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16. Abstract

Roadways are frequently widened to accommodate increased traffic loads in urban areas. In some cases, the widening will threaten existing trees that may have been planted as part of previous landscape projects or trees associated with historical sites. Roadway widening in rural areas (and sometimes urban) may threaten landscape features (landforms) that may be considered sensitive in nature due to one or more environmental or aesthetic characteristics. This report identifies the issues that affect tree and landform preservation and protection, and recommends standards and a new specification procedure as part of a tree protection program for the Texas Department of Transportation. The report includes a set of guidelines that explain the standards.

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RECOMMENDATIONS, PROCEDURES, AND GUIDELINES FOR THE PROTECTION OF TREES AND SENSITIVE LANDFORMS

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INTRODUCTION

Tree-lined roadways were once considered the epitome of highway design. These "parkways" then accommodated low speed vehicles and many fewer than are found on today's roadways. Faster vehicles, more drivers, and less available right-of-way has greatly reduced the opportunity for parkways, but with careful design, trees and other notable features can still be a part of the roadway.

Landscape programs in many cities and within TxDOT have added many trees to our roadways. Today, many of these mature, established plantings are being threatened by expanding or upgraded roadways. Roadway widening through suburban and rural areas frequently encounters naturally occurring trees, native plant communities, or other notable landscape features. Protecting established landscapes extends the initial investment and reduces the life-cycle investment costs. Preserving existing trees or other landscape features adds value to the roadway by reducing the need for additional investment in new plantings.

Trees in the landscape are valued for physical as well as aesthetic benefits. Some of the physical advantages realized from retaining and maintaining trees include reducing air pollution, lessening and slowing stormwater runoff, lowering air and soil temperatures, and maintaining biodiversity. The U.S. Department of Forestry, in a modeled study of the Chicago area, estimated that a single tree with a trunk circumference of 30 inches can remove as much as 200 pounds of carbon dioxide (CO_2), more than 1 pound of ozone, and 2 pounds each of sulfur dioxide and particulates each year. An acre of trees is estimated to absorb the CO_2 in one year generated by driving the average car 26,000 miles. A computer analysis of Austin, Texas found that with its current tree coverage of 27 percent, residents of the city save $15 million in pollution control devices. Computer calculations performed in 1996 estimated that Fort Worth's urban forest provides residents with a net $77.4 million in air quality, energy, and stormwater benefits. Studies of urban areas have found that when impervious groundcover exceeds 25 percent, serious stormwater problems can develop. Vegetation and its residue, or leaf litter, can increase water absorption, reduce runoff, retain soil nutrients, and provide a cool, moist environment for plant regeneration over time. Retaining trees, understory vegetation, and leaf litter can also reduce associated pollution by reducing the need for pesticides and fertilizers. In addition to reducing pollution, retaining native vegetation and avoiding disturbance of existing

trees and vegetation can preserve biodiversity and reduce the cost of maintaining the landscape. Integrating existing trees and vegetation into the site design plan can minimize the impacts of construction on existing vegetation (*1, 2, 3, 4*).

This project is intended to assess current industry practice concerning tree and sensitive landform protection and make recommendations for incorporating appropriate measures into the TxDOT construction process. The project looked at current industry practice as found in other departments of transportation and in major cities in Texas.

LITERATURE REVIEW

Most cities with significant populations have ordinances or guidelines for the protection of trees during construction. Although there may be some modification for climate and location, these ordinances or guidelines are fundamentally similar, particularly in their basic approaches and goals, and most of these are probably derived from the acknowledged authorities on the subject: the Tree Care Industry Association (formerly the National Arborist Association) and the International Society of Arboriculture.

The fundamental tree protection approach in city standards is the protection of the tree root system. This approach is accomplished through the designation of the "critical root zone" (CRZ) or "protected root zone" (PRZ) wherein the soil is specified to remain undisturbed. Methods for calculating the CRZ or PRZ vary. Some guidelines specify the area from the trunk of the tree to its drip line (outer edge of canopy foliage), but it is not unusual for one or more feet to be added to that figure. Other formulae are based on tree diameter. One such formula, promoted by the University of Minnesota Extension Service, is based on the tree's trunk diameter at 4.5 feet above the ground (diameter at breast height or DBH) in inches and calculates a "critical root radius" at 1 to 1.5 feet per inch of trunk diameter. The International Society of Arboriculture recommends a similar formula but also factors in other issues such as species tolerance and tree age, as well as tree size (*5, 6, 7, 8, 9*).

The root zone area is protected through the use of a physical barrier, usually protective fence, strong enough to prevent intrusion. Common specifications for protective fencing around trees at construction sites include location, height, materials, distance between posts, and means and materials for attaching fencing to posts. Fencing is usually placed at the drip line or CRZ, whichever is greater, and is usually required to be between 4 and 6 feet high. Material specifications include brightly colored vinyl construction fencing, snow fencing, chain link, or other sturdy and highly visible material. Most specifications discourage plastic fencing in areas where heavy equipment may accidentally encroach into the CRZ or where vandalism is likely to be problem. Chain link is the preferred choice for shielding tree protection areas because of its strength and durability. Fencing attachments devices are required to be sturdy as are the supports themselves, and fence post requirements vary from 6 to 10 feet in height, placed at distances as much as 10 feet apart. Signage is often required on fencing to advise of the tree protection area

or to provide contact information in the event that the barrier must be breached (*10, 11, 12, 13, 14, 15, 16*).

Trees are susceptible to changes in soil level, hydrology, exposure of roots, and root and trunk injury, any of which can create stress and increase the possibility of disease. Even trees in protected areas can be stressed due to construction activities nearby. Some extension agencies recommend pre-construction fertilization and watering to strengthen trees to give them a better chance for surviving construction disturbances. Fertilizing and watering may be of benefit to trees in an altered habitat, but fertilizing is often not recommended until the trees have recovered from the stress of environmental changes, and watering is usually recommended only during long, dry periods. Weakened or injured trees are susceptible to insect invasion, disease, and death. Since damaged trees may take years to show signs of decline, these trees should be inspected on a regular basis, and appropriate treatments applied if insects or disease are evident. Precautionary spraying with pesticides is usually not advised. Pruning of stressed trees is recommended only where branches have been damaged, or must be removed due to hazard or interference with construction activities. To lessen the chance of tree damage and disease, all activity should be excluded from the designated tree protection area (*17, 18, 19, 20*).

Other factors addressed in the literature include how to deal with grade transitions, trenching and boring near roots, and root pruning, as well as the placement or location of construction materials or processes to avoid negative impacts to the root system, particularly within the CRZ (*17*).

Standard references and most city guidelines also address post-construction tree care. This process begins with inspection for health and vigor as well as structural stability in light of any nearby construction. In addition, construction impact inspection includes (*19*):

- damage to any part of the root system;
- damage to limbs;
- changes in soils structure such as compaction, fills, erosion, or loss of organic matter;
- changes to wind loading in the crown; and
- the effects on any new structures.

Immediate post-construction needs may also include:

- removal of trees that may have died during construction,
- removal of any fill soil from root zones, and
- remediation of soils damaged during construction.

Maintenance needs for trees after construction are based on evaluations of individual trees and include:

- meeting irrigation needs,
- pruning damaged or diseased tree parts,
- mulching the root system,
- fertilization, and
- control of pests.

TREE VALUATION APPROACHES

The Council of Tree and Landscape Appraisers *Guide for Plant Appraisal,* ninth edition recognizes three main approaches to appraising a tree's value: the cost approach, income approach and market approach (*21*). For most TxDOT applications, the cost approach will probably be used. This approach uses the cost to replace or repair the plant or landscape feature using the criteria of condition, location and species to arrive at a total value. The evaluation will use the replacement method for plants that are generally less than 12 inches in trunk diameter (transplantable size plants) and can readily be replaced with nursery stock or the trunk formula method, for plants larger than 12 inches in trunk diameter that cannot easily be replaced.

The replacement method is simple in execution and requires information listed in the *Guide for Plant Appraisal* (examples are listed in the tables in the Appendix) for use in the following formula:

(Basic Replacement Cost + profit) x (Species Classification) x
(Condition) x (Location) = Appraisal Value of Tree

The replacement method may also "identify additional tree removal, site cleanup, restoration and preparation expenditures, and additional maintenance expenditures and so may result in value indications which exceed the cost of the replacement tree alone. Any such excess

may be related to additional damages rather than to a tree value in excess of replacement tree costs" (*22*).

The Basic Formula Method uses four major variables to determine tree value: size, species, condition, and location. The trunk size is determined using the trunk diameter or cross-section trunk area at 4.5 feet above the ground or diameter at breast height (DBH), which has a dollar value per square inch of the cross-section of the trunk. Different species of trees have different ratings due to the quality of the tree type as shown in Table A of the Appendix. Condition, shown in Table B of the Appendix, refers to the health and life expectancy of the tree, and location refers to the placement of the plant within the landscape. Table C of the Appendix shows values for common locations. These data are used to calculate the following formula:

Value of Tree = Size (cross-section trunk area in inches)
([(3.14) r2]) x $(Value Per Square Inch) x Species x
Condition x Location

Texas A&M University's *Value of Landscaping* syllabus demonstrates the formula. An example dollar value of $22 per square inch of cross-section trunk with an 18 inch Live Oak tree in good condition and located on a residential lot was used. The actual dollar value to be used in the formula is regional and will be assessed by a tree care and appraisal professional (*23*).

$254\ in^2 \times \$22 \times 95\% \times 75\% \times 80\% = \$3,185$

This is the same procedure (updated version) referenced in Special Specification 1049 and discussed in a later section of this report. The use of these formulas obviously requires some skill in application since judgments regarding the health of the tree and species identification are important components. For that reason, a certified tree specialist is the best person to use the formula to arrive at a tree value. The value of this formula is its defensibility if properly applied.

PRACTICE WITHIN OTHER DEPARTMENTS OF TRANSPORTATION

Tree protection practices among departments of transportation (DOTs) vary widely but are basically a reflection of industry standards and are generally limited to the designation of a CRZ and fencing instructions. In other factors much less detail may be present. Maryland DOT does not have any standards since they come under the purview of the Maryland Department of Natural Resources (DNR). Maryland DNR has very extensive requirements, the most important of which is the designation of an arborist for each project to guide the development of a tree protection plan. Actual practices in place in the DOTs surveyed appear to vary little from the widely accepted tree care industry standards.

One report documents a study in the United Kingdom that examined measures provided for the mitigation of adverse ecological effects of road construction on designated sites and protected species, to determine the extent of their success. Of the 14 schemes studied, possibly only three could be regarded as successful. The main reason for failure was inadequate management of the implementation of the scheme or inadequate post-implementation management (*24*).

The literature search did not turn up any specific U.S. program for the protection of "sensitive landforms" or other special features. The Washington State DOT has an Integrated Vegetation Management Program (the most advanced in the country) that formally designates some areas of the roadside as areas to be preserved. These areas are based on their distance from the travel lane or centerline of swale and are meant to be left undisturbed. Their Roadside Design manual does discuss "sensitive area" and defines this as areas so designated by other state and federal agencies. The guide makes no recommendations for protecting these areas, relying instead on the standards of the controlling agencies. Typically, DOTs surveyed considered sensitive areas to be addressed in the environmental impact assessment process.

Roadside Significant Sites

Researchers found one well-established program within a department of transportation that addressed sensitive areas. It is a program of the Transport SA, the department of transportation of the Government of South Australia.

Transport SA (TSA), has a "Roadside Sensitive Site" program. This program targets sites of "high environmental or cultural significance along public road reserves," that may be "highly

vulnerable to disturbance and have specific requirements for the protection." This protection includes vegetation and habitat types as well as historic structures, recreation access points, and geologic features (*25*).

The Roadside Significant Sites database records site information regarding the nature of the sensitivity, and the special precautions required are noted. Sites which are considered sensitive due to native vegetation, rare flora, rare fauna habitat, significant trees, and wetlands, are signed with roadside markers at their beginning and end points on the roadside. To prevent collection or disturbance of rare species of plants or animals, the reason for the special classification of a roadside site is not marked on the markers nor shared with the general public.

Transport SA provides a short set (three pages) of guidelines. The guidelines spell out specific activities that should not or must not be allowed within a significant site:

- stockpiling of raw materials,
- temporary placement of spoil material,
- excavation work or extraction of material,
- disposal of pruning debris,
- parking of vehicles and mobile equipment,
- temporary storage of equipment and materials,
- turning around of vehicles,
- where mowing may occur, and
- limits to the use of herbicides.

The guidelines do not include any specific protection devices other than the markers. Specific mention is made that the drip line of trees is the limit to any nearby activity, but that understory vegetation should also be respected.

This program does not approach sensitive sites from a "protection from construction damage" focus. Sites may be designated at any time, not just during construction. The key to the program is the database of sites that contains information about the site and the types of activities that may be limited or prohibited there. The other point worth noting is that the program recognizes that these sites must be protected at all times, not just during the construction phase (*25*).

This first point is one that should be addressed in greater detail but is outside the scope of this project. Comments have been made by staff from the Environmental Division during conversations regarding this project, that when an experienced environmental coordinator leaves TxDOT service, a great deal of knowledge about roadside sites goes with them. This information is not systematically recorded and must be rebuilt by the new staff person. This concern was confirmed in a conversation with an environmental coordinator. When asked if he used any referencing or map system to keep track of such information, he replied that he "just knew where things were" given his time and experience in the district.

The second point highlights a significant issue. Protecting a site or feature during construction has little merit if it will later be subject to typical roadside impacts that may destroy the very features that were protected. TxDOT currently uses "No Mow" signs in some areas but these have met with mixed success. In some cases, the signs are ignored. In other cases, an insufficient number of signs are present to inform workers. This report will address the protection of sensitive sites through the use of site markers later in this report.

CURRENT PRACTICE WITHIN TXDOT

Tree protection in TxDOT begins as part of the initial environmental impact assessment process when new roadways are planned or when existing roadways are widened. The persons initiating the process vary from district to district. In some cases, the district environmental coordinator (EC), or persons on their staff will conduct the environmental assessment personally and forward the report to the appropriate agency for review. The EC may identify features such as wetlands, wildlife habitat, endangered species, or single trees to be protected and forward mitigation or protection measures to the designers for inclusion in the construction plan set.

In some cases, the area engineer (AE), or their staff may perform these tasks, sometimes without the aid of the EC. Sometimes, the consultant contract for roadway design may include these services. It is possible in some of these situations that the EC will not see the assessment before it is submitted to the Environmental Affairs Division for processing.

In some projects, particularly roadway widening projects, vegetation such as trees or forest may be present that clearly does not represent any significant habitat value. This may be vegetation that has grown up along a fencerow or isolated stands of trees that are cut off from

larger woodlands by surrounding development. TxDOT is not generally required to mitigate for vegetation in these situations.

Even though not considered significant, district designers may wish to preserve some of these "micro-habitat" features or mitigate for them as part of TxDOT's mission to protect environmental resources of Texas wherever possible. TxDOT is currently working with the Texas Parks and Wildlife Department (TPWD) in developing a Memorandum of Understanding in which district designers may, at their discretion, determine to mitigate habitat or other special feature.

The as yet not-finalized agreement establishes "The Vegetation Types of Texas" as the standard map reference to be used for a general description of the vegetation types that will be affected by the project (*26*). It also identifies two categories (Unusual Vegetation Features and Special Habitat Features) to deal with elements or features not indicated on the map.

Unusual Vegetation Features are:

- unmaintained vegetation,
- trees or shrubs along fenceline (right of way) adjacent to a field (fencerow vegetation),
- riparian vegetation (particularly where fields/cropland extends up to or abuts the vegetation associated with the riparian corridor),
- trees that are unusually larger that other trees in the area, and
- unusual stands or islands (isolated) of vegetation.

Special Habitat Features are:

- bottomland hardwoods,
- caves,
- cliffs and bluffs,
- native prairies (particularly those with climax species of native grasses and forbs),
- ponds (temporary and permanent, natural and man-made),
- seeps or springs,
- snags (dead trees) or groups of snags,
- water bodies (creeks, streams, rivers, lakes, etc.), and

- existing bridges with known or easily observed bird or bat colonies.

The agreement further states that "at the TxDOT District's discretion," certain habitats will be given consideration for non-regulatory mitigation during project planning phases. These include:

- habitat for Federal candidate species (impacted by the project) if mitigation would assist in the prevention of the listing of the species;
- rare vegetation that also locally provide habitat for a state-listed species;
- all vegetation communities listed as S1 or S2; [These are state ranking categories for rare species. S1 = critically imperiled in state; S2 = imperiled in state.]
- bottomland hardwoods, native prairies, and riparian sites; and
- any other habitat feature considered to be locally important that the TxDOT District chooses to consider.

The project statement of project 0-4548 references this 1998 memorandum. The stated goals of the memorandum are to:

1) develop procedures and methodologies for providing habitat characterizations, and
2) to establish criteria for the appropriateness, planning, and implementation for compensatory mitigation.

Phone interviews with two of the team members reveal that no tools, guides, or procedures have been developed to extend the work of the memorandum.

Developed by a team with broad TxDOT representation, the above lists provide a good basis for categorizing or identifying "sensitive landforms" as noted in the Research Project Statement.

CURRENT TXDOT TREE PROTECTION SPECIFICATIONS

TxDOT currently has 13 Special Specifications dealing with tree protection and one dealing with construction fencing. With two exceptions, these were "one-time-use" specifications for specific projects. SS1042 is not project-designated but listed as district-wide for Houston, Austin, and Bryan Districts only. SS5013, Construction Perimeter Fencing is designated for statewide use.

The special specifications (with the exception of SS5013) share many similarities but also contain many distinct differences. SS1004 (Harris County, 1994) is the earliest specification and provides for chain-link fencing but leaves the location for installation at the discretion of the engineer. The specification also includes the use of root stimulator and wetting agents, practices not recommended by the tree care industry today. Most significantly, no mention is made in the specification regarding delineation or protection of the root zone of the tree, only pruning and fertilizing exposed roots.

The rest of the specifications can be placed in two groups: Harris County or all the other counties (Brazos, Travis, Walker, Guadalupe, and Austin, Bryan, and Houston Districts). These two sets are distinctly different.

The Harris County specifications, beginning with SS1020 in 1997, contain a much higher degree of detail and specificity regarding construction methods. Most importantly, these all focus on protection of the root zone and define the "critical root zone" as the drip line of the canopy foliage. The specifications evolved into their present form in 1998 in SS1026, SS1041, and SS1049. The last usage was in March 2002.

The second group of specifications begins with SS1021 in 1998 and remains largely unchanged. The last incarnation appears to be in August 2001 with SS1042. This set of specifications is definitely weaker in accomplishing effective tree protection for two main reasons:

1) Even though fencing is needed, no location is specified, so placement is left to the judgment of the engineer or perhaps plan notes. Fencing options (orange plastic or chain-link) are also left to the discretion of the engineer.
2) No root zone protection is specified. The only specific protection mentioned is the use of 1"x6" wood planks bound to the tree trunk.

Also, the specification is relatively short and would need to rely heavily on plan sheet notes for further explanation.

SS5013, Construction Perimeter Fencing is not designed for use in tree protection but is used as a method to pay for tree protection fencing in SS1042.

ADEQUACY OF THE CURRENT SPECIFICATIONS

The Houston District's most recent specification was likely first presented by consultants for the city of Houston as part of a TxDOT roadway project. District staff has made minor

modifications since then, but the majority of the original specification remains intact. Therefore, the Harris County set differs significantly from others in use.

The Houston District has also developed a standard sheet for tree protection showing the location of fencing for individual trees as well as tree groups. The sheet also contains detailed general notes. The sheets are lacking construction details regarding trenching and boring near root zones and grade changes near tree.

All specifications in use contain one or more features that contradict currently accepted industry recommendations. Specifically, the following:

- The use of special paints to cover exposed pruning cuts or other injuries. This practice is widely discounted as not necessary at the least and possibly a hindrance to healing at worse.
- Reference is made to allowing vehicle access within critical root zone if ¾" thick plywood is laid over the area. Industry research indicates that soil compaction under plywood was not significantly different than on unprotected soil. The research found that six inches of wood chips or four inches of ¾" crushed gravel offered significant protection against soil compaction at depths of up to four inches.
- Fertilization (called for in the Harris County project specifications), is not recommended for trees during or for one year after construction. Fertilization may be beneficial if applied a full season before construction begins.

Most of the standards found in SS1049 agree with industry recommendations and should be part of the new specification in some form, either as general notes or details. Some notable features that should also be kept include:

- use of a compost filter berm placed at the edge of the critical root zone to intercept any silt-laden runoff,
- requirement of the contractor to secure the services of a certified tree care specialist for assessment,
- references to site monitoring, and
- assessments on the contractor for damage to protected trees.

DEVELOPMENT OF CONSTRUCTION STANDARDS FOR TREE AND LANDFORM PROTECTION

ISSUES RELATED TO TREE PROTECTION

The protection of trees and other special landforms within the highway right-of-way raises a number of issues. These are listed below and should be addressed within the guidelines. Discussion will include:

- safety,
- circumstances where tree protection may be required,
- community related issues,
- sidewalks near trees,
- protection of environmental processes and community aesthetics, and
- approaches to dealing with existing trees or landforms.

BACKGROUND REFERENCE

A basic understanding of the nature of trees and other features that may warrant protection is necessary in order to enable future users to identify appropriate decisions during the course of construction projects. The following subjects should be a part of the guidelines.

The Growth Habit of Trees and Their Response to Disturbance

- Definitions
- Principals of tree growth
- Root system
- Trunk structure and role (support tree and transmit fluids)
- The decline and death of trees
- Growth habit related to other plants

Sensitive Landscape Features and Landforms

- Plant communities
- Unusual vegetation features
- Special habitat features

RECOMMENDED PROTECTION STANDARDS

As a basis for a comprehensive tree and landform protection program, the researchers recommend the standards shown in Table 1.

Table 1. Recommended Standards

RECOMMENDED TREE AND LANDFORM PROTECTION STANDARDS		
ITEM	**STANDARD**	**REMARKS**
Protected Root Zone	The protected root zone is the area from the edge of the tree trunk outward for a distance equal to one and one-half (1½) times the distance from the trunk to the outer edge of the tree canopy foliage (drip line) at it farthest dimension. Preferred Root Protection Zone – recommended area to be designated for protection, 1 ½ times the distance to the drip line. Critical Root Zone – minimum area to be designated for protection, the distance to the drip line.	Prohibited activities: • Parking of any vehicles • Erection of any shed or structure • Storage of any equipment or materials • Use by people for any reason • Dumping of any waste materials or liquids • Impoundment of water • Addition of fill-soil • Excavation of any type
Barrier Fences	6’ chain-link fence on 8’ steel “T-post” spaced 6’ on-center and driven 2’ deep into the ground.	Barriers will be erected on the line established by the engineer and/or according to the details and notes on the plan.
Filtration Berms	Shredded hardwood mulch berm placed immediately inside the protective fencing.	Compost is optional.
Grade Changes (cut & fill)	Grade changes are discouraged within the protected root zone.	Grade changes within the CRZ must follow procedures shown in the details.
Trenching	Trenching within the protected root zone is discouraged and forbidden within the CRZ except under specific conditions and using specific construction methods.	Within the CRZ: bore at 3’ below grade Outside CRZ: bore beneath, expose roots and prune, or expose roots and thread utilities below roots.
Exposed Roots	Roots exposed within the protected root zone will be covered with an approved material within 24 hours after exposure.	Hardwood mulch; compost optional
Root Pruning	Where root removal is required, roots greater than 1” in diameter must be exposed without damaging them and cut with approved tools.	Some sources recommend 2” or greater.
Sidewalks near Trees	Maintain minimum clearance of 3’ between tree and new sidewalks. If closer than 3’ consider flexible paving (pavers).	Recommend use of root barriers behind curbs if tree species warrants.
Watering	Supplemental irrigation will be not be required unless roots are damaged or removed within the CRZ.	Recommended but left to engineer.
Fertilization	The use of fertilizers will not be allowed on any tree or plant community that is to be protected.	Fertilization is not recommended within the industry.

Table 1. Recommended Standards (cont.).

RECOMMENDED TREE AND LANDFORM PROTECTION STANDARDS		
ITEM	**STANDARD**	**REMARKS**
Soil Compaction	Area of the protected root zone exposed to pedestrian or vehicular traffic must be covered with four inches of shredded hardwood bark or well-graded gravel over the affected area.	For temporary or permanent situations. Must be removed when access is no longer needed.
Pruning	Pruning must be performed by a qualified arborist in accordance with the International Society of Arboriculture's Tree-Pruning Guidelines and/or the ANSI 300 Pruning Standard.	Pruning will be required: • For reasons of safety • To allow clearance of equipment near the CRZ where breakage may otherwise occur • For removal of limbs that are dead or diseased • Clearance above present or future travel lanes
Chemical insect control	Chemical control of damaging insect pests will be required only if the pest is present and only by a qualified tree specialist.	Precautionary spraying for insect control is not permitted.
Dust control	There will be no requirement to spray trees or plants to remove foliar dust.	
Removal of understory trees and shrubs	Removal of understory will be selective and accomplished using hand tools only.	No wheeled or tracked vehicles such as front-end loaders or bulldozers will be permitted.
Protection of sensitive landforms	The protection of sensitive landforms shall conform to the standards for tree protection.	See guidelines for discussion of possible sensitive landforms.
Signage during construction	Metal signs at 50' spacing through the length of the fence. Single trees will have a minimum of two signs placed on opposite sides of the tree.	12" wide, 8" tall, 1" tall bold black letters.
Post-construction activities	Post-construction assessment required by certified tree specialist.	See guidelines for list of inspection items.
Post-construction protection alternatives for sensitive areas	Sensitive areas will receive post-construction protection.	Three alternative procedures are provided. See guidelines for list.

RECOMMENDED SPECIFICATION FOR TREE AND SENSITIVE LANDFORM PROTECTION

One-time use special specifications are time-consuming to prepare and redundant. District staff in Houston suggested an alternative approach: create instead a statewide-use Special Provision (SP) to Item 100, Preparing Right-of-Way. The SP would support the reference to tree protection in Item 100 by adding basic standards for all locations as well as measurement and payment alternatives (and also modify inappropriate practices in the 1993 edition). General notes and construction details should be supplied on a standard plan sheet to facilitate changes for site conditions.

The advantage of this approach over a stand-alone specification is that the needs for tree protection would be addressed as part of the earliest work on the project.

Tree and sensitive landform protection specifications will be appended to Item 100, Preparing Right-of-Way by Special Provision, Tree, and Landform Protection. The recommended Special Provision is as follows:

1. Void the last two sentences of **Article 100.2, Construction Methods, Subarticle (1) General**.

2. Add the paragraph under:

   Article 100.2 (1)

   Protection of tree, shrub, and landform feature shall conform to the notes and details provided in the plans.

3. Add the paragraph (new):

   Article 100.2 (4)

   Damage to Existing Trees - The Contractor will be assessed for damages to trees designated to be protected that result from the Contractor's negligence or failure to comply with the requirements of the specifications. Damages should be assessed in accordance with the criteria established in the guide for plant appraisal, 9th edition, by the International Society of Arboriculture. Damages at the rate applicable therein should be deducted from any monies due the Contractor as liquidated damages.

4. Add the paragraph:

Article 100.3 (1)(e) Measurement

Tree and Sensitive Landform Protection will be paid based on the actual linear feet of protective fencing installed.

5. Add the paragraph:

Article 100.4 Payment

Payment – The work performed and materials furnished for in accordance with this item and measured as provided under "Measurement" will be paid for at the unit price bid for Tree and Landform Protection. This price shall be full compensation for labor and material costs of all installation, removal, and repair of any protection measure; fencing, signage, bark mulch, compost, root barriers; the costs associated with securing a certified tree specialist, and all costs related to tree care during the construction period.

GUIDELINES

INTRODUCTION

These guidelines discuss the preservation of roadside trees and other environmental features and provide methods that may be used to protect them. Effort has been made to focus established tree-care industry standards to the common situations found in the highway roadway and to the procedures for designing, estimating, bidding, and carrying out tree protection tasks. Baseline standards for the protection of trees and other special environments are provided in the form of plans, details and notes to be used for the majority of situations.

Guidance and alternatives for more complex or special situations are also provided along with recommendations on ways to deal with them. Seeking specialized knowledge from professionals, such as arborists or foresters, will assist with accurately assessing site conditions or the health conditions of trees being considered for protection.

ISSUES RELATED TO TREE PROTECTION

Safety Issues Regarding Trees in the Roadside

Primary in the process of protecting landscape elements is the safety of the driving public. In some cases, trees may pose a significant hazard and should be considered for removal. A hazard tree is defined based on its location, size, health, maintenance requirements, or a combination of the four.

- Location - The most critical criteria for assessing a tree's potential as a hazard is its location relative to the travel lane.
- Size - The trunk diameter (also the potential size) of a tree relates to its capability to stop an errant vehicle that has left the roadway.
- Health - Trees in poor health may pose a hazard because limbs may break off and fall into the traffic lanes or pedestrian areas. Tall trees in a state of decline may fall into traffic lanes in high wind conditions.
- Maintenance - Trees may pose a hazard if an activity for or near the tree exposes personnel or equipment to unacceptable risk during maintenance tasks.

From the standpoint of safety, a tree is considered in the same way as any obstruction in the roadside. The criteria for determining when an obstruction poses a hazard involves the issues listed above plus other characteristics of the roadway such as the slope of the roadside where the obstruction is located, whether the slope is a cut or fill slope, the traffic speed, and whether the obstruction is located on the outside or inside of a curve. In addition, any past accident histories of an area may also be considered.

Safety standards from the American Association of State Highway Officials (AASHTO) operate on the concept of the "forgiving roadside" where obstructions are kept a minimum distance from the travel lane within a given set of conditions. Current guidelines recommend a 30-foot setback from the edge of the traveled lane for cut slopes of 1:6 gradient or flatter and as much as 46 feet for fill slopes steeper than 1:6 gradient, with speeds at 68 MPH with an average daily traffic load of 6000 or greater. While these limits may be used for rule-of-thumb estimates, each situation should be evaluated to determine the unique site conditions. For example, the figures used above do not take into consideration whether the obstruction is located on the inside or outside of a curve. The AASHTO guidelines provide recommended adjustments for horizontal curves based on the design speed of the roadway and the radius of the curve.

Due to the critical nature of placing elements in the roadside, the guidelines for tree protection should not rely solely on rigid standards. Instead, each site should be evaluated using the AASHTO guidelines as a beginning point for considering other site features as well. The *Roadside Design Guide* and the *Highway Design and Operational Practices Related to Highway Safety* should be consulted to provide more detailed discussions of evaluating roadside obstruction safety issues.

Circumstances Where Tree Protection May Be Required

New Roadway Alignment

New roadways often require the removal of many trees or other features. The goals of alignment design regarding this issue are:

1) avoid removing things that will have be mitigated for later, and

2) avoid including things in the roadway which will require protection later.

The best tree protection plan is one that does not have to be used and the best-protected plant is one that is not damaged. Early and careful assessment can save in construction costs and

in long-term maintenance costs that could be associated with the project for many years after construction.

Roadway Widening Projects

Existing facilities may have trees that have been established for a long time and so have strong connections to the community. Alternative alignments for avoiding trees completely in these situations may not be possible, and the cost of preserving them should be included in the project. In the case of very important trees, make sure that the alignment allows room for protective measures to be taken. Even though the roadbed itself may miss the tree, construction activities may require getting too close to the tree and causing permanent harm.

Utilities Within the Right-of-way

Utilities are typically accommodated within the right-of-way and may have a significant impact either through installations or maintenance. TxDOT must permit utility companies before utility work may begin, and tree or landform protection may be included as permitting requirement in the form of specifications and details.

New Construction on TxDOT Office Grounds

Trees are often incorporated into TxDOT office facility grounds. Trees in these areas will typically be subjected to later impacts such as new turf installation, permanent drainage pattern changes, irrigation systems, more frequent mowing, and pedestrian traffic. The suitability of an existing tree in such new surroundings is largely based on the individual species' tolerance for these changes. As noted above, trees respond to cumulative changes and in some cases, may not show the effects of these impacts until years later. Some species, however, are known to be sensitive to even slight changes. Such trees should be considered for removal rather than salvage, particularly if their location will make access to remove them more difficult once construction is completed. The standards for protecting trees in these areas are no different than for the roadway.

Rest Areas

Trees in rest areas are particularly critical since they are more likely to be used by people. Often, trees to be preserved in new rest area sites were once part of a stand or forest of trees. In these conditions, trees will have shallower, shaded root systems. Exposing tree roots to sunlight and turf may be too drastic for some species and send the tree into decline even if protection measures are adequate during construction. Since decline may take place over a long time, the

risk may not be readily apparent or may go unnoticed. Trees in a state of decline can shed limbs that may fall on users or even topple in high winds. For this reason, candidate trees that will be close to human activities should be carefully assessed with these issues in mind.

Sidewalks Installed near Existing Trees

Widening projects may also include the upgrading of ADA accommodations, which may mean the addition or widening of sidewalks. These changes also have the potential for damaging trees so attention should be paid to their layout and detailing. Where roadways have impacted one side of a tree's root zone, avoid damaging the protected side with the sidewalk. If walks must be installed, try to locate them within the same disturbance zone of the roadway.

COMMUNITY-RELATED ISSUES

Aesthetics

The aesthetics of trees is not just a community issue, but most aesthetic goals for preserving trees will be centered in communities or cities. Trees, singly and especially in groups, have a large presence on the roadside and so have the visual affect of reducing the apparent scale of the roadway, usually contributing to a more attractive scene and reducing the visual dominance of large expanses of pavement. Trees reduce the apparent scale in building-dominated sites, creating more comfortable walking and sitting areas. This aspect is important in road-widening projects in cities and small towns.

Areas of roadside that contain naturally occurring plant communities also help blend the roadway into the landscape beyond the right-of-way. Surveys conducted in urban areas as well as comments from community groups, show a preference for "natural looking" plant masses near the roadway. Recent approaches to landscape planting in TxDOT right-of-way have included the creation of dense groupings comprised of native plants in large interchanges and these have met with wide acceptance by communities. Costs for these types of plantings are typically just over $50,000 per acre. Preserving existing stands of native plants can save much of this amount by eliminating the need for replacement landscape plantings.

Preservation of Trees from Past Projects

Local communities are often very concerned about protecting existing trees. Trees that have been planted as part of community beautification efforts represent a large investment in time and money from the community. Protection of trees in these instances may be required as part of the project. Roadway projects may also threaten stands of trees (sometimes with understory vegetation) that have served as a visual buffer to residential areas. Replacing these trees in a reduced-width right-of-way may not be possible. These instances can best be avoided during the alignment-selection process. An alternative alignment may be much less expensive than building a noise wall.

Historic Trees

Widening projects in urban areas or in small towns may impact trees that have historic value to the local community. In instances where trees notable for their size or connection to history are likely to be an issue, early detection is crucial. For some trees, relocation would be prohibitively expensive, and the tree may still be lost. The least expensive alternative in such cases is likely to be avoidance, and this may entail modification to a proposed alignment. The environmental survey process should identify trees that may fall into this category.

City Ordinances and Standards

Community participation may be required in order to reach agreement on measures to be taken in dealing with existing trees. Some cities may have standing ordinances regarding tree preservation. TxDOT is not required to adhere to these standards, but designers should consider how to incorporate the cities goals as well if their standards are more stringent. Initial plan development meetings with the community may help accomplish this. At that time, assessments should be made concerning the safety issues involved, as well as the suitability of particular plants for protection.

An example is the City of Austin. The city has designated that trees with over an 8 inch caliper require permission before removal. Also, the city may give a tree a historical designation that will require special consideration. In some cases, a tree connected to a historical site may not be itself classified as “historic”, but may require special attention due to the sensitivity of the area.

Sidewalks near Trees

Basic Conflict between Trees and Sidewalks

Sidewalks require a stable sub-grade to be rigid and stable. A tree is continually growing and expanding its root system and likes a moist, loose soil.

Trees do damage to sidewalks as their roots grow thicker. The buttress roots close to the base of the tree usually cause most of the damage. However, in thin soils over hard sub-grades, roots may travel close to surface for greater distances and do damage.

Damage to trees by sidewalks typically occurs when roots are lost during construction. Concrete and sub-grade materials such as acid-rich clays or limestone aggregate may change the pH of the soil, which may affect the nutrients available to the tree in that area of the root system.

Location Alternatives

To avoid future damage to sidewalks, locate the sidewalk at least 3 feet from the base of the tree. This will lessen the chance of the sidewalk heaving due to growth of the buttress roots.

To avoid damage to trees, locate the walk as far as practical from the tree so that fewer large diameter roots (1 inch or greater) are damaged. Avoid cutting large roots if at all possible. If roots must be removed, prune them using the proper tools; do not leave them with splintered ends or cause ripping along their length by pulling with heavy equipment.

Material Alternatives

Concrete pavers on a sand foundation may be used where movement is likely. If a sidewalk must be installed in a location where a tree may damage it, consider using a flexible material that is easier to repair.

Preventing Damage to Nearby Pavement

Roadway widening may place pavement surfaces in close proximity of trees. If placed too close, root intrusion may affect the structure by heaving of soils due to root expansion. The minimum distance is related to tree species since some trees have a deeper rooting habit than others.

If it is determined that root intrusion may occur, root barriers may be installed at the back of the curb or edge of the structure (Figure 1). These barriers may be fabrics or hard barriers such as plastics or metals. Plywood has also been used but will have a short life in the soil. Alternative barrier systems may be found in the trades under listings for "root barriers."

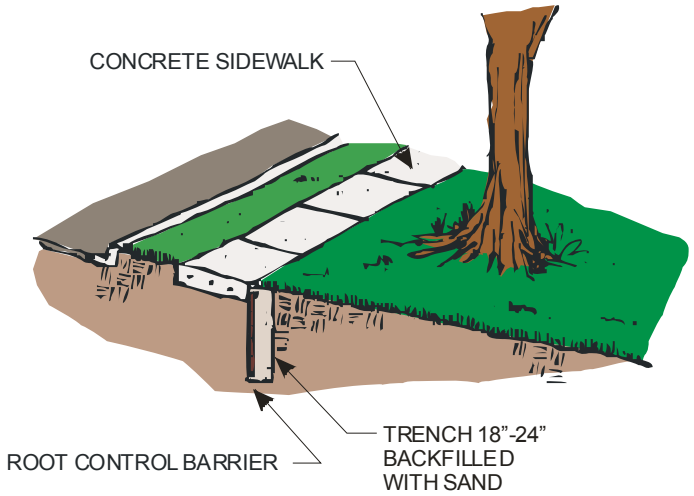

Figure 1. Root Barriers.

Tree Sensitivity and Damage Potential

Trees vary in their sensitivity to disturbance and in their potential for causing structural damage (Table 2). Generally, these characteristics are determined by their rate of growth and longevity. Long-lived, slow-growing trees (most oaks) usually have stronger wood and deeper root systems than fast growing species (such as some elms and cottonwood).

Table 2. Tree Characteristics.

Tree Characteristics of Some Common Species*				
Species	**Root Severance**	**Soil Compaction & Flooding**	**Hazard Tree Rating**	**Damage-Causing Roots**
Eastern red cedar	Tolerant	Sensitive	Low	.
Green ash	Tolerant	Tolerant	Medium	.
White ash	Tolerant	Intermediate	Medium	.
River birch	Tolerant	Tolerant	Low	.
Catalpa	Intermediate	Tolerant	Medium	.
Eastern cottonwood	Tolerant	Tolerant	High	Yes
American elm	Tolerant	Intermediate	Medium	Yes
Cedar elm	Tolerant	Tolerant	Low	.
Hackberry	Tolerant	Intermediate	Low	.
Hawthorn	Intermediate	Intermediate	Low	.
Honeylocust	Tolerant	Intermediate	Medium	Yes
Black locust	Tolerant	Sensitive	Medium	.
Red maple	Tolerant	Tolerant	Medium	Yes
Silver maple	Tolerant	Tolerant	High	Yes
Bur oak	Tolerant	Intermediate	Low	.
Red oak / Live oak	Tolerant	Sensitive	Medium	.
Post oak	Sensitive	Sensitive	High	.
White oak	Sensitive	Sensitive	Low	.
Pecan	Intermediate	Intermediate	Low	.
Black walnut	Sensitive	Intermediate	Medium	.
Black willow	Tolerant	Tolerant	High	Yes

* Adapted and summarized from Protecting Trees from Construction Damage: *A Homeowner's Guide* by Gary R. Johnson, University of Minnesota, 2003.

Rooting depth may be affected by the soils. More roots will develop in light, porous soils and tight, hard, subsoils near the surface may cause shallow root development.

Root sensitivity is a genetically determined characteristic and probably will not change between regional locations, but the health of the tree will also be a determining factor.

Most trees can tolerate temporary changes in soil moisture levels, but few can deal with it on a permanent basis. The same is true with soil compaction. In each case, however, tolerance should not be considered a reason to allow these conditions to occur if they can be prevented. These disturbances are considered a *negative cumulative effect* on the health of the tree.

A tree may pose some hazards due to its growth habits, susceptibility to pests or diseases that may weaken its structure, susceptibility to wind damage due to weakness of the wood, or a tendency to shed limbs. These are typically characteristics of fast-growing trees.

PROTECTION OF ENVIRONMENTAL PROCESSES

The role of trees in the environmental health of our landscapes is widely documented. Trees in urban areas now considered components of key strategies to improve air quality because:

- Trees increase oxygen in the air due to their respiration.
- Trees collect and hold dust on their leaf surfaces.
- Leaf surfaces collect and hold significant amounts of water, reducing the amount of runoff during short-duration storm events.
- Tree canopies reduce air temperature near the ground.
- Trees reduce glare from nearby buildings and road surfaces.
- Soil beneath trees holds moisture longer, allowing other plants to thrive.
- Trees create pleasant places for human activities.

Of critical importance to the condition and management of the roadway are issues of:

- erosion control,
- slope stability,
- water quality, and
- roadside maintenance.

Developing a strategy for considering these issues requires adopting an expanded set of goals that make use of existing environmental processes and conditions ***at a larger scale*** than that of an individual tree. Naturally occurring and long-established landscapes contain countless complex relationships and interactions between plants, soils, animals, insects, bacteria, and climate that have evolved over many millennia to create a fairly stable, self-sustaining community. These systems typically require no maintenance and are very resistant to erosion and weed invasion. The effort and expense of recreating such a complex system from scratch, in what was recently a highly disturbed construction site, is much less desirable than preserving one that already exists.

The protection and preservation of established landscapes provides benefits in three areas: management functions, environmental value, and aesthetics.

Management Functions

Preserving existing environments may aid in reducing maintenance tasks in the roadside:

- The establishment of stabilizing vegetation on disturbed soils is costly and sometimes very difficult.
- If erosion occurs during re-establishment, the effect of siltation on flow-lines and drainage structures can add significantly to the cost.
- Preserving the existing soil strata and vegetation, particularly on slopes, can reduce the chances of losing soils as well as eliminate the need for re-seeding.
- Undisturbed soils also contain seeds (soil seed bank), which, in cases where disturbance is unavoidable, can be salvaged and used to quickly revegetate construction sites with locally adapted plants.
- Exposed layers of sterile substrate soils may actually prevent vegetation establishment in the case of severely acid soils or where high concentrations of some minerals exist.

At the very least, disturbed soils invite a host of opportunistic weedy growth. Research has shown that soils that had been reworked during construction showed very different soil pH and nutrient levels than native substrates. The plant community differences between native and reworked soils also suggest that native plant communities on existing soils are more resistant to invasion by non-indigenous plant species. Preserving existing stands of native vegetation may be one way to reduce the spread of invasive, noxious weeds within the roadside.

General Environmental Value

The significance of an established plant community is the interdependent relationships that have developed between:

- plants,
- soils,
- animals,
- insects,
- bacteria, and
- climate.

Naturally occurring plant communities are self-maintaining in that they:

- conserve the moisture,
- recycle the nutrients it needs to survive, and
- are typically less susceptible to erosion due to the amount of leaf surface that intercepts rain droplets and plant litter that hold the soil surface in place.

The distinct layers or horizons of undisturbed soil profiles contain plant nutrients and store needed water for plant growth. They also help hold water that infiltrates the layers, reducing runoff and improving water quality.

Roadsides in some areas may also provide havens for native plants that are becoming less prevalent in the surrounding landscape due to land development, farming, and animal grazing. These may in turn be home to creatures such as birds, insects, small mammals, reptiles, and amphibians. Sites such as these may act as seed reservoirs for local plant species that may not be found in many other sites locally.

Incorporating SW3P Considerations

The Texas Pollution Discharge Elimination System (TPDES) Phase II emphasizes the importance of retaining and/or conserving existing vegetation for runoff control as a best management practice (BMP). The following recommendations are taken from the *Texas Non-point Source Pollution Assessment Report and Management Program 1999,* SFR-68/99, Chapter 7, Best Management Practices. Within the section, Highways, Roads and Bridges BMPs, vegetation is suggested as a vital BMP for runoff management. Specifically, these measures are listed below:

Project Sequencing and Phasing

- Maintain the maximum amount of existing vegetation as practical to assist in the control and minimize the exposed erodible area.
- Plan and designate an area that is not to be disturbed at all, or even at which phase in the project the area is to be disturbed. This can include limiting the type of access or operation in a given area.

Stabilization Practices

Preserving existing vegetation or revegetating disturbed soil as soon as possible during construction is one of the most important and cost-effective erosion control measures. A vegetative cover reduces erosion potential by shielding the soil surface from the direct impact of the rainfall, improves soil's water storage capacity, slows the runoff allowing sediment to settle out, and holds the soil in place. Vegetative cover may consist of grass, trees, mulch, straw, or retention blankets. Existing vegetation should be preserved as much as practical. Area not to be disturbed should be indicated on SW3P plans. The following BMPs should be considered for stabilization practices:

- preserve natural vegetation,
- maintain natural buffer zone, and
- limit disturbed areas.

Advantages:

- can handle higher quantities of runoff than seeded areas;
- increases infiltrating capacity due to denser root structure;
- water quality, aesthetic, and habitat benefits; and
- natural areas do not warrant pollution control devices thereby reducing the cost of control measures.

Disadvantages:

Requires substantial planning to protect areas.

Conserving the natural vegetation and soil structure also retains the native seed bank within. This retention is important, especially in arid areas such as the Odessa and El Paso districts where vegetation is sparse and difficult to re-establish after construction with standard revegetation practices. Often, vegetation can take several years to re-establish.

Approaches to Dealing with Existing Trees or Landforms

Three alternative approaches are available to the designer for where trees or landforms exist that are selected for preservation:

- *Avoidance* – Avoidance is the preferred alternative where possible. In some cases, realignment of the roadway may be necessary so that trees or sensitive areas are left outside the right-of-way. This action may avoid the need for expensive mitigation elsewhere. In other cases, lane alignments within the corridor may be considered for change so that elements or areas can be protected.
- *Protection* – When trees or other elements are slated for preservation, steps must be taken to prevent injury due to construction activities. This process may be accomplished by a variety of means from simple notes within the plan set to detailed procedures for barricading tree or special sites. Protection is most effective is conducted early in the project.
- *Mitigation* – Mitigation involves some form of compensation for plants or landscape features such as wetlands lost during construction. Trees that cannot be salvaged and moved may be compensated for by installing new plantings elsewhere, sometimes off right-of-way in areas such as city parks. Moving affected trees from one site to another is considered salvage and not protection since the plant is essentially transformed into a new landscape planting.

Trees and Tree Growth

Effective tree and landform protection practices are based on the particular needs and processes of trees and the conditions that brought them about and allow them to survive in a healthy or stable state. (This is also true for most special features and landforms.) The current standards within the tree care industry are based on these needs and so tree care standards are

virtually identical, regardless of which resource one finds. Fine points of study are still conducted in research, but the most critical considerations are in wide agreement among the most credible sources.

The leading sources of information are the Tree Care Industry Association (formerly the National Arborist Association) and the International Society of Arboriculturists. Publications from these organizations will be the principal sources of information regarding the effects of construction on trees and current recommended practices to prevent damage.

Tree Structure

Trees are comprised of three major components:

- foliar crown – energy production through the leaves,
- trunk – structural support, transport of fluids, storage of waste products,
- root system – provides access to moisture, nutrients, and minerals.

Foliar Crown. Leaves capture light energy and in the presence of water convert it to carbohydrate energy. The greater the amount of leaf surface available, the more energy a tree can produce for itself. Therefore, any reduction in leaf surface through damage or pruning will reduce the energy available to the tree. This reduction will be noticeable as a slower growth rate, shorter stature, thinner trunk, and most importantly, a reduced ability to resist disease and insect damage.

Trunk. The trunk supports the crown and is the conduit through which water is transported to and from the leaves (Figure 2).

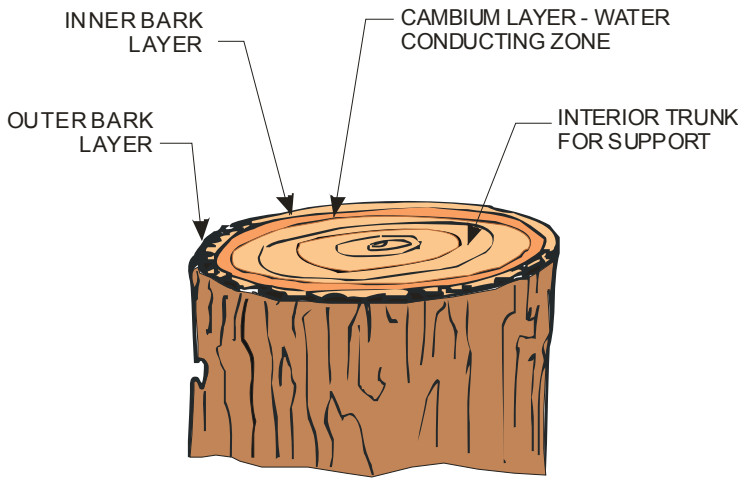

Figure 2. Tree Trunk Components.

Water from the root system will contain nutrients and minerals; water from the leaves will carry carbohydrate energy and plant wastes to other parts of the plant. The trunk is also the storage area for plant wastes. As the tree grows, these are deposited in the center of the trunk. These are sometimes noticeable as darker red or brown in color depending on the tree species. The trunk conducts fluids through what is called the cambium layer, just under the bark layer. In most trees, this conducting layer will be only a fraction of an inch thick. Even small gouges or scrapes in a tree's bark layer can easily reduce the amount of water that can be transported through the trunk.

The Root System. The root system (Figure 3) determines the amount of water available for use in energy production and respiration processes and therefore determines how much foliage can be produced.

The more roots a tree has, the better able to capture water, minerals, and nutrients. A large, healthy root system makes a tree more resilient and better able to deal with environmental extremes such as drought. Along with minerals and nutrients, roots must have access to oxygen in the soil. Since air enters the soil through pores in the soil, compaction of the soil has the effect of sealing off the soil and suffocating the root system.

Root systems do not seek out water; they grow and elongate where the conditions for growth are most favorable. Consequently, tree roots may not always be evenly distributed around a tree. Tree roots may extend long distances from the truck, often twice the distance or more than to the edge of the canopy foliage.

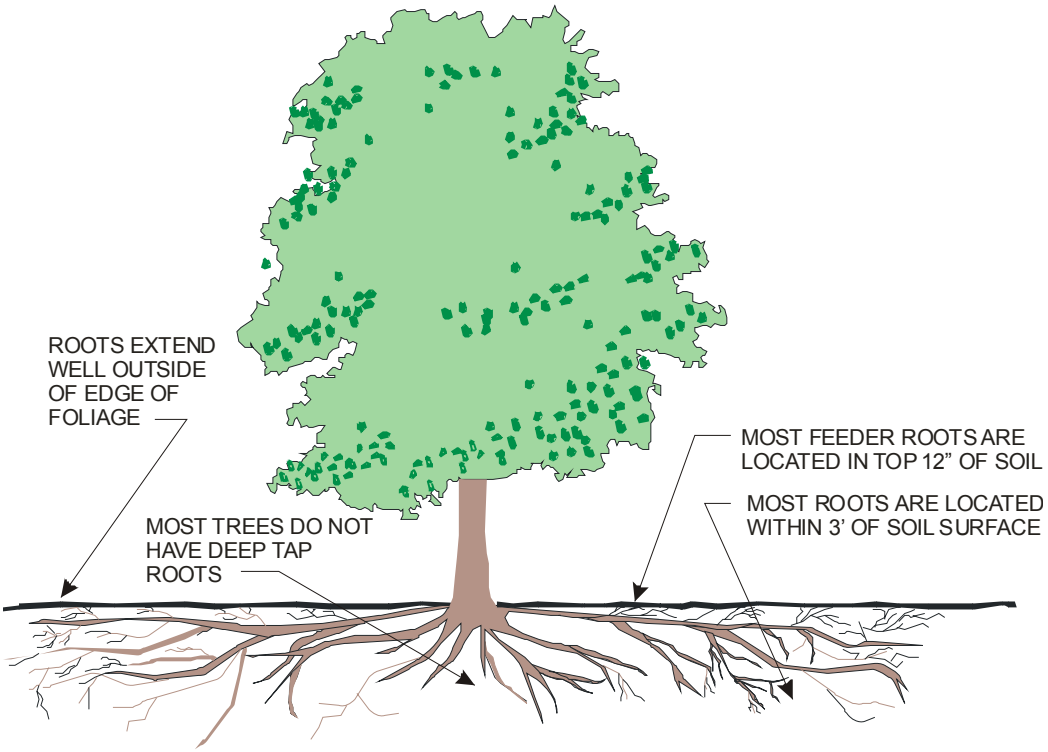

Figure 3. Tree Root System.

The great majority of roots are located within 3 feet of the surface. The fine, feeder-roots that take up moisture are found mostly within the top 12 inches of the surface.

Foliage, trunk, and roots are balanced within the function of a healthy tree. The most crucial component of a tree is the root system.

Note that a reduction in the capability of any single tree component (as through physical damage) will have a negative effect on each other component. Also, tree protection is synonymous with root protection.

ENVIRONMENTAL RELATIONSHIPS

Trees, and other plants as well, fine-tune themselves to their environment. This fine-tuning includes relationships with other plants, insects, soil moisture, soil chemistry, and the

many types of bacteria and fungi found in top layer of the soil. These relationships are the foundation of the plant's hardiness within its native environment, and why disturbance of long-established trees must be minimized.

One of the most important elements of a tree's immediate environment is the upper soil surface beneath its canopy. Protection of this zone greatly increases the chance for continued healthy growth of the tree.

- This shaded area is where leaves are deposited and then decomposed by insects and bacteria.
- Nutrients are recycled back into the soil, creating a rich surface layer that is well aerated and protected from drying winds.
- Fine, feeder-roots are located here to take advantage of the oxygen, nutrients, and short rainfall events.

Tree Response to Damage

Trees have a unique response to damage. Contrary to popular beliefs, trees cannot "heal" themselves. Once damage has been done, it is permanent and irreparable. A tree is unable to repair a cell that has been ruptured due to a cut, gouge, breakage, or pruning. Instead, trees have a defense mechanism called *compartmentalization* (Figure 4). Compartmentalization is the process where the tree surrounds the wound area and seals it off to resist the spread of decay and disease organisms that may invade the wound. Wounds permit organisms to enter the tree and infect the wood, spreading decay throughout the tree if not prevented by the tree's defenses.

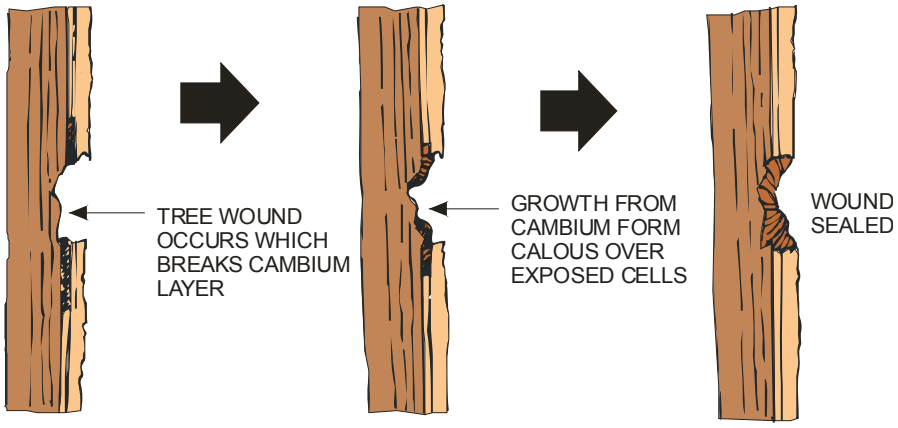

Figure 4. Tree Wound Compartmentalization.

Removing infected (decaying) limbs aids trees in compartmentalizing wounds and disease. Limbs that have been broken and have a splintered break are difficult to seal over, whereas the tree can grow a layer of cells over a cleanly pruned limb much quicker, making proper pruning so important. Cuts must be clean on all edges and made in an area of healthy cell growth.

It was once common practice to cover tree wounds with a paint-like material to prevent insect invasion and encourage the sealing-over process. Tree-wound paints are now considered unnecessary and may even inhibit the tree from doings its work in sealing wounds. These paints are no longer recommended for the majority of cases.

The Decline and Death of Trees

All trees die but the process may not always be discernable. In some cases, diseases such as oak wilt and Dutch elm disease may kill a tree quickly. In most cases however, the process is a slow one and may take years. Trees will most likely die from environmental degradation, pest damage, or structural failure.

The health of the tree is a critical factor in how it responds to these situations. A healthy tree has the energy needed to seal wounds and resist decay. It also is better able to combat the spread of fungi and disease-carrying bacteria.

The health of a tree is built through a complex process involving many factors. Changes in any of these factors may reduce a tree's ability to maintain its energy-production level and consequently, its ability to defend itself. The effects of damage to a tree are cumulative over time

and each instance hastens its decline and death, hence the maximum amount of care should be exercised to prevent even the smallest damage to the tree and its immediate vicinity.

Trees species do not all behave the same regarding disturbance. Some trees, such as live oaks, and winged elms, are more tolerant of disturbance and resist most diseases well. Other species such as pines are very susceptible to beetle infestation and post oaks are very intolerant of changes to its root system. It is important that a qualified specialist be used to make an assessment of the types trees in question to determine their species, growing conditions, protection needs, and their likelihood of survival.

Indicators of Tree Condition

Assessing the condition of trees requires skill and experience since not all problems may be readily apparent. However, there are indicators of possible or probable health or structure related conditions, some of which may determine if a tree is likely to survive very long or become a later hazard (Figure 5). These indicators include:

- crown dieback,
- evidence of poor pruning,
- tree wound cavities,
- cankers,
- structural cracks,
- damage to bark or missing bark,
- basal cavities,
- evidence of insect damage,
- damaged roots,
- fungus growths on the tree,
- soil heaving,
- weak fork in major trunk, and
- suckering from the basal area.

Not all these conditions mean that a tree should not be protected. Consult a tree specialist to determine the severity of the condition and find out what types of remedial steps, if any, may be taken.

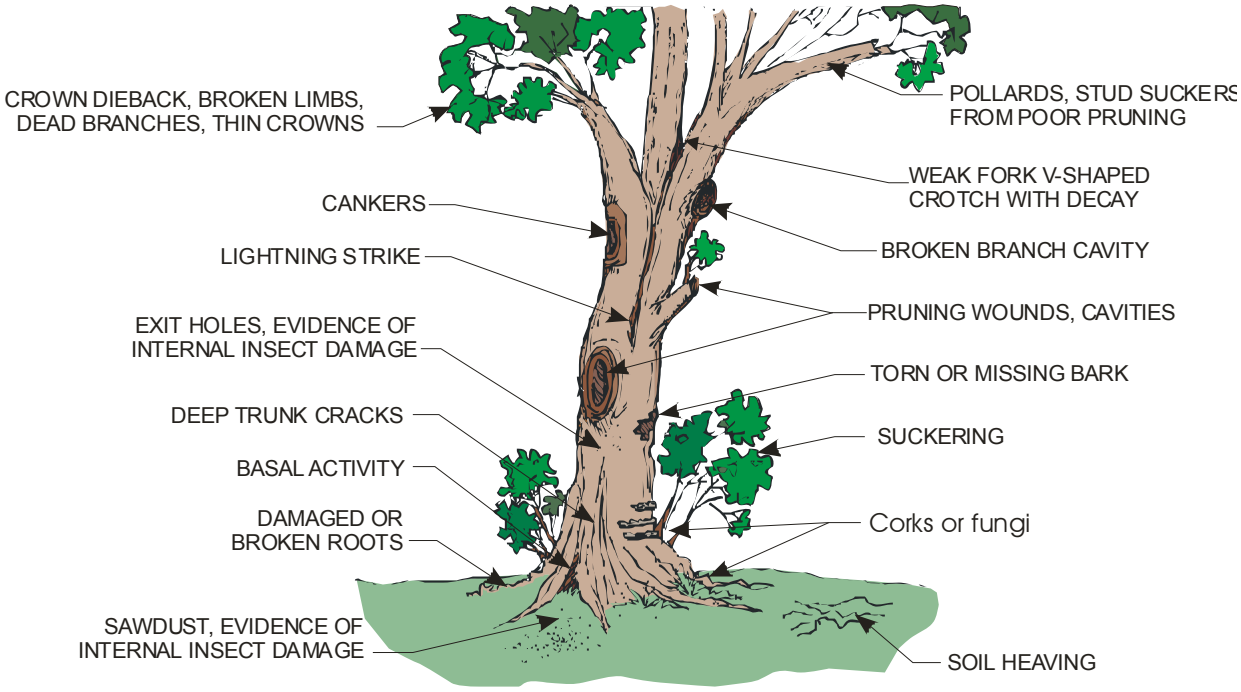

Figure 5. Indicators of Tree Health Problems.

SENSITIVE LANDFORMS

Sensitive landforms are natural elements or features that are valuable for their contribution to the environment and/or provide a value to the maintenance, preservation, and aesthetics of the highway.

Sensitive landforms may be single elements such as a rock outcrop or a standing dead tree (snag) but also include broader environmental processes and resources that may not be obvious. These processes include diverse native plant communities, undisturbed soil profiles, or minor watercourses. These types of features have an effect on the broader issues such as water quality, habitat preservation, air quality, and erosion prevention. In many cases, the preservation of these features will mean less (or no) cost to TxDOT to accomplish what is already being done for free.

Fundamental Protection Goal

The fundamental goal in the preservation of naturally occurring, sensitive landforms and features is similar in most respects to the measures taken to preserve trees: protection from disturbance. Tree protection may most often involve single individual plants. Sensitive landforms will usually cover larger areas and involve more dynamic issues, particularly water presence and flow through an area.

There are three major goals in protecting sensitive areas: avoid disturbing existing vegetated cover; avoid disturbing the existing soils, and protection of site hydrology.

Existing Vegetation Cover

Dealing with vegetation cover over an area means looking at ***plant communities*** in addition to individual plants. Existing vegetation may be trees, shrubs, grasses, and smaller plants (Figure 6).

As a community they may be a forest, a stand of trees, grassland, shrubland, or a wetland. Long-established plant communities are typically very stable and provide their own moisture-conserving and nutrient recycling mechanisms. In most cases, existing plant communities require no maintenance. An exception may be if the community has been previously invaded by a noxious species that might spread to other areas of the roadway.

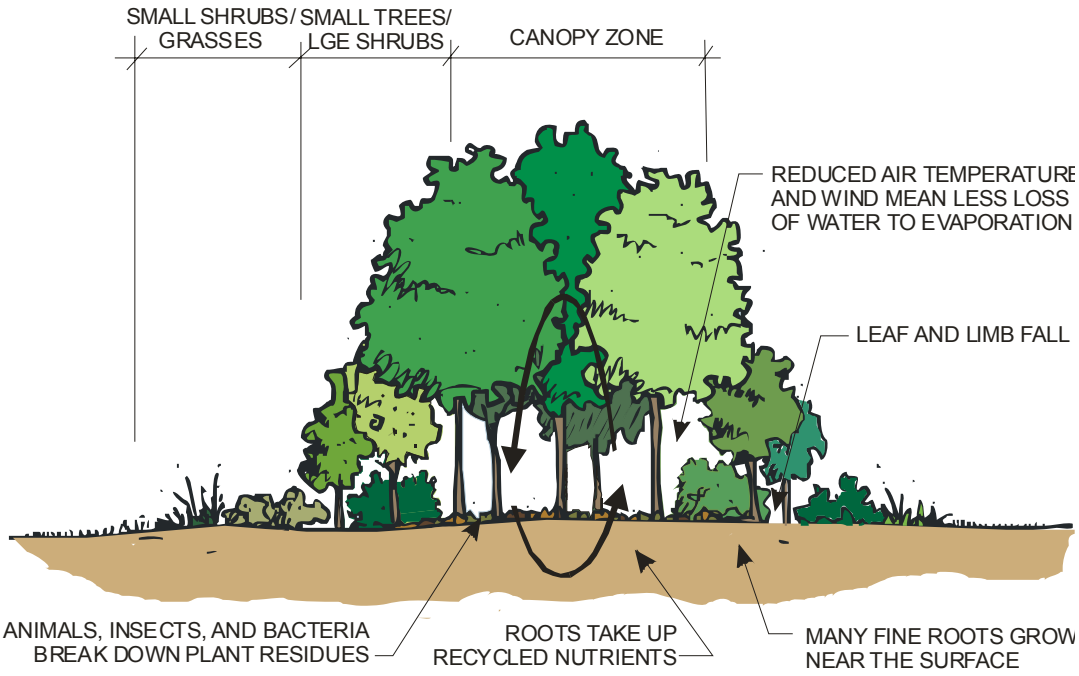

Figure 6. Natural Plant Community Structure.

Soil Protection

Stable plant communities provide habitat, improved air quality, and prevent the world from eroding away. Over many thousands of years, they have developed on and helped create, the soils on which they depend. Once the soil structure has been destroyed, it cannot be replaced and any benefit gained from the original landform will likely cease to exist also.

Site Hydrology

A key characteristic of a native plant community is its ability to intercept and store moisture. The leaves prevent the dislodging of soil due to raindrop impact and can hold a significant amount of water on their surface. The litter layer also may hold large amounts of water, but the upper soil layers can hold even larger amounts before runoff occurs. Subsoils in undisturbed soil profiles can hold up to 10 percent of the weight in water; topsoils can hold 60 percent, and decomposed leaf litter can hold 300 to 500 percent. This ability to hold precipitation can help reduce runoff flows in roadside drainage structures.

HABITAT AND SENSITIVE LANDFORMS

Frequent reference is made to "habitat." TxDOT's goal regarding the environment is to safeguard and improve the environmental fit of its structures and quality of the lands it manages. Habitat refers to any part of the natural or human-created landscape that may provide suitable food or cover for some type of creature. The creatures may be birds, small mammals such as mice and rabbits; retiles such as snakes, turtles, and lizards; amphibians such as frogs and salamanders; and insects. None of these creatures provide any benefit to the roadway function but they do no harm either. On the other hand, suitable areas of roadway may provide needed space for such creatures in areas where existing habitat is fragmented or lacking.

Insects will be mentioned a number of times. Insects form the foundation of the food chain for all of the animals listed above and are important pollinators of plants including crops. The roadside is already home to many insect species, but unique roadside vegetation may provide added diversity that attracts and holds a wider range of insect species, which may be very important in the crop regions of Texas. Many of the predator insects that prey on crop pests use other vegetation as cover and as places to lay their eggs and winter-over. Also, a wider range of insect species may attract a wider range of bird species that may also prey on crop pests. For these reasons, insect habitat will be frequently mentioned.

Habitat cover provides protection from predators, haven from the elements, and places to build nests. A tree limb or dense grass may provide nesting cover but bridges may also. Swallows are common residents of many bridges, and they forage widely for insects. Bats are known to frequent box culverts.

Sensitive Landform Types

Sensitive landform features may be obviously unique items but may be so typical as to go unnoticed. These may include the following:

Unmaintained Vegetation and Native Vegetation

Any vegetation group that appears to be long established, free from disturbance, and particularly those with native plants, should be investigated. It is likely that such areas will have intact soils and require little if any maintenance if left alone. These areas may also provide habitat for birds and small mammals.

Trees or Shrubs along Fenceline (ROW) Adjacent to Field (fencerow vegetation)

Vegetation along fencerows has typically developed as a result of limits to access during mowing and seed deposition by birds. These often very linear vegetation patches may provide habitat for birds and small mammals such as toads, lizards, snakes, and mice. More importantly in some areas, these become corridors in themselves for these and larger animals as they move from one vegetation group to another. The effect is to improve the habitat value of the area as a whole by linking otherwise disconnected food and cover patches.

Riparian Vegetation

Vegetation near watercourse is usually diverse and is valuable in preventing erosion, particularly where fields/cropland extends up to or abuts the vegetation. This vegetation may extend outward from the water's edge for some distance depending on the slope and soils. Riparian vegetation is an important filter for waters entering wetland areas, preventing siltation, and contamination. Establish as large a protected zone around as possible around areas containing this type of vegetation cover.

Unusually Larger Trees in the Area

Large trees have a big visual impact on their surroundings when by themselves but also shelter many other vegetation types when part of a plant community.

Unusual Stands or Islands of Vegetation

Pockets of vegetation such as forest stands, shrub groups, or grass communities that are isolated from large communities in the area, provide valuable habitat as well as aesthetic value. As mentioned above, animal migrations rely heavily on vegetated cover for protection, and stands of vegetation serve to reduce the time an animal may be exposed to predators. Some species of birds will not cross open areas if the distance is too great. Habitat patches are increasingly important in many urban areas.

Soil and Land Formations

The curvature and the rise and fall of the land itself may be a feature worth preserving. Some of these may just be pleasant as an aesthetic feature. Large mounds may reflect some underlying archeological feature, and small soil mounds may indicate animal populations. Large depressions in the soil may indicate an active subterranean drainage feature such as the playa lakes in the Panhandle. Soil depressions in the Hill Country may indicate the presence of a cave.

Small deformations in the clay soil region of Texas may be gilgai soil formations. These may occur as micro-relief ridges or running in the direction of the runoff from a slope or micro-depressions that will temporarily hold water after rains. These formations form due to the effect of freeze-thaw on moisture in the soil. As the soil expands during a freeze, the clay expands outward and upward, slowly building the surface features. The micro-relief and segregated soil types near the surface provides sufficient variety to support a very diverse set of grassland plant species as well as habitat for insects and even crayfish.

Any landform that appears non-typical or definitely different than the surrounding area should be investigated. These characteristics may reflect unique soil formations that support plant and animal communities and may also be supporting a stable plant community that is preventing erosion in an area where slopes may make vegetation establishment very difficult.

Bottomland Hardwoods

Bottomland hardwoods are forested wetlands. Most of these areas in Texas (4.2 million acres) occur in East Texas. The importance of the Bottomland Hardwood Forests is their critical role in watershed. Like bogs, they reduce the risk and severity of flooding to downstream communities. They improve water quality by filtering and flushing nutrients, processing organic wastes, and by reducing sediment before it reaches open water. Major plant groups found in these areas include Cottonwood-Hackberry-Salt Cedar Brush/Woods, Pecan-Elm Forest, Water Oak-Elm-Hackberry Forest, Willow Oak-Water Oak-Blackgum Forest, and Bald Cypress-Water Tupelo Swamp. These species have the ability to survive in flooded areas or areas flooded much of year.

Bottomland hardwoods are a major wetland category and as such must be addressed in the Environmental Impact Assessment.

Caves

Caves occur with some frequency in the limestone regions of the state, and it is not uncommon that one may be encountered in new roadway development. Caves are major geologic features and may house rare species of insects, crustaceans, and fish. Caves are most widely known as havens for bats, which are considered an important control of insect populations.

Caves on the right-of-way can be very problematic. If the cave is used by important animal or insect populations, sealing it may be not be possible. On the other hand, preventing access to a cave could be costly and the enticement to inappropriate sight-seeing could create

serious safety hazards. If a cave cannot be avoided, ample room surrounding the entrance must be attained in order to install adequate safety measures. The assessment of caves and the installation of security measures should be handled in close coordination with the Texas Parks and Wildlife Department.

Cliffs, Bluffs, and Outcrops

These types of features are commonly seen in or near road cuts. Cliffs are steep banks typically comprised of stone, and bluffs are more rounded prominences that may have gentler slopes but still rising significantly higher than the surrounding landscape. Outcrops are part of a rock formation that appears above the surface of the surrounding ground.

The most dramatic of these features occur in the Hill Country although they may be found in much of West Texas. Bluffs are most commonly associated with river terrace systems. Outcrops of rocks are not generally seen except in the more arid parts of the state where the maintenance of grass cover is not a significant issue.

Cliffs and outcrops are considered interesting geologic features but may also provide homes to some species lizards. In some cases, vegetation that could not exist elsewhere finds a niche in the cracks of rock faces.

Establishing vegetation on steep rock faces is generally not a workable alternative. A better approach and one that adds more visual interest as well as creating expanded habitat, is to terrace rock faces so that soils and gravels can collect and form a foothold for plants. These in turn may provide cover and food for insects and reptiles.

Native Prairies (particularly those with climax species of native grasses and forbs)

Prairies once covered most of Texas but today exist only as scattered remnants. Remnant parcels of native prairie may often go unnoticed but are important plant communities. They typically contain grass and other plant species that may no longer exist in the surrounding landscape. Undisturbed grasslands can absorb large amounts of water before runoff occurs and are very resistant to erosion. They are also very resistant to invasion by other noxious weeds if left undisturbed.

Ponds (temporary and permanent, natural and man-made)

Standing water provides the opportunity for a very diverse and attractive landscape. Even seasonal flooding of relatively small depressions can form suitable habitat for the life-cycle of some animals.

Seeps or Springs

Small springs, seepages, or just constantly moist areas often provide important micro-habitat for amphibians, insects, birds, and small mammals. Where possible, springs should be protected if occurring in areas of excess right-of-way and in large interchanges and incorporated into the drainage design in a way that not only protects but enhances the spring. Seeps may sometimes occur in the faces of steep road cuts. Although important water sources for insects and small animals, these areas typically will not be significant in terms of the amount of water nor accessible enough to warrant any special attention. In areas where the water table comes close to but does not rise above the surface of the ground, the continuously damp soil may support an oasis of vegetation that may be visually interesting, good habitat, and require no maintenance. Keeping any equipment or activity that might disturb the soil out of the area should protect these features.

Snags (dead trees)

Snags are standing dead trees. Snags provide nesting habitat for a number of species of birds, particularly woodpeckers, but also including bats, tree swallows, bluebirds, titmice, wrens, screech owls, and kestrels. Additionally, the decaying bark and wood of the dead tree provide habitat for insects, which many birds feed on. Abandoned nest cavities provide nest areas for mice, squirrels, tree frogs, climbing snakes, and lizards. Many birds-of-prey utilize standing dead trees as vantage points to scan for prey below. The U.S. Forest Service has guidelines for the preservation of snags as part of logging operations *(27)*. These guidelines specify the number of standing dead trees that should be left after logging and are used in the development of forest management plans.

The presence of snags in the right-of-way presents some obvious safety issues but instances may exist where they can be retained as part of an established plant community. Snags within a plant community that is to be protected should be left as-is if all parts of the snag will

remain outside the paved areas of the roadway should it fall and if the snag will not impact any pedestrian way, off-site roadway, or buildings.

Water Bodies (creeks, streams, rivers, lakes, etc.)

Most roadways must cross many streams or creeks, and sometimes border lakes. The proximity of these features and how the roadway will affect them are a major issue of the Environmental Impact Assessment procedure. Consequently, decisions regarding how to deal with them may include the input of the Texas Parks and Wildlife Department, the U.S. Corps of Engineers, flood control agencies, or stormwater management districts.

Existing Bridges with Known or Easily Observed Bird or Bat Colonies

Texas has become well known for some of its bat colonies. Bats are documented as an important controller of insect populations, and "bat houses" are commonly sold for residential areas. Bats frequent some bridges and even box culverts on TxDOT right-of-way. Some TxDOT districts have built box culverts that contain recessed roofs with textured surfaces to provide roosts for bats. If bat colonies are found on existing structures, contact the Texas Parks and Wildlife Department to determine what steps should be taken that may affect the bats. The design accommodation for bats in box culverts is not expensive and requires no added maintenance for them to be effective. Incorporate these wherever possible. TxDOT has posted information regarding bats and structures on its website at http://www.dot.state.tx.us/kidsonly/takecarepg/factsbats.htm. Bat Conservation International is a non-profit organization that has published a primer on bats and highway structures. It includes alternative design details for accommodating bat roosts. It may be found at: http://www.batcon.org/bridge/ambatsbridges/cover.html.

Special Plant and Animal Species

Texas contains a wide variety of plants and animals whose population numbers have fallen to critical or near critical levels. TxDOT, as part of its Memorandum of Agreement with the Texas Parks and Wildlife Department participates by protecting (where feasible and appropriate) the following:

- habitat for Federal candidate species (impacted by the project) if mitigation would assist in the prevention of the listing of the species,
- rare vegetation that also locally provide habitat for a state-listed species, and

- all vegetation communities ranked as critically imperiled or imperiled in Texas.

TPWD monitors these populations and maintains detailed lists of the status of both plants and animals that fall into these categories. Copies of the lists may be obtained through the Wildlife Diversity Program, Texas Parks and Wildlife Department, 3000 IH-35 South, Austin, Texas 78704, (512) 912-7011.

TREE AND LANDFORM PROTECTION AND PRESERVATION STANDARDS

THE PREFERRED ROOT PROTECTION ZONE (PRPZ) AND CRITICAL ROOT ZONE (CRZ)

The preferred root protection zone is the area extending outside the edge of the tree canopy (drip line) for a distance equal to the radius of the tree canopy at it largest dimension (Figure 7).

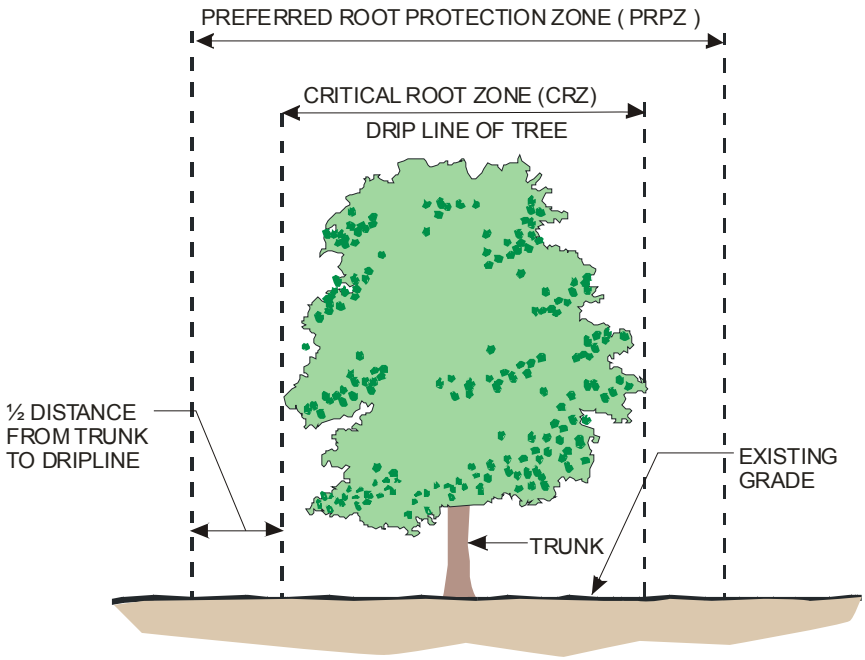

Figure 7. Root Protection Zones.

The following practices are prohibited with the PRPZ:

- parking of any vehicles,
- erection of any shed or structure,
- storage of any equipment or materials,
- use by people for any reason,
- dumping of any waste materials or liquids,
- impoundment of water
- addition of fill-soil, and
- excavation of any type.

The PRPZ should be used where space allows ensuring the maximum amount of protection for the trees. In cases where this not possible, the CRZ distance should be used.

Only that portion of the CRZ necessary for the completion of the required construction should be allowed open for access and only for the period need to complete the task. In all cases, measures will be taken to minimize any potential damage.

BARRIER FENCES

Pre-construction

Barriers to protect trees or other areas will be 6 ft chain-link fence (Figure 8). Posts will be 8 ft steel "T-post" spaced 6' on-center and driven 2 ft deep into the ground. Barriers will be erected on the line established by the engineer and according to the details and notes on the plan (Figure 9).

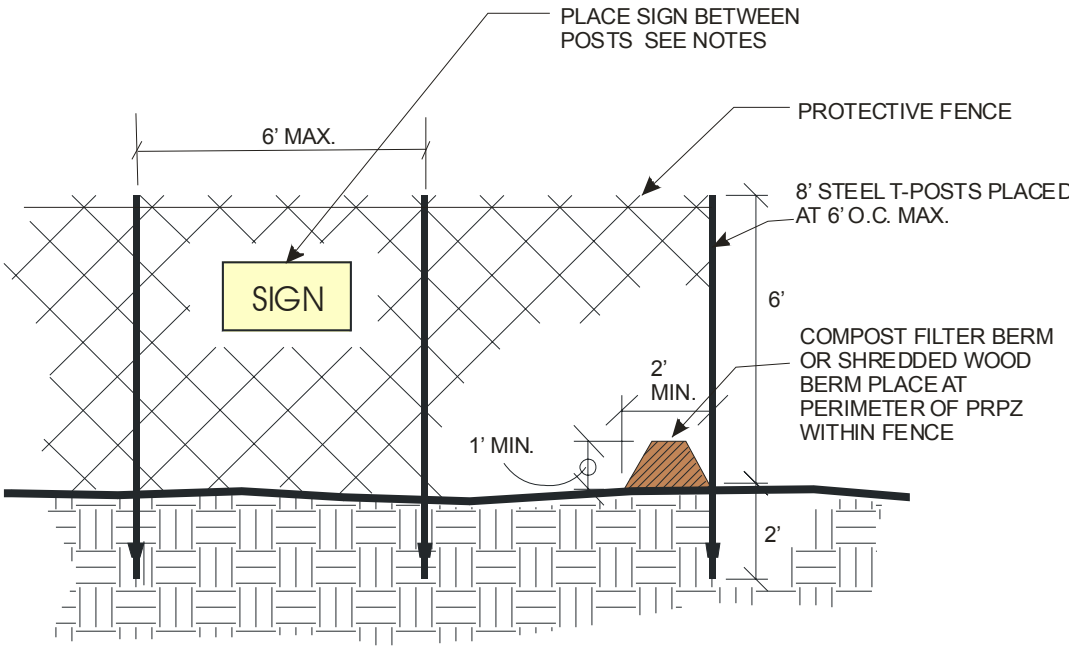

Figure 8. Protective Fencing.

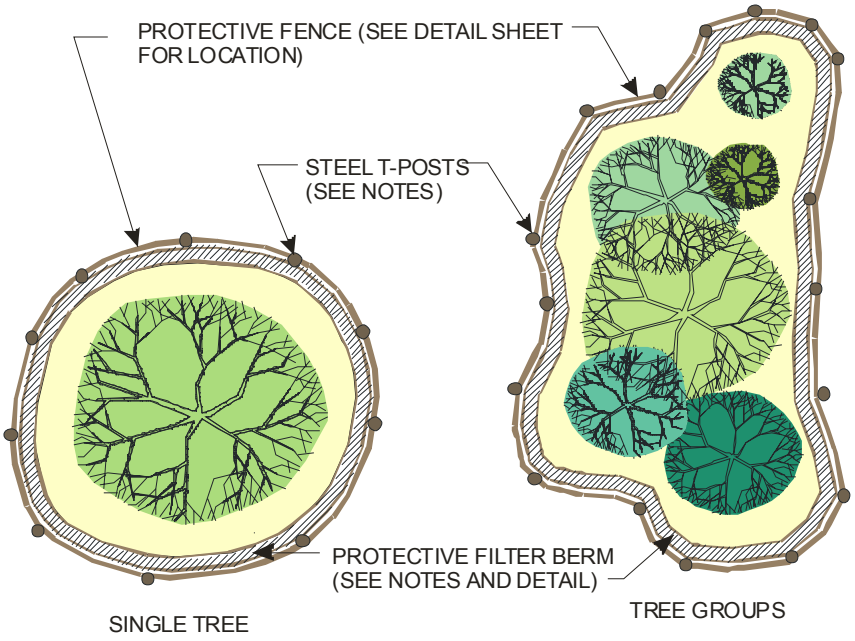

Figure 9. Plan View of Fencing Layout.

Metal signs denoting the area will be attached to the fence at the height of 5 ft, every 50 ft through the length of the fence. Single trees will have a minimum of two signs placed on opposite sides of the tree.

Post-Construction

Sites with sensitive natural features will be delineated with markers at the outside limits of the areas or feature and at 100 foot intervals through its length in the roadway. These sites will include:

- significant communities of native vegetation,
- rare vegetation,
- rare habitat, and
- wetlands.

Especially sensitive sites may be protected by continuous barriers such as suitable fencing. The type of fencing should be appropriate to the feature or area given the type of potential disturbance. If critically endangered plant species are present, the use of permanent chain-link fencing may be considered. More aesthetically pleasing fencing such as cedar railing

may be used in some areas to exclude common disturbances such as landowner use and mowing and to better delineate areas for removal from herbicide spraying.

WOOD PLANKING

In some cases it may be determined that a tree will be preserved even though construction activities must take place close to the trunk of the tree. In these instances, apply surface protection to combat soil compaction (see Soil Compaction) and keep as much of the root system as possible undisturbed (Figure 10).

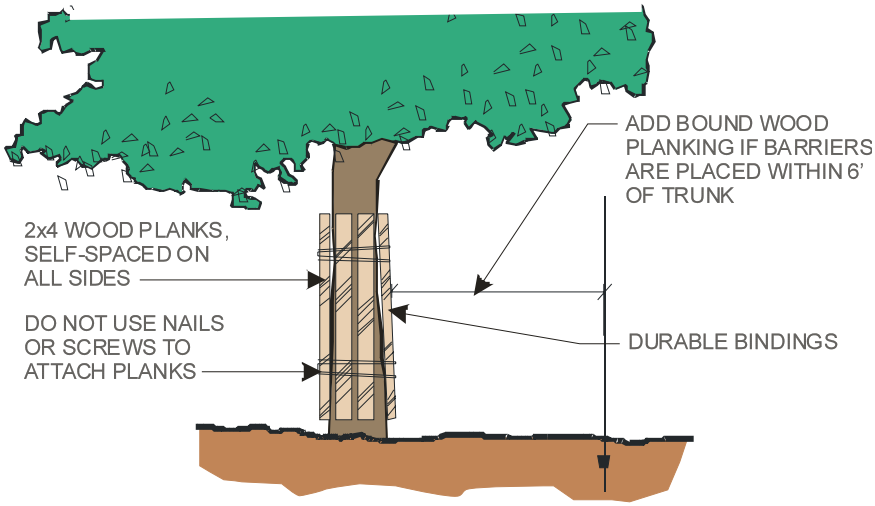

Figure 10. Wood Planking on Trunk.

To protect the trunk against any accidental contact with heavy equipment or tools, whenever construction activities must take place within 6 ft, secure wood completely planking around the trunk. The planking should be 2x4 lumber, self-spaced around the trunk, and bound with a durable wire or rope material. Do not use any nails or screws to affix the planks as this will damage the tree.

As soon the construction within the root zone area is complete, remove the planking and the surface protection. Use hand tools to remove mulch or gravel surface protection.

FILTRATION BERMS

Construction activities typically result in exposed soils over much of the site. Soils allowed to cover the root zone inhibit air movement to the roots and stress the tree. If the soils are silty-clays, a crust may form which may also inhibit water infiltration. In either case, the tree

or other plants may suffer. Removing silt later can be time-consuming and involve removing grassy vegetation as well.

Berms should consist of a well-drained organic material with sufficient fines to slow down and hold fine soil particles. Shredded hardwood bark has numerous fines with larger, stringy particles which tend to knit well and stay in place. Do not use pine bark chips or gravel.

Silt fences should not be used within the protected root zone. These devices required excavation at the point of installation and would damage the roots of the plants.

GRADE CHANGES AND TRANSITIONS

Changing the grade near trees involves either the removal or addition of soil or both. In each case, the goal is to protect the existing grade within the root zone (Figure 11).

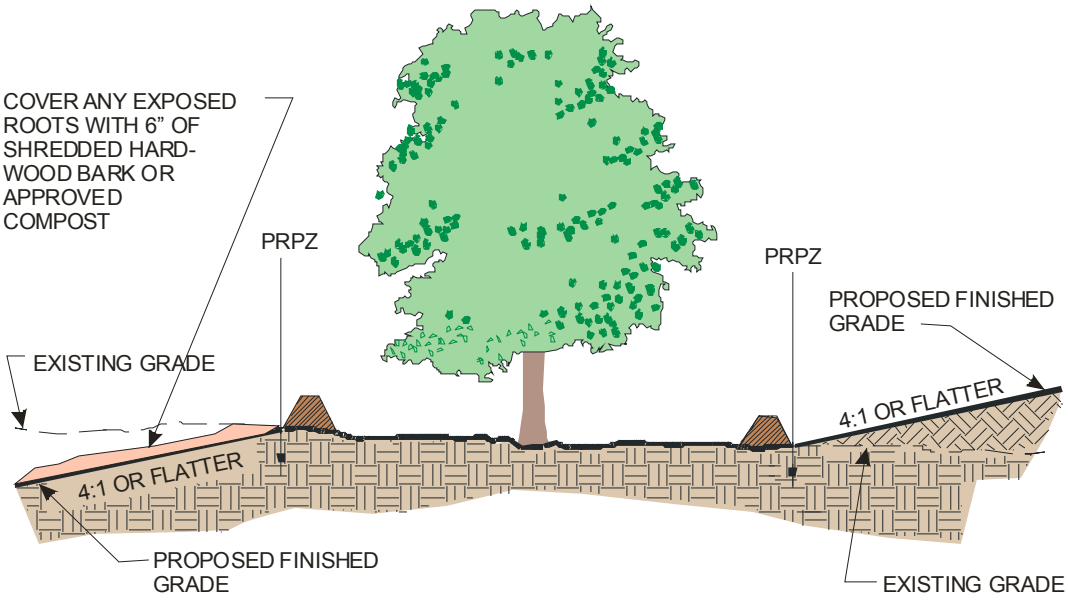

Figure 11. Grade Changes Near Trees.

Depending on the tree species and the type of soil involved, an industry rule-of-thumb is that 1 inch of soil may be added to the surface of the ground over a root zone *per year* before serious damage will be done. Silty-clay soils may crust over and should not be applied greater than ½ inch deep *per year*.

The addition of soils upslope from the tree but outside the protected root zone may likely create runoff onto the root zone. Where possible, stabilize the new soil with solid sod or approved erosion control materials immediately after installation. The use of either of these materials does not negate the need for a silt fence if required by regulation but silt fences should not be installed with the protected root zone.

A retaining wall should be installed if the finished gradient of upslope fill will not allow the establishment of a maintainable slope (4:1 or flatter) (Figure 12).

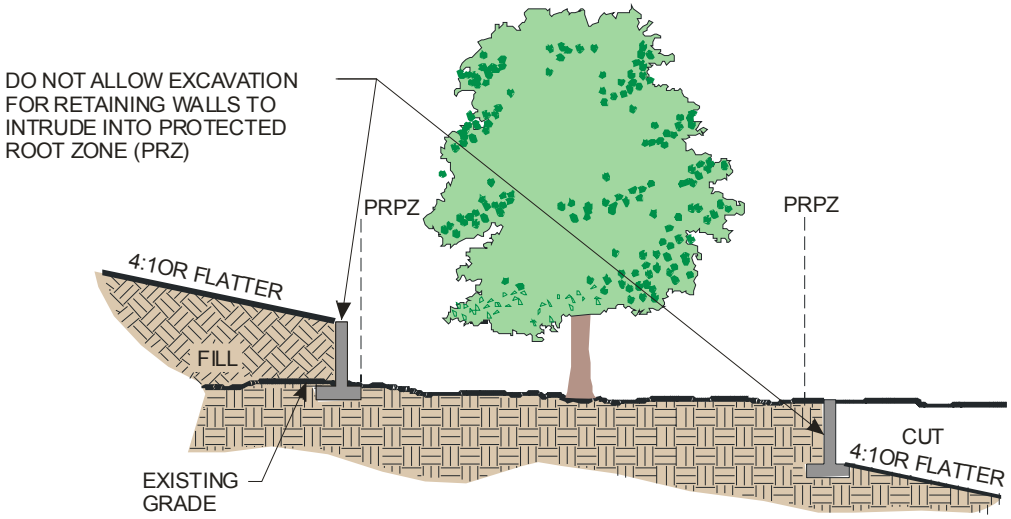

Figure 12. Cut and Fill near Trees.

Filling inside the protected root zone may be tolerated by some trees species if no other disturbance is made to other areas of the root zone. In these cases, however, the tree's tolerance depends on other factors such as soil type, moisture, and tree health. Filling within the root zone should be considered a last resort.

Cut conditions. Cutting soil to reduce grade near a tree will result in the permanent removal of tree roots and should be avoided whenever possible. Cutting into the soil also drains the soil profile and may result in water-stress conditions for the tree (Figure 13).

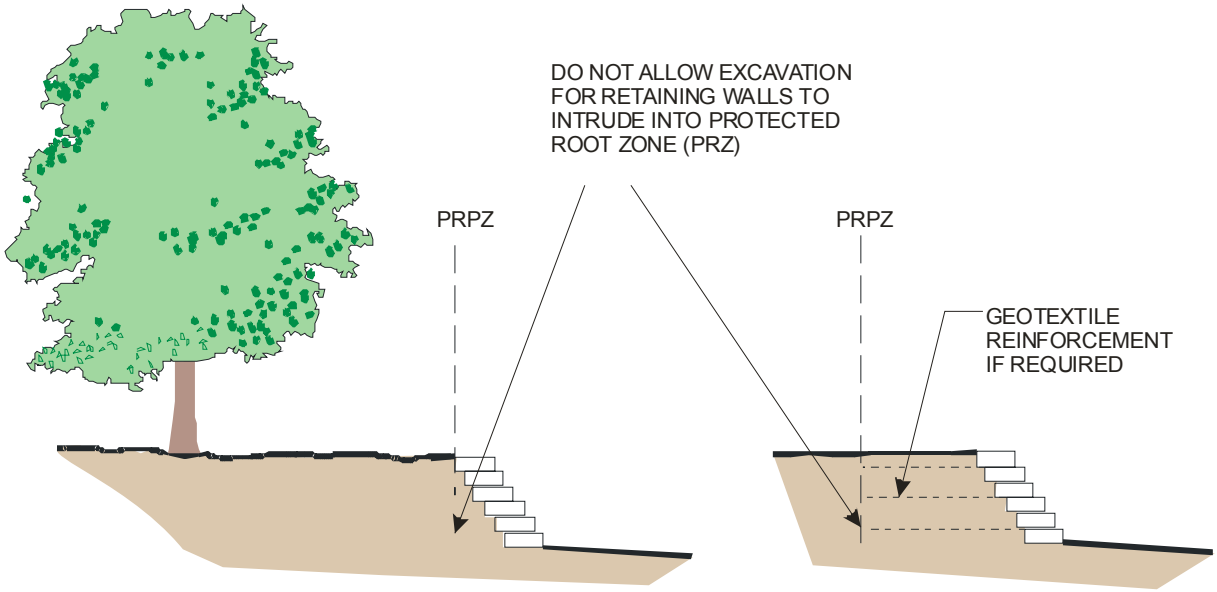

Figure 13. Cutting for Walls near Trees.

The first goal in changing grades near trees is to keep changes outside the protected root zone. The changes in these areas may then be sloped to a maintainable grade (4:1 or flatter). A retaining wall should be installed if the proposed change will not allow a maintainable finished grade.

Grade changes within the protected root zone may involve the removal of significant roots from the tree. Some tree species may be able to tolerate this condition if steps are taken to ease the transition.

Grade changes on all sides of a tree present a difficult situation. One of two conditions (Figure 14) may result:

- The tree is higher than the new finished grade.
- The tree is lower than the new finished grade.

Trees higher than the new grade have been completely disconnected from their previous hydrologic condition. In most places in Texas, this will probably result in the tree dying from drought as water drains from the perched root system. If a tree must be saved using this alternative, an irrigation system must be provided. This approach is not recommended except in special cases for significant trees.

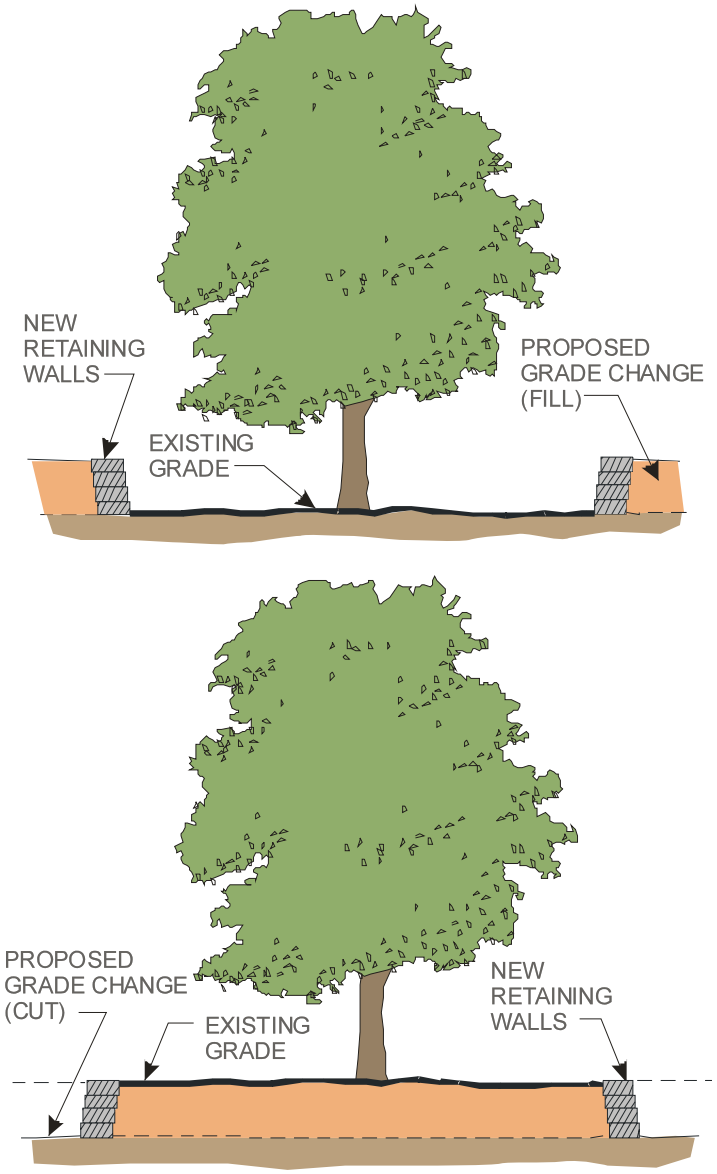

Figure 14. Poor Grade Change Conditions.

Trees surrounded by an elevated finished grade may:

- have their oxygen supply cut off due to root suffocation, and
- drown as water is impounded.

Installing a porous backfill, adding an internal drainage system, and installing an internal air-duct system down to the existing grade are traditional efforts at dealing with this type of problem. This approach is not recommended due to the costs involved and the high likelihood of losing the tree anyway.

TRENCHING

Avoid trenching near trees for utility lines and other piping, but when this is not possible, take steps to minimize the damage. Rather than cut across the root zone, lines should be bored below the root system (Figure 15).

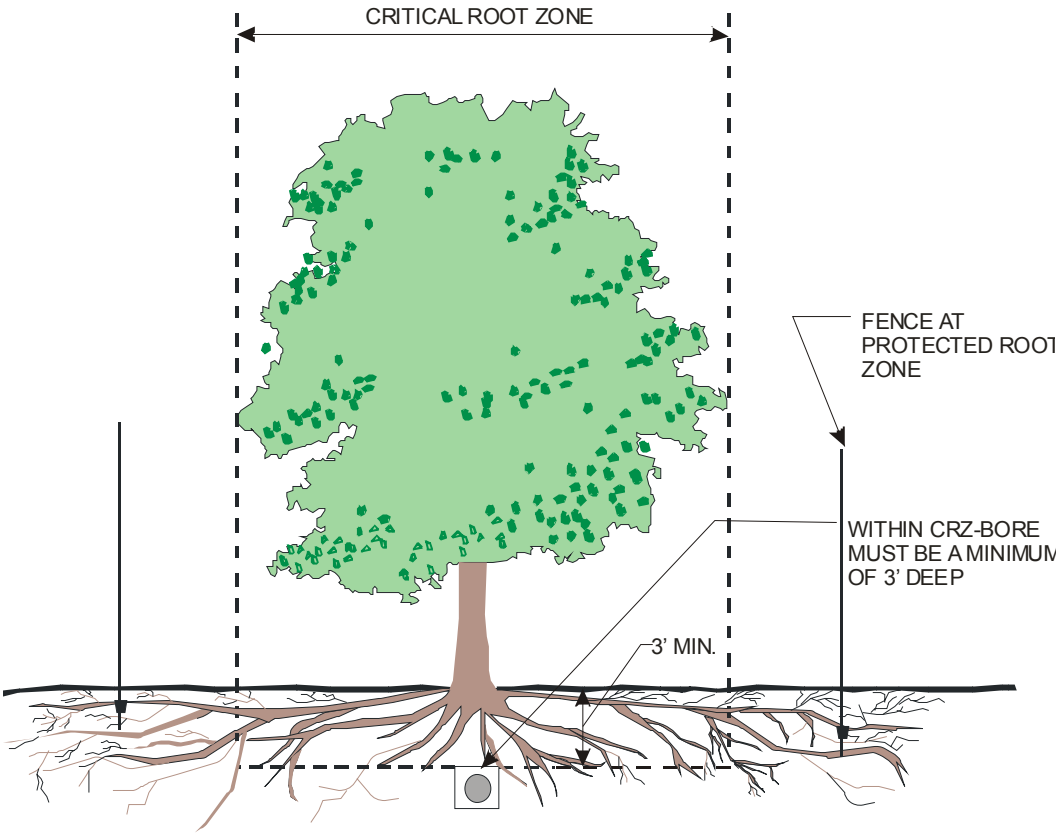

Figure 15. Trench Under Root System.

If necessary, boring can be performed directly towards the tree and go under all the major roots (Figure 16). If trenching does or must occur within the protected root zone, minimize the damage by digging from under the roots

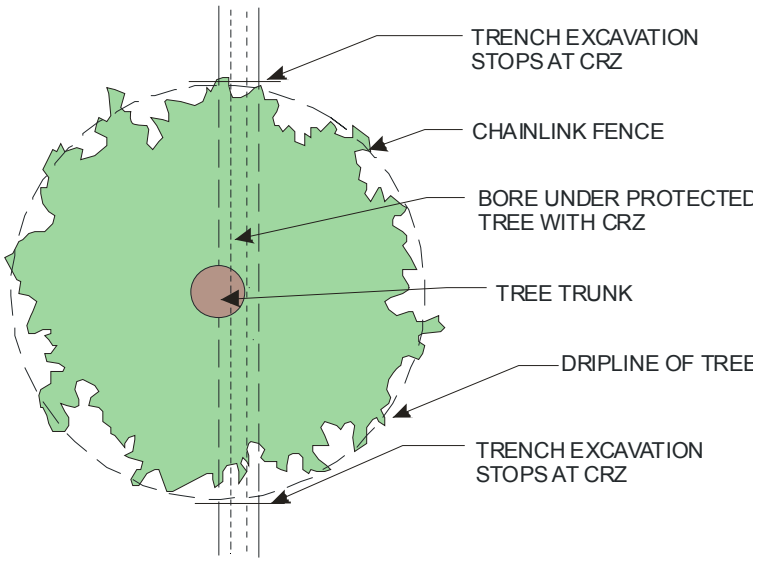

Figure 16. Plan View of Trench below Tree.

Dig the trench in shallow depths until roots are encountered and then excavate below the roots as the trench deepens. Once at the desired depth, thread the pipe or cable under the roots and backfill the trench (Figure 17).

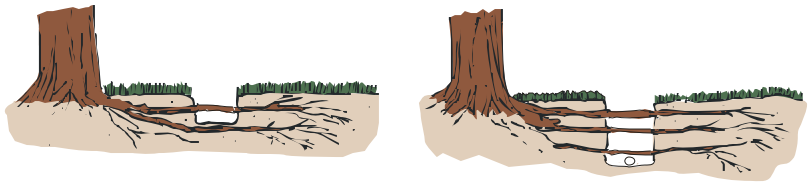

Figure 17. Trenching near Roots by Hand.

If roots must be cut to complete the operation, excavate as described above and prune all roots 1 inch or greater in diameter as they are encountered (Figure 18). The trench should be backfilled as soon as possible to minimize root exposure to the air. Roots that will be left exposed in the trench for greater than eight hours should be covered to prevent drying and to prevent insect invasion.

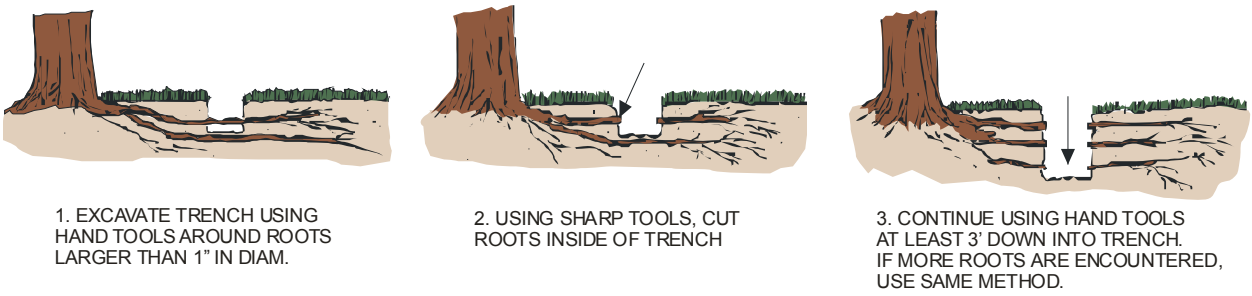

Figure 18. Proper Root Pruning Procedure.

EXPOSED ROOT SYSTEM

Exposing roots to the air invites drying and insect invasion as well as damage from foot traffic or other disturbance. Roots may be exposed by grade changes or trenching.

Exposed roots should be covered as soon as possible; ideally immediately after exposure. Cover roots with a layer of porous, organic material such as shredded hardwood bark mulch to a depth of three inches. A light soil such as fine sandy-loam (no silt or clay) may be used in a layer no more than 1 inch deep, but is not preferred since these may be easily eroded by water or wind, again exposing the roots.

ROOT PRUNING

Roots that are torn from the ground may rip along their length, further exposing tissue to insects and pathogens.

Soil may be excavated from the area to cut using backhoe equipment until major roots (1 inch thick or greater) are encountered (Figure 19). Use shovels to expose the roots thereafter to make the pruning cut.

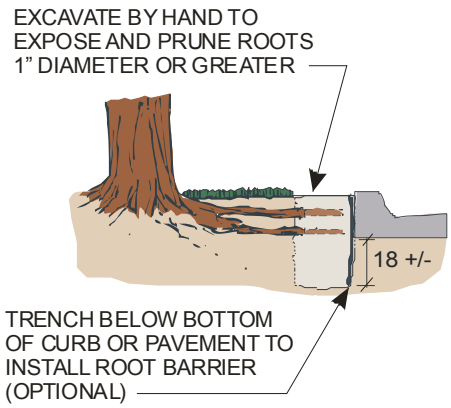

Figure 19. Root Pruning near Curbs.

Prune smaller roots with large lopping sheers. Use large circular saws and rock saws for larger roots exceeding four inches in diameter.

WATERING

It is not necessary to water protected trees unless the natural drainage flow over the protected root zone has been changed or if cuts in grade or trenching occur within the protected root zone. These changes have the effect of exposing subsoil layers and possibly draining the soils. Water replacement should consider rainfall frequency and species as well as slope, and other vegetation in the protected root zone. A rule of thumb for supplemental irrigation is one-inch of water per week made in at least two applications. A layer of porous, organic material such as compost or fine bark mulch may be applied to a depth of 1 inch to reduce evapotranspiration from the soil if no other vegetation cover is present.

FERTILIZATION

Fertilizers should not be used on any tree or plant community that is to be protected before, during, or after construction.

PRUNING

Avoid pruning limbs if possible. Remove dead or diseased limbs only or for clearance of equipment near the protected root zone. Pruning should be performed by a qualified arborist in

accordance with the International Society of Arboriculture's Tree-Pruning Guidelines and/or the ANSI 300 Pruning Standard. In all cases, no more than approximately 20 percent of the live foliage should be removed from a tree to be protected.

SOIL COMPACTION

If the protected root zone must be accessed, compacted soil can keep roots from accessing water and oxygen, causing tree damage during construction.

The area of the protected root zone exposed to pedestrian or vehicular traffic should be covered with 4 inches of shredded hardwood bark or 4 inches of 1-1/2 inch septic gravel over the affected area. Do not place mulch or gravel against the trunk of the tree. Do not use soil or compost because these will also compact. Pine bark chips should not be used because they provide too many large voids which allow too much air and are easily dislodged.

Remove the protective covering as soon as access is no longer necessary. Stockpile or dispose of the materials outside of the protected root zone.

CHEMICAL INSECT CONTROL

A qualified tree care specialist should evaluate for the presence of damaging insects and treat as necessary to maintain the tree's health. Do not conduct precautionary spraying for insect control before construction.

DUST CONTROL

Dust may accumulate on the leaves of protected trees or other vegetation during construction, but will not affect the vegetation health. There is no need to spray to remove foliar dust.

REMOVAL OF UNDERSTORY TREES AND SHRUBS

Understory trees, shrubs, vines, and groundcovers should be left undisturbed within tree protection zones. Understory vegetation helps shade the soil beneath trees, discouraging weed growth and preventing sun and wind from speeding evaporation of soil moisture. Understory plants also provide visual buffers to adjacent properties as well as habitat for nesting birds.

If it is determined that understory vegetation will be removed from an area that is otherwise to be preserved, removal should be selective and accomplished using hand tools only. Do not clear understory using any wheeled or tracked vehicles such as front-end loaders or bulldozers around trees that are to be preserved. Heavy equipment will dislodge the upper layers

of the soil, expose or sever roots, remove protective leaf-litter layers, and contribute to invasion by opportunistic weed seeds.

SIDEWALKS NEAR TREES

Sidewalks placed near trees may be displaced as roots grow beneath them. In most cases, this displacement occurs due to the thicker buttress roots at the base of the tree. To avoid damage, locate sidewalks at least 3 feet from the base of the tree (Figure 20).

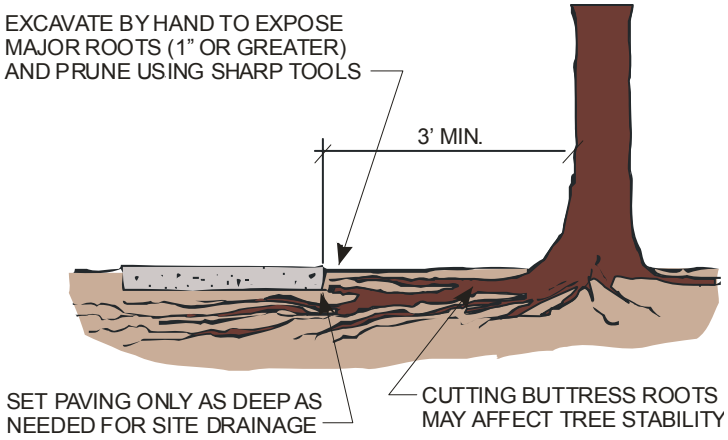

Figure 20. Sidewalk Placement near Trees.

If space does not allow 3 feet clearance from a tree, consider using a paving material such as concrete pavers to facilitate maintenance and repair and minimize the possibility of having the sidewalk become uneven and a hazard (Figure 21).

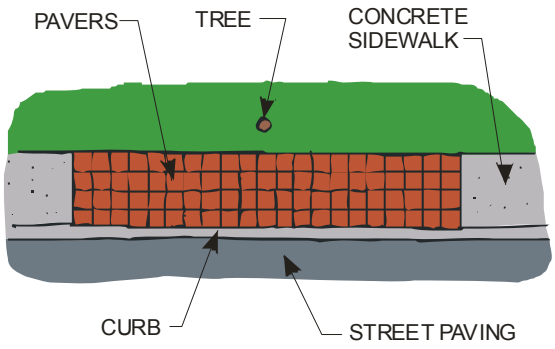

Figure 21. Flexible Paving near Trees.

PROTECTION OF SENSITIVE LANDFORMS

The protection of sensitive landforms such as natural vegetation communities, unique landscape feature, or areas of special aesthetic appeal shall conform to the standards for tree protection. In cases where no trees are present in the area to be protected, the limits of the protected area shall be established as designated on the plans and as determined by the engineer in the field.

When construction activities have ended, protective fencing, signage, filter berms, and all other devices shall be removed from the site and post-construction protection devices installed.

POST-CONSTRUCTION ACTIVITIES FOR TREES

Upon the completion of construction activities, a thorough final assessment of the protected areas should be conducted to determine the health and condition of trees or other sensitive features. A certified tree specialist should conduct tree assessments. If sensitive areas are involved, the appropriate specialist should conduct the assessment. The specialist should provide recommendations for post-construction measures. Inspection items to be noted include:

- damage to any part of the root system,
- damage to limbs,
- changes in soils structure such as compaction, fills, erosion, or loss of organic matter,
- changes to wind loading in the crown and,
- effects on any new structures.

Immediate post-construction needs may include:

- removal of trees that may have died during construction,
- removal of any fill soil from root zones, and
- remediation of soils damaged during construction.

Maintenance needs for trees after construction should be recommended and based on evaluations of individual trees to include:

- meeting irrigation needs,
- pruning damaged or diseased tree parts,
- mulching the root system, and
- controlling pests.

POST-CONSTRUCTION PROTECTION ALTERNATIVES FOR SENSITIVE AREAS

Sensitive areas must receive post-construction protection. Protection measures should take place as noted on the plans. Alternative protection plans are as follows:

Alternative 1 – Sites with natural vegetation not classified as rare or endangered, general environmental preservation, landscapes with special aesthetic appeal and where access may be necessary for periodic maintenance, or where the effects of occasional access would not be considered seriously damaging. With alternative 1:

- signage placed at the beginning and end of sites in linear roadway edges.
- signage placed at 100 foot intervals at the road edge side through the length of the site.
- signage placed at 75 foot intervals at the edge of sites with irregular edges in open interchanges.

Alternative 2 – Sites with natural vegetation not classified as rare or endangered, general environmental preservation, landscapes with special aesthetic appeal, and where access of any nature seriously damages the protected features. With alternative 2:

- aesthetic fencing placed that completely encloses the highway side of the protected area.
- signage placed at the beginning and end of the fenced area.
- signage placed at 100 foot intervals on the fence through the length of the site.
- signage placed at 75 foot intervals at the edge of fences sites with irregular edges in open interchanges.

Alternative 3 – Sites with natural vegetation classified as rare or endangered, special environmental functions, landscapes where unsafe conditions exist, where prevention of access is deemed critical. With alternative 3:

- chain-link fencing placed that completely encloses the highway sides of the site with lock entry gates.
- aesthetic fencing placed that completely encloses the highway sides of the site with lock entry gates.

- signage placed warning against entry as deemed appropriate for the conditions.

SIGNAGE

Protective Fencing - All barricades erected for tree or landform protection during construction must include signage denoting the area is protected and that entry is denied. The signs shall measure approximately 15 inches in width and 9 inches in height (15”x9”). Letters shall be 1 inch tall, bold, and black in color. Recommended wording is:

PROTECTED AREA
DO NOT ENTER
This fence may not be removed
or modified without the
permission of the Engineer
Contact XXX-XXX-XXXX

Post-construction signs for Sensitive Areas – Sensitive areas should have signs posted as determined appropriate for the area (See the previous section Protection of Sensitive Landforms) The signs shall measure approximately 15 inches in width and 9 inches in height (15”x9”). Letters shall be 1 inch tall, bold, and black in color. Recommended wording is:

SENSITIVE ROADSIDE AREA
NO VEHICLES
NO MOWING
NO HERBICIDES
Contact XXX-XXX-XXXX

In some cases, describing the reason for a site’s sensitivity may invite sightseeing, poaching of plant material, or vandalism. In some cases, it may be deemed appropriate to not share the reason for special classification of a site at all. The type of potential access should be carefully considered in deciding how to sign the area.

ASSESSMENT BEFORE AND MONITORING DURING CONSTRUCTION

The first step in tree or landform protection is the determination of what is capable of being protected and why. In most cases the decision must be based on many factors including judgment calls requiring experience in plant care or natural systems. Depending on the nature of the elements or areas to be protected, monitoring during construction should be included as part of the specification.

Routine assessment/monitoring should occur at three times during a project:

- at the beginning of the project for plant or area assessment,
- every six months during construction or as needed for special inspections, and
- at the end of the project for assessment and post-construction recommendations.

CERTIFIED SPECIALISTS

Professional expertise will often be required in decisions regarding the health status of trees or the effects of some disturbances. An arborist or someone who has been certified in the tree care industry should be consulted to make assessments and routine tree care decisions.

An arborist by definition is an individual who is trained in the art and science of planting, caring for and maintaining individual trees. Certification is a non-governmental, voluntary process by which individuals can document their base of knowledge and operate without mandate of law. Certification is not a measure of standards of practice. Certification can attest to the tree knowledge of an individual, but cannot guarantee or ensure quality performance.

Two organizations serve as the principal sources of information about trees for the tree care industry in the U.S. At this time, only one (International Society of Arboriculture) has an active certification program and carries an ISA Certified Arborist List on their web page. The other organization (Tree Care Industry Association) is currently developing a certification program.

The contact information for each is provided below.

International Society of Arboriculture

Post Office Box 3129

Champaign, IL 61826-3129

(217) 355-9411

http://www.isa-arbor.com/

Tree Care Industry Association

3 Perimeter Road, Unit 1

Manchester, NH 03103

Phone: 1-800-733-2622

(603) 314-5380

http://www.TreeCareIndustry.org

INFORMATION SOURCES IN STATE AND OTHER GOVERNMENT AGENCIES

Natural environments require a level of specialized knowledge that tree care specialists may not possess. In these cases, the best source will come from government agencies. The first agency of choice is TxDOT itself. TxDOT has a wide range of experience (found in many individuals) throughout its organization. The advantage of this choice is that this experience is derived from the highway rather than typical commercial or residential applications. The Environmental Division is most familiar with standard practices and also the sources of more detailed environmental information. Other agency sources include the:

- Texas Parks and Wildlife Department,
- Texas Council of Environmental Quality, and
- U.S. Department of Agriculture, Department of Forestry.

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APPENDIX A
BASIC FORMULA METHOD TABLES: SPECIES, CONDITION, AND LOCATION

Table A. Species Percentage Factor

SPECIES PERCENTAGE RATING	
CLASS NO. 1 – 100%	
Pecan	*Carya illinoiensis*
Flowering Dogwood	*Cornus florida*
American Beech	*Fagus grandifolia*
American Holly	*Ilex opaca*
Yaupon Holly	*Ilex vomitoria*
Sweet Gum	*Liquidamber styraciflua*
Southern Magnolia	*Magnolia grandiflora*
Tupleo	*Nyssa sylvatica*
White Oak	*Quercus alba*
Burr Oak	*Quercus macrocarpa*
Chinkapin Oak	*Quercus muhlenbergii*
Water oak	*Quercus nigra*
Shumard Oak	*Quercus shumardii*
Spanish Oak	*Quercus texanna*
Live Oak	*Quercus virginiana*
Mescal Bean Sophora	*Sophora secundiflora*
Bald Cypress	*Taxodium distichum*
Cedar Elm	*Ulmas crassifolia*
CLASS NO. 2 – 80%	
Hickories	*Arbuts texana*
Texas Persimmon	*Diospyros texana*
Modesto Ash	*Fraxinus velutina "glabra"*
Ginkgo	*Ginkgo biloba*
Black Walnut	*Juglan nigra*
Southern Golden Raintree	*Koelreuteria apiculata*
Panicled Golden Raintree	*Koelreuteria paniculata*

Table A. Species Percentage Factor (cont.)

Crepe Myrtle	*Lagerstroemia indica*
Sweetbay	*Magnolia virginiana*
Manzanilla Olive	*Olea manzanilla*
Colorado Blue Spruce	*Picea pungens*
Piñon Pine	*Pinus edulis*
Slash Pine	*Pinus allioti*
Aleppo Pine	*Pinus halepensis*
Austrian Pine	*Pinus nigra*
Loblolly Pine	*Pinus taeda*
Japanese Black Pine	*Pinus thunbergii*
Chinese Pistache	*Pistacia chinensis*
Texas Ebony	*Pithecellobium flexicaule*
Southern Red Oak	*Quercus falcate*
Willow Oak	*Quercus phellos*
Black Oak	*Quercus velutina*
American Elm	*Ulmas americana*
CLASS NO. 3 – 60%	
Huisache	*Acacia farnesiana*
Bigtooth Maple	*Acer grandidentatum sinuosum*
Red Maple	*Acer rubrum*
River Birch	*Betula nigra*
Deodar Cedar	*Cedrus deodara*
Desert Willow	*Chilopsis linearis*
Anaqua	*Ehretia anacua*
Loquat	*Eribotrya japonica*
Green Ash	*Fraxinus pennsylvanica*
Velvet Ash	*Fraxinus velutina (Select Male)*
Thornless Honeylocust	*Gleditsia tricanthos inermis*
Kentucky Coffeetree	*Ymnocladus dioca*

Table A. Species Percentage Factor (cont.)

Great Lead-tree	*Luecaena pulverulenta*
Tulip Poplar	*Liriodendron tulipifera*
Flowering Crab	*Malus species and varities*
Fruitless Mulberry	*Morus alba (fruitless)*
Avocado	*Persea Americana*
Redbay	*Persea borbonia*
Shortleaf Pine	*Pinus echinata*
Italina Stone Pine	*Pinus pinea*
American Planetree Sycamore	*Platanus occidentalis*
Honey Mesquite	*Prosopis glandulosa*
Callery Pear	*Pyrus calleryanna*
Post Oak	*Quercus stelleta*
Western Soapberry	*Sapindus drummondii*
Japanese Pagodatree	*Sophora japonica*
CLASS NO. 4 – 40%	
Silver Maple	*Acer saccharinum*
Paper Mulberry	*Broussonetia papyrifera*
Gum Elastic	*Bumellia lanuginose*
Common Hackberry	*Celtis occidentalis*
Hawthorns	*Cercis spp.*
Arizona Cypress	*Cupressus arizonica*
Chinese Parasol Tree	*Firmiana simplex*
Arizona Ash	*Fraxinus velutina (seedling)*
Junipers, Cedars	*Juniperus spp.*
Bois D'Arc	*Maclura pomifera*
Ornamental Plum	*Prunus blireniana*
Mexican Plum	*Prunus mexicana*
Chinese Tallow	*Sabium sebiferum*

Table A. Species Percentage Factor (cont.)

Evergreen Elm	*Ulmus parvifolia sempervirens*
Jujube	*Zizyphus jujube*
CLASS NO. 5 – 20%	
Boxelder	*Acer negundo*
Tree of Heaven	*Ailanthus altissima*
Silktree	*Albizia julibrissin*
Caltalpa	*Catalpa spp.*
Sugarberry	*Celtis laevigata*
Russian Olive	*Eleagus augustifolia*
Chinaberry	*Melia azedarach*
Red Mulberry	*Morus rubra*
Palo Verde	*Parkinsonia aculaeta*
Cottonwoods and Poplars	*Populas spp.*
Black Locust	*Robinia pseudiacacia*
Willows	*Salix spp.*
Tamarisk	*Tamarix spp.*
Arborvite	*Thuja spp.*
Chinese Elm	*Ulmas parvifolia*
Siberian Elm	*Ulmas pumila*

Table B. Tree Condition Factors

Factor	Variation of Condition Factor	Points
Trunk Condition	Sound and solid Sections of bark missing Extensive decay and hollow	5 3 1
Growth Rate	More than 6-inch twig elongation 2- to 6-inch twig elongation Less than 2-inch twig elongation	3 2 1
Structure	Sound One major or several minor limbs dead Two or more major limbs dead	5 3 1
Insects and Diseases	No pest present One pest present Two or more pests present	3 2 1
Crown Development	Full and balanced Full but unbalanced Unbalanced and lacking a full crown	5 3 1
Life Expectancy	Over 30 years 15 to 20 years Less than 5 years	5 3 1

Total Points	Condition Class	Condition %
23-26	Excellent	80-100
10-13	Good	60-80
19-22	Fair	40-60
14-18	Very Poor	20-40
6-9		0-20

Table C. Tree Location Factors

Location	Percentage
Feature or historical trees	90-100
Average residential, landscape trees	80-90
Malls or shopping center trees	75-85
Public and commercial area trees	70-80
Arboretum and park trees	60-80
Golf course trees, strategically located	60-80
Street and boulevard trees	60-80
Screen and windbreak trees	60-70
Recreational and picnic area trees	60-70
Industrial area trees	50-70
Out-of-city highway trees	40-60
Native, open woods trees	30-40
Trees in heavily wooded areas	10-20

The above information was adapted from: http://aggie-horticulture.tamu.edu/syllabi/432/article1.html

APPENDIX B
TREE PROTECTION SHEETS

GENERAL NOTES FOR TREE PROTECTION AND PRESERVATION

The contractor shall secure the services of a certified tree specialist to perform or oversee any operation involving limb pruning, root pruning, chemical application, or assessment of the condition of trees or effects of construction on trees designated for protection.

DEFINITIONS

Dripline - The dripline of a tree is defined as the line on the ground directly below the outer tips or ends of the tree limbs.

Critical Root Zone (CRZ) - The CRZ is defined as the ground area extending out from the tree trunk to the end of the limb tips or dripline.

Preferred Root Protection Zone (PRPZ) - The PRPZ is defined as the ground area extending out from the dripline of the tree a distance equal to one half the distance from the trunk to the dripline.

CONSTRUCTION METHODS

Prior to the start of construction, the Contractor shall mark all trees or other features indicated on the plans to be protected with yellow flagging for approval by the Engineer.

The Contractor shall erect protective barriers at all trees, groups of trees, or other features as shown on the plans, designated by the Engineer, or otherwise indicated for protection. The Contractor shall not remove or relocate tree protection fencing unless approved by the Engineer.

Prior to construction, protected trees shall be pruned as follows:
- Remove any diseased or dead limbs
- Remove limbs for necessary equipment access (as approved by the Engineer)
- Remove limbs that will be within fourteen feet (14) vertical clearance of vehicle travel lanes
- Remove limbs that will be within ten feet (10) vertical clearance of pedestrian areas

Pruning shall only be performed by a certified tree specialist using tools specifically designed for the job and in accordance with ANSI A300 pruning standard. Pruned material becomes the property of the Contractor and will be disposed of off-site.

Protective fencing for trees shall be erected at a distance equal to 1-1/2 times the distance from the edge of the trunk to the dripline of the tree. Placement of fencing in any other location shall be done only with the approval of the Engineer. The fence material shall be chain-link fence.
- Chain-link fencing shall be six-foot (6) in height and supported by eight-foot (8) steel T-posts spaced six feet (6) o.c., driven a minimum of 20" into existing grade.
- The fencing shall be continuous between posts and shall be firmly attached to the posts with a minimum of 4 wire ties.

The Contractor shall erect a filter berm composed of an approved organic compost or shredded hardwood bark to the dimensions and location shown in the details.

If it becomes necessary to locate a barrier within six feet (6) of the trunk of a tree, wood planking shall be secured to the trunk. The planking shall be nominal 2x4 dimension lumber secured with a rope, band, or strap of sufficient durability to remain in place for the duration of the project. Planks shall be installed to a height of ten feet (10) or to the lowest major branches whichever is lowest. Under no circumstances will nails, screws, or any other damaging attachment be used.

The Contractor shall have signs prepared and installed on the protective fencing with the following wording:
- No Construction or Maintenance Activities Permitted in this Area
- Do Not Enter
- This fence may not be removed or modified without the permission of the Engineer
- Contact (Phone number)

Within the Preferred Root Protection Zone, none of the following activities are allowed without the permission of the Engineer.
- Parking of any vehicles
- Erection of any shed or structure
- Storage of any equipment or materials
- Use by people for any reason
- Dumping of any litter, waste materials, or liquids
- Impoundment of water
- Addition of fill-soil
- Excavation, boring, or trenching of any type

The Contractor shall immediately remove any concrete, lime or other chemicals accidentally spilt within the protected root zone. The contractor shall immediately treat for accidental damage to any tree as directed by the Engineer. The Contractor shall seure the services of a certified tree care specialist to assess and/or treat for the damage. Treatment or repair costs for damages to tree or other protected areas shall be borne by the Contractor.

Contractor shall maintain all tree protection materials throughout entire length of project. Any damaged tree protection materials shall be repaired immediately at the Contractor's expense. Additional compost or mulch materials required during the project will be considered subsidiary to this item and not paid for separately.

Trees should be inspected for the presence of damaging insects during the project. If found, appropriate chemical controls should be taken by a certified tree specialist.

Contractor shall remove and dispose of all protective fencing and trunk protection at end of project.

REQUIRED GRADES CHANGES WITHIN THE CRITICAL ROOT ZONE

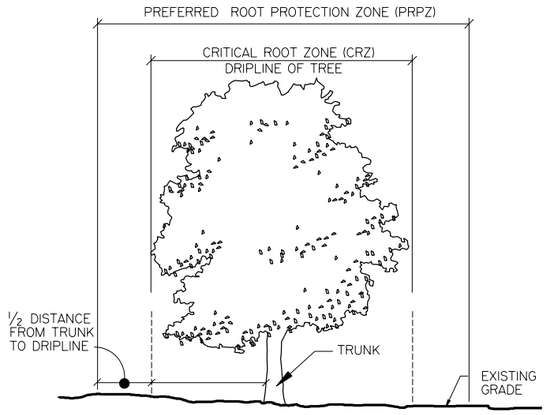
No trenching, excavating, filling, or compaction is allowed within the critical root zone except as specifically identified in the plans or approved by the Engineer prior to any trenching.

If root removal or excavation is unavoidable within the Preferred Root Protection Zone, excavation shall be preceded by hand-digging to expose major tree roots of one-inch (1") diameter or greater. Once exposed, roots shall be pruned with sharp, clean tools designed for that purpose. Exposed root ends shall be backfilled as soon as possible or covered with six inches (6") shredded hardwood mulch within the same day of excavation.

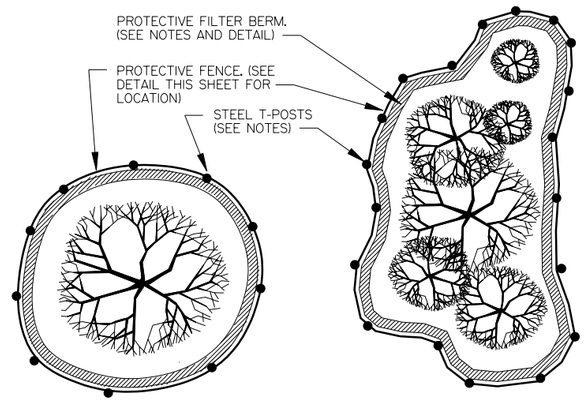
Any roots exposed by construction shall be pruned flush with the soil. Backfill root areas with good quality topsoil as soon as possible. If exposed roots are not to be backfilled within two days, they shall be covered with a minimum of six inches (6") of shredded hardwood mulch.

Should access across the Critical Root Zone be necessary, only that portion needed for the completion of the task shall be opened for access. Six inches (6") of shredded hardwood bark shall be installed in access areas before any wheeled or tracked vehices enter the Critical Root Zone. Protective barriers shall be replaced to their original positions as soon as possible after the construction task is completed and the bark mulch layer removed and stockpiled outside the Critical Root Zone.

Where shown elsewhere in plans, proposed underground utilities crossing the Critical Root Zone shall be bored at a minimum of three feet (3) below existing grade. Trench for bore shall not intrude into Critical Root Zone.

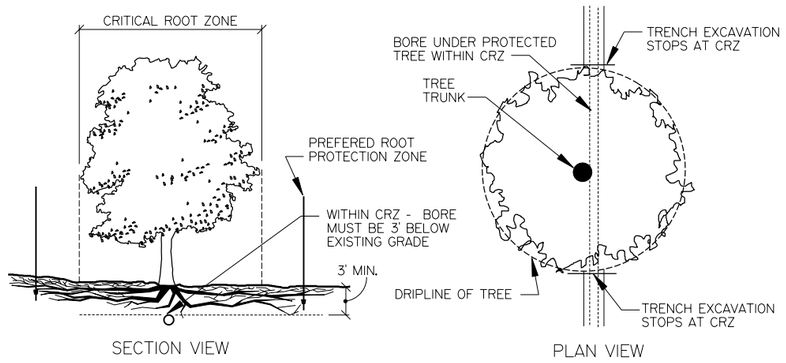


TREE PROTECTION ZONE DESIGNATION



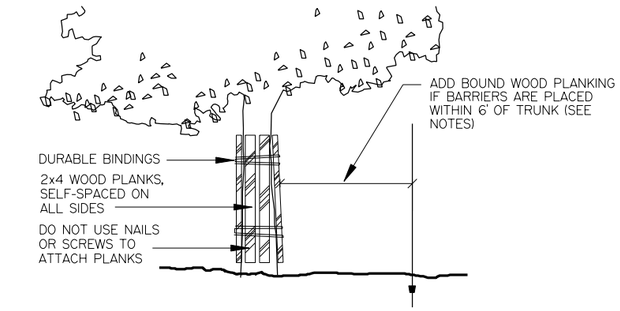
PLAN VIEW OF FENCING LAYOUT

NTS



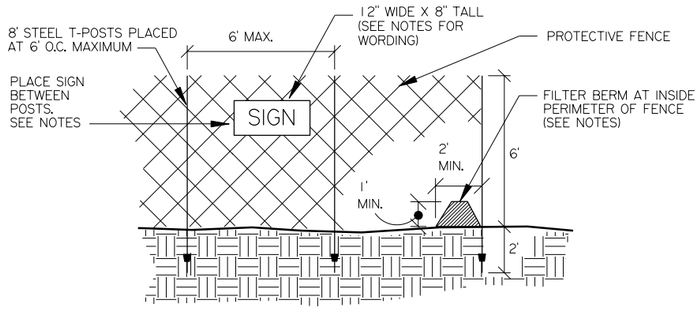
TRENCHING PAST TREES

NTS



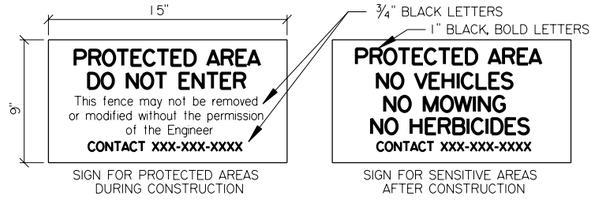
WOOD PLANKING INSTALLATION

NTS



PROTECTIVE FENCE AND SIGN PLACEMENT

NTS



SIGNAGE FOR PROTECTED AREAS

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Texas Department of Transportation

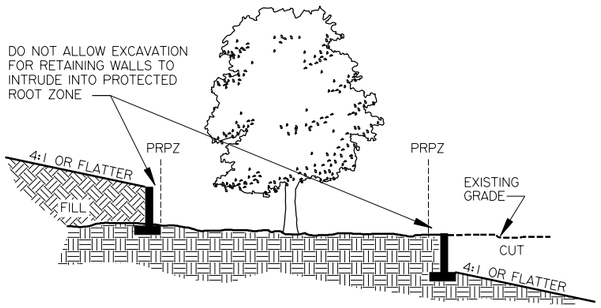
TREE PROTECTION

SHEET 1 OF 3

Details not to scale

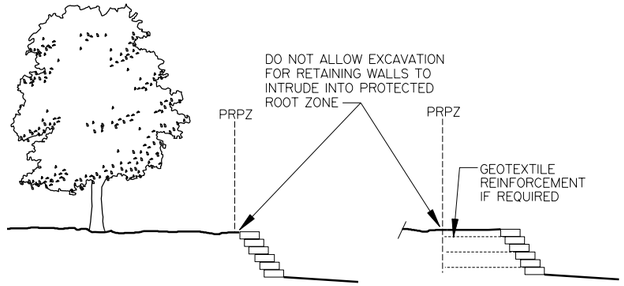
FILE:	FED DIV	STATE	PROJECT NUMBER			SHEET
	6	TEXAS				
ORIGINAL:	DIST	COUNTY	CONTROL	SECT	JOB	HIGHWAY
	12					

ALTERNATIVE DETAILS



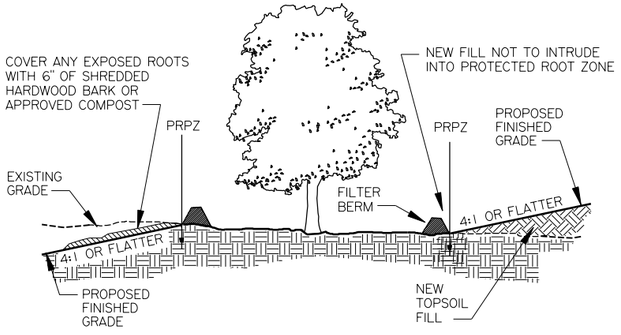
RETAINING WALLS NEAR TREES

NTS



RETAINING WALLS NEAR TREES

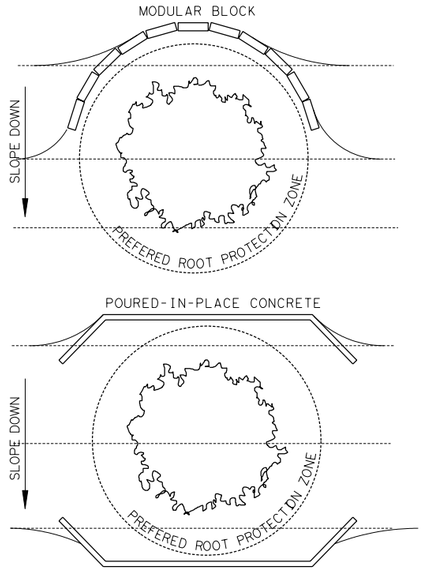
NTS

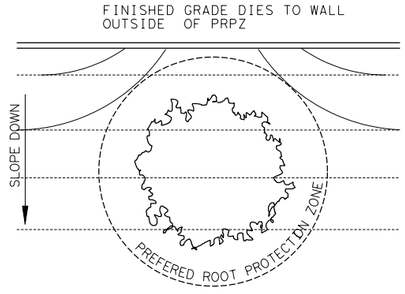


GRADE CHANGES NEAR PROTECTED TREES

4:1 FINISHED GRADE OR FLATTER

NTS





GRADE CHANGES NEAR PROTECTED TREES

RETAINING WALL PLACEMENT

NTS

Texas Department of Transportation

TREE PROTECTION

SHEET 2 OF 3

Details not to scale

FILE:	FED DIV	STATE	PROJECT NUMBER			SHEET
	6	TEXAS				
ORIGINAL:	DIST	COUNTY	CONTROL	SECT	JOB	HIGHWAY
	12					

NOTES:

1. Upon the completion of construction activities, a thorough final assessment of the protected areas shall be conducted to determine the health and condition of trees or other sensitive features. For trees, a certified tree specialist should conduct the assessment. Other ecologically sensitive areas shall be evaluated by an appropriate specialist approved by the Engineer.

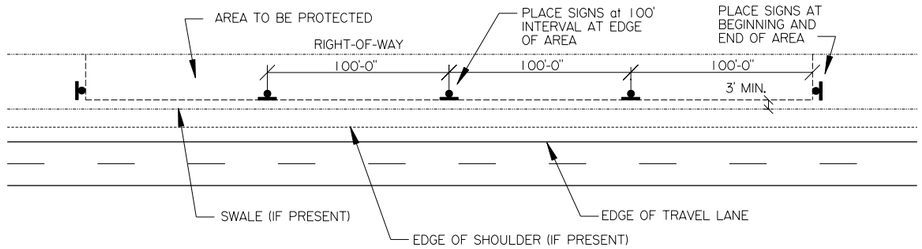
   The specialist(s) should provide recommendations for post-construction measures that may be needed. Inspection items to be noted include:

   * Damage to any part of the protected area
   * Damage to any plant material
   * Changes in soils structure such as compaction, fills, erosion, or loss of organic matter
   * The effects on any new structures.

   The contractor will:

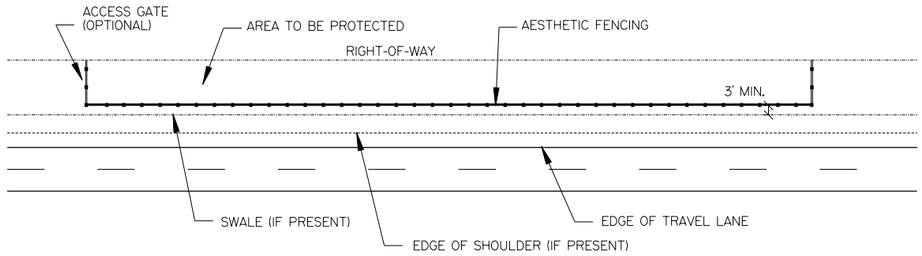
   * Removal of trees that may have died during construction as determined by the assessment
   * Removal of any fill soil from root zones
   * Repair areas damaged during construction

2. The contactor shall install permanant protective fencing and or signage as determined by the Engineer for all sensitive areas as shown in the details.



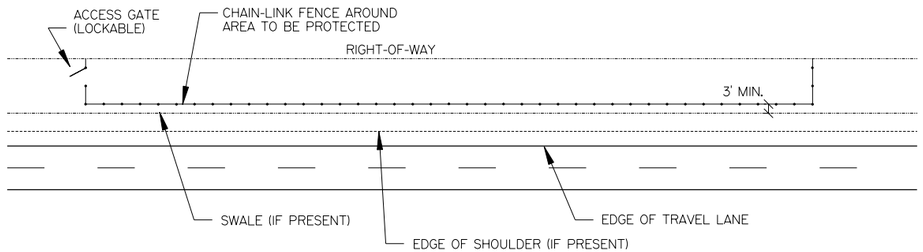
ALT. 1 - SIGNAGE FOR MINIMUM ACCESS CONTROL IN SENSITIVE AREAS

NTS



ALT. 2 - FENCING FOR ACCESS CONTROL IN SENSITIVE AREAS

NTS



ALT. 3 - FENCING FOR CRITICALLY SENSITIVE AREAS

NTS

Texas Department of Transportation

TREE PROTECTION

SHEET 3 OF 3

Details not to scale

FILE:	FED DIV	STATE	PROJECT NUMBER			SHEET
	6	TEXAS				
ORIGINAL:	DIST	COUNTY	CONTROL	SECT	JOB	HIGHWAY
	12					