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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
BUREAU OF PUBLIC ROADS

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Central Interchange, Minneapolis, Minn., at intersection of Interstate Highways 94 and 35W. The complex comprises nine bridges, a 400-foot vehicular tunnel, and 5,000 feet of reinforced-concrete retaining wall. (Photo courtesy Edwards and Kelcey, Inc., Minneapolis.)

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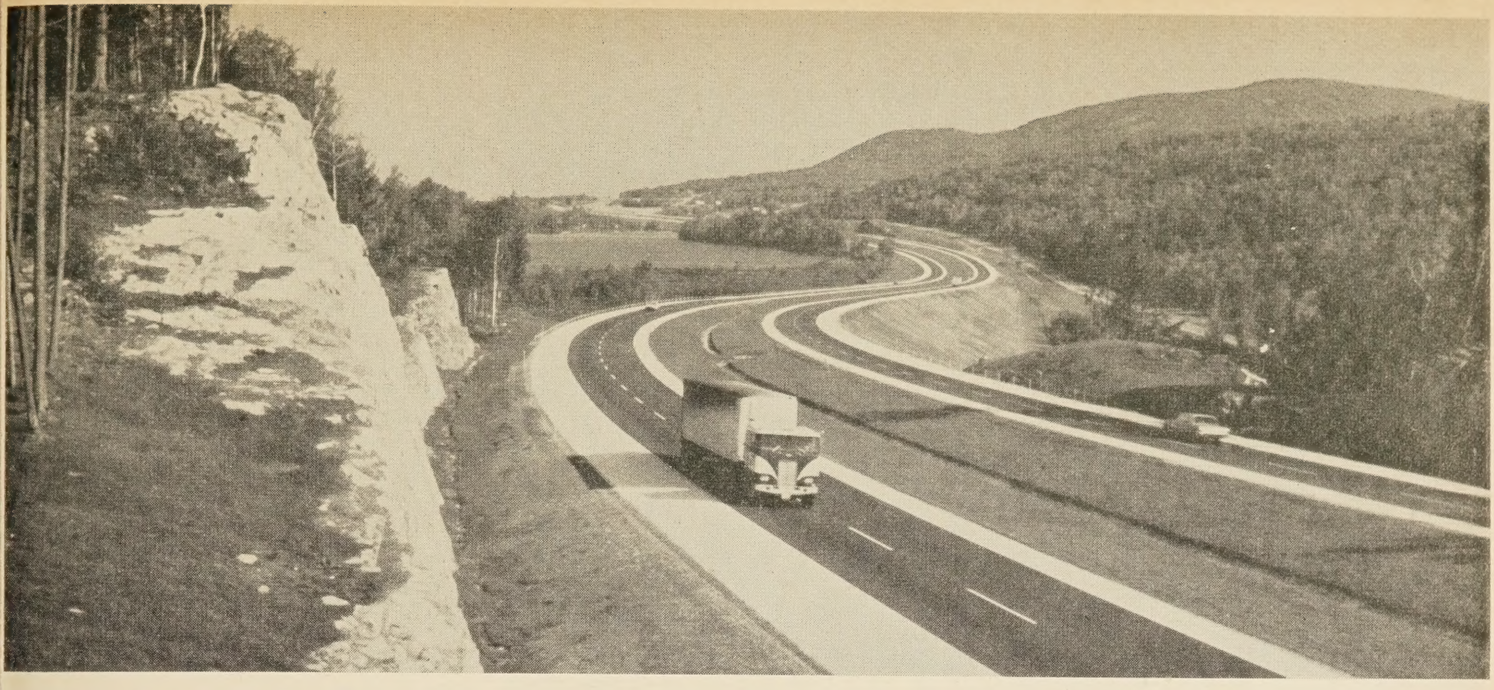

Erosion is controlled on construction scars, safety is enhanced, and a pleasing environment is created by turf—an ingredient necessary to the "complete highway."

Erosion Control, Safety, and Esthetics on the Roadside—Summary of Current Practices

Reported by [1] **WESLEY L. HOTTENSTEIN**
Landscape Architect
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BY THE OFFICE OF
RESEARCH AND DEVELOPMENT
BUREAU OF PUBLIC ROADS

Turf, an indispensable element of the highway, is almost as important as good design to control erosion and provide the roadside conditions necessary for safe highway travel.

Properly developed, grasses and native species also provide a bonus for the highway user—a complete highway that is esthetically desirable and pleasing. Current practices used to establish grasses, encourage natural regeneration, and manage roadside turf are summarized by the author who also reviews turf uses and design elements of cross section, grade, and earth stabilization.

COMPLETION of the National System of Interstate and Defense Highways will add more than 1 million acres to an existing 2,500,000 acres of roadside area. More than half, 60–75 percent, of a modern highway right-of-way consists of unpaved areas of earth. If left bare, the construction-scarred part of this vast acreage probably would erode and be unsightly. On an extensive scale, erosion can destroy an appreciable part of the highway investment and create serious hazards for the motorist. Turf-forming grasses that cover most roadside areas are the most effective, rapidly developing ground cover available and are a prime factor in the economic, esthetic, and safety aspects of a complete highway.

The need to control erosion along highways provided the initial impetus for developing roadside areas. During the first tremendous drive in the 1920's to construct a network of all-weather surface roads for automobiles, highway engineers became alarmed with the results of erosion on newly constructed cross sections. Structures were undermined, drainage installations were vitiated, and severe damage was inflicted by deposition of subsoil in water supply facilities and on agricultural lands beyond right-of-way boundaries. Erosion damage necessitated additional expenditures for maintenance. Economies motivated highway administrators to employ professionally trained men to develop methods and techniques for establishing vegetation on roadside areas disturbed by construction.

During the early decades of highway construction, indifference of engineers to erosion probably evolved from our forefathers' land-use concept of the nineteenth century. Natural resources then were considered virtually inexhaustible. Little thought was given to the possible consequences of pollutants poured into clean streams and clear,

[1] The original version of this report was published in *Turfgrass Science*, by the American Society of Agronomy, U.S. Department of Agriculture, No. 14 in the series Agronomy, pp. 603–637.

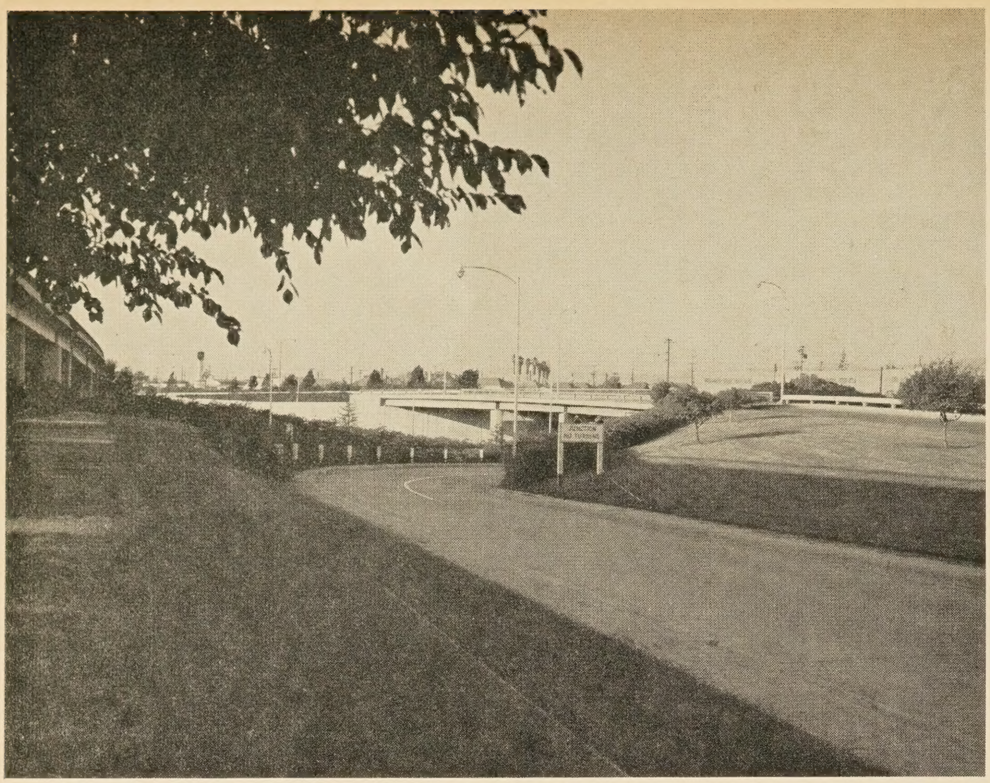

Figure 1.—Neatly mowed roadsides express the environment of an urban setting.

sparkling lakes or to destructive logging, mining, and farming practices that contributed to irreparable damage from fires, erosion, and siltation. These evils, too frequently, were accepted as the inevitable associates of progress.

During the 1920's and 1930's agronomists, landscape architects, and foresters emphasized the use of vines and shrubs for erosion control. However, labor and material costs not only had a limiting effect, but the fact that woody species needed two or more years to develop an erosion resistant ground cover, necessitated a shift to other forms of vegetation. During the late 1930's effort was directed to developing techniques and materials for establishing and maintaining turf species on roadside areas.

The grasses are an extremely adaptable family of plants. Varied species and manipulated management techniques can produce a wide range of environmental effects on a highway right-of-way. With appropriate grasses and maintenance methods, the milieu of an urban setting can be expressed with neatly mowed areas of uniformly textured turf (fig. 1), and the ecological associations of a natural swamp or marsh can be an integral part of the rural highway landscape. The most important facets of turf establishment and management along highways in the several climatic regions of the United States will be described later.

Grass also plays another major role. Highways today are more than a facility to hasten traffic and to make transportation more convenient. Highways today are for people. They are an integral part of urban and rural America and should enhance the motorist's environment, as well as that of residents adjacent to the right-of-way.

The current emphasis on highway beautification is due largely to the increase in pleasure driving as a form of recreation. More leisure time and awareness of environmental quality and safety are concomitant factors that accentuate the need to establish and maintain a visually attractive highway environment. Grass is the most useful vegetation for such a purpose.

Erosion control

For more than three decades, effective erosion control on highway roadsides has been intensively studied by the Roadside Development Committees of the Highway Research Board and by the American Association of State Highway Officials. Today erosion control is almost as important as design and location (fig. 2). To achieve an effective and harmonious transition between the highway right-of-way and the adjoining countryside, vegetation—normally turf—must be used with a minimum of delay to control erosion on construction scars and restore them as integral parts of an esthetically pleasing, unobtrusive, and natural roadside environment. The *complete highway* is not a reality until all soil areas are protected by appropriate vegetation (fig. 3). Knowledge of basic factors influencing soil erosion is important in recognizing

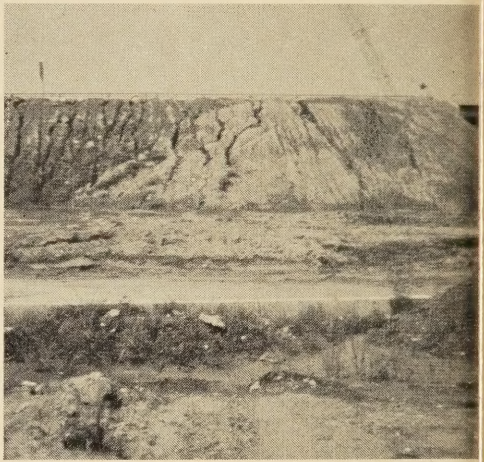

Figure 2.—Erosion control must be considered during design and location deliberations.

Figure 3.—Slope protected by appropriate ground cover following construction.

·rosion problems and arriving at their solu-ions. Principal factors that influence soil ·rosion have been summarized by A. W. Johnson (*1*).[2]

Slopes.—Good cross-section design is a basic actor in erosion control. Cut and fill slopes hould be constructed as flat as economically possible. As slopes become steeper (fig. 4), ·rosion-control costs increase rapidly and effectiveness and performance of control measures decrease correspondingly. The most economically practical flat slopes with ade-quately rounded tops and bottoms and appropriate transitional grading between cuts and fills improve appearance and highway afety, facilitate establishment of a vegetative over, and reduce maintenance costs. Other ·rosion-control considerations include climate, eologic formations, soil types, and drainage lesign in which adjacent land elements, as vell as the roadway itself, are considered.

Unfortunately, flat slopes are uneconomical n many sections of the United States. As radient and height of cuts and fills are ncreased, erosion-control problems become nore difficult. Special methods, materials, and quipment have been developed to cope with hese problems. Frequently additional meas-ures such as those listed below are needed to ontrol surface water and runoff.

- Drainage channels designed for need.
- Culverts located where erosion danger is vident; drop structures to prevent ditch rosion; aprons at outlets to minimize scour.
- Intercepting ditches for minor drainage rom above the highway; flume and special itch design for handling farm terrace water; nd diversion channels from culvert outlets to atural drainage.
- Gutter paving.
- Berms and spillways on large fills and side of elevated curves.

Drainage channels.—Drainageways present pecial problems that affect safety, appearance, nd adjoining lands. Vegetative cover as a ontrol of channel capacity and permissible elocity is limited. In addition to mechanical osion-control methods, such as temporary neck dams or permanent-type construction, any experiments have been developed to abilize and protect intercepting dikes and nannels pending the establishment of suitable egetation. Many materials including jute etting, glass fibers (alone or with asphalt), aper netting, and glass-fiber matting, as well concrete and asphalt linings, have been ed. Although results have not been uni-rmly conclusive, the variety of materials ggests that industry is aware of the problem nd is developing suitable materials for spe-al erosion-control problems.

Special areas.—Several erosion-control ethods have evolved from special problem eas. On high cut and fill slopes that could ot be worked with conventional equipment, elicopter or other aircraft have been used ccessfully for seeding and fertilizing. Costs these operations were comparable with ose of other mechanical methods. For sandy soils, which require special treatment, par-ticularly where high winds are erosive factors, each top grain of sand must be stabilized. Crushed rock or gravel have proved effective, and their application can be followed by seeding and fertilizing where vegetation is practical. Seeding, fertilization, and straw mulch tied down with wire netting have been used successfully.

Figure 4.—Steep slope effectively vegetated with appropriate species.

Sand dune control is difficult and costly. Culms of European and American beachgrass are usually applied as the first step in stabili-zation, followed by seeding of various grasses and legumes. Shrubs and trees are planted for the final cover.

In establishing vegetation speed is essential to effective, inexpensive erosion control. Often extensive seedbed preparation can be avoided by proper erosion-control measures applied immediately after construction (*2*, *3*).

Safety

Modern high-speed transportation arteries must have clear, unobstructed recovery areas adjacent to the travel lanes to provide safe zones for drivers who swerve or are forced from the pavement to roadside areas.

On recently completed expressways, several important features are incorporated for motorist safety: Streamlined cross sections with flattened slopes and swale-type drainage ditches, stabilized areas devoid of fixed traffic hazards, and roadside areas with vegetative covers of turf made up of grasses adapted to existing environmental conditions (fig. 5).

Turfgrass, one of the most adaptable and useful ground covers, contributes significantly to the safe use of roadside areas. Turf is the most rapidly established vegetative cover to control erosion, stabilize slopes, and provide safe off-highway emergency parking and stopping areas. It can be economically main-tained, and its appearance is pleasing to both highway users and adjacent residents.

As safe stopping distances are essential on high-speed traffic lanes, unobstructed sight lines (fig. 6) must be provided and maintained along all highways at intersections, railroad grade crossings, intersecting roads, and at relatively unimportant local streets and drive-ways. Visibility can be maintained by low-growing, functional turfgrasses that can be controlled to prevent visual restrictions.

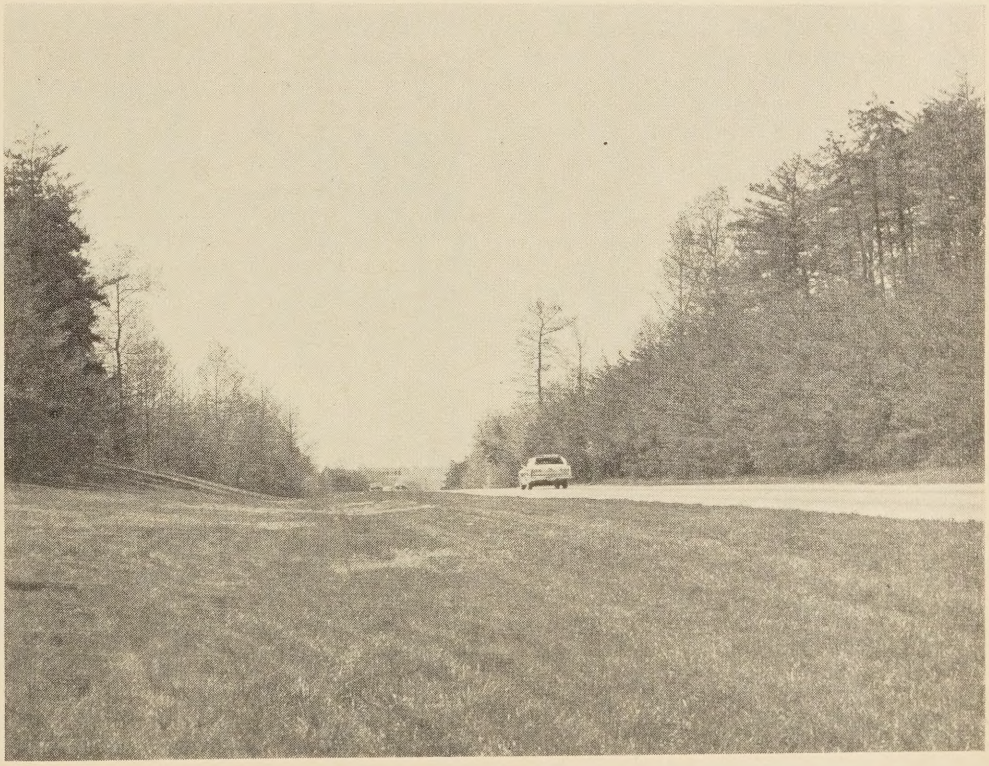

Figure 5.—Flattened, swaled area covered by well-maintained turf and free of fixed objects to enhance highway safety.

[2] Italic numbers in parentheses identify the references ·ed on p. 43.

Figure 6.—Dense ground cover of turf and unobstructed sight distances are important aspects of highway safety.

Appearance

Travel lanes framed with a turf cover (fig. 7) provide a transition to the natural environment of the rural countryside, as well as to the suburban and urban environment. Usually, residential streets and boulevards in towns and cities also have areas of grass. If properly established and maintained, grass improves the landscape, makes areas more desirable for many uses, and prevents erosion caused by wind and water. Turf cover adds pleasure and comfort to highway travel and allows clear views of distant countryside scenes. It also provides visual values in the urban environment.

Texture.—High-speed, expressway travel makes turf detail relatively unimportant. It is more important that the species be ecologically adapted and that they have desirable functional and esthetic values. A coarse texture is best for turf in rural areas, whereas a finer texture is better for areas in lawns, parks, cemeteries, etc., and for urban and suburban areas. However, the selection of turf should be governed by ease and economy of establishment and maintenance, functional value, and appearance.

Recreation.—Highways are used predominantly for recreational driving, and highway travel should be a pleasant and safe experience for the motorist traveling for pleasure or business. Unending ribbons of concrete and unimproved roadside areas are monotonous and unsafe, and it is essential that highway facilities include locations for the motorist to stop, rest, relax, and, perhaps, enjoy a picnic lunch. Small parks along the roadside with interesting paths to explore, scenic overlooks, historic sites, and other recreational facilities are all valuable roadside assets.

Restoration of sites.—Obviously, it is important to establish a vegetative cover on raw soil to elimina e erosion and stream sedimentation and pollution; thus, immediately after construction operations, slope stabilization, erosion control, and roadside rehabilitation should be undertaken. These objectives can be accomplished most efficiently and economically by establishing a grass cover. Seeding, fertilizing, and mulching should be done as soon as grading has been completed. In addition to the functional purposes it serves, grass contributes an additional dividend—esthetically pleasing roadside areas.

Conservation.—Preservation of native species obviates extensive replanting, and existing plants beyond construction boundaries should not be disturbed. Many areas must be disturbed, however, and these must be covere initially with grass. To reduce maintenanc operations, and also to provide a more estheti appearance, the regeneration of native specie of woody plants should be encouraged. Planne and well-developed highway roadsides will no only become more interesting but will also b more economical and less hazardous to main tain. Native growth usually abounds beyon construction limits, and sensible managemen practices encourage vegetation to extend ove slopes and other roadside areas so that road sides become integral parts of adjacen environments.

Design Elements

Cross-section and grade

Proper cross-section design contributes t highway appearance, promotes turf establis ment, and reduces maintenance costs. Roa side slopes with appropriately designed grad fitted into the terrain are basic elements in a pearance and should be considered as im portant as other roadside design features.

A slope with a flat gradient not only look better but is safer. Moreover, turf is estal lished more readily, and mowing, if require is easier. Although the advantages of flatt slopes are recognized by many State highwa departments, such slopes may be difficult t justify because of the additional constructic costs and the tendency to use standard cro sections regardless of slope height. Prop grading can be achieved by a contour-gradin plan in which different gradients are used fo different slope heights.

Rounding the top of a slope permits easi mowing and eliminates a starting point fo erosion where the planes of the slope and th original ground form an angular sectio

Figure 7.—Travel lane framed by well maintained grass and natural vegetation—the "complete highway."

Table 1.—Highway seeding in Northeast Region [1]

Grasses or legumes	Best seeding time	Seeding rate per acre (mixture)						
		Slopes		Medians and areas adjacent to shoulder [2]	Interior areas of interchanges		Non-mow areas [3]	Special purpose areas
		Mowed	Un-mowed		Mowed	Un-mowed		
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Red fescue	April–June and August–October.	30–40	------	------	------	------	30–60	------
Tall fescue	do	25–30	------	------	------	40–50	------	------
Ryegrass, annual	do	8	------	------	------	8	8	[4] 45
Birdsfoot trefoil	do	0–10	------	------	------	------	0–15	------
Ryegrass, perennial	do	------	45	------	------	------	------	------
or								
Red fescue	do	------	35–40	------	------	35–40	45	------
and								
Crownvetch	do	------	25–35	------	------	25–30	------	------
Kentucky bluegrass	do	------	------	20–25	[5] 20–25	------	------	[6] 20
Red fescue	do	------	------	45–50	45–50	65–70	------	[6] 35–45
Redtop	do	------	------	4	4	4	------	[6] 8–16
or								
Ryegrass, annual	do	------	------	8	8	8	------	------
Reed canarygrass	May–June	------	------	------	------	------	------	[7] 50
Redtop	August–October	------	------	------	------	------	------	[7] 16–20

1 Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, elaware, Maryland, and West Virginia.

2 Areas of frequent mowing.

3 Areas planned for natural regeneration.

4 Temporary.

5 Little or no Kentucky bluegrass in sandy areas.

6 Drainageways.

7 Wet areas.

ngular sections not only invite erosion but ıe sod may be scalped when the section is ıowed. Rounding the toe of a slope—blending slope with the original surface—also miniıizes erosion and facilitates mowing. When ppearance and ease of maintenance are ctors, or where snow drifting is a problem, at and well-rounded slopes are essential equirements.

The best slope ratio cannot be given cateorically, but unless the elevation is great, it may be appropriate to use a slope that is 3:1 or less. Depending on elevation, slope ratios may vary from 3:1 to 10:1. For the design of a cross section, the guiding principle is to blend the grade of the slope into the terrain so that it appears to be an integral part of the landscape.

Bridge embankments present special grading problems because of embankment heights and steep slopes beneath bridges. Often sodding the *nose* of the embankment is better than seeding turfgrasses. However, from the standpoint of safety and maintenance, it is desirable to flatten the embankment even though costs are increased. Turf cannot be grown directly underneath bridges except where structures are very high and the areas beneath receive sufficient sunlight and moisture to support turf covers. If turf cannot be grown, suitable surfacing materials should be used.

Cross-section designs of parking lots and public-use grounds of roadside safety rest areas should be graded for rapid drainage to insure dry areas for the convenience of the motorist.

Earth stabilization

Soil on which turf is to be grown must be at its natural angle of repose, and the area must be stable from the standpoint of soil mechanics before turf can be established. An adequate turf cover prevents surface erosion but does not control heavy seepage or flow of water from beneath the surface. If the areas of slippage or heavy seepage are not discovered until the slope is actually constructed, they can be controlled by *french* drains or, in serious situations, by placing stone blankets on the areas of seepage to prevent sloughing. Where sloughing occurs, the problem should be resolved in cooperation with a soil mechanics engineer.

If reasonable slope-grade and suitable soil exist, it is usually easier to establish turf on a fill than on a cut slope. The requirements for a specific area must be considered when the treatment to establish a turf cover is formulated.

The maximum slope ratio on which to attempt to grow grass is commonly agreed to

igure 8.—Erosion and slippage of topsoil can be decreased by proper bonding with slope surface materials.

Figure 9.—Slope area left unmowed to encourage regeneration of erosion-proof, natural ground cover.

Table 2.—Highway seeding in Southeast Region [1]

Grasses or legumes	Best seeding time	Seeding rate per acre (mixture)				
		Slopes	Medians and areas adjacent to shoulder [2]	Interior areas of interchanges	Non-mow areas [3]	Special purpose areas
Virginia, Tennessee, Western North Carolina, Northwestern South Carolina, Northeastern Georgia, Northern Arkansas						
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Kentucky bluegrass	March–May	------	40	40	------	------
White clover	August–October	------	3	3	------	------
or						
Kentucky bluegrass	do	30	20	20	------	------
Redtop	do	5	5	5	------	[4] 5
White clover	do	2	2	2	------	------
or						
Kentucky bluegrass	do	------	40	40	------	40
Red fescue	do	------	20	40	------	40
or						
Tall fescue	do	40	40	40	40	40
With one of the following grasses:						
White clover	do	2	2	2	------	2
Annual lespedeza	do	20	20	20	20	20
Sericea lespedeza	do	30	------	------	30	------
Crownvetch	do	5	------	------	5	------
Southeastern Virginia, Eastern North Carolina, Southeastern South Carolina, Mississippi, Alabama, Georgia, Northern Louisiana						
Bahiagrass	February–June	25	25	25	25	------
Annual lespedeza	do	20	20	20	20	------
or						
Bahiagrass	do	------	------	25	25	25
Sericea lespedeza	do	------	------	20	20	------
Bermudagrass	do	15	15	15	15	15
With one of the following grasses:						
Crimson clover	August–November	25	25	25	25	25
Annual lespedeza	do	20	20	20	20	------
Sericea lespedeza	do	------	------	30	30	------
or						
Weeping lovegrass	March–August	5	------	5	5	------
With one of the following grasses:						
Annual lespedeza	do	20	------	------	------	------
Sericea lespedeza	do	30	------	30	30	------
Crownvetch	do	5	------	5	5	------
Southern Louisiana, Mississippi, Alabama, Florida						
Bahiagrass	February–June	25	------	25	25	------
Sericea lespedeza	do	20	------	20	20	------
Centipedegrass	do	------	10–15	------	------	------
Annual ryegrass	August–September	5–25	5–25	5–25	5–25	[5] 5–25
Browntop millet	April–September	30	30	30	30	------
Sudangrass	do	40	40	40	40	------

[1] Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, and Tennessee.

[2] Areas of frequent mowing.

[3] Areas planned for natural regeneration.

[4] Drainageways.

[5] Temporary.

be 1.5 horizontal to 1 vertical, although some variation because of soil types is permitted. A ratio of 2 horizontal to 1 vertical is usually considered maximum for successful turf establishment on a large scale.

Occasionally when a fill slope constructed of rock is covered with soil and grass is planted, the angle of repose of the rock fill may be less than 2 horizontal to 1 vertical, but the placement of soil behind the rocks and in the crevices between them provides a stability that is not possible without the rock.

Topsoil may be removed from the road prism, depending on the depth of fill. In some States the height of the fill beyond which stripping is not required is 6 feet. All topsoil to be removed should be stockpiled and used on median areas, on slopes requiring flattening beyond the normal highway prism, and in other locations. Any excess of topsoil should be stockpiled for use on nearby projects where topsoil may not be available.

Although turf can be grown on subsoil containing at least 10 percent fines—particles of soil passing through a sieve with 200 openings per square inch—a higher percentage is desirable. Approximately 50 percent fines is optimum, but usually, the proportion of fines should not exceed 80 percent. It is not considered economically feasible to salvage topsoil with less than 20 percent fines. The seeming contradiction between the ability to grow turf on soil containing a minimum of 10 percent fines and the salvage of topsoil with a minimum of 20 percent fines is understandable when the economics involved are considered.

It has been shown in numerous studies that the organic component of topsoil is not essential for turf establishment and that with proper fertilization, soil completely lacking in organic material, but containing enough fines, can be successfully used for turf establishment.

The depth of topsoil required for turf growth depends on the kind of turf, nature of the underlying soil, degree of slope, type of maintenance the turf will receive, and to a lesser extent, the availability and cost of topsoil. It is not practical to spread topsoil less than 2 inches deep unless the area is relatively level and the underlying material has enough fines to aid turf establishment. Except for very special reasons, placing topsoil more than 6 inches deep is unwise.

On some slopes, a smoothly bladed subgrade and a thick layer of topsoil will cause serious slippage after the upper layer becomes saturated with water (fig. 8). The topsoil should be bonded to the subsoil by loosening the surface of the subsoil before the topsoil is placed. Sometimes slope exposure will contribute to slippage of the upper layer because of freeze-thaw cycles in late winter or early spring. This is particularly noticeable where the slope exposure is to the south and the soil is heavy.

Environmental considerations and management

The type of turf desired and how often an area is to be mowed, if at all, are important factors. In many sections of the country, unmowed areas are invaded by woody plants to regenerate naturally. To an extent that is consistent with safety and appearance, woody plants, particularly low shrubs, should be encouraged by prohibiting the mowing of desirable woody species that exist near adjacent fence lines.

Where mowing is not contemplated, plants other than grasses may be desirable substitutes for turf or additions to initial seed mixtures. Plants such as crown vetch and birdsfoot trefoil are excellent in soils that permit them to thrive.

The vegetation maintenance plan for an area should be determined before grass is actually established so that the turf produced will lend itself to proper management.

Rural.—Types of rural highways range from Interstate freeways on completely new locations with little or no adjacent development to older roads with many dwel.ings along the right-of-way. Hence no concrete set of rules can be made to cover all the different conditions along these different classes of rural roadways. Some roads pass through long stretches of heavily wooded sections where management differs from that in open farm land. In some locations, particularly areas devoted to agriculture, all roadside areas between right-of-way lines must be mowed to prevent the growth of noxious weeds.

On the Interstate Highway System many locations require no mowing, nor is mowing desirable. These areas include high, steep cuts and fills where mowing is impossible, and the establishment of the natural woody growth should be encouraged. When wide medians have been stripped of all vegetation and grass becomes established, much of the area should be left unmowed to develop a more natural environment, to encourage the regeneration of woody species, and to decrease mowing costs (fig. 9). Following the initial contract application, a maintenance fertilizer program may be required on rural highways where topsoil has not been used.

Suburban.—Suburban highways, which often become urban, usually require a higher degree of maintenance than rural highways. Higher design criteria for these areas may

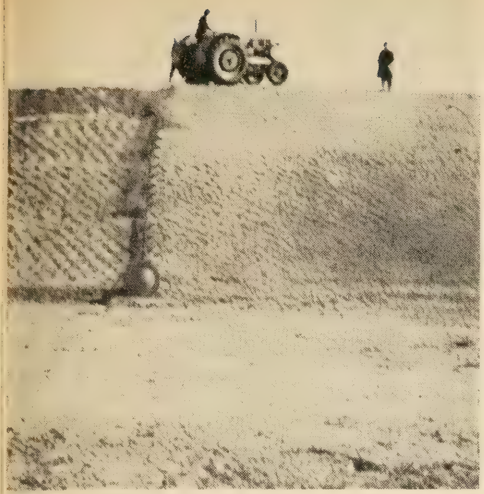

Figure 10.—"Clodbuster" preparing seedbed on slope area too hazardous for conventional equipment.

include flatter grades, use of topsoil for high-quality turf, careful selection of seed mixtures, and maintenance fertilizer programs. Usually, turf is mowed several times a year to a height of 3 to 4 inches, and herbicides used to eliminate weed growth and produce a more attractive appearance.

Along suburban routes turf should be mowed and not allowed to return to native woody material, except on roadsides that include existing woodland, stream beds, edges of marshes, or other natural sites.

Urban.—Often, roadside turf in urban areas is the only grass seen by motorists or pedestrians, and roadside areas should be designed with this in mind. In urban areas, requirements for topsoil, seed, and fertilizer should be carefully studied. (Refer to seeding charts, tables 1–6.)

Safety rest areas.—Design of turf areas at roadside safety parking areas is becoming more important as the number of areas increase. Turf in these locations should be grown on topsoil and should be of a character to withstand pedestrian traffic and wear, particularly at picnic sites. Where picnic tables are provided, pads of cement or bituminous asphalt should be placed under tables and immediately around them rather than attempt to maintain grass at such locations. Often picnic areas are located under mature trees, and heavy shade may reduce turf density.

Conservation

The establishment of turf on highway roadsides is necessary to protect roadside slopes and to enhance appearance. In some woodland areas, especially on new locations along Interstate highways, turf prevents soil erosion until woody species become reestablished. Grassed areas may tend to suppress certain woody plants, but after initial invasion by blackberry, sumac, trembling aspen, and fire cherry, the more tolerant and longer-lived species, such as the oaks and maples, move in.

The natural appearance of established turf contributes to the harmony of the highway environment—a major benefit of conservation.

Establishment Practices

To prepare a good seedbed for establishing new plantings of small seeded grasses and legumes, the soil should be finely divided and firm to allow rapid movement of water from the soil to the seed. Normal highway construction usually removes friable topsoil and leaves a difficult environment for plants.

Physical properties of roadside soils (*4, 5*)

Soil is said to be a mixture of highly weathered minerals that contain an organic fraction capable of supporting plant growth. However, roadsides seldom have good agricultural soils; consequently, a seedbed must be prepared from subsoil or geologic materials that are extremely low in plant food, void of organic matter, and of a structure that is not conducive to the preparation of a fine seedbed. Texture and physical composition of roadside soil material range from very rocky in mountainous sections to very dense marine clay in swampy areas. A seedbed must be prepared for all conditions—wet or dry, sand or clay.

Because subsoil is exposed during construction operations, the seedbed's physical nature is often more difficult to amend than its chemical properties, especially where highly compacted or dense clays and raw parent material exist.

Topsoil.—If the soils in a given region are usable, a good seedbed usually is prepared best from the topsoil. Topsoil is the highly weathered surface horizon of a soil, it is usually the most friable and fertile layer of a soil horizon, and it contains larger amounts of organic matter than the sublayers. Except where highways are built in very level terrain, such as the Great Plains, most of this desirable topsoil is removed during grading operations. Topsoil should be stockpiled and spread about 4 to 6 inches deep over selected subsoil areas exposed in the construction process. Though agronomically ideal for medians and other level areas where a fine quality of turf is required, this practice is not practical on extensive slope areas, particularly in rugged topography. (Refer to tables 1–6 for species appropriate for various roadside areas.)

Subsoil.—Most soils have a higher percentage of clay in the subsoil (B-horizon) than in the topsoil (A-horizon), especially those in humid sections. In subsoils high in clay content, the percolation of water is very slow, aeration is slight or lacking, and root penetration is limited. For these reasons heavy clay soils are droughty and very susceptible to erosion.

Usually, roadside slopes of clay subsoils are plastic when wet, very firm when moist, and hard when dry. Because subsoil is not exposed to surface weathering and the soil-building action of plant roots, it usually breaks up into large clods rather than fine particles when tilled.

Chemical properties of roadside soils (*4, 5*)

Subsoil materials used as seedbeds for most roadside plants are inherently low in plant nutrients. The chemical composition of these soil materials is strongly related to the geologic parent material, and the fertility and pH of the subsoils are similar to those of the parent material.

Table 3.—Highway seeding in Central Region [1]

Grasses or legumes	Best seeding time	Seeding rate per acre (mixture)					
		Slopes	Medians and areas adjacent to shoulder [2]	Interior areas of interchanges	Non-mow areas [3]	Special purpose areas: Urban	Special purpose areas: Drainageways
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Tall fescue, Kentucky 31	February–April and August–September.	40	40	40	40	40	40
Kentucky bluegrass	do	20	20	20	20	20	20
Perennial ryegrass or red fescue.	do	10	10	10	10	10	10
Clover [4]	do	3	3	3	3	3	3
Kentucky bluegrass	do	------	25–30	------	------	25–30	------
Red fescue	do	------	18–20	------	------	18–20	------
Perennial ryegrass or redtop	do	------	8–10	------	------	8–10	------
Clover [4]	do	------	4–5	------	------	4–5	------
Tall fescue, Kentucky 31	do	35–40	35–40	35–40	35–40	------	35–40
Red fescue	do	10–12	10–12	10–12	10–12	------	10–12
Redtop or perennial ryegrass	do	------	8–10	8–10	8–10	------	8–10
Clover [4]	do	4–5	4–5	4–5	4–5	------	4–5
Tall fescue, Kentucky 31	April–May	35–40	------	35–40	35–40	------	------
Bermudagrass	do	10–15	------	10–15	10–15	------	------
Red fescue or redtop	do	4–6	------	4–6	4–6	------	------
Clover [4]	do	3–4	------	3–4	3–4	------	------
Tall fescue, Kentucky 31	February–April	40–45	------	------	40–45	------	------
Kentucky bluegrass	do	18–20	------	------	18–20	------	------
Crownvetch	do	10–12	------	------	10–12	------	------
Crownvetch	do	18–20	------	------	18–20	------	------
Perennial ryegrass	do	6–8	------	------	6–8	------	------

[1] Kentucky, Ohio, Indiana, Michigan, and Illinois.
[2] Areas of frequent mowing.
[3] Areas planned for natural regeneration.
[4] White Dutch, Ladino, or Alsike clover.

Table 4.—Highway seeding in North Central Region [1]

Grasses or legumes	Best seeding time	Seeding rate per acre (mixture): Slopes	Medians and areas adjacent to shoulders [2]	Interior areas of inter-changes	Non-mow areas [3]	Special purpose areas
Northern Plains areas—low precipitation (North Dakota, South Dakota, Western Nebraska, Northwestern Minnesota)						
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Oats [4]	March–June and August–October.	16	-	16	16	[5] 9–73
Rye [6]	do	24	-	24	24	[5] 9–73
Buffalograss	do	2	5–25	2	2	-
Intermediate wheatgrass	do	3–17	-	3–17	3–17	-
Slender wheatgrass	do	1–4	1	1–4	1–4	-
Crested wheatgrass	do	3–16	3	3–16	3–16	-
Alfalfa [7]	do	3–6	2–7	3–6	3–6	-
Smooth brome	do	[8] 4–16	-	4–16	4–16	[9] 15
or						
Switchgrass	do	2–4	-	2	2	-
Indiangrass	do	3	-	3	3	4
Little bluestem	do	1–3	-	1–3	1–3	-
Big bluestem	do	1	-	1	1	4
Intermediate wheatgrass	do	3–17	-	3–17	3–17	-
Crested wheatgrass	do	3–16	-	3–16	3–16	15
Sideoats grama	do	2–4	-	2–4	2–4	15
Hairy vetch [7]	do	3	-	3	3	3
Perennial ryegrass	do	-	3	-	-	-
Kentucky bluegrass	do	-	2–6	-	-	-
Blue grama	do	-	2	-	-	-
Buffalograss	do	-	5–25	-	-	-
Sudangrass	do	-	-	-	-	[5] 11–13
Central Plains areas—low precipitation (Western Kansas, Nebraska)						
Annual ryegrass	March–June and August–October.	6	6	-	-	-
Tall fescue	do	15	15	-	-	-
Kentucky bluegrass	do	6	2–6	-	-	-
Western wheatgrass	do	3–4	-	-	-	-
Switchgrass	do	-	-	2–4	2–4	-
Smooth brome	do	-	6	6	6	-
Alfalfa	do	3–6	2–7	4–13	4–13	-
White clover	do	-	-	3–15	3–15	-
Blue grama	do	-	2	3	3	-
Sand lovegrass	do	-	-	2–5	2–5	-
Sand dropseed	do	-	-	2–4	2–4	-
Buffalograss	do	-	-	18	18	-
Cool humid lake States—Eastern Minnesota, Wisconsin, Iowa, Missouri						
Crownvetch	March–June and August–October.	5	-	3	3	-
Tall fescue	do	10	-	10	10	10
Smooth brome	do	6	-	6	6	6
Birdsfoot trefoil	do	4	-	4	4	-
Switchgrass	do	3	-	3	3	3
Alfalfa	do	5	-	5	5	-
Perennial ryegrass	do	4	-	4	4	4
Reed canarygrass	do	-	-	-	-	[10] 10–30
Tall fescue	do	[11] 25	-	-	-	-
Kentucky bluegrass	do	[11] 8, [12] 40	-	-	-	-
Birdsfoot trefoil	do	[11] 3	-	-	-	-
White clover	do	[11] 3	-	-	-	-
Perennial ryegrass	do	[11] 8, [12] 8	-	-	-	-
Red fescue	do	[12] 18	-	-	-	-
Redtop	do	[12] 18	-	-	-	-

[1] Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin.
[2] Areas of frequent mowing.
[3] Areas planned for natural regeneration.
[4] Spring.
[5] Temporary.
[6] Fall.
[7] Not to be used in areas where herbicides applied.
[8] High rate with mulch.
[9] Drains.
[10] Wet areas.
[11] Rural.
[12] Urban.

pH.—Roadside seedbeds in humid sections of the eastern United States usually have an acid reaction, whereas those of the western United States have subsoils in which the pH ranges from 7 to 9 owing to the combination of the alkaline parent material of the seedbed and low rainfall. Sometimes strong alkali deposits exposed in construction must be buffered with gypsum, organic matter, or topsoil before seedings can be established.

In the southeastern States extremely acid backslopes have been exposed in road construction through *lignite* soils, which require as much as 20 tons of lime per acre to neutralize acids in the surface layer (*6*).

Fertility.—Most roadside soils in humid sections of the United States need additions of plant food to support a ground cover. Nitrogen content is universally inadequate to sustain healthy grass sods because of the very low organic-matter content of exposed subsoil. Phosphorus content also is low in many subsoil areas of the United States—usually less than 10 pounds per acre. The same is often true for potassium, although generally, soils have more potassium than nitrogen or phosphorus.

Organic matter in roadside soils

Organic matter in soils is influenced by climate, topography, kind of vegetation, nature of the parent material, and time. More plant growth, hence more organic matter, is produced in humid areas than in dry climates, but it is also decomposed more rapidly in warm and humid climates. In the United States, the percentage of organic matter in the soil decreases from north to south because the rate of decomposition overrides production. Organic matter is important to the rooting zone of turf because it supplies nitrogen (soil organic matter is about 5 percent N), helps develop a more stable soil structure, and holds water and nutrients.

Unfortunately, the supply of organic matter is inadequate in most soils. The average subsoil contains less than 1 percent organic matter; consequently, stability of the soil structure is poor. High intensity rains tend to *puddle* soils low in organic matter and cause rapid surface sealing so that much of the rainfall is lost as runoff.

Amending roadside soils with organic matter is not practical unless high-intensity magagement is practiced after establishment. Use of peat, sawdust, or other organic-soil amendments on small areas, like lawns around rest stops or roadside parks, possibly could be justified.

Seedbed preparation for seeding and fertilizing

Regardless of species, seeding method, fertilizer, or mulching practice, a well prepared seedbed is advantageous to establish roadside seedings. Ideally, the soil should be tilled 6–8 inches deep and the top 4 inches pulverized into small aggregates. However, soil texture, soil structure, and topography rarely permit the seedbed to be broken below 4–6 inches, and the surface is left cloddy. On flattened slopes and median areas a tractor-mounted disk-harrow can be used to prepare the seedbed. If the harrow leaves the seedbed cloddy a tractor-mounted rotary tiller or cultipacker should be used to pulverize clods into smaller aggregates. If the soil is hard it may be necessary to chisel plow before disking after which the surface can be further smoothed and conditioned. A spike-tooth harrow worked parallel to the roadway is an excellent tool for smoothing and conditioning, as it not only helps pulverize and firm the seedbed, but also leaves horizontal grooves. These grooves act as miniature checks for seed and rain water to create a more favorable germination environment.

To avoid accidents, only tractors with low centers of gravity should be used to prepare seedbeds on steep slopes. Ordinary farm tractors, if used, should be equipped with dual wheels set at the widest spacing possible. If slopes are too steep for safe tractor operation, specialized equipment must be used. The seedbed can be tilled either with an attachment on a crane from the roadbed, or with equipment that hangs from a tractor at the top of the slope. Where adequate space for operating a tractor is available at the top of slopes, a heavy spike-toothed chain, or *clodbuster*, is an excellent tool for soil preparation. These special-purpose chains have a ball or swiveled weight at the end that rolls along the base of the slope. As the tractor moves the chain turns rapidly, and the spikes dig into the seedbed. Several passes may be needed to pulverize the seedbed to the desired texture (fig. 10).

Fertilization

Most roadside soils must be fertilized at high rates to support erosion-resistant sods. Enough phosphorus and potassium should be added first to meet the needs of plants for 1–2 years (*7*). Sufficient nitrogen should be applied to supply the new turf for 6–12 months, and lime should be added to adjust the pH to 6.0–6.5.

The initial fertilizer treatment given a new roadside planting is similar in all parts of any given geographic region. However, routine soil analyses for pH, and for phosphorus and potash, can be made on soils obtained from the test borings performed during the grade and drain phase of the highway project. Abnormal soils that require special amendments or a change in average rate of fertilizer and lime should be noted. Regardless of the amount and kind of fertilizer and lime applied, it should be mixed with the soil to a depth of 4–6 inches during seedbed preparation. Fertilizer may, however, be applied on the surface if steep terrain makes equipment operation hazardous.

More fertilizer is needed to establish sod on roadsides than to seed farm pastures, but the amount is less than that used to establish fine turf. Except in the western United States, where soils are well supplied with potassium, a complete fertilizer with a 1–2–1 ratio of N, P_2O_5, and K_2O should be incorporated into the seedbed. The rate varies from region to region, but in the humid east, about 1,000 pounds per acre of a 10-20-10, or a similar fertilizer, is used. Higher rates can be applied on very infertile soils, and somewhat lower rates on soils in the drier western States where 1–2–0 ratio of N,P_2O_5, and K_2O is normally used.

Seeding

Conventional farm equipment such as grain drills and cultipacker seeders can be used to seed roadside terrain that is reasonably level and not too rocky. However, on slopes that are too steep for conventional equipment, cyclone seeders, tractor- or truck-mounted centrifugal seeders, and *hydroseeders* (*8*) can be used. The *hydroseeder*, the most frequently used seeder on steep terrain, sprays both seed and fertilizer onto the seedbed (fig.11).

The objective in compounding mixtures for roadside seeding is to develop a sod in a short time. The seeding rate and species to use in the different regions of the United States (*9*) are given in the tables 1–6. Usually, seeding rates on roadsides are several times higher than those on pastures. For example, tall fescue is seeded at 10–15 pounds per acre in pasture, but 40–60 pounds per acre on roadsides. The higher seeding rates are needed to offset the high seed losses caused by the poor quality roadside seedbeds.

When seeding on highly erosive soils, or seeding *out of season*, it is often necessary to use a rapidly growing companion species such as ryegrass, millet, or a small grain. The seeding rate of these species should be kept low—5 pounds of ryegrass, 15 pounds of millet, or ½ bushel of smallgrains—otherwise they shade out desirable permanent grasses.

Equipment

Inadequate equipment has caused many seeding failures on roadsides. In some sections lime and fertilizer are still applied to the seedbed by hand from a bag or by a shovel from a truck bed. Fortunately, for planting, mulching, and fertilizing roadsides there have been several equipment innovations, chiefly the *hydroseeder* (*8*), which permits the planting of slopes from distances as much as 200 feet away. This equipment consists of a large slurry tank and centrifugal pump powered by a gasoline engine. Water, seed, and other ingredients—fertilizer, lime, fungicides, and even certain types of mulch—are placed in the tank and agitated constantly. The resulting slurry is sprayed at a prescribed rate onto the areas to be seeded. Slurry tanks with capacities of from 250–1,500 gallons are available. The largest of these holds enough seed, water, and fertilizer to cover 1–2 acres. If wood cellulose fiber mulch is added to the slurry, the area covered by a *single fill* is reduced by 50 percent. Some slurry machines, capable of pumping sprigs with the mulch and fertilizer, are often used to relime or refertilize steep slopes that are inaccessible to conventional equipment (*10*).

Specially designed *air guns* for blasting pelleted fertilizers onto slope areas have also

Table 5.—Highway seeding in Northwest Region[1]

Grasses or legumes	Best seeding time	Seeding rate per acre (mixture)				
		Slopes	Medians and areas adjacent to shoulder[2]	Interior areas of interchanges	Non-mow areas[3]	Special purpose areas
Western Oregon and Western Washington						
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Red fescue	March–April and September–October.	10–25	10–25	10–25	10–25	30–40
Chewings fescue	do	8–20	8–20	8–20	8–20	20–30
Perennial ryegrass	do	3–12	2–12	3–12	3–12	15–20
White Dutch clover	do	3–6	3–6	3–6	3–6	4–5
Highland bentgrass	do	3	3	3	3	4–5
Kentucky bluegrass, Newport	do	5	5	5	5	5
Eastern Oregon and Eastern Washington						
Hard fescue	March–April	10–20	10–20	10–20	10–20	20–30
Crested wheatgrass	do	10–30	10–30	10–30	10–30	30–40
Big bluegrass, Sherman	do	10	10	10	10	20–30
Perennial ryegrass	October	5	5	5	5	5–10
Irrigated lawn areas:						
Kentucky bluegrass, Merion.	March–April and October.	--------	--------	50–80	--------	--------
Chewings fescue	do	--------	--------	80	--------	--------
Red fescue	do	--------	--------	80	--------	--------
Under 12-in. precipitation:						
Crested wheatgrass	Spring	5–10	5–10	5–10	5–10	5–10
12 to 20-in. + precipitation:						
Pubescent, crested or streambank wheatgrass.	Spring and fall	10–20	10–20	10–20	10–20	10–20
Hard fescue	do	20	20	20	20	20
Winter clover	do	4	4	4	4	4
Alaska						
Crownvetch	June–July	25	--------	--------	25	25
Red fescue	do	40	--------	--------	40	40
Smooth brome	do	95	--------	--------	95	--------
Chewings fescue	do	25	--------	--------	25	--------
Kentucky bluegrass	do	40	40	--------	--------	--------
Red fescue	do	60	60	--------	--------	--------
Smooth brome, Manchar	do	15	--------	--------	15	--------
Oats	do	15	--------	--------	15	--------
Northern California						
Annual ryegrass	Late summer	100–200	--------	--------	--------	--------
Barley	do	100	--------	--------	--------	--------

[1] Washington, Oregon, Idaho, Montana, Wyoming, Alaska, and northern Califronia.

[2] Areas of frequent mowing.

[3] Areas planned for natural regeneration.

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been developed. They operate by compressed air, and consist of a suction pipe and controlled orifice nozzle that blasts a fan pattern of pelleted fertilizer as far as 80 feet. In rural areas, airplanes are sometimes used to apply fertilizer.

Mulching

Next to properly selected seed a good mulch is the most important material for developing highway turf. Erosion of an unprotected soil surface may create greater maintenance expenses than the initial cost of shaping, seeding, fertilizing, and mulching. It is believed that a good mulch is more important on slopes than a topsoil cover.

Successful hydroseeding (*11*) of slopes depends on the use of a suitable mulch. Hydroseeding and the subsequent application of a hay mulch—an effective technique that was developed more than 25 years ago—can be used, with or without topsoil, to establish turf on highway slopes at about ⅓ of the cost of other methods. Today, turf is established on highway slopes in humid regions at a much lower price per unit area than 30 years ago.

Mulch is required to temporarily stabilize a disturbed soil surface until a cover of vegetation can be established. It protects the soil surface against wind and water erosion, holds seed in place, protects seed from rapid temperature fluctuations and direct sunlight, reduces surface evaporation, permits penetration of rainwater into the soil, and helps prevent formation of a crust on the soil surface.

Mulching materials

Hay and straw have long been the universal mulching materials for highway areas. In some States they are still used over a seeding of cereal rye to initially establish growth on slopes until native grasses and weeds gradually stabilize the area. This practice is being supplanted by the judicious use of grass and legume species adapted to local soil and climatic conditions. In the last few years the scarcity of good mulch hay, presence of undesirable weed seed, costly labor and equipment required to place hay mulch, the improved quality requirements for turf, and the magnitude of current highway construction programs have shown that other more suitable mulching materials and faster applications are needed.

In the last decade sodium silicate, liquid dispersed polyethylene, various synthetic plastic emulsions, latex formulations, petroleum resins and other similar materials have been tried as soil binders and mulches with varying degrees of success. Latex formulations are now on the market but have proved neither as versatile nor as efficient as hay. A thin film of these materials on a slope is easily ruptured and does not readily permit the gentle entry of water through the soil surface. Petroleum, resin-based stabilizer emulsions, although still in the experimental stage, have shown some promise for stabilizing very sandy areas against wind erosion until seedings emerge.

Materials such as bran, crushed corncobs, bagasse, sugar-beet pulp, cocoa, and peanut hulls have been tried somewhat successfully, but they will probably be limited to areas where they are available locally. Usually these byproducts require a heavy application of asphaltic emulsions to hold them in place. Light applications of wood chips over seeded areas have been used successfully in some States. A significant development is the wood fiber mulches manufactured by chemically or mechanically reducing pulpwood to discrete fibers that can readily take up water and be mixed in water slurries of seed and fertilizer for application as a heavy spray to soil surfaces.

Uniformly applied at rates of about 1 ton per acre, wood fiber mulch holds seed in place and provides an erosion resistant cover that is

Table 6.—Highway seeding in Southwest Region [1]

Grasses or legumes	Best seeding time	Seeding rate per acre (mixture): Slopes	Medians and areas adjacent to shoulder [2]	Interior areas of inter-changes	Non-mow areas [3]	Special purpose areas
Arizona						
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
6–10-in. precipitation:						
Lehman lovegrass	June	2	2	2	-------	-------
10–16-in. precipitation:						
Lehman lovegrass	do	2	2	2	-------	-------
Boer lovegrass	do	2	2	2	-------	-------
Blue grama	do	3	3	3	-------	-------
10–20-in. precipitation: [4]						
Western wheatgrass	June or October	8	8	8	-------	-------
Crested wheatgrass	do	5	5	5	-------	-------
Pubescent wheatgrass, Luna	do	4	4	4	-------	-------
Alkali sacaton	do	5	5	5	-------	-------
Sand dropseed	June	1	1	1	-------	-------
Spike dropseed	do	2	2	2	-------	-------
Blue grama	do	2	2	2	-------	-------
Indian ricegrass	October	4	4	4	-------	-------
Smooth brome	June or October	5	5	5	-------	-------
California						
Annual ryegrass alone or with barley.	Late summer or early fall.	200	-------	-------	-------	-------
Colorado						
Less than 15-in. precipitation: [4]						
Blue grama	Late fall or early spring.	1	1	1	1	1
Sideoats grama	do	3	3	3	3	3
Western wheatgrass	do	5	5	5	5	5
Buffalograss (treated)	do	6	6	6	6	6
Yellow sweetclover	do	3	3	3	3	3
Sand lovegrass	do	1	1	1	1	1
Madison vetch	do	4	4	4	4	4
Crested wheatgrass	do	3½	3½	3½	3½	3½
15–30-in. precipitation: [4]						
Blue grama	do	1	1	1	1	1
Sideoats grama	do	3	3	3	3	3
Little bluestem	do	2	2	2	2	2
Big bluestem	do	3	3	3	3	3
Sand dropseed	do	½	½	½	½	½
Madison vetch	do	4	4	4	4	4
Western wheatgrass	do	5	5	5	5	5
Smooth brome	do	6	6	6	6	6
Orchardgrass	do	2	2	2	2	2
Intermediate wheatgrass	do	5	5	5	5	5
Pubescent wheatgrass	do	5	5	5	5	5
Hard fescue	do	2	2	2	2	2
Slender wheatgrass	do	4	4	4	4	4
Meadow foxtail	do	2	2	2	2	2
More than 30-in. precipitation: [4]						
Intermediate wheatgrass	Early summer and early fall.	5	5	5	5	5
Orchardgrass	do	2	2	2	2	2
Smooth brome	do	6	6	6	6	6
Mountain brome	do	4	4	4	4	4
Pubescent wheatgrass	do	5	5	5	5	5
Kentucky bluegrass	do	1½	1½	1½	1½	1½
Timothy	do	2	2	2	2	2
Nevada						
Irrigated lawn areas:						
Kentucky bluegrass	Late spring	3	3	3	3	3
Red fescue, Rainier	do	1	1	1	1	1
Chewings fescue	do	1	1	1	1	1
White Dutch clover	do	½	½	½	½	½
Oklahoma						
15–30-in. precipitation: [4]						
Coarse-textured soils:						
Weeping lovegrass	Feb. 20–May 20 in west, Apr. 1–May 31 in east.	6½	6½	6½	6½	-------
Sand lovegrass	do	½–1	-------	1	½–1	-------
Sand bluestem	do	1½–2	-------	2	1½–2	-------

[1] Arizona, southern California, Colorado, Nevada, New Mexico, Oklahoma, Texas, and Utah.
[2] Areas of frequent mowing. [3] Areas planned for natural regeneration.
[4] Mixtures vary, use components given below to total 15–20 lb. pure live seed/acre.

Table 6.—Highway seeding in Southwest Region [1]—Continued

Grasses or legumes	Best seeding time	Seeding rate per acre (mixture)				
		Slopes	Medians and areas adjacent to shoulder [2]	Interior areas of interchanges	Nonmow areas [3]	Special purpose areas
Oklahoma—Continued						
15–30-in. precipitation: [4]						
Coarse-textured soils:						
Switchgrass	Feb. 20–May 20 in west, Apr. 1–May 31 in east.	1½	-------	-------	1½	-------
Sideoats grama	do	2–2½	3–4	2½–3½	2–2½	5
Blue grama	do	1–2½	2–5	1½–2	1–1½	3
Bermudagrass, common	do	3	3	3	3	3
Fine-textured soils:						
Weeping lovegrass	do	6½	6½	6½	6½	-------
Sideoats grama	do	2½–3½	2½–3½	2½–3½	2½–3½	3½
Blue grama	do	1½–2	1½–2	1½–2	1½–3½	2–3½
Buffalograss	do	2½–4	3–4	3–4	3–4	4
Bermudagrass, common	do	3	3	3	3	3
Miscellaneous soils: [4]						
Weeping lovegrass	do	6½	6½	6½	6½	-------
Yellow bluestem	do	2–2½	2½–3½	2½–3½	2–2½	3½–5
Blue grama	do	1–1½	1½–2	1½–2	1–1½	2–3
Bermudagrass, common	do	3–6	3–6	3–6	3–6	6–12
More than 30-in. precipitation: [4]						
Weeping lovegrass	Apr. 1–May 31 in west	6½	6½	6½	6½	-------
Switchgrass	do	1–2	1½–3	-------	2½–3	-------
Little bluestem	do	1–2	1½–3	1–3	1–2	2–3
Sideoats grama	Apr. 8–June 10 in east	2–2½	2½–3½	2½–3½	2–2½	3½
Bermudagrass, common	do	3–6	3–12	3–12	3–6	3–12
Buffalograss	do	-------	-------	-------	-------	4
Yellow bluestem	do	½	-------	-------	½	-------
Tall fescue	do	-------	-------	-------	-------	16
Smooth brome	do	-------	-------	-------	-------	9
Texas						
15–25-in. precipitation:						
Northwest Texas:						
Sandy soils:						
Sideoats grama	Feb. 1–June 1	½	½	½	-------	½
Green sprangletop	do	2	2	2	-------	2
Switchgrass	do	2½	2½	2½	-------	2½
Plainsbristlegrass	do	4	4	4	-------	4
Bermudagrass	do	-------	7	-------	-------	-------
Weeping lovegrass	do	-------	-------	-------	1½	-------
Heavier soils:						
Sideoats grama	do	½	½	½	-------	½
Green sprangletop	do	2	2	2	-------	2
Western wheatgrass	do	3½	3½	3½	-------	3½
Blue grama	do	½	½	½	-------	½
Southwest Texas:						
Buffalograss	do	1	1	1	-------	1
Rhodesgrass	do	1½	1½	1½	-------	1½
Yellow beardgrass	do	2	2	2	-------	2
Sideoats grama	do	½	½	½	-------	½
More than 30-in. precipitation:						
Bermudagrass (hulled)	Feb. 1–May 15	7	7	7	-------	7
Green sprangletop	do	2	2	2	-------	2
Weeping lovegrass (deep sands).	do	1½	-------	-------	1½	-------
Bermudagrass (unhulled)	Sept. 1–Dec. 15	7	7	7	-------	7
Annual ryegrass	do	12	12	12	-------	12
Weeping lovegrass (deep sands).	do	1½	-------	-------	1½	-------
Irrigated lawn area:						
Bermudagrass	Feb. 1–June 1 [5]	7	7	7	-------	-------
St. Augustinegrass [6]	March–June	Sodding	Sodding	Sodding	-------	-------
Utah						
Less than 15-in. precipitation:						
Clay and loam soils:						
Crested wheatgrass	September–February	15	7½	7½	7½	43
Streambank wheatgrass	do	15	7½	7½	7½	43
Sandy soils:						
Crested wheatgrass	do	14	7	7	7	-------
Streambank wheatgrass	do	10	5	5	5	-------
Sand dropseed	do	6	3	3	3	-------
15–30-in. precipitation:						
Crested wheatgrass	do	10	5	5	5	-------
Streambank wheatgrass	do	10	5	5	5	-------
Smooth brome	do	10	5	5	5	-------

[5] Depending on latitude. [6] Spot sodding, 8 to 10 in. centers, in southern ½ and eastern ⅔ of State.

almost as effective as hay. It is free of weed seed, is more fire retardant than hay or straw, permits gentle entry of water through soil, prevents formation of a surface crust, and requires less equipment and labor for application. However, compared with properly applied hay or straw, wood fiber mulch seldom lasts as long, is more expensive, and does not provide the same degree of insulation. These two materials should be carefully evaluated in deciding which to use for a particular area.

Fiberglass, applied as continuous filaments with a compressed air gun, has been tried in many areas; however, it lacks some of the requirements of a good general purpose mulch. Because it defies decomposition, the long, tough filaments pose a hazard to mowing operations and are difficult to anchor on slopes unless they are tied in place with a heavy application of binder such as an asphaltic emulsion.

Different types of paper or jute nettings serve well to hold hay or straw on steep slopes, but the labor necessary for installation makes asphaltic emulsions more economical. Heavy jute netting has been used as a mulch material with some success; however, its use is usually limited to ditch lining, as the wide mesh does not effectively reduce surface evaporation or buffer the soil surface against temperature fluctuations. Excelsior matting is perhaps one of the better mulch materials for slope surfaces. The loose mat of tough, coarse fibers protects soil surfaces from evaporation and direct sunlight and permits water to enter the soil. Disadvantages of the material for slope protection are the amounts of labor and time required for installation and the high initial material cost.

Mulching application and anchoring

Hay or straw is applied to highway slopes by modern mulch blowers into which bales of mulch can be fed. The machine separates the stems and blows them through a nozzle that can be directed vertically and horizontally to place mulch on almost any part of a slope surface (fig. 12). The better machines can blow the mulch as far as 200 feet in calm weather, and by adding flexible plastic tubes to even greater distances. Recent models also deliver asphaltic emulsion from the nozzle, so that the hay or straw sticks together as it falls uniformly on the soil surface. Hay or straw mulch is applied at rates of 1–2 tons per acre, and asphaltic emulsion at 200–800 gallons per acre. The 2-ton rate usually is more satisfactory for mulch applications. The emulsion can be applied as a separate spray after placing the mulch, but the injection method is more desirable. Hay or straw mulch can also be held in place on relatively level, sandy areas by cutting into the soil surface with a heavy cutaway disk harrow, a brush harrow or a tractor-drawn mulch-packer.

Petroleum resin-based stabilizer emulsions, designed primarily to protect sandy areas from wind erosion, are mixed with water in a tank truck and applied as a coarse spray under low pressure at rates as low as ¼ gallon per square yard. These recently developed materials are too new to permit a complete evaluation of them at this time.

Although wood fiber mulches can be applied with a hay mulch blower, they are preferably applied as a slurry spray at rates of 1 ton per acre for mulching slopes, and ½ ton per acre for level areas. Slurry mixes containing wood fiber mulch can be delivered by hydroseeders to distances of more than 100 feet or pumped through several hundred feet of hose to more distant and difficult-to-reach areas.

Sprigging and sodding

Efficient seeding and mulching techniques developed during the past 25 years have almost eliminated the need to propagate grasses and legumes by other methods. In the East, except on golf courses, very little sprigging of grass species is done. Recently, however, bermudagrass or bentgrass sprigs have been mixed in a slurry with wood fiber mulch and sprayed on the soil surface—an operation that requires a hydroseeder equipped with a gear-type pump. The fiber is usually applied at a rate of nearly 3,000 pounds per acre.

In the Northeast, most sprigging is confined to American beachgrass for sand-dune stabilization where encroaching sand is a highway-safety and maintenance problem. The operation consists of digging beachgrass culms from an adjacent area and transplanting them 18 inches apart in rows 18 inches to to 3 feet apart by hand, or by modified, tractor-drawn tree or tomato transplanters. It would seem that petroleum resin-based stabilizer emulsions applied immediately after sprigging the beachgrass might promote establishment of new plants by reducing the abrasive action of blowing sand.

Although sodding is the most expensive turf-establishment method, its use may be justified on certain steep, short slopes. Good quality bentgrass and bermudagrass sod should be cut to a thickness of ½ to ¾ inches and Kentucky bluegrass and the fine-leaved fescues to a thickness of 1 to 1¼ inches. Sod should be laid on a well prepared, friable, but firm soil surface as soon after cutting as possible. The sod should be tamped lightly as it is set to ensure complete contact with the soil surface, and water must be applied regularly to prevent drying of the edges. On steep slopes sod should be secured with wooden pegs to prevent slippage during heavy rains.

Special liners for drainageways

Drainageways that carry water most of the year and those that have grades of more than 4 percent should be permanently paved with bituminous or concrete materials. Drainageways that carry water for only short periods and those that have grades less than 4 percent can be stabilized with a vegetative cover of grasses and legumes that thrive under local drainageways conditions. Lists of species suitable for a given location can usually be obtained from the local offices of the Agricultural Experimental Station or the Soil Conservation District. (See tables 1–6.)

Because it is difficult to determine when drainageways are carrying peak water loads, the seeding or new seedlings must be protected until a resistant sod can be developed. Hay and straw mulch as a protective cover tends to float away under high water conditions and can cause damage by plugging catch-basins and blocking drainageways; several other materials for ditch linings have been developed in recent years.

The time-tested material for protecting drainageways has been Dutch-type burlap, which has a loose weave, weighs 4 to 6 ounces per square yard, and is made in strips 5 feet wide. Economical 50-foot rolls are available and can be handled easily. A clean and uniform surface grade completely stripped of all vegetation is necessary for installation, and the soil should be friable, but firm. The burlap is laid from the extreme downstream end so that the centerline of the burlap strip coincides longitudinally with the center line of the drainageway bottom. Special staples pin the burlap to the soil along the centerline of the ditch bottom and both edges. Upstream ends of the burlap overlap the downstream end by at least 12 inches, and staples are placed 6 inches apart across the overlap. Soil at least 2 inches deep and 1 foot wide should be carefully raked over the edges of the burlap on both sides of the drainageway. Prior to placing the burlap, the soil surface of the drainageway should be fertilized and seeded.

Jute netting with a weave of 1.6 to 1.1 yarn count is used extensively to line drainageways while sod is being established. Installation of this material is similar to that of burlap and has gained acceptance in many States.

Excelsior matting also serves well as a ditch liner and is relatively easy to place. Its thickness and loose weave provide an insulating effect that promotes rapid germination and emergence of grass seedlings.

Continuous filament fiberglass material applied carefully over freshly seeded drainageways has been used successfully in some States. A light application of asphalt emulsion is used to anchor the fiberglass. Fiberglass mats stapled to drainageways and coated with asphalt emulsions or bituminous materials also have been used in many States. Whether or not turf can be established under these mats depends on the porosity and thickness of the mat and on the thickness and type of bituminous coating. Fiberglass mats coated heavily with bituminous materials are not a durable or economical substitute for ditch paving.

Wood fiber mulch mixed with asphalt emulsion, or wood fiber mulch followed by an application of asphalt emulsion at about 800 gallons per acre, has also been used to provide drainageway protection; however, burlap, jute netting, and excelsior matting seem to be better materials for drainageway protection until the sod develops.

Figure 11.—Hydroseeder used to pump basic ingredients for turf cover on steep slopes.

Maintaining Fertility and pH Levels

Once established, quality turf along the roadside is maintained only by effective and continuing fertilization. An erosion-resistant cover of grass does not happen because seed is sown and an indulgent mother nature provides the elements necessary for growth. Steel bridges need repainting, concrete pavements must be patched and resurfaced, and grass, for functional reasons, must be fertilized and otherwise maintained to ensure a dense, erosion-resistant cover.

Because of the harsh growth environment, good management is even more critical on most highway rights-of-way than on golf courses and home lawns. Rule-of-thumb guidelines for roadside fertilization are as follows:

- Use maximum amounts of fertilizer to produce a dense turf quickly.
- Provide nutrients that are adequate for the least fertile soil in the area where turf is to be maintained.
- Expect all soils to be deficient in nitrogen.

On average roadside areas disturbed by construction, these guidelines should help to maintain a thick turf and dense root system to protect soils from erosion.

Enough fertilizer must be used to supply nutrients for the different types of soils and soil materials in the area. Grading operations often create more soil differences than would be expected for normal differences between soil series over wide areas. In subsoils, and many topsoils, nitrogen is deficient, and other plant nutrients, especially phosphorus, may be lacking. Data on subsoil and topsoil should be consulted when roadside fertilizer and liming programs are planned. A complete fertilizer containing nitrogen, phosphorus, and potassium applied in accordance with soil test information insures against nutrient deficiencies or imbalance among the several essential elements.

A soil that has been disturbed requires twice as much fertilizer to produce a given plant stand as the same soil prior to grading. Costs of hauling and spreading topsoil are excessive, and there are few topsoils of sufficiently high fertility to maintain a turf cover without added fertilizer. Fertilizer can be applied annually over a 20-year period on poor soils at 1/5 to 1/10 the initial cost of topsoil.

When nitrogen is withheld or restricted, response to fertilizer is poor. Response to phosphorus and potassium is much less marked. Some nitrogen may be lost through leaching, but the phosphorus and potassium in plants are returned to the soil for reuse from season to season. Each ton of grass (air dry) contains about 30 pounds of nitrogen, 10 pounds of phosphorus, and 30 pounds of potassium.

Maintenance fertilizer should be applied when turf shows evidence of poor growth and vigor. Heavy single applications should be avoided, as heavily fertilzed grasses require excessive, costly mowing. Nitrogen refertilization is needed, however, to prevent degeneration, and readily soluble nitrogen sources or mixtures of 1/2 to 1/4 and 1/2 to 3/4 ureaformaldehyde are being used with good results. For normal grass maintenance 30 to 50 pounds of nitrogen per acre should be adequate for each application. Symptoms of trace-element deficiency on roadside areas are rare. If grasses are adequately fertilized during the first 2 years following establishment, and perhaps during the third year on certain types of soil, the need for annual applications will decrease.

A thick, well-fertilized turf and dense root system helps slow water movement and keeps moisture in the rootzone to develop a deep root system that is very important under roadside conditions. Fertilized turf keeps soil temperatures lower than those of the air. Thin turf does not cover the soil and soil temperatures increase to the detriment of grass plants. A vigorous turf competes better with undesirable weeds; thus, proper fertilizer use can reduce populations of certain unattractive weeds.

Although soil materials used in construction may vary greatly in relatively short distances, soil tests provide excellent guidelines for determining pH levels and phosphorus and potassium content. The soil pH is very important to the proper use of plant nutrients. Soil pH values may range from 5.5 to 7.5 under roadside conditions. Values below 4.5 usually have a detrimental effect on the establishment of vegetative cover. Some acid soils are high in aluminum and other metallic ions that retard establishment and result in thin turf stands. Lime should be applied when soil tests and experience indicate the necessity for it. As a general rule, apply lime to soils that have pH levels below 6.0. Agricultural ground limestone, at least 50 percent of which passes a 100-mesh sieve, is recommended.

Turf cover can be successfully managed on soils with a wide range of organic content. High levels of organic matter, although desirable, are not essential and need not be added if their supply is low. Turf tends to increase organic content through normal growth processes. Microbiological populations normally associated with organic matter, and usually rich in nitrogen, phosphorus, and other readily available plant nutrients, increase following sod establishment.

Weed Control

When a dense and permanent vegetative cover is established on areas disturbed during construction, roadsides are safer for out-of-control vehicles and soil erosion is minimal. Weed growth can seriously deter the establishment of a desirable turf for several reasons. Many annual weeds, because of restricted root development and sod formation, do not have the same soil-holding ability as the permanent grasses. Furthermore, annuals that develop in late spring and die with the first fall frost offer little protection from erosion during most of the spring, fall, and winter seasons. Perennial weeds, most of which do not develop a dense, erosion-resistant cover, have deep root systems and are difficult to eliminate.

Most weeds provide poor erosion control and compete detrimentally with permanent grasses for moisture, nutrients, and light. Weeds produce a fast, lush growth and use large quantities of moisture and soil nutrients. Broadleaf weeds shade lower-growing grasses and reduce their production of carbohydrates. Lower carbohydrate production reduces growth rate and the vigor of permanent grasses. Good weed control practices reduce or eliminate competition from weedy plants.

Weed control practices are dictated by the reproductive and physiological characteristics of the species. Perennial weeds, reproduced by seed and vegetative means, present an entirely different control problem than those reproduced only by seed. Each species is physiologically different and chemicals that are toxic to one species may not eradicate another. The type of control is governed somewhat by the topography. For example, chemical weed control may be necessary in areas that are inaccessible to mowing.

The two basic methods of weed control are cultural and chemical. Chemical methods should be used only when cultural methods fail. Weed-free seed and mulch should be used and be supplied by an established seed dealer or a certified grower. Seed should be obtained from the latest available crop and meet the requirements of the State's Department of Agriculture or other regulatory agency. It should be as pure as practical and rejected if weed seed levels are high. Mulch, too, should be free of weeds.

Grass species that develop best and give the most competition to weed species should be selected for all areas. Because grasses usually respond better to fertilizer, a program that provides optimum nutrient levels aid survival and competitive ability of the seeded grasses. Purity and germination levels, set as high as practicable will help assure a strong, healthy, weed-free turf.

Mowing is the most widely used cultural method to control both annual and biennial weeds. If the seed heads are removed prior to maturity, annuals will not be able to reseed or become reestablished in the following year. Biennial weeds can be similarly treated, but two seasons of mowing are required to control or reduce plant populations. Perennial weed populations can be partly controlled by mowing, which reduces seed production, but mowing cannot control vegetative reproduction. Food reserves in perennial weeds are at comparatively low levels when flower buds appear, and repeated mowing at this stage of growth gradually reduces food reserves, weakens regrowth, and reduces competition. Control of this type requires timely mowing, which is sometimes impracticable on roadsides.

The other method of controlling weeds is to use selective phytotoxic chemicals, which must be applied with caution. Chemicals that have

Figure 12.—Mulch blower used to apply hay or straw mulch to slope areas.

little effect on seeded grasses, but are toxic to broadleaf plants, should be selected. Unfortunately, many desirable species for highway use are legumes, which are usually of a broadleaf character. When selecting a herbicide, the chemical should affect only weedy plants and not harm desirable species. In general, spot spraying with a selective chemical of low volatility is the most efficient way to control perennial weeds.

Mowing Requirements

Highway mowing when correctly performed not only enhances the natural beauty of the roadside, it also improves highway safety by providing definition to roadside areas beyond the travel way. Also, in snow-belt States, it removes tall grasses that increase snow accumulation on shoulders and pavements. Mowing may also help control the invasion of right-of-way areas by undesirable species.

Several factors influence mowing time. Very early spring mowing, although desirable, is not recommended because taller grasses shade germinating weeds. At this time of the year areas are usually wet, and mowing equipment may become stuck, cause rutting, damage large areas of turf and encourage erosion. In addition, the wheels of the equipment pack the wet soil, and damage the root structure of the grass; dull mower blades can actually pull grass plants from the soils rather than cut them.

Areas containing the shorter growing grasses, depending on their growth rate, may require routine mowing. These areas—medians, shoulders, interchange islands, etc.—should be mowed when the grass height is 50 percent above the desired mowing height. Areas established with the taller grasses should not require mowing, except for spot weed control. Such weed control mowing should be delayed until the seed heads of the weeds are present but have not yet reached maturity.

Fall mowing is not recommended, as grass plants should be permitted to mature and harden off before winter. Mowing may stimulate lush growth, which makes the plants more susceptible to winter kill.

Legumes, useful as a long-lived nurse crop, help establish a permanent grass cover. Mowing height need not be based on legumes in the area. The lower growing legumes, such as white clover and birdsfoot trefoil, are sometimes used as more permanent species with the lower growing grasses in medians, rest areas, etc. Legumes easily withstand the same mowing regime used for grasses. On slopes, legumes such as crownvetch usually should not be mowed more than two times during the establishment period and then should be cut high to control undesirable species.

Another consideration is the root-shoot balance of the grass plant. Usually the part of the plant above ground balances with the part below ground, and reduction in one may cause a reduction in the other. Close mowing not only reduces the leaf surface of the plant, but forces a corresponding reduction in the root system. Thus, the plant's erosion-control effectiveness is reduced, as is its resistance to extended periods of hot, dry weather.

Mowing usually eliminates seed production of grass species, although seed production is not essential for those grasses that reproduce by rhizomes or stolons. Bunch grasses, however, must produce seed to perpetuate and increase the extent of turf areas. On newly seeded roadsides, seed production is an important factor in the establishment of a dense, functional turf. Vegetative reproduction of some species, such as Kentucky bluegrass, is stimulated by mowing. When the seed head, or plant top, is removed, the plant's food reserve increases normal vegetative reproduction rather than seed production. However, if too much of the leaf area is removed at this stage, recovery might be slow.

Mowing needs differ on different parts of the right-of-way. Areas that usually require mowing are the medians, parts of interchange islands, and areas along the foreslopes to frame and define the roadway. Areas that require more intensive mowing should be established in grass species that will tolerate frequent cutting. Backslopes, fill areas and, generally, the remaining parts of the right-of-way do not require mowing unless weed control is necessary.

As complex as it may seem, selection of the right mowing height is not difficult. Grass plants can withstand a great deal of abuse. Even under the worst possible mowing regime, it may take several years to kill a species of well established turf.

For highway purposes, grasses and legumes may be divided into two general groups—those that tolerate low mowing (4- to 5-inch minimum mowing height) and those that only occasionally are mowed low. Some of the more commonly used species that tolerate close mowing are as follows:

Tolerant	*Less tolerant*
Grasses	Grasses
Bentgrass	Bluestem, big and little
Bermudagrass	Brome, smooth
Bluegrass, Canada	Canarygrass, reed
Buffalograss	Mixed native grasses
Fescue, red and tall	Orchardgrass, reed
Redtop	Switchgrass
Ryegrass	Wheatgrass, crested
St. Augustinegrass	
Legumes	Legumes
Birdsfoot trefoil	Crown vetch
Clover, white	Hairy vetch

Safety should be considered when highway mowing equipment is selected. Mowers should have low centers of gravity and wide-set wheels with flotation tires to provide optimum safety, reduce turf damage, and prevent rutting. They should be designed so that debris or foreign objects are not thrown into the path of passing vehicles.

Most highway mowing equipment is tractor-drawn or tractor-mounted. Small lawn-type rotary mowers may be used for trimming in rest areas or other special-use locations. Small, self-propelled, sickle-bar type mowers are useful for maintaining comparatively inaccessible and rough areas that are mowed infrequently. Hand scythes should not be used except in special areas not accessible to field equipment.

The four types of mowers generally used are, reel, sickle-bar, rotary, and flail.

Reel mowers, although used extensively in some sections of the country, are limited to portions of the right-of-way that are comparatively level and smooth. They are especially designed for fine-textured turf and usually require more maintenance than any other mowing equipment.

The sickle-bar mower has been used for highway mowing longer than any other type. It is still especially valuable for use in tall grass or weeds, but it does not produce as uniform or as level a cut as some of the other equipment. Its slow speed is also a limiting factor.

Rotary mowers are most widely used. They produce a fairly uniform and level cut, but many throw foreign objects into travel lanes. Because of this hazard their use is being restricted, particularly in urban areas.

Flail mowers, the most recent type developed, do not throw objects—an extremely important safety feature. Turf cut with these units has a rougher, more ragged appearance, but not as uneven as that cut with sickle-bar mowers.

Regardless of the type of mower used, cutting units should be kept sharp. Dull cutting edges tear leaves, cause premature browning of leaf blades, and may increase disease incidence.

A carefully planned roadside mowing and maintenance program is becoming more and more essential as the amount of turf acreage expands and as traffic volume and vehicle speeds increase. As many maintenance budgets are unable to support all required operational functions, mowing requirements should be carefully evaluated.

The following steps are important in analyzing mowing practices:

- Classify roadside areas, based on existing right-of-way conditions and desired mowing standards.
- Determine performance characteristics of mowers of different widths, types, and sizes.
- Establish a periodic mowing cycle to attain desired standards.
- Rate mowers for a particular type of right-of-way by field performance tests.
- Appraise operating cost including depreciation, repair, maintenance, and fuel costs.
- Assign mowers according to the character of the area to be mowed, duration of the mowing cycle, available machine time for each cycle, average production rate for each type, in accordance with the classification of the right-of-way, special requirements, and the cost and time involved.

Classification factors considered of prime importance are as follows:

- Size and shape of the roadside areas.
- Topographical conditions—steepness of slopes, relatively flat areas, drainage channels, and surface configuration.

- Geological conditions—bogs and soil types.
- Obstructions—utility poles, culverts, signs, etc.
- Turf density and height of cut desirable.

Such management techniques make possible better operating efficiency and supervisory control, thus reducing or preventing an increase in the cost of this necessary maintenance operation.

Growth Retardants

In recent years a few growth retardant chemicals have been developed for turf areas, which make it possible not only to decrease the exposure of maintenance workers and their equipment to highway traffic, but also to reduce mowing costs.

Maleic hydrazide, the most effective growth retardant for roadside use, has not been widely accepted because application time is critical. Research is continuing and, hopefully, new materials or improved formulations and application techniques may be developed to improve the effectiveness of growth retardants. In some areas proper use of control chemicals reduces mowing frequency by 50 percent or more and improves appearance. Under such circumstances mowing equipment can be used more efficiently, maintenance costs are reduced, and traffic safety is enhanced.

Insect and Disease Control

Good management is just as important to roadside turf as it is to lawns, parks, and golf courses. Insect pests and diseases have been known to destroy extensive areas of turf with the ultimate threat of complete loss of vegetative cover, the creation of large unsightly areas, and an increase in costly erosion.

Crowded turf plants compete for air and soil space as well as for light, water, and nutrients. Humidity abets the spread of disease organisms from plant to plant. Spores of fungi are carried from infected areas by wind, water, and mowing. Some of the major diseases in roadside areas are leaf spots and blights, anthracnose, red thread, copper spot, Ophiobolus patch, spring dead spot, and Fusarium blight. Successful disease control requires sound cultural practices, beginning with clean seed and soil. A fungicide should be used only when the cultural practice or other management practices are not completely effective.

Insect pests can be devastating in many areas, and vigilance is necessary to keep sod webworm, beetle grubs (Japanese and Asiatic), chinch bugs, etc., under control. Potential invasions can be averted by applying appropriate insecticides. Eradication of grubs overcomes the problem of moles, which often are the indirect cause of erosion and other adverse effects. Insecticides must be chosen carefully and quantities applied cautiously to prevent harm to wildlife. Movement of insecticide residue into drainage systems and adjacent streams, with the consequent effects on aquatic biota, must be prevented.

Figure 13.—Mowed turf provides desirable transition between highway right-of-way and adjoining areas.

Proper turf management can provide favorable conditions for growing healthy roadside grass and help reduce the damaging effects of diseases and insects. A vigorously growing turf is more resistant to traffic damage and weed invasion. Good surface and subsurface drainage must be provided as well as the sowing of high-quality, adapted, disease-resistant grasses and seed mixtures. A sound fertilization program with lime and other soil amendments as required is essential in any roadside turf management program. Mowing too closely should be avoided; higher cuts improve root depth, tolerance to drought, and high summer temperatures. If the soil becomes compacted, an aerifier should be used so that proper amounts of air, water, and nutrients reach the root systems of desirable species.

Reseeding—Renovation, Aeration

Roadside turf areas are probably subjected to more physical damage than other locations where turf is used. Accidents, vehicles forced or driven off the paved areas, improper mowing practices, and numerous other incidents cause rutting and breaks in the turf cover. Failures in interception drainage ditches, excessive periods of adverse weather (too wet, too hot, or too dry), and the use of de-icing compounds are some of the principal causes of damage.

Accordingly, turf should be repaired as soon as possible after damage occurs. Topsoil, fertilizer, seed, and mulch should be placed as necessary. In some locations, it will be necessary only to renovate turf in so-called spot areas. Where there is an almost complete loss of turf, restoration is similar to initial seeding operations. Damaged turf areas must be detected promptly and repaired and renovated hastily to avoid further damage caused by delayed maintenance.

Perhaps one of the most neglected maintenance items is soil aeration. The generally poor soil and severe compaction (*11*) caused by vehicular traffic and mowing equipment are factors that should be given consideration. With the modern, efficient equipment that has been developed, the roadside can be easily aerated to enhance both the quality and functional value of the turf.

Conclusions

Except in arid sections of the United States grass is the indispensable plant on the highway roadside. Grass contributes substantially to highway economy by controlling erosion. An effective cover of turf eliminates the deposition of eroded soil in ditches and drainage facilities, and affords protection to agricultural lands and streams and water supplies contiguous to the highway.

By preventing erosion, grass also makes highways safer. Originally designed surface contours with swaled ditches, smooth shoulders, and flat slopes can be maintained with grass to insure safer operation of motor vehicles when they leave roadway pavements in emergency situations (fig. 13).

Improved appearance is perhaps the most obvious value that grass contributes to the motorist's pleasure. It is a basic component in the highway environment and gives an appropriate setting for trees and shrubs. Well maintained grass provides the frame for the highway *picture* and tends to assure the driver and his passengers that the highway is safe, esthetic, and utilitarian—a *complete highway*.

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REFERENCES

(*1*) *Erosion Control Along American Highways*, by A. W. Johnson, American Society of Agricultural Engineers, 1957.

(*2*) *Roadside Development, A Selected Bibliography*, Highway Research Board, Bibliography 26, 1960, pp. 11–17.

(*3*) *Bibliography on Roadside Development and Beautification*, Highway Research Board, 1965, pp. 10–14.

(*4*) *The Nature and Properties of Soils*, by Harry O. Buckman and Nyle C. Brady, 1960, 6th ed., McMillan Co., N.Y., Chapter 3, pp. 55–68.

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How Drivers Locate Unfamiliar Addresses—an Experiment in Route Finding

BY THE OFFICE OF
RESEARCH AND DEVELOPMENT
BUREAU OF PUBLIC ROADS

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Introduction

THE motorist's route-finding behavior is of interest to the highway engineer because it helps determine what type of guidance information is needed to navigate streets and highways efficiently. If the driver follows his route point by point, he should be given detailed information at each road juncture. If he orients himself in the general direction of his goal, as certain psychological studies indicate (*1, 2, 3*), overall information should be provided. If he uses certain large cities as milestones, they should be included on the highway signs. It is important to know whether the drivers mainly use route numbers or road names in planning their trips. Drivers' mistakes and delays particularly are of interest, as they reveal difficulties that should be corrected.

The study reported here is concerned with the informational aspects of route-finding. One group of drivers was given destinations and permitted to travel to them by whatever routes the drivers chose, using whatever information they could obtain. A second group of drivers went to the same destinations aided by information supplied by the experimenters. The second group, or control group, provided a standard against which the performance of the first group, or experimental group, was compared in distance traveled, speed, and time spent on the road. The drivers' methods, tools, and mistakes were also noted to furnish the basis for improved guidance procedures.

Previous studies of driver wayfinding were carried out in California by Schoppert, Moskowitz, Hulbert, and Burg (*4*), these investigators were interested in the principles underlying good freeway signing, but they also considered basic driver behavior in trip planning, use of road maps, and sources of information used by the driver. The Schoppert surveys provide a general background of information for the quantitative experimentation on wayfinding in the study reported here.

Method and Procedure

To conduct the experiment the drivers of the experimental group were instructed to drive to destinations in the Annandale and Bethesda suburbs of Washington, D.C. The trips required travel on a freeway as well as on secondary roads. The trip speed and the effectiveness of the drivers' performances were compared with those of the drivers in the control group who received continual guidance on the routes.

The following four groups of drivers were used in the experiment:

Group 1—Ten experimental drivers who were to find their way to the Annandale destination, but who were unfamiliar with the area.

Group 2—Five control drivers who traveled to the Annandale destination with full instructions from the experimenters.

Group 3—Ten experimental drivers who were to find their way to the Bethesda destination, but who were unfamiliar with the area.

Group 4—Five control drivers, the same drivers as those in group 2, who traveled to the Bethesda destination with full instructions from the experimenters.

The four groups were composed as follows:

	Males	*Females*	*Average age (years)*	*Average driving experience (years)*
Group 1	6	4	21	4½
Groups 2 and 4	8	2	21	5½
Group 3	3	2	25	8

All drivers were obtained from a university employment office and paid $2 an hour for their work.

The Annandale and Bethesda addresses were on residential streets that had names rather than number or letter designations (see fig. 1). The Annandale destination was 14.2 miles from the Public Roads Fairbank Highway Research Station (FHRS) in Langley, Virginia, the starting point. The Bethesda address was 10.8 miles away from FHRS. The local route in Annandale has three traffic lights on Old Georgetown Road. The Bethesda local route has three lights on Route 236 and on Columbia Pike. The two trips were approximately of equal complexity.

The drivers in the experimental group showed by their performances that they were unfamiliar with the routes. Each driver was instructed to drive to a selected destination. If he drove directly and turned in the right direction on the main route; without asking directions, he was judged to be familiar with the route and was then used as a control subject.

Each trial started with a driver and an experimenter seated in the test vehicle, a 1968 4-door Plymouth sedan, parked at the starting point on Route 193 near FHRS. Each driver was given the following instructions:

"The purpose of this project is to study normal driving behavior. During the study, I will be recording mileage, time, and conversations. Therefore, if you want to ask a question just say: "Question" and proceed. This will give me enough time to start the recorder. Your objective is to go to Annandale (or Bethesda), driving as you usually drive. Are there any questions? You can pretend that I am a passenger in this car, that this is your car, and that you have to go to this destination."

If a driver proved familiar with the route, he was placed in the control group, and told the distance to be traveled as he entered each road. He was also given the name of the exit to be used, and was alerted at the exit point.

On the Annandale route, each control driver was given the following instructions:

Table 1.—Frequency of information sources used by 20 drivers traveling to unfamiliar addresses

Information source	Destination: Annandale	Destination: Bethesda	Total: *Number*	Total: *Percent*
Service station	15	18	33	61.1
General knowledge of direction	2	4	6	11.1
Map (supplied by experimenter)	3	2	5	9.3
Pedestrian	1	1	2	3.7
Post Office	2	0	2	3.7
Miscellaneous	4	2	6	11.1
Total	27	27	54	100.0

[1] Italic numbers in parentheses identify the references listed on p. 47.

Table 2.—Comparison of driver wayfinding, with and without information

Destination	Total trip: Control	Total trip: Experimental	Total trip: Difference, Actual	Total trip: Difference, Percent	General area: Control	General area: Experimental	General area: Difference, Actual	General area: Difference, Percent	Local area: Control	Local area: Experimental	Local area: Difference, Actual	Local area: Difference, Percent
Distance												
Annandale...miles..	14.3	19.91	[1] 5.61	39	12.0	13.85	1.85	15	2.30	2.80	0.50	22
Bethesda...do....	10.8	16.78	[1] 5.98	55	9.3	11.03	1.73	19	1.50	7.20	[2] 5.70	380
Mean...do....	------	------	5.8	47.0	------	------	1.79	17	------	------	3.10	201
Speed												
Annandale...miles per hour..	41.68	31.88	[1] −9.80	−23.5	55.30	42.70	[1] −12.60	−23	18.64	12.13	[1] −6.51	−35
Bethesda...do....	42.38	23.18	[1] −19.20	−45.3	48.86	42.85	[1] −6.01	−12	23.28	14.23	[2] −9.05	−39
Mean...do....	------	------	−14.50	−34.4	------	------	−9.30	−17.5	------	------	−7.78	−37
Time												
Annandale...minutes..	20.66	37.52	[1] 16.86	81.6	13.06	19.65	[2] 6.59	50	7.60	14.13	[1] 6.53	86
Bethesda...do....	15.34	44.30	28.96	188.8	11.46	15.55	[2] 4.09	36	3.88	29.85	[1] 25.97	669
Mean...do....	------	------	22.91	135.2	12.26	17.60	5.34	43	5.74	21.99	16.25	377.5

[1] Significant at 0.01 level, two tailed t-test.
[2] Significant at 0.05 level, two tailed t-test.

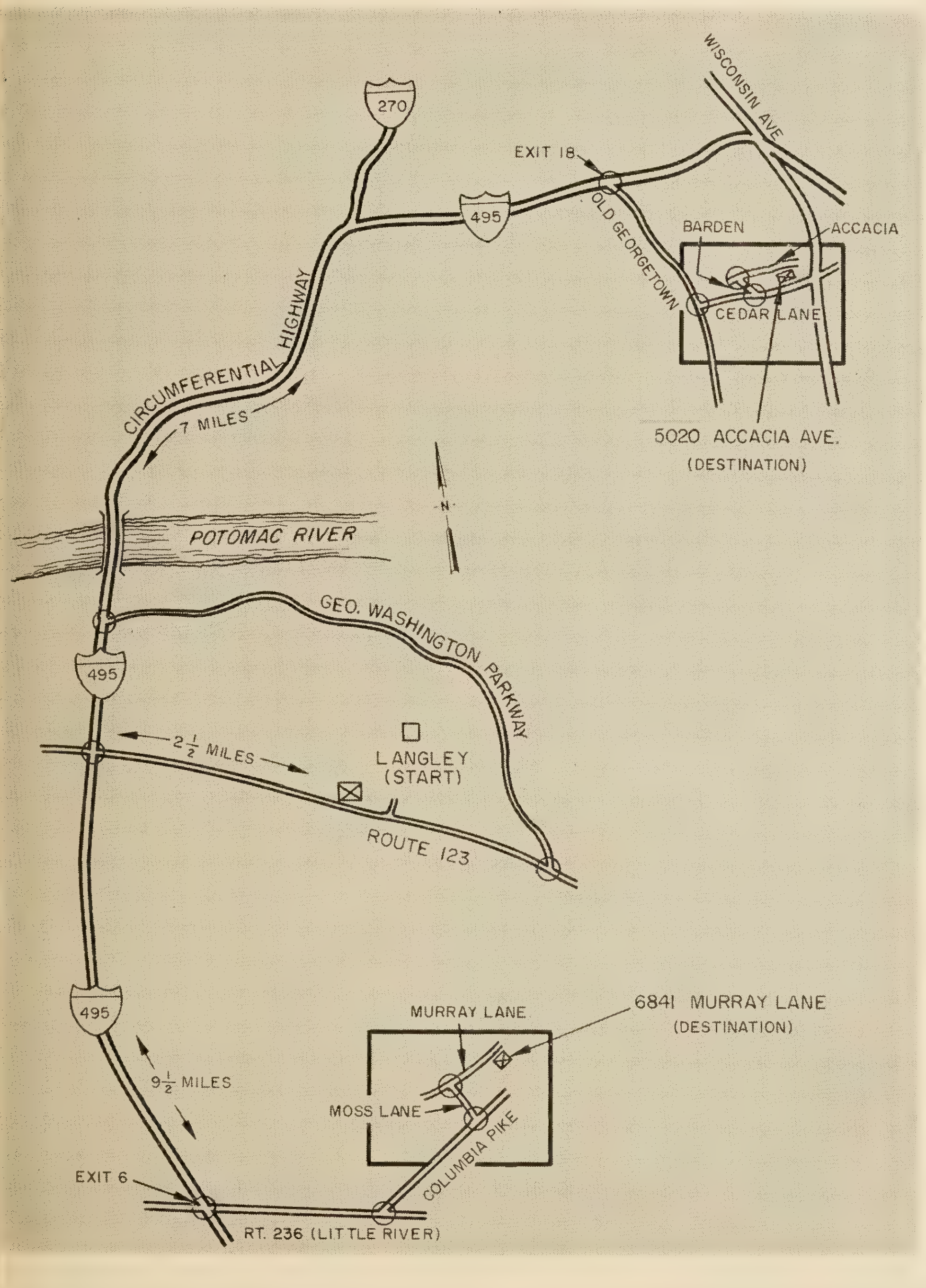

Figure 1.—Routes used in the study.

On Route 495—"You are to go 12½ miles to Exit 6, which is the Annandale exit."

At Exit 6—"You are to get off at this exit."

On entering Route 236—"Go about 1½ miles and turn left on Route 244, which is Columbia Pike."

Just before the intersection of Routes 236 and 244—"Turn left here."

On entering Route 244, Columbia Pike—"Go about 1 mile and turn left onto Moss Drive, etc."

The same type of planned instructions were given to the Bethesda control group. The experimenter recorded the starting time, completion time, choice point-passage times, and the drivers' questions and statements.

Sources of Information

Information sources used by the drivers are listed in table 1. The information obtained at service stations included map consultation and directions by station attendants when they were familiar with the destinations. The category, general knowledge of direction, applied if a driver started to his destination without consulting any apparent information source. Six drivers were in this category. The miscellaneous category included consultations with mailmen, other drivers, and road maintenance crews.

Gasoline station attendants were consulted more frequently than all other information sources combined, and seemed expected to provide all necessary travel information. The method of starting out without travel information may seem odd, but apparently many drivers begin trips in this manner. Schoppert et al. reported that 58 percent of his survey respondents started for an unfamiliar destination without advance preparation, and 15.5 percent explicitly stated that this was their customary travel behavior (2, p. 84). All but one of the 20 experimental drivers used in the experiment report here adopted the strategy of going as close as possible to their goal in the local area and then asking the way to the address. This strategy is based on the fact that a station attendant or inhabitant is likely to know the location of a local address. Also, it is easier to ask on the way than to remember an entire route of five or more unfamiliar choice points.

As might be expected, the effectiveness of route finding performance differed among drivers. One driver simply got information at a gasoline station at the start and went directly to his address. Another driver asked information five times along the way.

The Effectiveness of Drivers' Route Finding

Total trip

Data on the drivers' travel performances are given in tables 2–4. In table 2, the distance, speed, and time required by experimental and control groups to complete their trips are summarized. Detailed subject data on the Annandale runs are listed in table 3, and on the Bethesda runs in table 4. The local Annandale area was considered to start in Annandale at the junction of Routes 495 and 236. The general area included the highways used to this point. The Bethesda local area was considered to start at the junction of Route 495 and Old Georgetown Road. The times shown in the tables include those spent obtaining information, as well as traveling on the road. Speeds are also based on gross times.

The experimental groups who had to find their own way, performed more poorly than the informed control groups. They traveled longer distances, at slower speeds, and hence, required more time. As shown by the averages in table 2, the experimental groups traveled 5.8 miles (47 percent) farther than the control groups at a 14.5 m.p.h. (34.4 percent) slower speed, and required 22.9 minutes (135 percent) longer to complete the trip. Stated differently, the group provided with information required less than half the time to get to their assigned addresses. The differences in distance traveled, speed, and time spent are all significant at the .01 level in favor of the control groups.

Distance

The driver who obtained his own information tended to choose a longer-than-optimal route. On the Annandale trip, four experimental drivers chose a route that differed from the *good* one used by the control group. They traveled an average of 10.7 miles farther than the control drivers, and an average of 8.5 miles further than other experimental drivers who followed the *good* route. The difference between control and experimental drivers who followed the same route is due to small errors in routing by the experimental group and the tendency of experimental drivers to detour to obtain route information from gasoline stations in local areas.

Speed

The slow speed of the experimental group is due mainly to time lost obtaining travel information. Experimental drivers stopped an average of 2.7 times per trip to obtain information. Speed was also reduced by the selection of slow secondary roads. In going to the Bethesda address the four experimental drivers who chose routes off the Interstate highway averaged 19.65 m.p.h. for the trip, compared with 42.4 m.p.h. for the control group, and 25.5 m.p.h. for experimental drivers who followed the *good* route.

Local area travel

Local wayfinding, particularly, is a problem. On the Annandale trip, 38.1 percent of the experimental group's time was spent on local roads that were only 16.1 percent of the total road. On the Bethesda trip, 67.4 percent of the time was spent on the 13.9 percent of local road. Once they entered the local area, the control group found the address in a quarter of the time required by the experimental group—5.7 minutes instead of 22.0 minutes (see table 1). This time saved in the local area was significantly more than that saved by guidance in the general area.

Local wayfinding is difficult because the driver must obtain detailed information that is not available on large scale maps. The driver may have to detour, as he did in the Bethesda area, to obtain help at a gasoline station. The number of choice points in the general and local areas is about the same. The main routes are clearly marked and simpler to follow, but at high speeds, it is not possible to find a poorly marked house address.

Application of Results

On the basis of the reported experiment, several wayfinding aids can be suggested:

• Streets arranged on numerical or alphabetical grids—to let the driver know the direction to his destination and approximately how far he was from it.

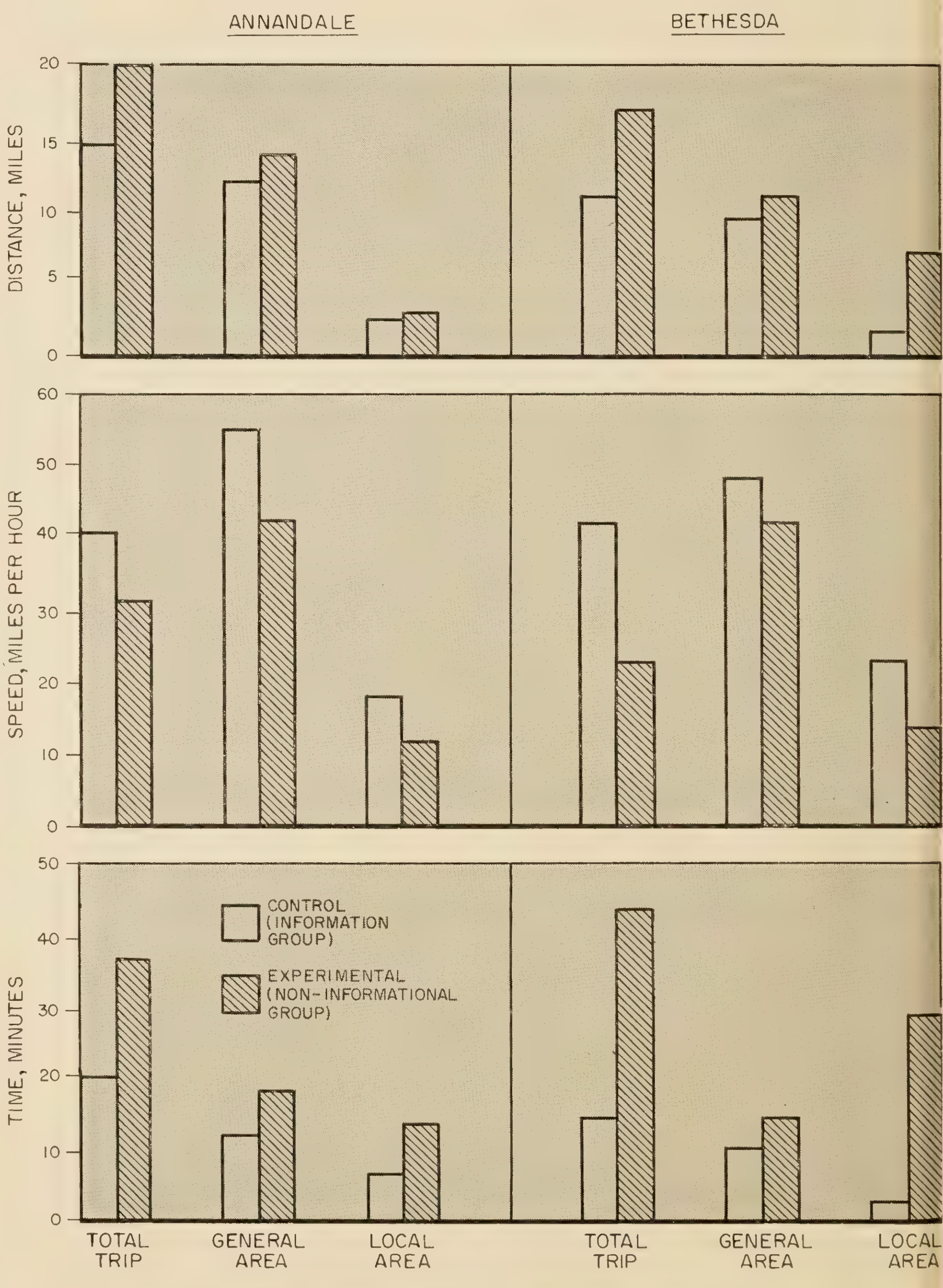

Figure 2.—Distances traveled, speeds, and trip times of experimental and control groups

- More rapid, reliable, and readily available sources of information in local areas—to direct the driver, possibly by road signs, to local gasoline stations equipped with local maps or automatic locator devices.
- Systematic, highly visible house numbering—to aid the driver in locating final addresses.

In the future, automatic systems may furnish the driver complete and continuous guidance. The Public Roads Traffic Systems Division currently is developing such a system—an electronic route guidance system (ERGS) that provides automatic route guidance information inside the driver's vehicle.

Summary

To study drivers' performances in wayfinding 20 drivers were observed as they drove to two unfamiliar addresses, 11 and 14 miles from a starting point. The distance traveled, speed, and time spent were compared with the performance of a control group, in which the drivers received on-route guidance information.

The performance of the observed group was not efficient. To get to the same destinations, drivers traveled almost half again as far as the control group, achieved less than ⅔ the speed, and took more than twice as long to complete their travel. The evidence indicates that most time is lost in the area of the local address.

Almost all drivers adopted the strategy of going to the local area and asking service attendants there for detailed routing information. Six of the 20 drivers started out without obtaining any advance information at all.

The implications of these findings were pointed out for the improvement of motorists' route guidance.

REFERENCES

(1) *Direction Orientation in Maze Learning by the White Rat*, by J. F. Dashiell, Comparative Psychological Monographs, vol. 7, No. 2, 1930.

(2) *Cognitive Maps in Rats and Man*, by E. C. Tolman, Psychological Review 55, 1948 b, pp. 189–208.

(3) *Experimental Psychology*, by R. S. Woodworth, Holt publishers, New York, 1938, p. 135.

(4) *Some Principles of Freeway Directional Signing Based on Motorists' Experiences*, by David W. Schoppert, Karl Moskowitz, Slade F. Hulbert, and Albert Burg, Highway Research Board Bulletin 244, 1960, pp. 30–87.

Table 3.—Wayfinding to Annandale address

Driver	Total trip			General area			Local area		
	Distance	Time	Speed	Distance	Time	Speed	Distance	Time	Speed
Experimental group:	*Miles*	*Minutes*	*m.p.h.*	*Miles*	*Minutes*	*m.p.h.*	*Miles*	*Minutes*	*m.p.h.*
W. B	14.0	29.6	28.4	12.0	18.0	40.0	2.0	11.6	10.3
B. M	14.0	34.2	24.6	12.0	21.3	33.8	2.0	12.9	9.3
T. S	18.0	39.0	27.7	15.6	19.6	47.8	2.4	19.4	7.4
D. S	16.8	30.4	33.2	13.0	16.5	47.3	3.8	13.9	16.4
C. G	31.9	44.9	42.6	------	------	------	------	------	------
C. H	14.3	25.7	33.4	11.8	15.5	45.7	2.5	10.2	14.7
D. T	27.4	52.8	31.1	------	------	------	3.8	16.8	13.6
E. C	21.8	41.1	31.8	18.7	27.0	41.6	3.1	14.1	13.2
L. B	20.1	46.3	26.0	------	------	------	------	------	
J. B	20.8	31.2	40.0	------	------	------	------	------	
Mean	19.91	37.52	31.88	13.85	19.65	42.70	2.80	14.13	12.13
Control group:									
E. D	14.3	19.5	44.0	12.0	13.0	55.4	2.3	6.5	21.2
J. H	14.3	21.4	40.1	12.0	14.5	49.6	2.3	6.9	20.0
C. F	14.3	20.7	41.4	12.0	12.2	59.0	2.3	8.5	16.2
M. G	14.3	19.0	45.1	12.0	12.6	57.1	2.3	6.4	21.6
F. S	14.3	22.7	37.8	12.0	13.0	55.4	2.3	9.7	14.2
Mean	------	20.66	41.68	------	13.06	55.30	------	7.60	18.64

Table 4.—Wayfinding to Bethesda address

Driver	Total trip			General area			Local area		
	Distance	Time	Speed	Distance	Time	Speed	Distance	Time	Speed
	Miles	*Minutes*	*m.p.h.*	*Miles*	*Minutes*	*m.p.h.*	*Miles*	*Minutes*	*m.p.h.*
Experimental group:									
P. H	17.0	31.9	32.0	12.0	17.75	40.6	------	------	------
R. S	19.0	44.3	25.7	13.0	19.0	41.1	6.0	25.3	14.2
B. T	16.7	60.0	16.7	------	------	------	------	------	------
R. H	17.3	40.8	25.4	10.9	14.6	44.8	6.4	26.2	14.7
P. G	14.8	39.0	22.8	------	------	------	------	------	------
E. B	13.7	45.8	17.9	8.9	13.75	38.8	4.8	29.8	9.7
B. L	10.9	38.5	17.0	------	------	------	------	------	------
J. S	23.7	54.7	26.0	12.1	16.6	43.7	11.6	38.1	18.3
T. H	20.2	54.8	22.1	------	------	------	------	------	------
R. H	14.5	33.2	26.2	9.3	11.6	48.1	------	------	------
Mean	16.78	44.30	23.18	11.03	15.55	42.85	7.2	29.85	14.23
Control group:									
E. D	10.8	16.0	40.5	9.3	12.0	46.5	1.5	4.0	22.5
J. H	10.8	16.3	39.8	9.3	12.0	46.5	1.5	4.3	20.9
C. F	10.8	14.2	45.6	9.3	10.5	53.1	1.5	3.7	24.3
M. G	10.8	14.4	45.0	9.3	10.8	51.7	1.5	3.6	25.0
F. S	10.8	15.8	41.0	9.3	12.0	46.5	1.5	3.8	23.7
Mean	------	15.34	42.38	------	11.46	48.86	------	3.88	23.28

Erosion Control, Safety, and Esthetics on the Roadside

(Continued from p. 43)

(5) *Soil Survey Manual*, U.S. Department of Agriculture Handbook No. 18, 1951, pp. 231–235.

(6) *Seeding Highway Roadsides in the Southeastern United States as Influenced by Species Adaptation, Fertilization, and Mulching*, by C. Y. Ward, S. L. Simpson, W. J. Gill, and H. D. Palmertree, Southeastern Association of State Highway Officials Proceedings, 22d Annual Meeting, 1963, pp. 149–155.

(7) *Seeding Highway Slopes as Influenced by Lime, Fertilizer, and Adaptation of Species*, by R. E. Blaser and C. Y. Ward, Virginia Council of Highway Investigation and Research, Reprint No. 21, 1959.

(8) *Hydraulic Seeding on Motorway, Verges and Other Marginal Areas as Practiced in England*, by Francis J. Bellingham, Twenty-Third Shortcourse on Roadside Development, Ohio State University and Ohio Department of Highways, 1964, pp. 44–48.

(9) *Timing of Seeding Throughout the Growing Season*, by Evangel J. Bredakis and John M. Zak, Twenty-Fourth Shortcourse on Roadside Development, Ohio State University and Ohio Department of Highways, 1965, pp. 65–69.

(10) *Fast Seeding and Mulching*, by R. H. Stamm, Midwest Regional Turf Conference Proceedings, 1966, pp. 72–74.

(11) *Infiltration and Soil Surface*, by J. V. Mannering, Twenty-Fifth Shortcourse on Roadside Development, Ohio State University and Ohio Department of Highways, 1966, pp. 103–106.

Relationship of Fatality Rates and Fatal Accident Rates to Travel Densities on the Interstate System

BY THE OFFICE OF
TRAFFIC OPERATIONS
BUREAU OF PUBLIC ROADS

Reported by **BENJAMIN V. CHATFIELD,**
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IN its series of annual reports entitled *Fatal and Injury Accident Rates on Federal-Aid and Other Highway Systems,* the Federal Highway Administration is issuing tabulations of accident information furnished for 1967 and subsequent years by the State highway departments. Much of the value of this information lies in its potential usefulness to those who are seeking ways to make our highway systems safer, and interpretation of the material is the first step toward realization of its potential value.

Rate–Density Relationships

The general nature of the relation of State fatality rates and fatal accident rates to State travel densities on the Interstate System is implicitly described in the annual-report series. *Travel density,* as used in this context, refers to the volume of travel per unit of highway length within specified regions of space and time. When travel density is expressed in daily vehicle miles per mile, the definition of *travel density* is equivalent to some definitions of *average daily traffic* or *ADT*.

Approximations of the relationships between travel densities and fatality rates and between travel densities and fatal accident rates are illustrated in figures 1 and 2. These approximations are based on statewide figures for calendar years 1967 and 1968. In figures 1 and 2, State travel density is expressed in daily vehicle-miles per mile, and has the same magnitude as statewide average *ADT*.

Limitations

The curves in figures 1 and 2 are intended to illustrate only the general nature of the relation between State rates and travel densities. A number of technical problems should be kept in mind when using these relationships.

First, in manipulating the data on which the curves are based, it was assumed that the risk of fatalities or fatal accidents was uniform on both the rural and urban portions of the Interstate System in each State. Because of this assumption, the usefulness of the curves is limited; there is no reason to believe, for example, that the curves are good representations of rate–density relationships on short sections of highway.

Second, in the calculation of fatality rates, it is implicit that exposure to fatalities is adequately measured in vehicle-miles. This measurement neglects differences in vehicle occupancy, which would be accounted for if exposure were measured in passenger miles. Because vehicle occupancy is usually higher in rural areas than in urban areas, the effect of the measurement of exposure in vehicle-miles is an understatement of the difference between urban and rural fatality rates at a given travel density. Contrary to popular notions, the curves in figure 1 indicate that the probability of occurrence of a fatality is lower on rural Interstate highways than on urban Interstate highways with comparable travel density.

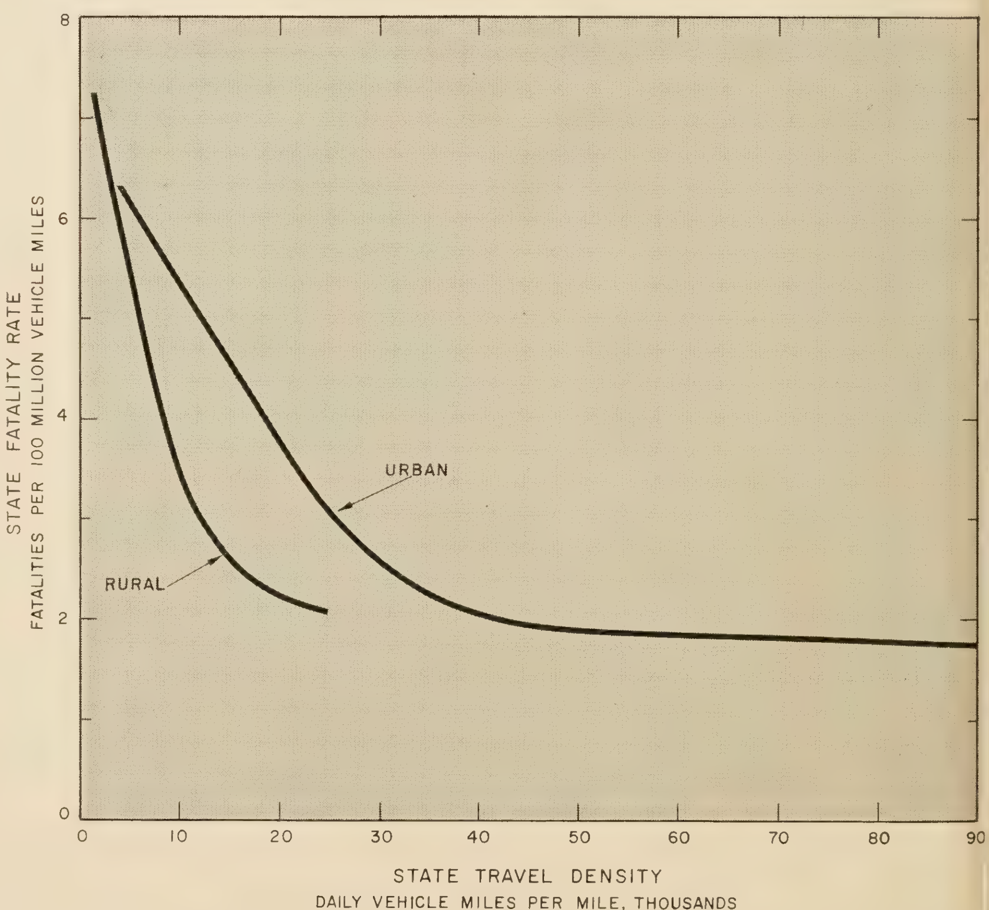

Figure 1.—Relationship of State fatality rates to travel density on the Interstate System 1967–1968.

Third, in the calculation of fatal accident rates, it is implicit that the vehicle-miles of exposure to the risk of involvement in a fatal accident divided into the number of fatal accidents is an appropriate measure of the risk. It is reasonable to expect, however, that the average number of vehicles in an accident will increase as travel density increases. For this reason, in the curves in figure 2, the risk of involvement in a fatal accident is understated more at high travel densities than at low travel densities.

Fourth, though it is possible to derive from the curves in figures 1 and 2 an approximation of the relationship between State fatality–fatal accident ratios and State travel densities, one would expect the approximation to be inferior to an approximation derived more directly from the basic data.

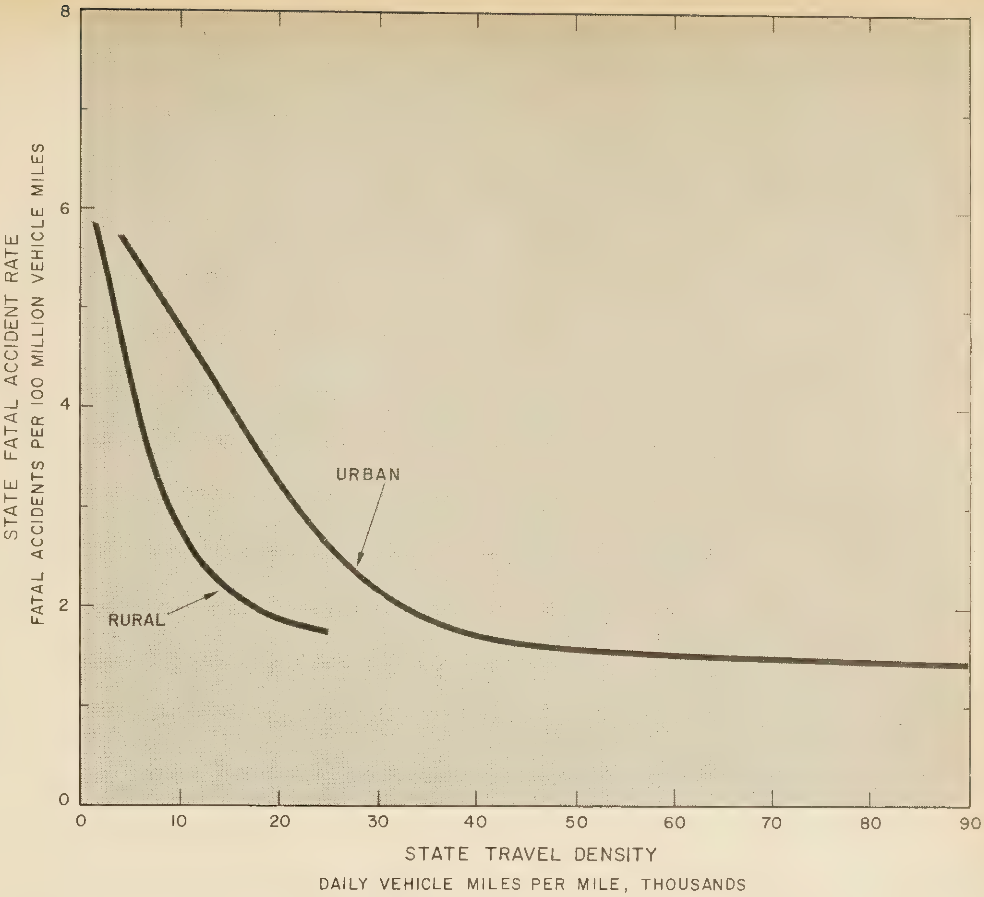

Figure 2.—Relationship of State fatal accident rates to travel density on the Interstate System, 1967–1968.

Mathematical Representation of Relationships

The relationships represented by the curves in figures 1 and 2 can also be represented mathematically as follows:

- All four curves are hyperbolic curves of the general form:

$$b^2[(x-h)\cos\theta-(y-k)\sin\theta]^2$$
$$-a^2[(x-h)\sin\theta+(y-k)\cos\theta]^2-a^2b^2=0$$

- Values of x bear the following relations to travel density:

  For rural Interstate highways—
  $x=(1/2{,}000)\times$(daily vehicle-miles per mile)

  For urban Interstate highways—
  $x=(1/10{,}000)\times$(daily vehicle-miles per mile)

- Values of y bear the following relation to fatality or fatal accident rates:

  y=fatalities (or fatal accidents) per 100 million vehicle-miles

- Values of the constants in the general formula for the four curves illustrated are:

	θ	a	b	h	k
Fatality rates—rural	−64°	1.8	$a\tan\theta$	4.5	1.7
Fatality rates—urban	−60°	0.7	$a\tan\theta$	3.0	1.7
Fatal accident rates—rural	−64°	1.8	$a\tan\theta$	3.5	1.4
Fatal accident rates—urban	−60°	0.7	$a\tan\theta$	2.8	1.4

The standard error of estimate for each of the four curves illustrated in figures 1 and 2 has been compared with the standard error of estimate for linear models. Each of the hyperbolic models is superior to linear models.

Applications

The application most immediately apparent for the rate–density curves in figures 1 and 2 is to compare the record of an individual State with the national pattern. Deviations from the national pattern may represent differences in the characteristics of highway construction and use. Identification of such deviations is a step toward reduction of both State and national fatality and fatal accident rates. To some extent—particularly in those States where rural or urban travel is relatively low—deviations will reflect random fluctuations rather than differences in characteristics and, sometimes, the deviations may reflect only differences among State accident reporting systems.

The 1968 rural Interstate fatality rate in Wyoming was 7.55 fatalities per 100 million vehicle-miles. This rate is about twice the national fatality rate for rural Interstate highways. Although every highway fatality is cause for serious concern, the Wyoming rate is not startling. Travel density in Wyoming was quite low in 1968—only 2,447 daily vehicle-miles per mile of rural Interstate highway. At this density, the figure 1 curve of the national pattern for rural Interstate highways indicates that a rate near 7 fatalities per 100 million vehicle-miles is normal. Increasing travel density in Wyoming over the next decade will probably be accompanied by downward trending fatality rates.

Conversely, although Connecticut's rural fatality rate for 1968 was only slightly more than the 3.74 national rate, its rate appears somewhat higher than normal for its travel density. If it were assumed that the characteristics of Connecticut's rural Interstate System were more typical of urban Interstate highways in the United States than of rural Interstate highways, then a comparison with the urban curve in figure 1 would indicate that Connecticut's 1968 rural Interstate fatality rate was about what one might expect.

Predicting fatality rates is a critical step in the computation of accident costs on alternate routes for proposed highways. Both average-rural and average-urban fatality rates have sometimes been applied in comparisons of rural and urban alternates carrying similar amounts of traffic. The curves illustrated here indicate that the use of averages in this manner may produce misleading results.

Conclusion

The risk of fatalities and fatal accidents on the Interstate System differs with travel density, more or less as illustrated in figures 1 and 2. Highway engineers and others concerned with the planning and operation of Interstate highways should be aware of the general nature of the rate-density relationships described in this article.

Highway Research and Development Reports Available From Clearinghouse for Federal Scientific and Technical Information

The following highway research and development reports are available from the Clearinghouse for Federal Scientific and Technical Information, Sills Building, 5285 Port Royal Road, Springfield, Va. 22151. Paper copies are priced at $3 each and microfiche copies at 65 cents each. To order, send the stock number of each report desired and a check or money order to the Clearinghouse. Prepayment is required.

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Differences in Fatal-Accident Patterns by Type of Vehicle on the Interstate System

Harold R. Hosea, Office of Traffic Operations, Bureau of Public Roads

In a recent analysis of fatal accidents on the Interstate Highway System during 1968,[1] a fairly close agreement was shown between the vehicle-miles operated by the several types of vehicles and the extent of their respective responsibilities for fatal accidents. Actually, the rates for property-carrying vehicles were slightly less than those for passenger cars, as indicated by the data in table 1, which were computed without regard to differences in accident types.

Significant differences in the accident patterns of the several types of vehicles were revealed by a supplementary analysis of the Interstate accident data. These differences in accident patterns are shown in table 2 in which vehicle-miles operated by the different types of vehicles and their responsibilities for individual categories of fatal accidents are related. As compared with their percentages of the total vehicle-miles operated, passenger vehicles were responsible for larger proportions of both single-vehicle, off-the-road accidents and head-on collisions, whereas tractor-trailer combinations were responsible for larger proportions of collisions with parked vehicles as well as rear-end collisions and sideswipes.

The accident pattern for single-unit trucks differs significantly from that for tractor-trailer combinations and is particularly apparent for head-on collisions. The variation may be explained in part by the fact that seven of every 10 single-unit property-carrying vehicles were pickup- or panel-trucks, usually of 1-ton capacity of less. These smaller vehicles, which basically resemble passenger vehicles, differ significantly from the large combination vehicles. It is also likely that relatively fewer of these light commercial vehicles were driven by professional drivers of the caliber of those employed by the large fleet operators of combination vehicles.

Although the data on which this analysis is based are somewhat limited, in that they relate to a single highway system, the information nevertheless may be of some assistance in reviews of enforcement and accident-prevention programs.

[1] *Fatal Accidents on Completed Sections of the Interstate System, 1968*, PUBLIC ROADS, A JOURNAL OF HIGHWAY RESEARCH, vol. 35, No. 10, October 1969, pp. 217–224.

Table 1.—Fatal accident and fatality rates by type of vehicle primarily responsible, Interstate Highway System, 1968 [1]

Type of vehicle	Fatal accident rate [2]	Fatality rate [2]	Fatalities per accident
Passenger	2.53	3.09	1.22
Tractor-trailer combinations	2.22	2.55	1.15
Single-unit trucks	2.31	2.59	1.12
Total property carrying vehicles	2.26	2.57	1.14
All vehicles	2.47	2.99	1.21

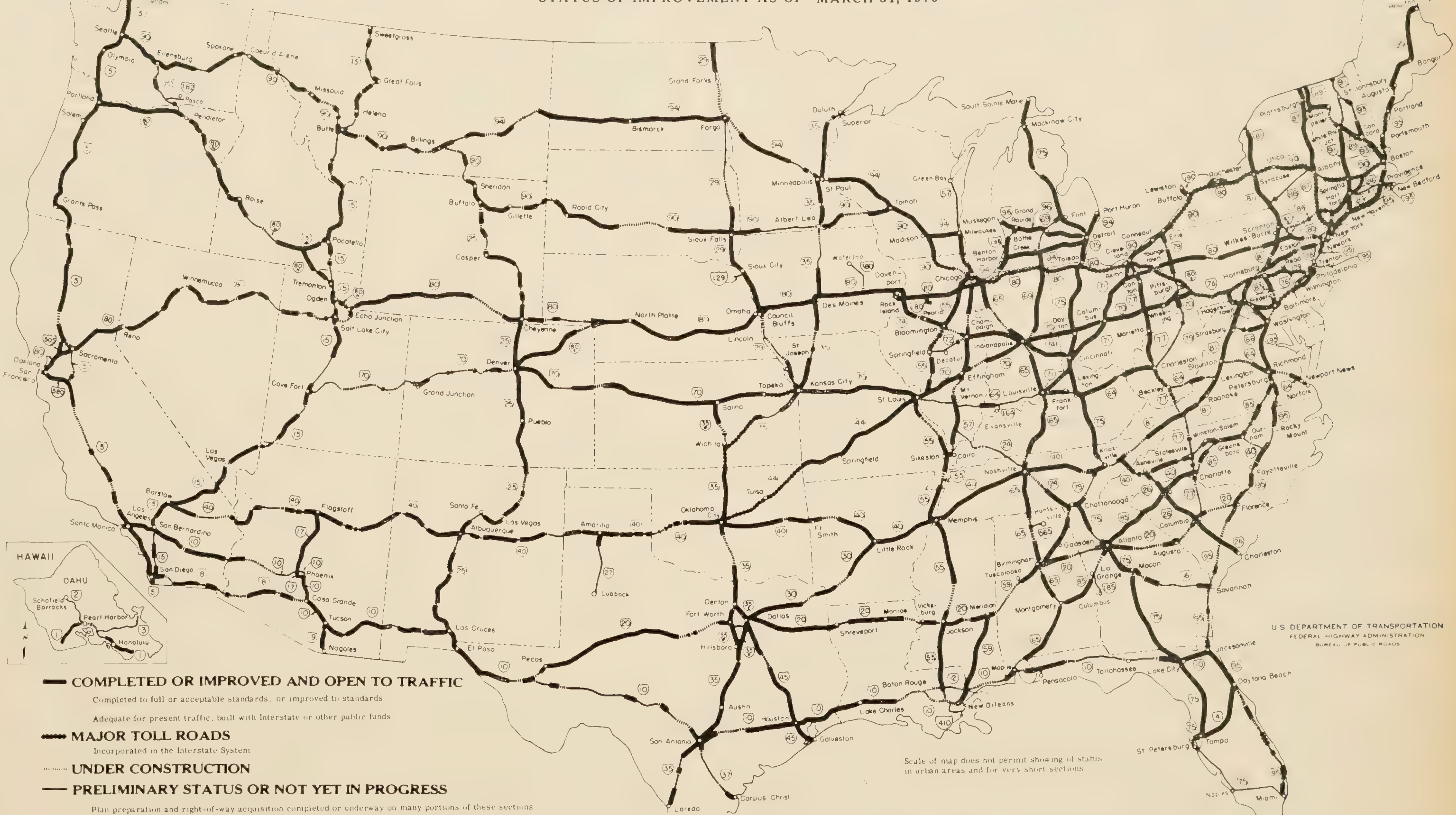
[1] Based on data used in the original study reported in October 1969 issue of PUBLIC ROADS, vol. 35, No. 10.
[2] Per 100 million vehicle-miles.

Table 2.—Percent distribution of vehicle-miles operated and primary responsibility for the several types of fatal accidents, by type of vehicle, Interstate Highway System, 1968

Vehicle-miles and accident type	Type of vehicle			
	Passenger	Property-carrying (P.C.)		
		Tractor-trailer	Single-unit truck	All P.C.
Vehicle-miles ... percent of total	79.7	10.2	10.1	20.3
Fatal accidents, total ... do	81.4	9.2	9.4	18.6
Single vehicle ... do	84.1	7.5	8.4	15.9
Off-the-road ... do	86.4	6.5	7.1	13.6
Pedestrian ... do	77.6	9.3	13.1	22.4
Collision with parked vehicle ... do	71.9	19.8	8.3	28.1
Multiple vehicle ... do	76.1	12.5	11.4	23.9
Rear-end collisions ... do	68.6	19.5	11.9	31.4
Head-on collisions ... do	86.7	2.9	10.4	13.3
Wrong-way drivers ... do	86.3	0.0	13.7	13.7
Vehicles from opposing lanes ... do	88.4	4.9	6.7	11.6
Sideswipes ... do	68.5	16.5	15.0	31.5

THE NATIONAL SYSTEM OF INTERSTATE AND DEFENSE HIGHWAYS

STATUS OF IMPROVEMENT AS OF MARCH 31, 1970



— COMPLETED OR IMPROVED AND OPEN TO TRAFFIC

Completed to full or acceptable standards, or improved to standards

Adequate for present traffic, built with Interstate or other public funds

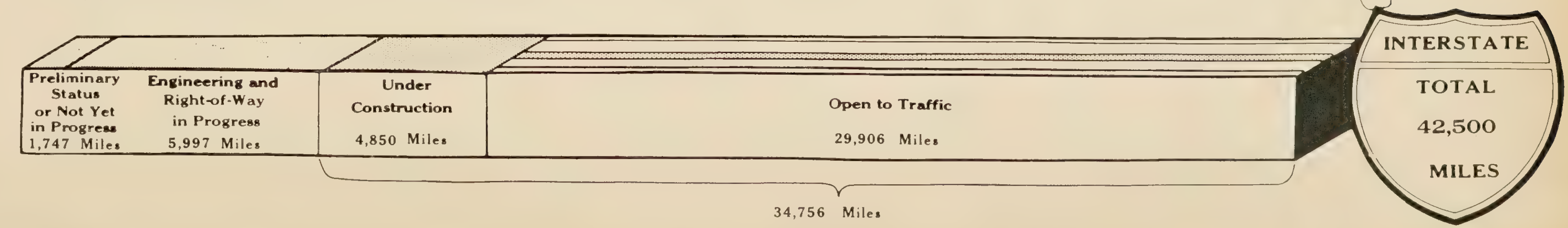
MAJOR TOLL ROADS

Incorporated in the Interstate System

UNDER CONSTRUCTION

— PRELIMINARY STATUS OR NOT YET IN PROGRESS

Plan preparation and right-of-way acquisition completed or underway on many portions of these sections



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Fatal and Injury Accident Rates on Federal-Aid and Other Highway Systems, 1968. 45 cents.

Federal-Aid Highway Map (42 x 65 inches) (1965). $1.50.

Federal Laws, Regulations, and Other Material Relating to Highways (1965). $1.50.

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Handbook on Highway Safety Design and Operating Practices (Supplement No. 1, November 1968. 35 cents). 40 cents.

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