Tree Protection Standards in Construction Sites

"To exist as a nation, to prosper as a state, and to live as a people, we must have trees."
- President Theodore Roosevelt

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PLEASE TAKE THIS GUIDE WITH YOU TO THE CONSTRUCTION SITE.

Why Should I Follow This Guide?

This guide gives your trees the best chance of survival both during and after construction. You are following advice from professional arborists combined with published standards and practices (Coder 1996, 2000, Elmendorf et al 2005, Johnson 2001, and Matheny and Clark 1998). Use these standards to show a reasonable effort on your part to protect trees from damage. We cannot guarantee 100% success, but if standards are followed and a tree dies, then it is not your fault.

If you ignore these standards and a tree is injured, then you could be held liable for thousands of dollars in damage (Table 1). Tree damage may also lead to structural failure, ranging from the dropping of dead limbs to the entire tree falling over. This structural failure has the potential to injure people and property, which could also be your responsibility.

Table 1. *Approximate loss in property value caused by injury to a tree. Actual loss may be higher or lower based on a plant appraisal and what can be determined in court.*

Stem Diameter[1] (in.)	Loss in Property Value[2] ($)	
	Sicken Tree	Kill Tree
5	131	350
10	525	1400
15	1181	3150
20	2100	5600
25	3281	8750

1 Diameter of tree stem measured at 4.5 feet above ground
2 Appraisal of loss using the trunk formula method (Gooding et al 2000)
Assumptions: tree is a desirable species in good condition, properly located in the front yard of a well landscaped $100,000 residential home.

Trees and Roots

Tree roots are not like carrots. Roots spread out over a large area and are concentrated at the soil surface. A tree actually looks like a wine glass setting on a dinner plate (Figure 1). A wine glass represents (1) leaves and branches, (2) tree stem, and (3) the structural root plate. A large dinner plate (4) represents the transport and feeder roots that spread out farther than the branches.

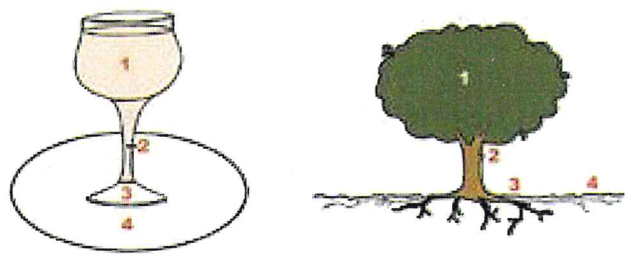

***Figure 1**. A tree looks like a wine glass on a dinner plate.*

Roots hairs are so small and prolific they essentially are one with the soil. So any little activity that compacts or moves soil can kill roots. Fortunately not all roots are created equal. Tree roots closest to the stem are more essential than others for survival (Figure 2).

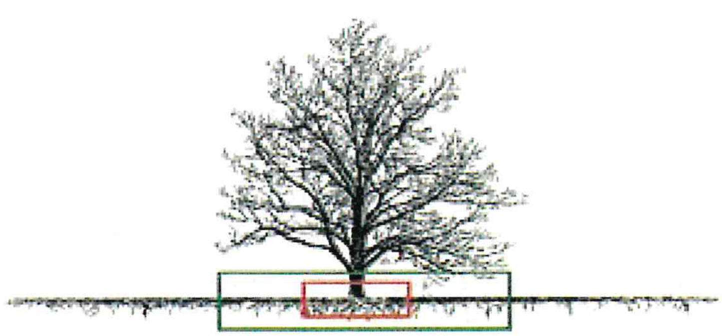

***Figure 2**. Tree roots most important for survival are the structural root plate (red area) and the critical root area (green area).*

To estimate the size of the structural root plate and the critical root area, we used a common tree measurement, **Stem Diameter** at 4.5 feet above the ground. Stem diameter can be measured directly with calipers or a diameter tape. Or you may measure stem circumference and divide by pi (3.14) to calculate diameter.

The most essential roots form the **Structural Root Plate** (Figure 2 red area). These large strong roots extend up to 11 feet from the stem in larger trees (Table 2). Damaging these roots in any way is usually fatal and may leave a tree unable to hold itself up. This could spell disaster.

Second in importance is the **Critical Root Area** located under the reach of the branches (Figure 2 green area). This area contains about 85% of the root mass. Any damage to the transport and feeder root system in this area will likely reduce tree health and survival. The size of the critical root area is estimated again using stem diameter (Table 2). The area is defined as a circle with a radius that is 1.25 feet for every inch in stem diameter. Thus, the distance from the tree stem you would like to stay away from a tree is called the **critical root radius**.

Tolerance to Damage

To ensure tree survival the entire critical root area should be protected from construction damage (Figure 3). This is especially true for trees classified as **Susceptible** to damage. These are trees in poor health, very old, or a susceptible species (Table 3). Any kind of root damage reduces the survival of susceptible trees significantly. The survival rate drops below 50/50 once 25% of the critical roots are injured (Figure 3).

Table 2. *Critical root radius and critical root area increases with tree size (Coder 1996).*

Tree Stem Diameter (in.)	Structural Root Plate Radius (ft.)	Critical Root Radius (ft.)	Critical Root Area (ft.^{2})
2	2	2.5	20
4	3	5	79
6	4	7.5	177
8	5	10	314
10	6	12.5	491
12	7	15	707
14	7	17.5	962
16	8	20	1256
18	8	22.5	1590
20	9	25	1963
22	9	27.5	2375
24	10	30	2826
26	10	32.5	3317
28	10	35	3847
30	10	37.5	4416
32	10	40	5024
34	10	42.5	5672
36	10	45	6359
38	11	47.5	7085
40	11	50	7850

Trees classified as **Resistant** to construction damage are healthy, young to middle aged, and of a resistant species (Table 3). Resistant trees generally are able to tolerate some root damage, at least until it approaches 1/3 of the critical root area (Figure 3).

Trees **Moderate** in their tolerance to injury include those in fair health, past middle aged to old, or a moderate species (Table 3). These trees fall between resistant and susceptible in their survival of critical root damage.

Roots outside of the critical root area are the least important for tree health (Figure 2). A tree can lose all these roots with minimal problems. But to compensate for this root loss, extraordinary care must be given to roots within the critical root area.

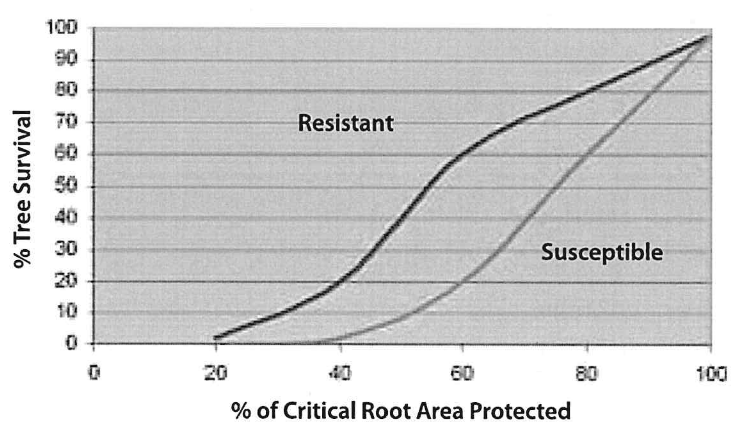

Figure 3. *Tree survival depends on the amount of critical root area protected and the tolerance of a tree to damage. (Coder 1996).*

Table 3. *Ranking of common tree species in tolerance to construction damage. Survival rates are high for resistant species and low for susceptible species with the same level of damage (Matheny & Clark 1998).*

Species Resistance to Construction Damage		
Resistant	**Moderate**	**Susceptible**
Ash - Green	Ash - White	Basswood
Bald Cypress	Dogwood - Flowering	Beech
Birch - River	Hickory - Pignut, Shagbark, Mockernut	Chinkapin - Allegheny
Elm - most species	Hophornbeam - Eastern	Maple - Silver
Gum - Black, Tupelo	Hornbeam - American	Sourwood
Hickory - Water, Pecan	Magnolia - most species	Sugarberry (Hackberry)
Holly - American, Dahoon, Gallberry, Yaupon	Maple - Florida	Walnut - Black
Maple - Red, Boxelder	Pine - Shortleaf	Yellow - Poplar
White Oaks - White, Swamp Chestnut, Overcup, Bur	Sweetgum	
Red Oaks - Water, Willow, Shumard, Nuttall, Northern Pin	Sycamore - American	
Pines - Loblolly, Longleaf, Slash		
Willow		

Construction Damage

Most people are not aware that tree roots are on the soil surface and very vulnerable to injury. That is why damage to the root system is the number one killer of trees. Unfortunately, any activity under a tree is a potential root killer, including the storage of equipment or supplies as well as minor vehicle and foot traffic. Injury to roots within the critical root area is capable of slowly killing **Healthy** trees (Figure 4). The process of tree death following injury is termed a "mortality spiral". The further a tree falls down the mortality spiral the harder it is to get back up to Healthy. So, if restorative treatments are to be effective they need to be applied immediately after damage occurs. Do not wait until the tree is **Stressed** or **Declining**.

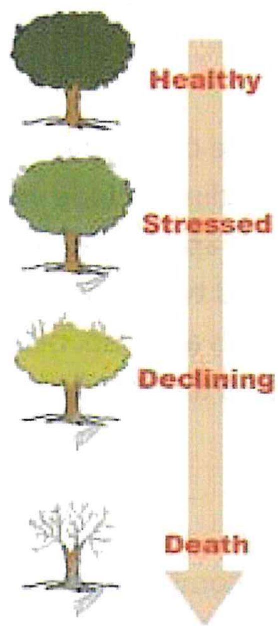

Figure 4*. Construction damage to roots begins a mortality spiral that can kill healthy trees in 1 to 10 years. (Matheny & Clark 1998).*

Stressed

Construction damage weakens a tree and sets it up to be injured by another stress that normally would not cause damage. Thus, drought and insect/ disease attacks can be deadly when combined with construction. As stressors accumulate, a tree becomes weaker and weaker. The tree does not usually show any signs of a problem, except maybe the foliage appearing a little sparse and off color. The severity and longevity of these stressors determines if tree health can be restored.

Declining

Upper growing points in the tree cannot be supported and die. Signs of decline include very low leaf density and leaves may appear yellow and small. Many dead branches and twigs are in the top portion of tree. Wood borers and bark beetles may attack. Once a tree reaches this stage, they are considered beyond help.

Death

A tree usually dies from a fatal combination of structural failure, health degradation, and pest infestation. Pine trees will typically die within a year following severe root damage. Generally, hardwoods are slower to die. After a fatal blow, hardwoods may live for another 2-10 years.

Fences

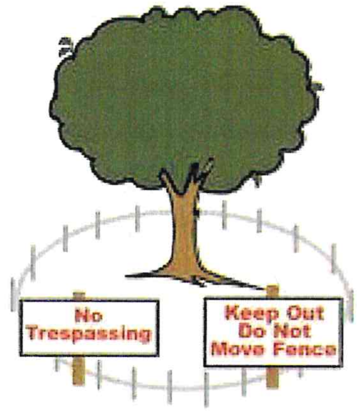

Figure 5a. Placing a protective fence around the critical root area assures tree survival.

To prevent root damage, construction activity needs to be diverted away. One of the best tree protectors is a fence placed around the critical root area (Figure 5a). Fences should be erected before construction begins and kept intact until final inspection. This temporary fence should be at least three feet high, clearly visible and supported by steel T-bar or similar stakes. Warning signs as shown in Figure 5a should be prominently displayed. Assign someone the job of monitoring the fences. To further prevent fence removal and injury to critical roots add a penalty clause in contracts. See Table 1 for reasonable penalties.

Protecting groups of trees instead of individuals is recommended when possible. To protect a group of trees, determine the critical root radius for each individual tree. Place a protective fence outside the critical root area of all trees in the group (Figure 5b).

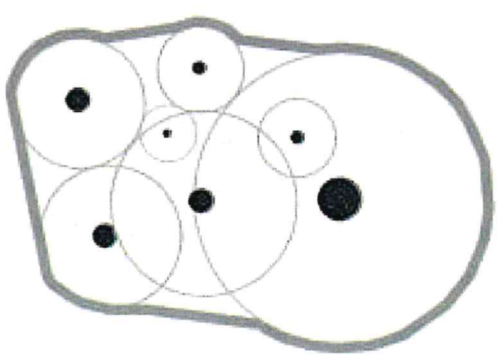

Figure 5b. *Overhead view of a tree protection zone (gray fence) for a group of trees. Dots represent tree stems and light circles are each tree's critical root area.*

Which Trees to Save?

Trees classified as resistant to construction damage should be a high priority for saving. These healthy, young to middle-aged trees of a resistant species (Table 3) have the highest likelihood of survival. Avoid trying to save trees classified as susceptible to damage. These trees are unhealthy, old, of a susceptible species or may have a serious to fatal defect (Figure 6). Problems make susceptible trees less valuable and much more difficult to keep alive and healthy.

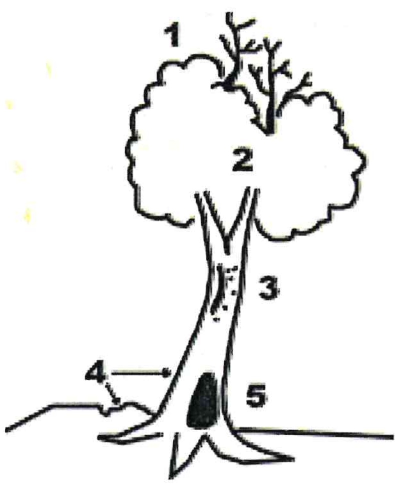

Figure 6*. Avoid trying to save trees with serious to fatal defects. 1- dead top and/or dieback in the larger top branches, 2- narrow branch angles and/or co-dominant stems, 3- history of damage from lightning, insects, and/or equipment, 4- lean and/or soil heaving, and 5- cracks, cavities, rotten wood, fungal conks, termites, carpenter ants, and cankers. (Elmendorf et al 2005).*

The size of trees should be compared to ownership goals and finances. Large trees may be desired and extremely valuable to a property but they are also very difficult and expensive to save. Construction activity may have to be adjusted considerably to protect a large tree's root system. The owner must have the willingness to pay for construction adjustments before a big tree can be saved. Owners with moderate budgets may have to concentrate on saving smaller trees. These are much easier and cheaper to protect and save.

Some species of trees are a better long-term investment. Live oaks for example tend to grow into large extremely valuable trees. Strong wood in their branches, stem, and roots resists breakage during storms. Live oaks also have a long life span and display few pest problems. Species of trees that display these kinds of characteristics are more desirable for saving than others.

Four Steps to Protecting Trees

1. Mapping and Prescription

Planning is needed up front to keep trees and construction activities separated from each other. Begin with an initial walk-through to identify which trees to save. Mapping these trees before development of the construction plan is very important (Figure 7). Compromises and adjustments made up front to protect trees are easier, cheaper and more effective at saving trees. Incorporate the exact location of each tree's stem and its critical root area into the construction plan. Determine where construction conflicts will occur. Predict the extent of damage each tree's critical root area will receive. Prescribe how to adjust construction activities to protect tree roots and improve survival.

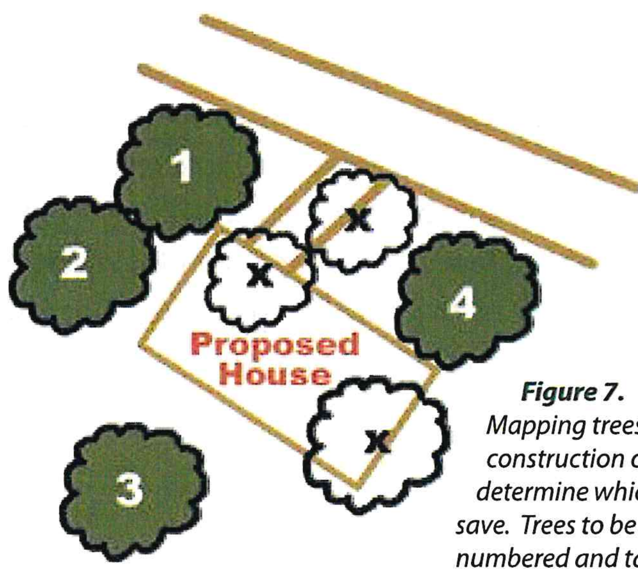

Figure 7. *Mapping trees before construction can help determine which trees to save. Trees to be saved are numbered and tagged. Trees to be removed are marked with an x.*

How close can trees get to structures?

The ideal distance between a tree stem and structures is the critical root radius plus at least 10 feet (Table 4). This distance allows a protective fence around the entire critical root area and leaves enough room for normal construction activity.

Whenever a tree is closer than ideal to a structure, the protective fence may have to be moved closer to the tree, which exposes some of the critical root area to construction activity. An additional **Root Buffer** is needed to protect the exposed critical root area outside the fence. To create a root buffer, begin by covering the exposed critical root area with wood chips to a minimum 6-inch depth. Overlay this with quarry gravel to stabilize a working surface and place ¾ inch plywood or mats on top. The root buffer should be maintained throughout the construction process.

Damage-resistant trees can be located within 20 feet of buildings and 10 feet of sidewalks. A combination of fencing and a root buffer will be needed to protect the roots (Table 4).

Structures must be kept outside the critical root radius of damage-susceptible trees (Table 4). Use a stem wrap to protect scaffold branches or the stem itself whenever they are exposed to construction injury. Wrap exposed tree parts with 2 inches of plastic orange fencing as padding and then securely bind 2x4s on the outside. During installation avoid damaging any bark or branches.

Table 4. *Minimum distances between structures and trees and required tree protection.*

Type of structure	Tolerance of tree to damage[1]	Minimum distance	Tree protection required
All	All	CRR[2] + 10 ft	Fence[3]
All	Susceptible	CRR[2]	Fence[3] + Root Buffer[4]
Buildings	Resistant	Lessor of 20 ft or CRR[2]	Fence[3] + Root Buffer[4] + Stem wrap[5]
Sidewalk or Driveway	Resistant	10 ft.	Fence[3] + Root Buffer[4] + Stem wrap[5] + Adjust construction

[1]Trees tolerance to construction damage classified using health, age, and species (see page 8 and Table 3)
[2]CRR=Critical root radius (see page 6 and Table 2)
[3]Fence protecting CRR (see page 11)
[4]Buffer protecting roots outside fence (see page 14)
[5]Stem wrap to prevent a direct hit to stem

What if a tree is too close?

Generally when a tree is closer to a structure than the minimum distance above your options are to remove the tree or move the structure. But in some situations you may consider alternative construction techniques. This includes ramping a walking surface over roots on a lifted slab. Or you could substitute driveway concrete with interlocking pavers or flexible paving, elevate porches on posts and brick or create flagstone walkways on sand. Seek out professional advice from an arborist on how to install these alternatives and still protect critical tree roots.

Trenching

Trenching is any linear excavation for utility lines, foundations, roads, sidewalks and irrigation. Foremost, protect the structural root plate from trenching. This plate can extend up to 11 feet from a tree stem (Table 2). Protecting the critical root area is also very important. Its size is also predicted using the stem diameter measurement (Table 2). No trenching machinery should ever be allowed in the critical root area.

Utility lines may be placed under the roots by digging a tunnel using a soil auger (Figure 8). Tunneling within the critical root area at a minimum depth of 2 feet will avoid most roots. Tunnel at least one foot deeper if utility is located directly under the stem.

Another option is to dig a trench that leaves the roots intact. This can be done with a pneumatic air excavator. Another option is careful hand digging below the roots from the side for short distances. Avoid trenching on hot, dry, or windy days. Protect exposed roots by immediately wrapping with wet burlap and keep moist. Do not leave the trench open for very long (1 hour is best), quickly replace the soil and soak with water to pack. If a root is severely damaged it heals quicker if a clean cut is made above the damage. Cut with a reciprocating saw or small pruning saw.

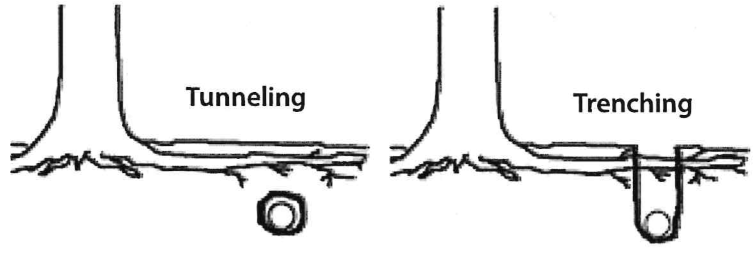

Figure 8. *Utility lines may be placed near trees without root injury by tunneling underground. An alternative is trenching with a pneumatic air excavator or careful hand digging.*

Grade Changes

Ideally all grade changes (raising or lowering the level of the soil) should occur outside the critical root area (Figure 9). Large cuts and fills may require retaining walls to keep the original grade around a tree. Try to avoid any grade change that will drastically alter the water table or how water drains around trees. Add drains where the critical root area now collects water and provide extra watering to areas that are now excessively dry. Also do not allow machinery on the critical root area when changing grade, this will compact the soil.

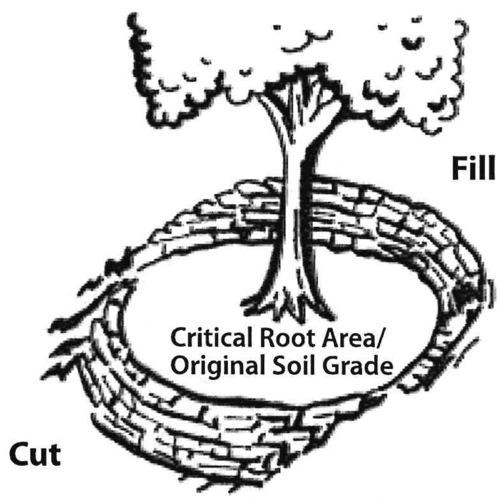

Figure 9*. Retaining walls can keep original soil grade within the critical root area and allow deep cuts and/or fills to achieve the grade changes needed for construction.*

Fill can damage root systems primarily by cutting off the oxygen and water supply. Within the critical root area the maximum depth of fill that will be allowed depends on the texture of the fill material. Up to 8 inches of sand may be added without much damage to the roots. With the help of an arborist, you may be successful with fill mixtures up to 4 feet deep. But no fill should ever be allowed to touch the tree stem. That means either slowly taper down the fill or build a wall around the stem to protect it.

Cuts in the critical root area can easily damage roots. Therefore we do not recommend lowering the grade in this area. A retaining wall outside the critical root area will allow cutting a lower grade for construction needs (Figure 9).

2. Preconditioning

Remove competition from weeds, vines, and grasses by clipping, not pulling. Spraying with Glyphosate is also effective. Correctly prune and remove all branches that will likely conflict with construction activities. This prevents ripped or broken branches (Johnson 2001).

Before construction begins, improve the soil conditions within the protected critical root area. The goal is to "bait" new roots into the protected

Figure 10. *Aeration of soil to relieve compaction in critical root area.*

area and away from unprotected soil. If the soil is already compacted then aerate on a regular basis, not just one time (Figure 10). Aeration applications can be made twice a year for two years, then once a year thereafter. Apply a low nitrogen, slow release fertilizer to stimulate root growth not more foliage (use a soil test to determine the amounts of N-P-K). The most important soil treatment is mulching the protection zone to a depth of 4 to 6 inches. Aged pine, cypress, and hardwood chips (wood and bark) are good mulches to add organic matter to the soil and hold water. Avoid placing mulch against the tree stem. If you plan to remove the mulch, place a synthetic weed free barrier fabric down before mulching to make removal much easier.

Watering is very effective in maintaining tree vigor. Use soaker hoses or another technique to apply one inch of water weekly on the critical root area during droughts. When trees are damaged and more frequent watering is needed, use a tensionmeter to determine when soil moisture is less than adequate. Do not use a timer to schedule watering, this usually provides too much water. An early application of paclobutrazol to the soil before construction begins also has been effective at encouraging trees to produce new roots and maintain health during construction. Evaluate the herbicides and soil sterilants that will be used near trees. Read the labels to make sure their application will not harm trees.

3. Supervision

Meet with all contractors. Express your desire to save trees and review the penalty clause for tree damage. Tell them your expectations, everyone is to leave intact the protective fencing and soil buffers. Assign someone the job of monitoring the fences daily. If any damage occurs immediately repair or mediate the injury.

4. After-Care

One of the most common soil disturbances during construction is soil compaction. Several treatments are available to ameliorate compaction and increase aeration.

1. Maintain and refresh the mulch layer of 4 to 6 inches annually.
2. Use a high pressure air spade or injector to create holes and fractures in the soil to provide air space (Figure 10). This should be done at least twice a year for several years.
3. Dig trenches one to two feet deep oriented like spokes of a wagon wheel around a tree. Pneumatic air excavators do this well. Replace the soil with a porous material.
4. Apply vertical mulching by drilling 2–3 inch diameter holes 12 inches deep using a power auger. Start beyond the tree's structural root plate and drill on 18 x 18 inch and up to 24 x 24 inch grid within the critical root zone. If large woody roots are encountered, avoid root damage by slightly moving the drill hole. Backfill the holes with compost, mulch, or other organic material.

To receive full benefits from a treatment apply immediately following damage. Do not let compaction move a tree down the mortality spiral before treating. These treatments can be effective individually and in combination with the tree growth regulator paclobutrazol.

Need Help?

Expertise in tree care can be provided by arborists certified by the International Society of Arboriculture. A list of local certified arborists can be queried by zip code or city at www.isa-arbor.com. You may also contact the local office of the Mississippi Forestry Commission (www.mfc.state.ms.us) or Mississippi State University Extension Service (msucares.com), both have certified arborists on staff.

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Checklist

1. Mapping and Prescription

- ☐ Determine what the client desires and the relative importance of preserving trees.
- ☐ Inventory the construction site and prepare a map that identifies the soil, trees, vegetation, and other resources. Determine which trees are healthy, structurally sound, and located away from construction.

Include in the Construction Plan:

- ☐ A map showing where protection fences are to be located and areas off limits to construction activity.
- ☐ List what alterations in construction are needed to protect important trees.

2. Preconditioning

- ☐ Build access roads and staging areas for construction workers. Ideally these should be part of the final site design. Confirm that soil sterilants to be used are safe for trees.
- ☐ Review with utility personnel the location of lines, trenching, and tunneling activities required.
- ☐ Cut and remove (do not pull) unwanted trees and vegetation in protected areas. Fertilize and mulch the protected root zone of trees to be saved.
- ☐ Install protective fences, drainage, and irrigation (if needed).
- ☐ Determine where to hold topsoil and where construction spoil will be piled.

3. Supervision

- ☐ Meet with the general contractor and agree on construction limits, sites for material storage, parking areas for workers, and location of trailer and portable toilets.

- ☐ Agree on material disposal, especially cement, paint, and plastic.
- ☐ Agree on water management. This includes erosion, storm-water run-off, and cleaning cement trucks.
- ☐ On the first day make sure someone is charged with protecting fences from encroachment.
- ☐ Install utility lines first, second driveways, walks, and parking, and third buildings.
- ☐ Check all last minute changes against the plan to ensure tree protection.
- ☐ Inspect the site twice a day.
- ☐ Provide extra water, fertilizer, and insect and disease control to protected trees.
- ☐ Prune/repair injured trees. Reestablish favorable soil conditions following any disturbance.
- ☐ Maintain mulch.

4. After-Care

- ☐ Remove temporary fences and irrigation systems.
- ☐ Rehabilitate compacted and eroded areas.
- ☐ Provide extra water, fertilizer, and insect and disease control to trees protected.
- ☐ Maintain mulch.

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