Roadside Vegetation Maintenance Manual: Update

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16. Abstract:
The need to update the Roadside Vegetation Management Manual, a publication of the Texas Department of Transportation (TxDOT), can be attributed to a better understanding of the roadside environment. This document is a total revision of TxDOT Manual Notice 96-1 (March 1, 1996), which itself was an update of the November 1993 edition. The 1996 document was a modified version of the 1993 publication with various pages and chapters removed and recycled and replaced with changes. This Roadside Vegetation Management Manual is divided into two components-functional components and aesthetic components. As in all TxDOT decisions, safety is the primary concern. The roadside must be maintained in a safe condition. When no safety concerns are present, the functional components of the roadside management system are high priority. When the functional components of the roadside management system are satisfied, the aesthetic components are considered. The users of the Tedxas highways want safe, functional and pleasing highway right-of-ways. This document aids TxDOT professionals and others in maintaining roadside vegetation.

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ROADSIDE VEGETATION MAINTENANCE MANUAL: UPDATE

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IMPLEMENTATION STATEMENT

Considering the data received from this research study, TxDOT will revise the RMP recommendations currently contained within the Roadside Vegetation Management Manual. Data will be furnished to all district vegetation managers and to all TxDOT personnel who are involved in the performance of routine right-of-way maintenance operations.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

AUTHOR'S DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view of policies of the Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PATENT DISCLAIMER

There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new useful improvement thereof, or any variety of plant which is or may be patentable under the patent laws of the United States of America or any foreign country.

ENGINEERING DISCLAIMER

Not intended for construction, bidding, or permit purposes. The engineer in charge of the research study was Richard Zartman, Ph.D., Texas Tech University, Lubbock, Texas. .

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
	AREA			
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
	VOLUME			
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
	ILLUMINATION			
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
	FORCE and PRESSURE or STRESS			
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
	AREA			
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
	VOLUME			
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
	ILLUMINATION			
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
	FORCE and PRESSURE or STRESS			
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate

(Revised September 1993)

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STATEMENT OF OBJECTIVES

Integrated roadside management requires a system that provides systematic interaction among all disciplines involved. The vegetation management decision process involves safety as well as functional and aesthetic concerns.

Specific objectives of an integrated roadside management plan include:

Safety

Functional Components

Vegetation

1. Too much vegetation
2. Inappropriate vegetation
3. Too little vegetation

Site

1. Erosion and sediment control
2. Drainage

Aesthetic Components

1. Mowing and litter pickup
2. Loss of established vegetation
3. Ornamental plantings (urban)

Process Guide

Each roadside and region of Texas has unique characteristics. Therefore a uniform, standard, statewide management plan is not possible. While management concepts are universal, implementation of these concepts must be site specific. Some locations will require extensive effort, while others will require only a limited effort to maintain a high quality roadside environment. Consideration must be given to regional roadside management plans that recognize when climatic differences apply (arid, semiarid or humid), or soil differences apply (texture, depth to rock, pH and salinity), or vegetation differences apply (e.g., desert, prairie or forest regions).

Maintenance is the preservation and upkeep of a right-of-way. Management, however, is the dynamic process that identifies and guides the accomplishment towards long-range goals. While roadside management planning should begin at the inception of the project, it must continue through project construction and into maintenance and operation.

A concentrated effort is required to arrive at a comprehensive, cost-effective integrated roadside vegetation management plan. Care must be taken to maintain or improve

existing conditions. Since right-of-way management is a dynamic process, and involves long-term planning, flexibility is the key to usability. A regularly scheduled observance and evaluation component should be part of each plan to keep roadsides safe, functional and aesthetically pleasing.

Level of Management

The level of intensity for an integrated management right-of-way program should be determined by three factors:

1. Type of location for the highway right-of-way
2. Climatic conditions at the site
3. Soils resources

Needs and visual aspects of the integrated right-of-way development depend upon many factors. After safety, the first factor is the type of location for the highway right-of-way. Urban areas are generally high traffic areas and should be managed intensively. Mowing frequencies should be based on vegetation growth. Tall growing vegetation such as Johnson grass needs to be controlled by herbicide application, then mowed. Mowing alone will not control Johnson grass. Landscaped areas need to be pruned, weeded, irrigated and delittered frequently. Rural areas need to be monitored for safety first, then function and finally for aesthetic purposes. This may mean delayed mowing until after the wild flowers have gone to seed. Or, this may mean mowing early to prevent weeds (e. g. sunflowers) from going to seed.

A second factor to be considered is the climatic conditions at the site to be managed. Texas is such a large and diverse state that no one-management system can be efficient for all of the climatic zones within the state. Warm, humid regions, such as the Gulf Coast, require frequent corrective actions for vegetation control. Arid regions, such as far west Texas, will require management to conserve and maintain vegetation, thereby minimizing erosion. Finally, clean up mowing occurs in the cooler portions of the state before the same mowing practice is carried out in the warmer regions. Far south Texas does not freeze and cleanup mowing is not done "after the first freeze."

A third factor is the soils resources within the state. Steep slopes must be managed to deter soil loss by erosion. Mowing should be minimized to prevent rutting and down gradient slippage of soil and vegetation. Special care when mowing should be taken on shallow soils or soils with rock protruding above the surface to prevent accidents to passers by or damage to equipment. Soils with low pH (East Texas), very high pH or salinity problems (far West Texas) should be managed to preserve existing vegetation.

INTRODUCTION

An Integrated Roadside Management System is the inclusion of several interrelated components of a highway right-of way management system. The management decision-making process is governed by both vegetation and site characteristics. At all locations the first concern is a safety problem. These must be addressed before other concerns are evaluated. In the absence of safety problems the second level of concerns are the functional problems. These *functional components*--determined by *Vegetation* (too much vegetation, inappropriate vegetation, too little vegetation) and *Site* (erosion and sediment control, drainage)—take precedence over the aesthetic problems. The *aesthetic components* (mowing and litter pick up, loss of established vegetation, ornamental planting--urban) are the visual elements that the traveling public sees.

FUNCTIONAL COMPONENTS

Vegetation

Much of the vegetation established on the roadside provides desirable visual qualities, shade for roadside stops, soil stabilization and a richer habitat for wildlife such as rabbits or quail. Excessive vegetation, however, results in reduced visibility, loss of function for the shoulder and increased danger from fire. Controlling excessive vegetation is warranted in many situations.

Maximizing the effectiveness of controlling vegetation on the highway right-of way is of constant concern throughout the State of Texas. Existing vegetation on the roadsides needs to be maintained in a healthy status for safety and aesthetic considerations as well as to prevent soil erosion with the least amount of inputs. Many factors and interactions influence the vegetation along the highways in Texas.

Plant growth is a function of many environmental and management components. The environment is a function of the climate of the area and the soil resources of that area. Climate cannot be controlled, in general, other than by irrigation and/or drainage and will not be discussed in this document. Soil resources are generally a function of the native resources and the history of the highway's construction at that location. These resources can be amended by the addition of fertilizer or liming materials. Since these practices are generally not considered to be justifiable due to the acreage encompassed, these factors will not be included in this review. The factors of control of established vegetation and loss of vegetation will be discussed. The primary methods of vegetation control are mowing and herbicide application and will be discussed in some detail. Other control options such as pruning and manual control methods will be discussed in brief.

Too Much Vegetation: The primary management tool available for TxDOT to control non-woody vegetation is mowing. Mowing is the most fundamental practice utilized to maintain the aesthetics and safety functionality of the highway right-of-way. Previous TxDOT management references such as the Roadside Vegetation Management Manual: A volume of the Infrastructure Maintenance Manual: Manual Notice 93 -1 (TxDOT, 1993); Roadside Vegetation Management Manual: Manual Notice 96-1 (TxDOT, 1996) and Giving Nature a Hand booklet (TxDOT, 1999) are available. While herbicide

management must be incorporated into the overall management program (See Herbicide Operations Manual, TxDOT, 2001), mowing provides a uniform surface for viewing traffic and limits potential hazards to driving. Since mowing defoliates the plants, many physiological changes of the vegetation occur. While maintaining visibility, mowing must not deplete the carbohydrate reserves of the plant material to such an extent that the vegetation dies. The criteria for selecting the mowing height and frequency are physiological conditions and growth habit of the vegetation as well as safety considerations such as visibility and flammability.

Mowing Operations

Modified Full-Width Mowing: Modified full-width mowing includes all unpaved right-of-way, except for delineated non-mow or natural areas. Generally, non-mow or natural areas would begin at the toe of the slope in fill areas or the back of the ditch for cut sections, as long as clear zone requirements are met.

The frequency of modified full-width mowing for a given roadway will depend on the level of vegetation management assigned to the segment of roadway.

Strip Mowing: Mowing the area five to fifteen feet from the edge of the shoulder (whether paved or unpaved) is called strip mowing. A five-foot strip may be adequate on highways with paved shoulders. In addition to the strip along the shoulder, all strip mowing operations will include:

1. Mowing from the pavement edge or shoulder to the right-of-way line next to developed areas (cemeteries, schools, churches, private dwellings, community centers, etc.);

2. All mowing necessary to maintain adequate sight distances for intersections, private entrances, curves, off-ramps, on-ramps, signs, delineators, and other appurtenances;

3. Mowing around all appurtenances (signs, delineators, guardrail, culvert headwalls, etc.) that are within the designated strip width;

4. Mowing the entire width of narrow medians and outer separations;

5. Mowing full-width, from right-of-way to right-of-way for drainage where appropriate;

6. Mowing a smooth and gradual transition that will blend the designated strip width with other areas that require a greater or lesser mowing width.

Spot Mowing for Safety: Spot mowing will be performed when and where necessary to maintain adequate sight distances for inside curves, off-ramps, on ramps, intersections, private entrances, signs, delineators, and other appurtenances. Spot mowing is generally performed when safety needs arise between scheduled mowing cycles.

Transitions

When Required: Wherever two areas requiring different mowing widths are adjacent, a smooth and gradual *transition* should be achieved to visually blend the two areas.

Examples: A transition would be required between

1. the designated strip mowing width and the greater width required around a sign;
2. an area that is mowed full width and a non-mow area;
3. the designated strip mowing width and the extra width required to maintain sight distances at a curve, driveway, or intersection.

Rate: The rate of transition should be gradual enough to allow adequate sight distances for prevailing traffic conditions and also provide a smooth visual effect.

Special Mowing Situations

Urban Areas: Urban areas should be maintained with frequent mowing. Ornamental plantings should be maintained appropriately. This may mean pruning of ornamental plantings of trees and bushes.

Rural Medians and Outer Separations: The entire area of rural medians and outer separations should be mowed during spot and strip mowing operations, unless the grade is too steep or the area is covered with trees, shrubs or other vegetation desirable for wildlife benefit or erosion mitigation. On extremely wide medians and outer separations, normally only transition and shoulder strip mowing should be performed on all divided highways.

Rural Intersections: During spot and strip mowing operations, the area around rural intersections or interchanges will be mowed as necessary to provide adequate sight distances.

Cut and Fill Sections: Normally, on fill sections, only some mowing will be necessary. Strip mowing may be adequate in cut sections; however, at deep cuts, mowing must extend across the ditch line to the beginning or base of the backslope.

Rest Areas and Picnic Areas: Rest areas and picnic areas should be maintained with frequent mowings.

Other Precautions: The main purposes of the vegetative cover on the right-of-way are to maintain water quality and safety of road surfaces. Protection of the roadside from erosion is also important. Left unprotected, deterioration occurs, threatening the paved surface of the roadway. Mowing is an important component of roadside vegetation management, but it must be conducted with care to preserve the vegetative cover.

Observing the precautions contained in this section will help:

1. Ensure efficient and environmentally sound mowing operations;
2. Maintain seed sources for the state's native flora;
3. Promote wildlife habitat.

Delay Mowing When Soil is Wet: When the soil is wet, delay mowing. Tractor tires cause severe rutting in wet soil. Rutting, especially on slopes, causes erosion and leads to the spread of noxious weeds and the loss of existing vegetation. Erosion leads to deterioration of the road system and threatens adjacent structures and property.

Avoid Mowing Steep Slopes: Avoid mowing steep slopes (3:1 ratio or steeper), even in urban areas, whenever possible. Mowing steep slopes increases compaction, causes slope failure and rutting, and decreases the vigor of the vegetation. Loss of plant growth results in slope erosion.

Use Appropriate Cutting Height: Mower height should not be lower than seven inches in rural settings.

Low cutting (also called "scalping") is undesirable because it:

1. produces stress in the vegetation, especially during dry, hot conditions, resulting in loss of vegetative cover;
2. increases the number of objects thrown by mowers;
3. deprives ground-nesting wildlife of cover.

Avoid Mowing Too Frequently: Without supplemental watering and fertilization, frequent mowing puts undue stress on native grasses. Many noxious weeds and grasses such as Johnson grass have food storage capacity in a rhizome root system and can withstand frequent mowings. Frequent mowing may allow unwanted vegetation to dominate and also deprive wildlife of food and cover.

Coordinate Mowing with Grass Seed Production: Effective mowing operations require coordination with seasonal cycles, as well as with other roadside maintenance activities.

In late summer and early fall, grasses produce seed-heads. Seed-heads develop very rapidly and, if cut, will regenerate in eight to twelve days. Mowing operations during seed-head production results in wasted time and money.

After seed-heads mature in the fall, grasses will become dormant. Mowing after this period will result in a clean right-of-way until spring.

NOTE: Where K.R. bluestem, little bluestem, sideoats grama, Indian grass, switchgrass, sand bluestem, western wheatgrass, or plains bristlegrass is the predominant grass, they should be mowed in late fall.

NOTE: Remember to cut grass no less than seven inches high to provide residual material to protect next year's early ground-nesting wildlife and ensure healthy grass

regeneration. Panhandle roadsides, for example, provide much needed protective cover for pheasants with proper management of key backslopes. (The backslope is the area of right-of-way beyond the drainage ditch that slopes away—either up or down—from the plane of the roadway.)

Coordinate Mowing with Herbicide Application: Effective mowing operations require coordination with herbicide applications so that neither effort is wasted. Mowing soon after herbicide application would limit the effectiveness of the herbicide.

Non-Mow or Natural Areas and Acreage Evaluations: Each district maintenance engineer, vegetation manager, or designated representative must evaluate all unpaved sections of right-of-way to establish non-mow or natural areas and calculate acreage to be mowed. The department encourages consultation with the Texas Parks and Wildlife Department field biologists to maximize the wildlife habitat benefits on a local basis.

Establishing Non-Mow or Natural Areas: Maximizes the designation of non-mow or natural areas throughout the right-of-way. Suitable non-mow or natural areas may include steep slopes, wide rights-of-way, and other areas that are covered with desirable vegetation. Clearly mark these areas to prevent accidental mowing during modified full-width mowing.

Calculating Acreage to be Mowed: In addition to the establishment of non-mow areas, the amount of modified full-width and strip acreage to be mowed must be calculated for each section of roadway. These figures will be used in drawing up contract bid proposals and determining maintenance costs.

Additional Information: Additional information will be presented in the following **inappropriate vegetation** section. Details on herbicides are covered fully in the Herbicide Operations Manual (TxDOT, 2001), available from the Maintenance Division.

Inappropriate Vegetation: Control of woody and herbaceous plants along highway rights-of-way is another vegetational problem encountered by TxDOT. Inappropriate vegetation can be controlled by chemical, mechanical or manual means. Regardless of the species targeted for herbicidal control, the plants must be physiologically capable of responding to the herbicides applied and the environmental conditions must be conducive to elicit a response. Likewise, mechanical control must be applied under such environmental conditions and plant physiological status or stage of phenological development to inflict the greatest impact on the target species. Pruning is the manual control of choice for trees that are to remain in the right-of way. At times, manual control is necessary for willows etc. growing in drainage ways.

Herbicide Operations: Herbicide application on highway right-of-way is a very broad topic. Herbicide activity may be influenced by many factors that include plant species, soil type, wind, humidity, rainfall, temperature, water quality, mixing, application procedures and timing as well as individual herbicide application (TxDOT, 2001). Proper herbicide selection and application depend upon the type of vegetation, species of vegetation as well as the condition of the vegetation.

Plants may be characterized as annuals, biennials or perennials. Annuals and biennials propagate by seed. Perennials rely on extensive root systems for propagation more than seed production. Another category of plants is associated with water or wetland areas. These may be annuals, biennials or perennials.

For very specific information, refer to the Herbicide Operations Manual (TxDOT, 2001). This specific information is beyond the scope of this document, but some general information will be presented.

Herbicides may be differentiated into soil-active (residual) or foliar-applied categories. Residual herbicides remain active within the soil for periods of time and prevent seed germination and root growth. Vegetation should be present before applying residual herbicides. Since the residual herbicides move to the root zone by water and rainfall they must NEVER BE APPLIED TO BARE GROUND.

Foliar-applied herbicides must be applied to green and growing foliage to be effective. Since the herbicide must be absorbed through the foliage and translocated throughout the plant, several days are typically required before the toxic affects appear. Certain plant species may be herbicide resistant requiring multiple herbicide applications or multiple chemicals.

A final consideration for herbicide application is type of contact. The types of contact fall into BARE GROUND, SELECTIVE WEEDING, and CHEMICAL MOW.

The bare ground vegetation control is appropriate when there is a specific reason. Treating the edge of pavement or vegetation encroachment within paved shoulders are good examples of this type of control. Bare ground applications are not recommended around fixtures, signposts, or under guardrails.

Selective weeding is the use of a herbicide or combination of herbicides for control of target plant species, but does not permanently harm desirable vegetation.

Chemical mowing is the practice of controlling undesirable vegetation, which is in close proximity to desirable plant material. This procedure may be utilized to control vegetation along fence lines, under guardrails and within landscaped areas.

Environmental Conditions Conducive to Effective Herbicidal Control

As previously mentioned, application of soil-applied herbicides should be timed with the growing season in the geographical part of Texas under consideration.

Soil temperature, air temperature and soil-water content are also important, but in perceptibly varying degrees. Vegetation must actively grow for herbicides to be effective. Higher surface soil water is important for shallow-rooted perennials and annual plants, and perhaps even non-sprouting woody perennials. "Actively growing" plants respond more favorably to herbicide application than stressed plants. Deeper-rooted perennials have access to greater volumes of soil from which to extract water; therefore, they seem to be less impacted by localized limited soil water conditions. As

long as perennials such as mesquite, broom snakeweed, field bindweed, and silverleaf nightshade have adequate foliage, there is ample soil water to produce root mortality from herbicide application (assuming the herbicide is applied at the proper physiological stage).

Mowing and Herbicide Application

Need for Coordination: Overspray herbicide applications must be coordinated with mowing operations to:

1. Ensure effective control of target plant species.

2. Avoid damage to desirable plant species such as wildflowers, legumes, and forbs beneficial to wildlife (examples include Illinois bundleflower, Engelmann daisy, Maximilian sunflower).

How Overspray Herbicide Works: Overspray herbicide applications target noxious weeds. For the herbicide to be effective, both of the following conditions must be met:

1. The target species must be in an active growing condition just prior to or during the seed head stage for Johnson grass not thistles.

2. The herbicide must have about 14 days to translocate from the leaf surface to the root system of the target species.

Guidelines: To coordinate mowing and herbicide operations, observe the following guidelines:

1. Do **not** apply overspray herbicide after a mowing operation or before the target species attains a proper growing condition. (*To do so would be ineffective and cause damage to desirable species.)*

2. Allow a **minimum of 14 days** before mowing in overspray areas. *(This will allow the herbicide to translocate to target species' root system.)*

Tree Control: Excessive tree growth may need to be controlled to prevent limited sight lines and potential hazards to personnel and vehicles due to high winds, ice storms, insect infestations and disease.

Figure 1 - Woody plants encroaching on line of sight.

Mechanical Means: Mechanical control is a viable option in urban areas, when those trees that need to be controlled, are weedy sprouts or seedlings that can be controlled with the mower blades in horizontal (mowing) or boomax. The results are fairly effective for the labor and expense invested.

1. The shorn appearance of the woody plants as a result of the mowing action must be an acceptable product.

2. There is no ability to select between desirable and undesirable materials. All materials fall into the category of undesirable when mechanical methods are used.

3. Weed trees such as honey mesquite pose an additional hazard as they can cause flat tires when motorists pull off the highway on to the shoulder. Their low stature and ability to resprout after mowing makes them a particularly difficult problem to control. Since the mesquite is low to the ground and hard to see in high grass, it is not readily visible to drivers. When mesquites are mowed down, the cut stems left hidden in the grass clipping easily result in tire punctures.

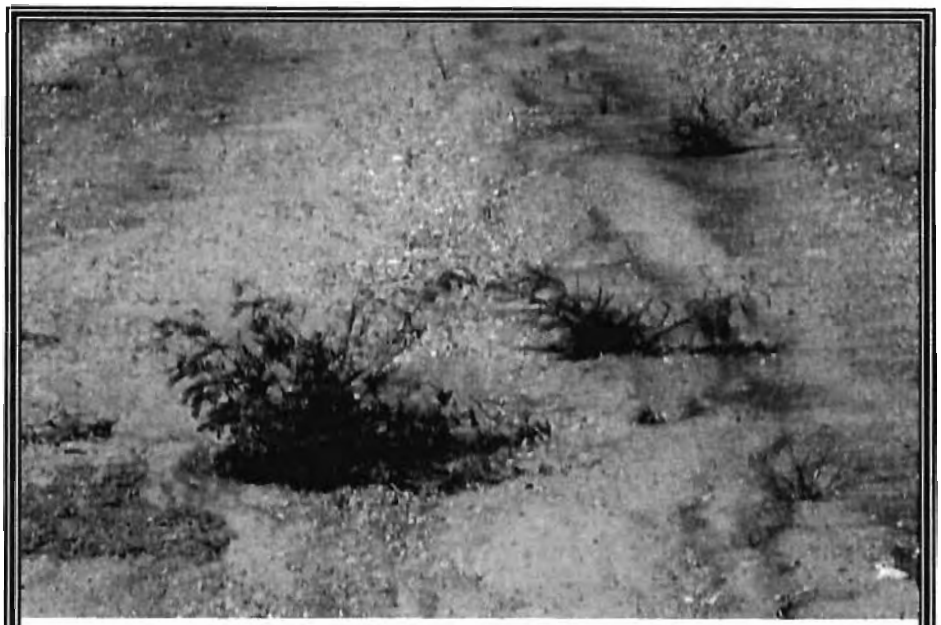

Figure 2 -Honey Mesquite has the potential to cause a flat tire.

Manual Means: The pruning of urban trees must be infrequent to stay within limited budgets, but appropriately timed to enhance the value of the tree. General guidelines for pruning may be found in the "Aesthetic Problems Options" section of this manual.

1. *Desirable Trees*

   The following situations with high visibility trees may warrant tree pruning:

   a) Low branches should be removed to allow mowing equipment easy access. This would best be accomplished during the late fall or early winter when deciduous trees would be defoliated exposing the branching pattern and trees are dormant. This timing places the least amount of stress on the trees and occurs when other maintenance activities are minimal.

   b) Broken or diseased branches should be removed to prevent breakup. Severely affected trees may need removal. This is best accomplished as soon to the occurrence as possible.

   c) Trees with growth headed toward power lines should be pruned to a bud or branch directing growth away from the power lines during the dormant season.

   d) Trees encroaching on site lines may need to be limbed or shaped during the dormant season. If the problem is severe, the tree may need to be entirely removed with timing based on the severity of the visual barrier created.

2. *Undesirable Trees*

Frequently, weedier species of trees self-seed along the roadway. In these cases, their placement may obstruct lines of sight, impede maintenance equipment, and limit access into drives or cutouts rendering these trees undesirable and in need of removal. In addition, trees whose overall health has declined to the point they are a liability also become undesirable and may need to be removed.

a) Seedlings can be removed much easier than mature trees. Any volunteer trees that will develop into a future problem should be addressed early in their growth.

b) Mature plants should be removed flush with the ground to prevent the creation of trunks or stumps that present mowing and driving hazards for motorists. Stump grinding and removal is generally reserved for high visibility areas demanding a high level of maintenance.

c) Removing all limbs and debris at the time of tree removal prevents high grass from hiding potential mowing hazards.

d) Weedy species such as mesquite should be controlled to prevent making the shoulders hazardous for motorists.

e) Cut stump treatments are effective in removing stump hazards.

Figure 3 - Pruning debris that could become a mowing hazard.

Summary and Conclusions

To re-emphasize control of nuisance plants: Control is relatively easy and can be extremely successful if one plans herbicidal control to the plant's ability to respond to the herbicide and to the environmental conditions that are conducive to plant physiological activities.

- Annual plants (summer annuals, winter annuals and biennials) must be sprayed in the vegetative stage for effective control. Spraying when plants are in the rosette stage is ideal. After the plants become reproductive and bolt (elevate a flower stalk), they are difficult to impossible to control.

- Perennial herbs (used in the botanical sense of herbaceous plants, not in the culinary senses) can be effectively controlled in the rosette stage (if they overwinter as a rosette). It is very difficult to achieve root-kill when the plants are in the initial reproductive or flowering phase. If the perennial herbs do not produce rosettes, or if spraying is delayed until the plants become reproductive, then control is nearly impossible to obtain. Effective control can be achieved during the post-flowering/fruit maturation phase when photosynthates (by which herbicides are distributed throughout the plant) are translocated throughout the plant to perennating organs and tissues.

- Suffrutescent or "half" shrubs, likewise, are easily and effectively controlled if sprayed during the "rosette-like" phase that occurs after the completion of the annual reproductive cycle. It is also nearly impossible to obtain a satisfactory control of suffrutescent shrubs during the initial reproductive and flowering phases. Effective control can be obtained if spraying is done post-flower during the seed/fruit maturation phase.

- Non-sprouting woody plants are relatively easy to control by foliar application of herbicides when the plant is actively photosynthesizing.

- Sprouting woody plants are perhaps the greatest nemesis confronting brush and weed control in Texas highway rights-of ways. For effective control with foliar broadcast sprays it is **imperative** that herbicide application be timed to the period in the annual growth cycle when the plants can be physiologically responsive to herbicides. Complete canopy coverage with the herbicide solution or mixture is very important.

In conclusion, timing of herbicide application is very important. If herbicides are applied at the appropriate time in the annual growth cycle of a plant, very effective control is achievable (and should be expected). If details of timing of the herbicide applied are ignored, control of nuisance plants is usually very ineffective and the degree of control is unsatisfactory. Although there are effective and non-effective herbicides and degrees of effectiveness of herbicides, selection of an herbicide of choice becomes secondary to the primary concern of time of application.

Too Little Vegetation: The aesthetic benefits of vegetation management include the creation of aesthetic vistas by using wildflowers and other low maintenance plant

materials. When there is insufficient vegetation, erosion, and lack of aesthetic appeal, functionality and potential tourism of the area can be affected.

Soil Preparation for Renovation or Repair of Existing Plantings: Repairs and renovations are conducted when a small portion of an area needs to be replanted due to failure of establishment or excessive maintenance concerns. Renovations occur when grade changes must be made to maintain the planting at an acceptable level.

1. Correct the problem causing the need for renovation or repair

    a. if there are grade issues resulting in problems such as erosion, remove and stockpile topsoil, adjust the grade and replace topsoil;

    b. to remove rocks if contributing to maintenance concerns;

    c. and till if the soil is compacted and the infiltration of water is not adequate;

    d. to adjust the fertility as needed and

    e. secure seedbed with soil retention blankets to prevent erosion if the slope is steep (3:1 or greater) or erosive.

2. Amend the soil with a fertilizer or lime based on soil analysis.

3. Fine grade just prior to planting.

Plant Establishment: Vegetation is established through both seeding and vegetative methods. Environmental conditions, desired effect, and budget are some of the determining factors guiding which method to use. Seeding is the least expensive method, especially when large areas of right-of-way must be established. Sod, sprigs, and plugs are used only in difficult or high visibility areas were quick coverage is a necessity.

1. *Seeding*

    a. *General Guidelines*:

    Common factors that affect seeding establishment include the following:

    1) Select adapted plant species in seed mixtures.

    2) Select a suitable date to capitalize on favorable soil temperature and moisture.

    3) Uniformly apply fertilizers, lime or gypsum.

    4) Maximize periods of available soil water.

    5) Uniformly distribute the seed at the recommended rate across a firm seedbed. If the seed is very small and difficult to distribute, mix the seed in with sharp sand (such as builder use) before distribution. The sand will act as a carrier.

    6) Apply a light application of mulch to conserve moisture, prevent erosion, reduce soil temperature, and limit seed washing during rainfall events.

7) Control the weeds that compete with the desirable seeded species.

b. *Wildflowers*

The use of wildflowers is based on the idea of an "unannounced" right-of-way. This is the concept that the surrounding landscape blends in to the environment rather than contrasts with it. Wildflowers also promote tourism during the spring of the year.

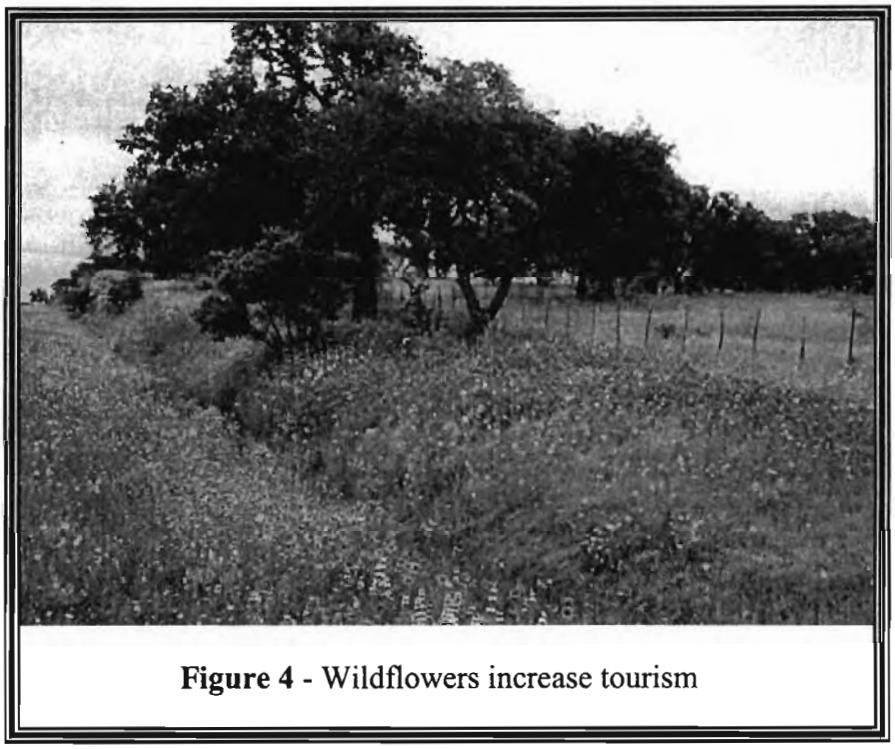

Figure 4 - Wildflowers increase tourism

The following are some establishment guidelines.

1) For newly constructed roadsides, follow the general guidelines for seedbed preparation for native grasses. (Listed above)

2) For existing right-of-ways, soil/seed contact is a very important factor to the success of the planting. Seed scattered on thatch, debris, or on thin soil without sufficient coverage is not likely to germinate.

3) Many native species have complex dormancy factors. Appropriate freezing and thawing cycles along with adequate moisture generally overcome these dormancy factors.

4) It is best to use a mixture of species so that if one species does not receive enough chilling or other environmental stimulus, there will still be color impact.

5) It is advisable to use a mixture of both annuals and perennials, as annuals will give immediate seasonal color while perennials may take a second year before providing flowers.

6) It is not unusual to have wildflower seeding efforts to not result in color for several years, especially when the seed is drilled into existing vegetation. This is due in part to the difficulty in supplying adequate moisture at the appropriate time. Seeding should be done in the fall.

c. *Grasses*

The use of grasses, including native species, is desirable as many are adapted to the regional environmental demands of heat, drought, and soil. Given the narrow road verges and embankments present in the right-of-ways, grass species are especially appropriate for revegetation efforts.

1. *Species Selection*

For the plant materials to remain a positive feature on the right-of-ways, it is important that the appropriate selection be made. Desirable features for grass production in the highway right-of-way are low growing height, good germination and tolerance to variable climatic and soil conditions.

Different species bring different characteristics to the roadway. The rooting systems of native species are different from Bermuda grass.

2. *Timing*

Timing is an important consideration when establishing turf grass by seed.

a. In the drier portions of Texas, fall planting may be an option depending upon moisture levels.

b. In west Texas, fall planting of grass is not a good option. Temporary seeding should be done if a perennial seeding is being used.

c. In addition, the northern portion of the state should plant later than the southern parts because of the variation in climate.

d. It is essential that turf be established as quickly as possible to prevent loss of soil by wind and water erosion. It is recommended seeding should be initiated as soon as the roadbeds are shaped.

e. It is recognized that in the arid regions of the state, there is less time in which to establish grass by seed effectively allowing for longer periods in which the soil is subjected to the forces of erosion. If the window of opportunity for seeding grass passes, a temporary mix of seed plus a soil retention blanket, straw or hay mulch may be used to hold the area until the desired species can be reseeded.

f. For most of the Southern Plains, April 1 is the peek period for seeding as it avoids drought and the erosion caused by failed seeding.

3. *Grade of Slope*

   a. The grade of the slope has a significant effect on the success of vegetative establishment.

   b. How smoothly the slope is graded is also of concern. The slope should be left with some texture, as a smoothly graded slope will not provide the surface necessary for seed and mulch to catch on and to allow moisture to penetrate.

4. *Level of Establishment*

   Areas that are without vegetation, often become heavily infested with weeds. Native grasses should be established wherever possible. Green Sprangletop may be used as a nurse crop. This species is quick to grow and establish to control erosion. A nurse crop allows time for other native grasses to establish.

5. *Soil Considerations*

   When establishing grass by seed, there are several issues concerning the soil that have to be addressed.

   a. Tillage before seeding. TxDOT guidelines (ITEM 164) state that all seeded areas are to be cultivated to a minimum depth of 4 inches or mowed before the placement of permanent seed.

   b. pH

      1) Soils located in the eastern part of the state have pH values that are as low as 1.8, thus prohibiting plant growth.

      2) Soils in the western part of the state have high pH values, thus inhibiting plant growth.

      3) It is also reported that in the eastern portion of the state, there are many slopes with difficulty in establishing plant growth and could support vegetation more successfully with the addition of lime, based on soil tests.

6. *Seeding Methods*

   a. Hydraulic Seeding

      1) Hydraulic seeding or hydromulching seed has become a very popular way to establish seed on interstate highways. Fertilizer and seed can be applied in one step. After this step, cellulose fiber mulch should be applied.

      2) Other advantages include having access to areas around rocks, signs, stumps or outcroppings that are limited to tractor-drawn rollers or spreaders.

3) Hydraulic mulching provides adequate soil to seed contact whereas broadcast seeding does not.

4) Seed that is covered by soil or pressed into the soil is less affected by desiccation. Hydraulic seeding is also susceptible to sheet erosion.

b. Mechanical/Broadcast seeding

1) Broadcast seeding is probably the simplest but least effective method to establish turf. The seed is scattered on the surface of the soil and kept moist until germination. There is some utility for flat surfaces but none with slopes where the addition of water will wash the seed down the slope.

2) Seed drills are useful for the establishment of grass in many locations as the seed and fertilizer are precisely placed and covered with a light mulch of soil to prevent desiccation. The rate of establishment is good but the practice is limited to areas with tractor accessibility. Straw or hay mulch is recommended here also.

3) Corrugated roller-seeders are another implement for usage in grass establishment. These scatter seed and then the seed is pressed into the furrow by the roller. There is some seed waste, but this is generally considered to be fairly efficient for grass. This equipment places the seed in direct contact with the soil and also provides a light covering of soil over the surface to prevent desiccation or washing of the seed. Cultipacker seeders are used frequently in the Southern Plains region.

7. Mulches

The use of some form of mulch is suggested utility no matter which method of grass establishment is used. Mulching is a very important practice in ensuring establishment.

a. The use of mulch is recommended to support rapid grass establishment.

b. Quality mulch should help provide available moisture to the seed for germination

c. Mulches are effective for about the first two weeks of establishment but generally show little difference after that period of time.

d. TxDOT has specific guidelines (ITEM164.3.B, C, and E) for the use of mulches.

1) First, if straw or hay mulch is used, it must be free of nuisance weeds such as Johnson grass. It must also be dry, not rotted or molded.

2) The mulch needs to be appropriate for use in hydraulic or conventional planting techniques and it should retain moisture without needing to have an asphalt binder.

3) The need exists of a tacking agent to prevent the straw or hay from washing or blowing. Because of these limitations, straw or hay is not recommend for use on slopes steeper than 3:1.

4) A light cover of mulch is desirable as it provides the needed moisture retention while allowing growth of the seedling.

5) It is recommended that straw mulch should be applied at a rate of 80-100 lbs per 1000 sq feet that is equivalent to 1.5-2 tons per acre.

8. *Sodding*

The benefit of sodding is the rapid establishment of grass also providing enhanced erosion control. This method also allows for the use of grass that does not readily establish from seed.

a. Large blocks or rolls of sod are cut and transplanted to provide an instant solid cover.

b. The purpose of sodding is to quickly and permanently establish vegetation to prevent erosion, to stabilize soil, to reduce mud or dust, to prevent runoff causing sediment deposits, and to help control drainage patterns.

c. Live, growing grass sod with a healthy roots system and dense matted roots throughout should be used.

d. TxDOT specifications (ITEM 162.2.2) for sod state that the sod must be live growing grass sod of the type specified on the plans. It must have a healthy root system and dense matted roots throughout the soil of the sod for a minimum thickness of one inch. Do not use sod from areas where the grass is thinned out. The grass must not be dried out or thin at the time of installation and it must be kept moist from the time it is harvested until it is planted. It must not have noxious weeds, Johnson grass or any matter deleterious to the growth and subsistence of the sod.

e. TxDOT guidelines state that sodding should be done between the average date of the last freeze in the spring and six weeks prior to the average date for the first freeze.

f. Installation

1) Soil preparation is the same as for seeding.

2) It is recommended that sod strips be placed across the slope starting at the bottom and working up.

3) The guidelines further state that joints should be snugged together and staggered to prevent drying.

4) The sod is then rolled or tamped to insure solid contact with the soil and pegged with wood pegs if the slope is steep and slippage is a possibility.

5) Irrigation should immediately follow until water penetrates the soil below, especially during periods of high temperature or wind

9. *Plugging*

Small pieces of sod about 3 inches square are planted in shallow depressions or furrows. The less distance between plugs, the faster the fill will be.

10. *Sprigging*

Stolons of warm season grasses are broadcast over a prepared seedbed and then pressed in or top-dressed. A variation of this in practice is used on right-of-way vegetation projects when the stolons, shoots, roots and rhizomes are mixed in with topsoil and the mixture is then disked into the seedbed or pressed in place by a roller or heavy equipment tires. This is referred to as sod mulching and is recommended when topsoil had been removed by erosion. Sod mulch will be disked no less than 4 inches deep and in two directions. It also specifies the sod material will not be excavated deeper than 2 inches and will be kept moist at all times.

Site

Erosion and Sediment Control

General Considerations: Erosion and sediment transport occur naturally in nature. Our concern, however, is not with the natural rate of erosion, transport, and deposition of soil, but with the "accelerated erosion" caused by humans. Accelerated erosion occurs when humans influence the processes of erosion. In our case, we are concerned with accelerated erosion caused by the construction and maintenance of highway right-of-ways.

There are many factors that contribute to the natural erosion rate and accelerated erosion. To aid in the evaluation of erosion and sediment control methods, we primarily need some understanding of the role of vegetation in preventing water erosion. Mulching is an alternative method to temporarily control erosion while vegetation is being established. An understanding of these processes will provide the major technical considerations for selecting the ***best management practices*** for minimizing soil erosion in the maintenance of highway right-of-ways.

Initiation: Erosion starts with detachment of individual soil particles from clods or other soil structure. The erosive forces of raindrops and the surface flow of water cause detachment. The energy required to detach soil is much greater than that required to transport soil by moving water. If the rainfall reaches the soil before being intercepted by vegetation, significant splash erosion occurs. Splash erosion occurs when raindrops strike bare soil. The impact causes soil to be detached and "splashed." Particles may rise as high as 2 feet. Often the fines and organic matter are separated from the heavier

particles. If the soil surface has a slope (e.g., shoulders, side slopes, and back slopes), the soil will have a net migration down the slope. Vegetation also ties soil particles together with its root system.

Whenever soil erosion control is needed, vegetation should always be considered. The erosivity of rainfall and the erodibility of the soil cannot be changed for a location. Vegetation is something, however, that can be controlled (within reason) for a site. If possible, the natural vegetative cover should be maintained. If the vegetation is damaged or destroyed, an alternative material should be used to absorb the energy from the soil. When artificial mulches or erosion blankets/mats are used, synthetics are replacing growing vegetation or residue from vegetation.

Basic Principles for Erosion and Sediment Control

Principles of erosion and sediment control presented include:

1. Design slopes consistent with soil limitations or minimize length and steepness of slopes.

2. Reduce the area of unprotected soil exposure.

3. Protect soil with vegetative cover, mulch, or erosion resistant material.

4. Retard runoff.

5. Trap sediment by temporary or permanent barriers, basins or other measures.

6. Keep runoff velocities low.

7. Prepare drainage ways and outlets to handle concentrated or increased runoff.

The above principles are all consistent with the theory that erosion is minimized when the erosive energy of water is lessened.

Mulching: There are two main purposes for applying mulch to disturbed land with respect to water erosion—to protect the soil surface from the forces of raindrops and overland flow. Mulches provide immediate protection from these forces. In addition, mulch can help in vegetative establishment by reducing evaporation and suppressing weed growth.

Mulch should be applied to disturbed soil in the time period before temporary or permanent vegetation is established, usually shortly following seeding. The needed sediment control practices such as diversions, grade stabilization structures, berms, dikes, and sediment basins should be installed prior to mulching or seeding. If there is a high probability of storms and the time it takes to install the sediment control practices is relatively long, then mulching should follow construction activities where immediate temporary stabilization of soil is necessary.

Drainage: The drainage ditches in the right-of-way are necessary to intercept storm water runoff and transport the flows to natural receiving waters. Often the drainage ditches must pass through a culvert, bridge, or other water or erosion control structure. To maintain the ability of the ditches and structures to transport the design flow rates, the ditches and entrances must be maintained too so that they are free flowing.

Open Natural Flow Patterns: Most drainage ditches are designed knowing that grasses and weeds will be maintained within the flow path of the channel. Vegetation, as stated above, is necessary to stabilize the channel and prevent soil erosion. Excess vegetation can accumulate especially in low areas where a wet soil conditions exist. The excess vegetation, however, may need to be mowed or sprayed. Vegetation changes the roughness or retards the flow in a channel and thus the ability to transport water. For example, a channel with grass and some weeds can transport 20 percent more flow than a channel with medium-high dense weed and 100 percent more flow than a channel with high dense weeds. Willow is vegetation that can severely retard flow. Another concern would be plant materials such as cattails and Johnson grass that can grow to a height of five feet, has thick stems, and forms dense vegetation. In these cases, it would be necessary to have a planned removal by using herbicides if they were established in a critical drainage channel.

Debris and Silt Removal: To maintain drainage capacity as designed, drainage structures should be maintained with no more than a maximum of 1/5 of the cross sectional silted. If the ditches have excessive amounts of silt, the silt should be removed.

Large amounts of debris should be disposed in a State-approved solid waste site or used in other revegetation efforts. Drainage structures should be checked within one month of a major storm event to insure all structures are in working order and debris will not hinder water flow.

AESTHETIC COMPONENTS

Roadside vegetation is not only important for safety and functional problems, but also for aesthetics. There are also environmental and economic considerations of maintaining an aesthetically pleasing highway right-of-way. Vegetation absorbs the kinetic energy of raindrop impact and buffers the soil from this erosive action. Velocity of runoff is also diminished with good surface cover. Vegetation also acts to minimize the wind impact on the soil surface in those areas susceptible to wind erosion.

A factor of equal importance to highway right-of-way vegetation is the soil chemical properties and amelioration of these problems or corrections of deficiencies. Again, there are many general references that address these problems but, for the most part, are not typically utilized in right-of-way vegetation management. Only in the most drastic cases in which a severe soil problem is encountered, are remedial actions taken.

Mowing and Litter Pickup: Litter pick up operations should be conducted *before* mowing operations. Mowing a littered portion of right-of-way would:

1. Increase the risk of the mowers striking unseen objects and causing harm to people, machinery, and passing traffic

2. Cause shredding of large pieces of litter, resulting in more time-consuming litter pickup operations

3. Expose more litter to view.

Loss of Established Vegetation: Loss of established vegetation can result in unsightly areas on right-of-ways.

1. Standard practices for renovating or repairing the vegetation are in a previous section (see Functional Components section).

2. Identify the cause for the vegetation loss such as lack of supplemental irrigation, soil compaction, damage by automobiles, and weather related issues.

3. Correct the cause for the vegetation loss. If the cause cannot be remediated, selection of a more tolerant plant material or permanent structures may be desired.

Ornamental Plantings (Urban): In the urban setting, ornamental plantings exist primarily for aesthetic purposes. For that reason, their overall appearance must meet higher standards than on rural right-of-ways.

Figure 5 - Ornamental plantings must meet higher standards in an urban setting.

1. Ornamental plantings of grasses, trees, and color plants may need to be supplied with permanent irrigation

2. Mulching of the plantings will help prevent excessive moisture loss. (These guidelines will be similar to those found in the turf seed establishment section.)

3. Trees will need to be pruned following standard pruning practices. Pruning will be done to shape the plant as well as for safety issues.

4. A greater plant pallet will generally be used to improve the aesthetic appeal. If plantings become old and worn, consider renovating with different plants or multiple species rather than with a monoculture. Limit the variety to no more than 6 species in any one area to prevent visual clutter.

Figure 6 - Many durable plants can be used in urban settings.

5. Mowing is generally done much more frequently.
6. Seed heads on the grass are considered to be unsightly.
7. Trees and shrubs will be shaped and limbed to provide better function as well as aesthetics.
8. When plantings are designed, consider the ease of maintenance before installation occurs.
9. Wildflowers are less dependable for instant color unless established for several years.

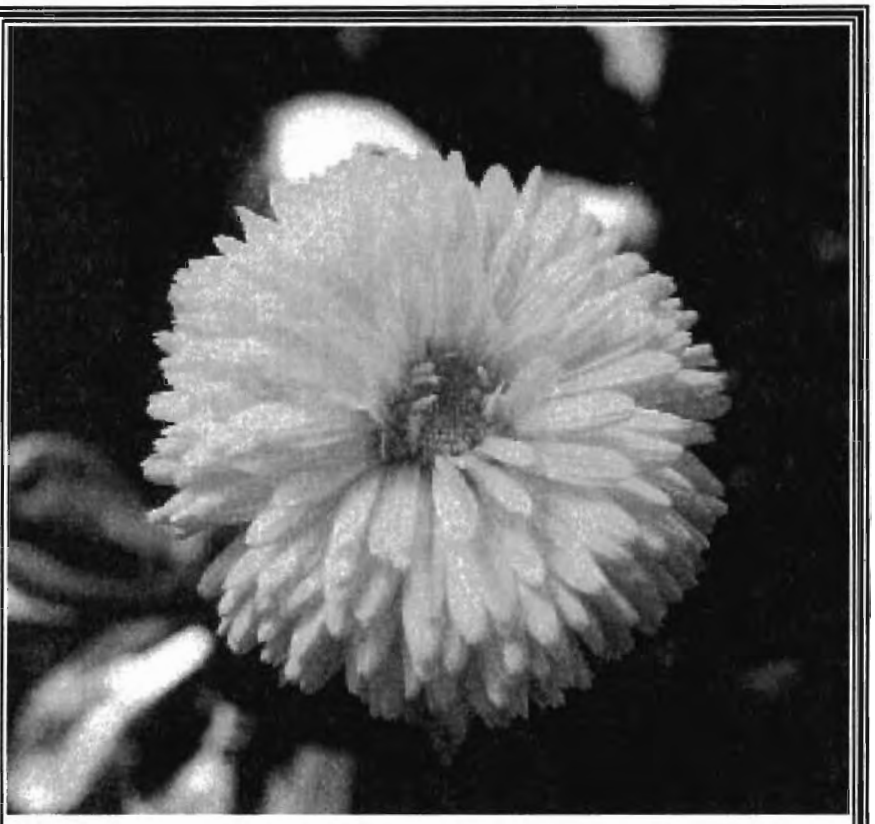

Figure 7 - Light colors are more visible at a distance.

10. Group similar water users together.

11. Amend beds with organic matter for better water retention and drainage.

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