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REDUCING DAMAGE TO SHADE AND WOODLAND TREES FROM CONSTRUCTION ACTIVITIES

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Abstract. Guidelines are given for reducing damage to trees from installing underground utility lines, making road and grade cuts and fills, and constructing home developments. Observations and experience, especially in supervising construction that affected trees on rights-of-way in Maryland, and the available literature provide the basis for the guidelines. Case histories are cited illustrating a range from no apparent injury to extensive damage.

Widespread road building, construction of underground utility lines (for sewage, water, electricity, telephone, and gas), and construction of homes have greatly affected woodland and shade trees in recent years. Sometimes efforts have been made to save many trees; in other cases all trees have first been removed to facilitate construction. Removal of some or all trees was justified in some instances on the assumption that they would die from construction effects. Even some landscape architects (e.g., Hancock 1956) have thought that complete clearing followed by planting of new trees may be advisable in home developments. On the other hand, many people believe that trees, especially large trees, add greatly to the value of properties (Gold 1977) and that they should be saved if possible.

Knowledge about the effects of construction activities on trees and about measures that lessen tree damage has been accumulating in Maryland, as elsewhere. Under the Roadside Tree Law of 1914, the State Forestry Department, now the Maryland Forest Service, was given the task of protecting all trees growing on public rights-of-way, of supervising all tree work involved in the installation and maintenance of overhead or underground public utilities on the rights-of-way, and of issuing permits for the trimming or removal of such trees. Earl Yingling was employed in this work for 40 years, and between 1969 and 1975 was in charge of the program statewide. In recent years, Charles Keeley and other employees of the Maryland Forest Service have been advising builders of home developments in wooded areas. In addition, Keeley followed changes in vegetation over a 3-year period during the construction of homes on wooded lots in Columbia, Maryland.

This report summarizes the knowledge gained in Maryland, particularly in the suburban Baltimore and Washington sections, and presents guidelines for reducing damage. Pertinent literature is mentioned throughout, rather than in a review section. Silas Little wrote the report, and James Burtis took the photographs.

Underground utility lines

The construction of underground utility lines may adversely affect established trees in at least two ways; by destroying a portion of the root system and by changing soil-moisture conditions.

To reduce damage to root systems, the Maryland Forest Service requires tunneling as soon as roots of a certain size are found in digging utility trenches. Formerly this size was 2 inches in diameter; now it is 1 inch. Furthermore, tunnels are usually made to leave at least the top 2 feet of soil undisturbed. Soil removed in tunneling or trenching is used to backfill, and an attempt is made to replace the soil in tunnels so that it has the same compactness as before removal. In the Washington area, 10-6-4 fertilizer is added to the backfill near trees at the rate of 4 pounds per inch of the tree trunk diameter. In the backfill of trenches, the fertilizer is scattered in the top 2 feet.

Tree size and age are other criteria to consider in deciding whether to trench or tunnel. Maryland experience suggests that in the vicinity of small trees, those less than 6 inches dbh (diameter at breast height), open trenches should not extend under their crowns, regardless of the size of roots found. In an area where open trenches were used under portions of the crowns of flowering crabapple trees, many stems died. Our current recommendation is either to establish the trench so that it is completely outside the crown cover of such trees or to tunnel whenever the area passes directly under the crowns. The U.S. Department of Agriculture (1965) has published a similar recommendation, but for *all* trees.

When trees are large and old, they have extensive root systems and are somewhat less vigorous, so more care has to be taken in constructing underground lines than for somewhat smaller trees. On the basis of his experience in central Maryland, Yingling places the dividing line at 23 inches in diameter, but in Delaware O'Rourke (1976) found a marked decline in tree survival starting at 10 inches and very poor survival of trees 16 inches and larger in diameter. In a Massachusetts study, trees over 6 inches dbh were less vigorous in developments than in undeveloped stands (van der Grinten et al., 1977), but in both the Delaware and Massachusetts studies, the effects of several construction activities were grouped.

In part because soil conditions affect depth of rooting and available moisture, and thereby modify susceptibility of trees to construction damage (Howe 1973), the division of trees into resistant and susceptible groups based on size or other criteria should be determined locally.

Examples of the effectiveness of Maryland measures are as follows:

(a) In the Pikesville area a 66,000-volt underground line was installed under street trees, with little damage to them. Here trenches were 5 feet deep and extended until a root 2 inches in diameter was encountered, from which point a tunnel was dug to the other side of the tree. Lines were in two 6-inch conduits, which were centered in an 18-inch layer of sand to dissipate heat, and the layer of sand was covered with 6 inches of concrete. The excavated soil was hauled away and then hauled back to backfill. Most of the street trees were silver maples planted about 1904, or at least 64 years old when the line was installed. Surviving trees are up to 44 inches in diameter (Figure 1), and only two of the 34 silver maples died in the 8 years after the line was installed. Younger trees in or near the path of the line included a pin oak, a red maple, and a honeylocust, and they show no adverse effect. The excellent results may have been partly due to the short time, only about 2 weeks, that most of the trenches and tunnels remained open.

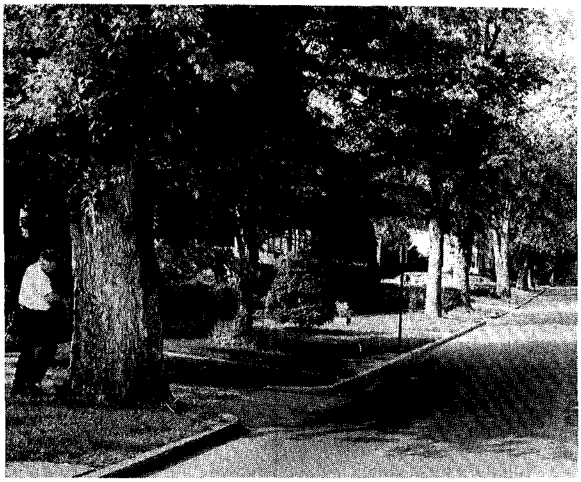

Figure 1. Large silver maple still healthy although an underground powerline was installed under it 8 years previously.

(b) In Frederick, a nine-hole conduit (9 inches by 16 inches) was installed 36 inches below ground in 1951, directly under 21 London plane trees. Because trenches and tunnels were dug by hand, the trenches were 5 feet deep. Trenches extended until roots 2 inches in diameter were found; then tunneling began. Some of the tunnels were 40 feet long. Constant supervision was needed to insure that the tunnels were carefully backfilled. None of the London plane trees died. The largest tree in 1974 was about 27 inches in diameter and, on the basis of an increment boring, had grown about 10.5 inches in diameter since the installation of the conduit. Survival and vigor of these trees have probably been favored by frequent pruning of crowns for clearance of overhead lines (Figure 2).

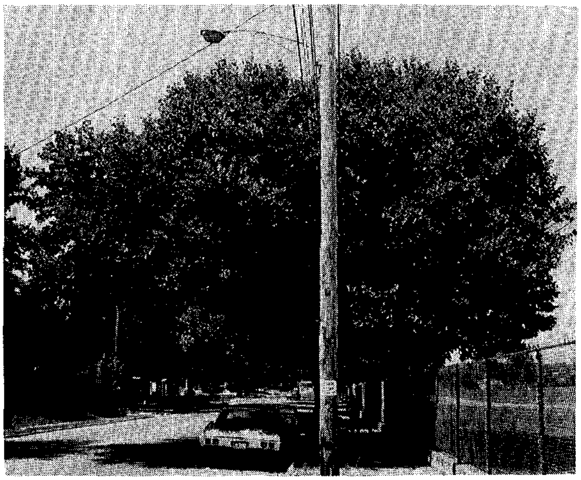

Figure 2. London plane trees under which a powerline was installed 23 years earlier by trenching and tunneling. Survival and vigor of these trees were probably favored by frequent pruning of crowns for clearance of overhead lines.

(c) In a development in Montgomery County, heavy-duty utility lines were installed under flowering cherry trees 14 to 16 inches dbh. In the following 4 years, no damage to these trees was apparent, probably because the recommended tunneling procedures of the Maryland Forest Service were used.

Survival and recovery of trees affected by tunneling can be favored by pruning, fertilizing, and watering. If root systems are appreciably reduced, we and some others (Grounds Maintenance 1973) recommend reducing the crown by a similar proportion. A slightly higher proportion of the crown should be removed from trees of low vigor than from vigorous trees.

Twenty years ago most tunnels were made by hand or by primitive machines, so that cave-ins were a problem, especially in sandy soils. Consequently, few tunnels have been used on the Eastern Shore or in certain other sections of Maryland. Even in the Piedmont, open tunnels were a problem during rainy periods. For example, along Reistertown Road there was an open tunnel 11 feet below the surface (under a storm-drain vault) at a time when 2.5 inches of rain fell in 1½ hours. The deluge caused a severe cave-in that toppled two large red maples.

Advances in equipment no longer require that tunnels be left open or shored up in unstable soils. Certain machines, such as hydraulic rams, permit the installation of pipe as fast as a tunnel is created by an auger.

Tunnels are often unnecessary where utility lines are laid under long-existing shoulders of roads. Yingling's experience indicates that few tree roots occur there. For example, along one avenue in Baltimore County a utility line was installed under the existing shoulder. Even though the edge of the trench was within a few feet of yellow-poplar stems 24 to 30 inches in diameter, no tunneling was done because so few roots were encountered, none over 1 inch in diameter. In the following 5 years the trees showed no ill effects.

Soil-moisture changes resulting from construction of utility lines sometimes affect trees at an appreciable distance from the lines. Such effects apparently vary with type of soil, amount of drainage difference created, and age of tree. One extreme case can be described. In Randallstown an old, very large white oak was on a knoll about 6 feet above the roadbed when a sewer line was installed 23 feet below the road surface. Crushed rock was placed around the pipe. Even though the edge of the trench was 16 feet from the bole of the tree, the rate of internal drainage of the soil was so increased that the tree was adversely affected. A branch died 2 years after the trenching, and the tree died 2 years later. Applications of large amounts of water during all dry periods might have delayed the loss of this tree.

Road and home construction

Road and home construction can cause several types of damage to remaining street and woodland trees. These include:

(1) actual severing of portions of root system, as in grading road cuts or around houses and in excavating for cellars or foundations;
(2) indirect killing of roots by (a) compaction of soil surface, especially by heavy equipment, (b) fills over existing surfaces from road con-

struction, grading around houses, or sediment deposits, or (c) impediment of drainage so that flooding or a raised water table results, usually in swamps or poorly drained soils;

(3) indirect damage by reducing amounts of soil moisture, as brought about by (a) an increased rate of soil drying after exposure of mineral soils in cuts or in grading, or (b) an increased rate of soil drainage resulting from road cuts, utility lines below road surfaces, or channelization of streams in swamps;

(4) damage to boles by heavy equipment, especially bulldozers; and

(5) sunscald wounds on thin-bark trees after exposure of previously shaded boles.

Severe damage to trees is often so extensive that some people recommend clearing home sites before construction. Haddock (1961), for example, suggested both avoiding disturbance to existing trees and complete clearing in some instances, as in stands of decadent old-growth trees or in areas where the most economical and efficient construction was desired. On the other hand, Howe (1973) recommended removing all trees closer than 13 feet to soils disturbed in construction.

Road and grade cuts. —The various effects of road cuts cannot be easily separated, but in Earl Yingling's opinion a road cut usually causes a more serious loss of soil moisture to nearby trees than does the installation of an underground utility line. In his opinion, the mortality of nearby trees will be high enough that they should be removed in proportion to the depth of the cut: remove trees for a distance of 1 foot back from the top of the cut for each foot of depth of cut; for example, 10 feet back for a 10-foot cut. He reported one case in the Piedmont where three white oaks about 36 inches in diameter grew at varying distances from a 15-foot cut. The nearest tree, only 10 or 12 feet from the cut, soon died; a second one, about 30 feet from the cut, developed dieback in its crown; while the tree at least 40 feet remained healthy.

In wooded areas, the death or dieback of residual trees above new road cuts is both prolonged and variable. The variation is such that sound predictions for individual trees appear unlikely. Yingling's formula would remove some trees that might survive. However, if it is not followed, the only alternative is continued and costly removal of scattered dying trees.

In housing developments, similar damage can be expected both near road cuts and on house lots that are graded. Certain developers grade a short slope at the edge of house yards and on the border of adjoining "green belts." Nearby trees gradually develop dieback in the crowns, and over a period of years some trees die. Other developers level between trees to create lawns, thereby causing several injuries to residual trees: severing of surface roots; indirect damage to roots and tree vigor through compaction and more rapid drying of surface soils, which change soil-moisture and soil-aeration conditions; and bole wounds from bulldozers. Again, many trees develop dieback or die as a result of the injuries and changed conditions. Old trees are particularly susceptible.

Fills. —Damage to trees from fills is caused by depositing new soil on top of the previous soil surface through grading, filling, or sedimentation. Heavy fills are very damaging to trees unless special measures are taken to reduce the effects (Duling 1966, Pirone 1972). Fills 6 inches or less in depth will not harm most species of trees if the fill material is good topsoil that is high in organic matter and loamy in texture (U.S. Department of Agriculture 1965). Meserve (1937) was somewhat less specific, saying that a few inches of fill is not seriously damaging if it is not clay, but he did recommend watering and the thinning of crowns of affected trees.

The standard measure in shade-tree work is to create wells (U.S. Department of Agriculture 1965, Pirone 1972, Grounds Maintenance 1973). These can be effective if trees are vigorous and the well area is adequate. For example, in 1966 the developer of a shopping center in Baltimore County wanted to raise the level of the parking lot by 3 feet or less. Six London plane trees were in the lot (current diameters up to 20 inches). A well 9 feet in diameter was constructed around each tree and filled with coarse rock up to the level of the parking lot. No trees have died, and all appear vigorous (Figure 3). However, annual topping of these trees because of overhead lines has probably favored their health, because any root damage has been offset by reduction of crown. In the case of old trees, even greater care than used in this shopping center has not prevented dieback or death of stems subjected to fills of similar depth.

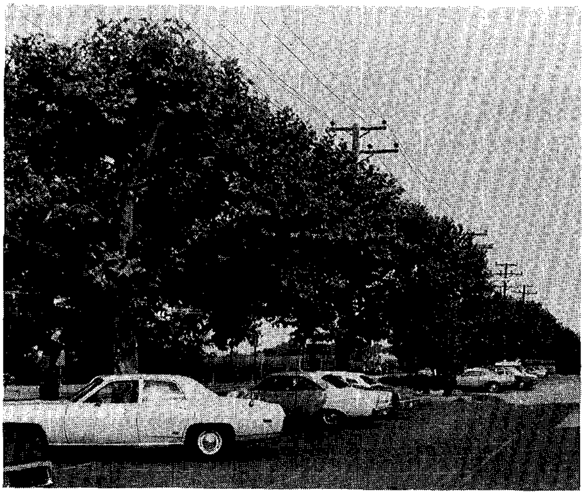

Figure 3. Vigorous London planes in a parking lot constructed 8 years earlier. Both the construction of a large well around each tree and annual topping because of overhead lines have favored their continued vigor.

Except for small roads, driveways, and the like, direct damage to trees from road fills is not usually seen in developments. Even then, other factors are usually partly responsible.

Drainage changes in wet soils and swamps. Changes are made in the drainage of wet soils and swamps when roads are constructed. In some cases the channel is deepened. While this may have ittle effect away from the stream in tight soils, in many soils the water level in the whole swamp may be lowered. Lowering the water table may cause the dieback or death of an appreciable number of established trees on such sites.

More often the road impedes drainage, forming a dam for water that previously moved downstream through the swamp soil or through minor streams. Such an effect arises from failure to install enough properly spaced culverts. The result is death of existing trees, often in a large pocket, from the decrease in soil aeration. In Minnesota, flooding from a pipeline without adequate cross drainage killed wetland trees up to ½ mile back from the pipeline (Boelter and Close 1974). Even on poorly drained soils there may be an impoundment of water, especially in wet periods, killing trees in the most affected area.

A broken or clogged culvert in an old road can cause similar damage. For example, under one old road in Baltimore County, the culvert was clogged during the Agnes storm of 1973. Water stood on about 1 acre for 6 weeks, killing the pole-size yellow-poplars there.

Bole damage. Many trees in areas graded by bulldozers receive bole wounds. While the wounds are conspicuous and form an entrance for decay fungi, evidence indicates that a wound affecting only a part of the bole circumference does not unduly disrupt the life processes of a tree. For example, Jemison (1944) found that severe wounding of yellow-poplar, white oak, and scarlet oak by fire did not decrease the diameter growth of surviving trees. Partial wounds caused by bulldozers are probably not a major factor contributing to the dieback or death of trees in the first 10 years. Over a longer period, however, the decay entering such wounds can result in weakened boles that break during severe windstorms.

Developers frequently paint the wounds caused by bulldozers, although Shigo (1976) reports that commonly used wound dressings do little to stop decay. In his opinion the paints serve chiefly to hide decay, and other actions are more important than painting wounds. He recommends removing broken bark, properly cutting back the edges of wounds, and increasing the vigor of trees by fertilizing or watering.

Another damage to boles is less direct. Trees unharmed in the actual clearing process may suddenly be exposed to greater sunlight as other trees are removed. Sunscald can cause wounds on thin-bark trees when they are exposed to full sunlight. Although such bole damage is usually considered unimportant, there are some differences among species and sizes of trees. Oaks seldom develop such a wound, while in maples and white pines the damage is somewhat more common. Differences within species because of size are especially noticeable in sweetgum, small stems with thin, smooth bark being sometimes susceptible; larger trees with furrowed and thicker bark being immune.

Varying damage in home developments

Because all of the above factors can affect the survival and appearance of residual trees, there are great variations in the success of different developers in leaving nearly all, many, or some of the trees in wooded areas. Developments made in recent years in the Baltimore and Washington sections reflect the great variability.

Some developers attempt to place homes and utilities in wooded areas without disturbing trees and understory plants. For example, one developer who built expensive homes on large lots in Baltimore County made no cuts or fills in building roads and driveways, excavated cellars with care and hauled away the removed soil, and did no grading of lots. He also used care during the construction of houses so that trees were not damaged. As a result, nearly all of the pole-size to mature oaks and yellow-poplars survived, even those within 3 feet of a house or within 1 or 2 feet of a roadway or driveway. The only dead tree was on the downslope side within 3 feet of a house. Its death was probably caused by a combination of severe reduction of its root system and change in soil drainage because of the cellar. Because care was used during construction, the lots are relatively large, and no attempt was made to establish lawns, understory vegetation in the remaining wooded areas appears healthy and little affected by the installation of houses, roads, driveways, and utility lines. A similar development in Montgomery County also has healthy trees and shrubs close to expensive houses.

Other developers create a combination of lawns and wooded areas, and again few of the residual trees die if adequate precautions are taken.

In one development in Baltimore County the roads were built with hardly any cuts or fills. Most of the residual patches of woods in the older portion of the development were not disturbed by grading on their borders. Soil excavated for cellars was hauled away. Even though a portion of each lot was cleared and put into lawn, the residual patches of woods still look natural, with the understory apparently undisturbed. Even many of the scattered trees left in lawn areas appear healthy. In contrast, in a newer portion of the same development some dieback and some mortality of residual trees are noticeable because slopes bordering the remaining patches of woods were graded, cellar soil was piled under some of the trees, and construction equipment damaged roots, and occasionally the boles, of some trees.

Actions in the new portion of the development violate guidelines published in *Grounds Maintenance* (1973). The importance of leaving an undisturbed forest floor in residual patches of woods, as was done in the older portion, was stressed many years ago by Weakley (1935).

In a development in Montgomery County there is also an appreciable difference among areas. Some of the houses were built in relatively young stands of Virginia pine, black locust, and oaks. Sufficient care was taken so that the remaining wooded patches show little or no effect from the development. Only where there is a graded cut have some of the edge trees died or suffered dieback. However, damage is much more evident in the portion where more road cuts were made and where lots were graded. There grade cuts border the remaining wooded patches, and scattered trees left in lawn areas were affected by soil removal, soil compaction, and damage to surface roots and to boles. Some of the affected trees have dieback, and a few have died. Here dieback and death were also favored by the age and species of the trees: relatively mature stems of yellow-poplar, oaks, and beech (Figure 4). O'Rourke (1976) found that higher proportions of black oak, beech, and yellow-poplar died as a result of construction activities in Delaware than of sweetgum, red maple, and white oak.

In another development in Montgomery County there is again an appreciable difference among sections. Here small "green belts" were left between clustered houses, and some trees were also left in areas put into lawns. Where the green belts are a few trees deep and their borders were not graded, most of the trees appear healthy (Figure 5). Where green belts are only one tree deep, or where occasional isolated large trees (mostly oaks) were left in yards, dieback is common and a few trees have died.

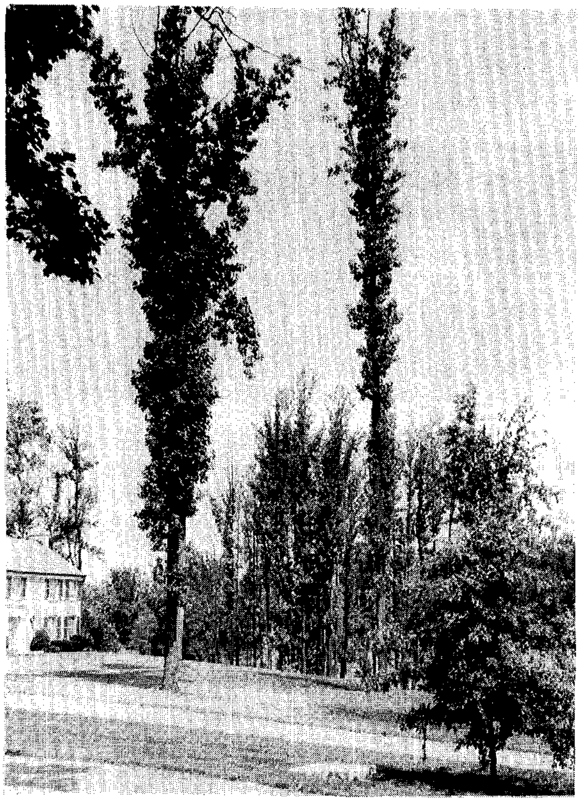

Figure 4. Two trees left as shade trees in constructing homes on a formerly wooded site. Note the dieback in the crowns of these trees.

Figure 5. Healthy trees in a "green belt," the remnant of a forest stand. Because the edge between this clump of trees and house yards was not graded, the remaining trees are still healthy.

Area-wide grading by bulldozers may severely affect the remaining trees. One developer in Montgomery County built expensive houses on large lots. He left some lots with many trees and some with few but graded the whole area with bulldozers to establish lawns (Figure 6). As a result, most of the remaining trees, large oaks and yellow-poplars, have one or more noticeable wounds on their lower boles. More important is damage to root systems through removing 3 inches or so of the surface soil in spots, adding soil in other spots, and compacting the soil. While beech seems particularly susceptible to such damage, in this development many trees of all species are stag-headed only 3 years after grading (Figure 7). Less decline is noticeable in clumps than among scattered individual trees, but one clump looks doomed because a driveway impedes drainage from a low spot stocked with yellow-poplars. The damage already evident in this development will eventually cause high mortality among the trees left by the developer.

Figure 6. A stand in which the soil surface was graded by a bulldozer before houses were built. Bole wounds are noticeable, but more important, the grading severed roots and compacted the removed or added soil, thus causing damage that will result in dieback of many tree crowns within 3 years (Figure 7).

In developments, some crown dieback and tree mortality may not be limited to a short period after development but may extend over 20 years or more, particularly if the trees are subjected to increasing stress. In one old development in Baltimore County the lots are small, green belts are narrow, and trees within the belts receive increasing stress because of soil compaction resulting from high usage of the belts as children's play areas. Consequently, dieback of a few trees and death of an occasional one still occur (Figure 8).

Figure 7. Stag-headed trees, ones that died back, in areas graded just a few years ago to create lawns.

Damage from grading cuts or slopes in developments may be reduced if affected trees are mulched, fertilized, and watered. Trees bordering a recent cut made for landscape purposes in the Botanic Garden of the Montgomery-Prince Georges Counties Park Commission were mulched with wood chips, fertilized, and watered, and so far are very vigorous.

Figure 8. In narrow green belts of developments, tree damage from high usage, such as in play areas for children, can continue for 20 years or more. Note the dieback of some tree crowns in this old development.

Other authors, such as Van Camp (1961), have discussed tree losses from changes in grade and from soil compaction by heavy machinery on building sites and have suggested remedial measures. Van Camp considered such losses staggering in amount, and he recommended such remedial measures as aeration wells, application of deep mulch over root zones, and crown pruning to reduce transpiration losses.

Guidelines

On the basis of information given in this paper and in the literature, the following guidelines are suggested.

In installing underground utility lines. (1) Use tunneling as soon as roots an inch in diameter are encountered, except that in the vicinity of trees less than 6 inches dbh either tunnel under crowns or locate the trench outside of their crown cover. (2) Near old and large trees take great care, trying especially not to disturb soil-moisture relations. (3) If a root system is reduced, reduce the crown by a similar proportion. (4) Fertilizer and water affected trees to aid their recovery. Watering is especially important, if feasible.

In making road and grade cuts. (1) Remove trees back from the cut for a distance of 1 foot for each foot of depth of cut (10 feet back for a 10-foot cut).

(2) On minor grade cuts, such as the grading of a short slope between house yards and a green belt, an alternative is to mulch the cut and the area under affected trees (as with wood chips) and to fertilize and water these trees.

In making fills for roadways. (1) Use sufficient culverts properly spaced so that drainage in the adjoining soils is modified as little as possible, neither impounding water in wet periods nor increasing the drainage rate so that water tables are lowered.

(2) Dredging of channels is inadvisable in many wooded swamps, because in porous soils the water levels may be lowered throughout the swamp.

(3) Maintain culverts in good working condition.

In constructing home developments. (1) The least damage to existing trees is created when: (a) Roads are planned, laid out, and constructed, with as few cuts and fills as possible, well in advance of house construction. (b) Soil levels around remaining trees are not altered by grade cuts or fills nor by stockpiles of soil excavated from cellars. (c) Damage by construction equipment to roots or boles of remaining trees is prevented. Passage of heavy equipment compacts the soil and changes the root habitat, so roots may die. Injury to part of a bole may cause only long-term damage, as from heartwood rots, but becomes important over an extended period.

(2) Proper treatment may save affected trees. If dieback starts, remove a portion of the crown, as by topping, and if stem sprouts develop, thin and manage the sprouts to form attractive crowns.

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