.6	18.2	6.8	6.0	5.3
Canada Bluegrass	6	x	x	x	x	x	x	x		x	x	x	x		x
Orchardgrass	4	x	x	x	x	x	x	x		x	x		x	x	
Timothy	4	x				x	x	x	x	x	x		x	x	
Kentucky Bluegrass	2	x						x		x	x		x	x	
Chewings Fescue	2	x	x	x	x	x	x	x	x	x	x	x	x		x
Colonial Bentgrass	1	x						x	x	x	x				
Redtop	11	x				x	x	x	x	x	x		x		x x
Domestic Ryegrass	10	x		x		x	x	x	x	x	x		x	x	x x
Alsike Clover	6	x			x	x	x	x			x	x	x	x	
Sweetclover	6	x		x	x	x	x			x	x	x	x		
Black Medic	5	x	x	x	x	x	x	x		x	x	x	x		x
White Clover	1	x						x			x		x		
Half Ladino Half White Dutch															

Total ... 58 lbs.

Figure 1. On the left is shown a slope facing northeast 'blown' in August 1941. The slope on the opposite side of the Turnpike received no treatment.

Figure 2. A closer view of the untreated slope shown in Figure 1.

Figure 2-A. A closer view of the growth on the 'blown' slope shown in Figure 1. The cover protection was adequate to control erosion. All pictures taken in the late Fall of 1942. (Photos by the Pennsylvania Turnpike Commission).

Station 148---"Blown" December 12, 1941. Shale, no soil. North-facing slope 1½:1. Ryegrass reseeding. Poorest growth at top of 15-ft. slope where moisture is limited. Best growth at toe of slope. Distribution of plants: heaviest population in rills which had formed prior to seeding, other well-distributed. Results: very good.

Station 139.2-Excellent roadside cover of lespedeza, natural growth.

Station 125---"Blown" in August 1941 during driest part of lowest rainfall season in 54 years. Shale, no soil. South-facing slope 2:1. Plants scattered but successfully established. Only the most drought tolerant succeeded. Nearly a complete legume failure. Results: Poor.

Station 118.2-"Blown" August 11, 1941. Shale, no soil. North-facing slope 2:1. Nearly complete legume failure. Seed lay dry until late in season. Good grass cover. Results: fair.

Station 118---This is the point at which the Gun method was first used on July 29, 1941 in the middle of the worst drought in 54 years in this section. Shale, No soil. South-facing slope 1½:1. Results: poor.

Station 116.7-"Blown" August 11, 1941. Shale, no soil. South-facing slope, 1½:1. Nearly a legume failure, grass cover good.

Station 116.5-Similar to 116.7. (Burnt Cabins)

Station 116---"Blown" August 11, 1941. Soil slides due to ground water seeping. Cover excellent. Results: good.

Station 35.5--Hand-seeded and mulched by W.P.A. South-facing slope 3:1. Some slippage of face. Good cover of grasses, no legumes. Results: fair.

Station 19.8--"Blown" September 1, 1941. South-facing slope 65 feet high. Rock, no soil. Cover natural-looking but not solid. Rock faces softened by cover. Results: good.

Station 18.6--"Blown" September 11, 1941. Soil slides. (Jacobs Creek). Good growth of grasses where soil has not slipped. Legumes thin. Hairy Vetch added here has not succeeded well. Results: good.

Station 18.2--"Blown" September 12, 1941. Rock, no soil. South-west facing slope 50 ft. high. Excellent cover of Black Medic and Sweetclover, producing a soft green slope. Results: good. This location suffered a half-inch rain in 20 minutes soon after seeding. Practically none of the FLOSS was washed off the slopes.

Station 6.8---Hand-seeded by others on 3-in. of topsoil placed on 6-ft. slope laid-back to 3:1. Excellent cover where soil did not slide off into the gutter. Results: poor.

Station 6.0---"Blown" during favorable moisture period in August 1941. Shale, little soil. North and east-facing slope, 2:1. Good cover. Toe of slope very heavy in Orchardgrass where moisture collects. Results: very good.

Station 5.3---"Blown" August 1941. Shale, no soil. Slope nearly vertical. East-facing slope. Excellent cover of Ryegrass and Redtop with some Black Medic. Results: very good.

Station 4.2---"Blown" August 1941. Shale, little soil. Thin cover. Need for mulch indicated. Results: poor.

Trailing blackberry, buckhorn, field speedwell, wild aster, and goldenrod represent outstanding examples of native adapted plants occurring naturally and providing slope protection.

CONCLUSIONS OF SLOPE PROTECTION METHODS

1. The "shotgun" type of seed mixture has been used to good advantage on slopes along the Turnpike. Ecological factors have resulted in a specialized selection from the relatively complex mixture. The more drought-tolerant species occur most frequently and in the greatest abundance but the more moisture-tolerant species abound in localized favorable areas. Slope design varies so greatly that the population of a single face may vary from most drought-tolerant at the top of the slope to the most moisture-tolerant at the toe of the slope, justifying the inclusion of all types in the seed mixture.

2. The "Gun" method of blowing FLOSS on steep slopes is satisfactory. With certain improvements to increase the volume output and the acreage covered in a day, and to decrease the weight and size of the outfit, the method will represent a rapid, low-cost procedure for accomplishing slope protection. Using the "experimental" assembled units, figuring all costs on an amortization basis of 36 months, it cost less than 10 cents a sq. yd. to seed slopes varying in height from 10 ft. to 60 ft. Not counting amortization and W.P.A. labor used, the actual cost of slope seeding to the Turnpike commission was about 4 cents a sq. yd.

3. The FLOSS mixture is a satisfactory medium to use in connection with the "Gun" method of seeding slopes. The proportions of the ingredients may be changed on ths basis of further testing and study but at the present they appear to be satisfactory.

4. Slope design to avoid excessive "drought" areas at the top will do much to favor establishment of ground cover. Rounding of the tops and flattening of the toe of slopes seem to favor plant growth. Rounding the top of a $1\frac{1}{2}$:1 slope to promote plant growth represents a great saving in earth-moving as compared to "laying-back" a high (over 30 ft.) slope to 2:1 or flatter, in addition to saving space for right-of-way.

5. Excessive smoothing or "sandpapering" of slopes is undesirable for the "Gun" method of seeding. Rough surfaces as left by the grading contractor,

rough-dressed to remove loose stones, are most favorable to this method of slope seeding.

6. Mulching of slopes is a valuable adjunct to seeding. Where the FLOSS was blown through a light mulch previously applied, the results were very good. There is need for a machine which will cut and blow a moistened mulch on the slopes just prior to "blowing" them with FLOSS. The design for such a machine has been proposed by Mr. Keyser.

7. Slope ground cover need not be a dense turf, but should approximate a natural, mixed growth of plants selected for their harmonious relationship to the environment and surroundings. Such a ground cover will require little or no mowing and will be low in maintenance cost.

8. Seeds of Coronilla varia (Crownvetch Coronilla) planted in October 1941 at different locations failed to show any results.

INTERCHANGE SEEDINGS

Table 2 presents observations of populations, supplemented by notes. During the 1942 season these areas were mowed regularly with a Locke mower set at about 1¼ in. Due to a good supply of natural precipitation, mowing was frequent (about once a week).

Table 2

Interchange Mixture	Lbs. an Acre	Interchange Locations by Name							
		Blue Mountain	Willow Hill	Fort Littleton	Breeze-wood	Bed-ford	Somer-set	New Stan-ton	Irwin
Canada Bluegrass	15	x	x	x	x	x	x	x	x
Kentucky Bluegrass	5	x	x	x	x	x	x	x	x
Chewings Fescue	5	x	x	x	x	x	x	x	x
Colonial Bentgrass	3	x	x	x	x	x	x	x	x
Domestic Ryegrass	12			x		x			
Redtop	11	x	x	x	x	x	x	x	x
Black Medic	14	x	x	x	x	x	x	x	x
White Clover	5	x	x	x	x	x	x	x	x
Half Ladino									
Half White Dutch									
Total ...	70 lbs.								

INTERCHANGES. Mostly hand-seeded and mulched, fall of 1940 and spring of 1941. Limed and fertilized, 800 lbs. of 4-16-8 to the acre.

Blue Mountain. Poor thin soil on shale. Excellent lawn turf, good cover. Mowed about 1¼ in. which is too close for this type of soil which tends to dry out readily. Ryegrass has disappeared in one season.

Fort Littleton. Excellent cover on south-facing slope. Legume population high. On the top of a shale fill there were good plants of Orchardgrass, Black Medic, and Chewings Fescue.

Breezewood. Good cover, high in legumes. This shows excellent recovery after being severely injured by drought last summer.

Bedford. Excellent cover, high in legumes. The height of cut on all interchanges was discussed at length and a 3 in. cut was agreed upon as being in the interests of lowered maintenance costs, less frequent mowing, and a less 'refined' appearance more in harmony with the surroundings.

Somerset. Excellent cover, good color. Bentgrass more in evidence here than further east at lower altitudes. Black Medic is very adaptable to any height of cut. The proportions of the various species in the turf seemed to be in nearly the same proportion as they were present in the seed mixture.

New Stanton. Like Somerset. Rich in legumes, high green color, dense turf.

Irwin. Excellent cover. A nearly solid ground cover composed of principally Ryegrass and Black Medic. One year later no Ryegrass is present, permanent species are forming a dense turf.

CONCLUSIONS ON INTERCHANGE SEEDINGS.

1. The design of the seed mixture, liming and fertilizing practices seem to be well-balanced and consistent with the beauty and utility reqirements for the locations.

2. The proportion of Redtop in the mixture could be reduced without impairing the value of the mixture.

3. Black Medic is a valuable ingredient in the mixture for these non-traffic areas because of its ability to start quickly, to withstand drought and poor soil, and to adjust itself to varying management practices.

4. Light mulch has been very helpful in establishing stands in a dry season.

5. Mowing interchange turf at about 3 in. would result in lowered maintenance costs and a more harmonious appearance.

CONCLUSIONS ON MEDIAN STRIP NATURAL GROUND COVER

1. The ground cover ranges from sparse to dense, according to the quality of the replaced topsoil and the seeds contained in the topsoil. In general, the cover is satisfactory and presents an harmonious pleasing appearance.

2. A sparse ground cover is sufficient because at the normal rate of speed of vehicles, the eye sees only an unbroken appearance of ground cover ahead.

3. The snow removal equipment operations discourage all but the hardiest plants in the median strip. Species with rhizomes seem to be favored because of their ability to renew growth after all aerial parts are scraped off.

4. Low-growing plants, unbroken by plantings, favor the safety of a high-speed road. Color distinction is necessary to delineate clearly the edges of the paved surfaces.

SUGGESTIONS FOR IMPROVEMENTS IN METHODS OF ACHIEVING SLOPE PROTECTION IN RELATION TO SLOPE DESIGN.

1. Since slope protection is the first principle of landscape design, it is essential to establish seeding contracts in connection with the prime contractor or with a seeding contractor in such a way that, if possible, a slope is seeded within a few days following acceptance of the graded slope by the inspector. When slopes lie unprotected for a year or more before protection measures or landscaping are started, erosion becomes serious with resultant high maintenance costs and damage to high-cost installations.

2. Seed mixtures composed of species having wide tolerances permit of seeding at almost any time of the year, except when the soil is frozen, thus extending considerably work that is known as "seasonable."

3. The "Gun" method of "Blowing" FLOSS on banks and slopes merits considerable time and study for the purpose of improving the machinery, increasing the volume output, and acreage capacity.

4. Improved mulching methods are indicated, particularly in the amount and manner in which it is applied to steep slopes.

5. Rounded tops and flattened toes of slopes appear to enhance the possibility of establishing more uniform ground cover.

6. The need has been shown for further study on the design of well-drained stabilized pervious base courses for road shoulders on which turf grasses can be grown.

7. The design of the Turnpike seed mixtures exemplifies a significant trend in more closely computing the relative numbers of seeds with relation to nurse, permanent, and legume species and to unit area. This phase deserves further study.

8. Slope protection in its relation to highway design should represent the natural expression rather than the individual expression. This approach indicates the desirability of selecting species to fit the given site and the subsequent operations.

9. The Turnpike offers unlimited opportunities for study and research in highway development. A research plan has been developed and plant materials are being increased to establish test plots at various locations along the Turnpike. These plans were developed by H. B. Musser, Professor of Agronomy, The Pennsylvania State College, and the author and are in the Agronomy files at the Pennsylvania State College.

10. Actual tests are needed to establish the degree of "slippage" or the reduction in the coefficient of friction of turf surfaced shoulder areas, due to various legumes in a grass mixture for roadside and airfield surfaces subject to traffic wear. No figures are available at the present time.

11. Specialized situations may be benefited by a study of the pre-germination of seeds for the purpose of rapid establishment and coverage.

12. Selection of locally adapted species is a promising approach to natural-appearing roadside plantings, slope protection, and reduced maintenance costs. The ideal ground cover is one which requires no mowing, is perenially pleasing in appearance, presents no fire hazard, and is harmonious with its surroundings.

THE VIEWPOINT OF THE MAINTENANCE ENGINEER

The following comments by Mr. Harold Webber, the Maintenance Engineer of the Turnpike Commission, are included as a part of the conclusions of the third field inspection report:

1. The cut slopes, seeded by the Landscape Division, unquestionably have decreased maintenance costs due to removal of cut sloughage.

2. Best results were obtained where slopes were properly mulched, although but a small percentage of the slopes seeded by the blowing method were so treated. It doubtless would be more economical if methods could be developed for mechanical mulching.

3. Good coverage was secured from the designated mixtures. The grass seed mixtures were combined very well for both slope and lawn (interchange) areas.

4. The slopes selected for experimental treatment varied in height from 8 to 70 ft.

5. At least 15 per cent initial coverage of the shaly cut slope area was noted during the inspection. These were treated by blowing the seed-topsoil-fertilizer (FLOSS) mixture on them.

6. With the blowing method it was possible to obtain growth on slopes that had about 60 per cent rock ledges. The "Gun" pressure was a great asset in bedding and securing germination of the seed. On slopes where erosion was evident, the grass had started to grow in many of the washes.

7. The "Gun" method proved to be more satisfactory than hand seeding on the higher cut slopes.

8. All slopes should be covered with some vegetation to prevent erosion. Grasses seem to be the quickest growing coverage available but their use is restricted to the flatter slopes. Therefore, for the most economical maintenance, it is apparent that slopes should be flattened more than they have been in the past.

9. Basic slope protection operations should be considered in design and made a part of the construction contract:

a. Work such as mulching and seeding can be done most economically before the highway is thrown open to traffic.

b. This would eliminate "sand-papering" of slopes, a costly hand labor operation which tends to retard ground cover establishment. Shortening the interval between rough grading and the establishment of protective vegetation on slopes will reduce maintenance costs.