VTrans Technical Landscape Manual

for Vermont Roadways and Transportation Facilities

JUNE 2005

***Cover Photo*: Interstate I-89, Randolph, Vermont.**

Technical Landscape Manual

for
Vermont Roadways & Transportation Facilities

Prepared by
Craig A. Dusablon, VTrans Landscape Coordinator

Jane C. Brown, VTrans Landscape Architect
802-828-2724

Funded by
VTrans
The Vermont Agency of Transportation
National Life Building
Montpelier, VT 05633

Acknowledgments

This guide was developed by the Vermont Agency of Transportation staff from the Operations and Program Development Divisions. Many thanks to the following for support and use of materials: United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS), N.Y. State Department of Transportation, United States Army Corps of Engineers (ACOE), the Federal Highway Authority (FHWA), Ducks Unlimited Canada and the Ontario Ministry of Transportation.

Graphic design and layout for this document was completed by Graphic Solutions of Middlebury, Vermont.

Related Documents

Landscape Guide for Vermont Roadways and Transportation Facilities, June 2002
Vermont Department of Forests, Parks and Recreation, Urban and Community Forestry Program

Recommended Trees for Vermont Communities, 2001
University of Vermont Extension

Planting Sustainable Landscapes- A Guide for Reviewers, 2001
Vermont Department of Forests, Parks and Recreation and the Vermont Chapter of the American Society of Landscape Architects

Bicycle and Pedestrian Facilities in Vermont:A Planning and Design Manual, 2002
The Vermont Agency of Transportation

Landscape Guide for Vermont Roadways & Transportation Facilities, 2002
Prepared by the Vermont Chapter of the American Society of Landscape Architects for the Vermont Agency of Transportation

Traffic Calming Process, 2003
The Vermont Agency of Transportation

Draft Traffic Calming Details
The Vermont Agency of Transportation,

Practice Standard,
Natural Resource Conservation Service (NRCS)

Vegetating with Native Grasses in Northeastern North America
Natural Resource Conservation Service (NRCS)

Table of Contents

1. Introduction/Purpose of the Document v
2. Grass Seed Establishment 2-1
   a. Best Management Practice (BMP 32) 2-1
   b. Critical Area Planting 2-9
   c. Vegetating with Native Grasses in Northeastern North America 2-15
   d. Seed Mixes: Urban Seed Mix 2-47
      Rural Seed Mix 2-47
      Low-Grow Seed Mix 2-47
      Wet Meadow and Riparian Mix 2-51
      Sand and Gravel Seed Mix 2-52
      Upland Native Mix for Dry Sites 2-52
3. Wildflowers 3-1
   a. What is Native? 3-1
   b. Wildflowers and the Federal Aid Program 3-2
   c. Native Wildflower Requirement Agreement - FHWA Executive Order 3-4
   d. Federal Regulations CFR ..... 3-?
4. Invasive Species 4-1
   a. Green Invasion 4-1
   b. The Problem with Invasive Plant Species 4-6
   c. Vermont Agency of Agriculture Noxious Plants Rule 4-6
   d. Vermont Agency of Agriculture Invasive Species Quarantine #3 4-10
   e. Executive Order and Federal Regulations 4-13
5. Establishment of Wet Area Vegetation along Highway Corridors 5-1
6. Soil 6-1
   a. How to take a Soil Sample 6-1
   b. Soil Test Report, University of Vermont 6-2
   c. University of Vermont Testing Lab Analysis Results 6-3
   d. Estimating Moisture Soil by Feel and Appearance 6-4
   e. Mycorrhizal Management 6-7
   f. Compost definition and Compost Use on State Highways 6-12
   g. CU - Structural Soil - An Innovative Medium under Pavement 6-19
7. Vermont Stormwater Management Manual: Introduction to Process 7-1
8. Trees 8-1
   a. Tree Benefits 8-1
   b. Selection and Variety/Bare Root and Balled and Burlapped 8-2
   c. Buying High Quality Trees 8-3
   d. New Tree Planting Methods 8-4
   e. Soil Volumes 8-6
   f. Tree Appraisal and Value 8-8
   g. Tree Health Assessment and Street Tree Inventories 8-10
   h. Maintenance- Pruning, Watering, Mulching 8-12
   i. Utility Conflicts 8-14
9. Treatment of Trees Damaged During Construction 9-1
10. Soil Bio-Engineering 10-1
   a. NYDOT – Soil Bio-Engineering Design Guidelines 10-1
   b. NYDOT – Soil Bio-Engineering Specifications 10-18
   c. NYDOT – Soil Bio-Engineering Details 10-32

Appendix A-1
   a. Invasive Species - Executive Order & Code of Federal Regulation A-1
   b. Wildflower - Executive Order & Code of Federal Regulation A-5
   c. Landscape web-sites A-7
   d. General Guidance for Landscaping Activities in the Highway Right-of-Way A-9

Bibliography B-1

Introduction

I Introduction

Purpose of the Document

This manual is meant to serve as a "how to" manual for landscape treatment for roadsides and transportation projects in Vermont. An earlier document entitled ***Landscape Guide for Vermont's Roadways and Transportation Projects (2002)*** was created for VTrans to outline the planning and design process answering why, when and where landscape may be integrated into transportation projects. This technical manual addresses specific areas and details involved with implementation of a broad range of topics such as: seeding for varied roadside conditions, erosion control, bio-engineering, soil improvements, tree planting, tree protection during construction, hazard tree assessment and critical area planting to name a few.

The purpose of the document is to provide information to select the appropriate materials and methods for various locations and site conditions. Emphasis is on developing specifications and on successful implementation for landscape improvements to transportation projects.

Users

This document shall be used by Divisions of the Vermont Agency of Transportation (VTrans) to include in planning, design and maintenance of transportation projects. Landscape architects and engineers who design for landscape improvements to transportation facilities may find helpful information as well. Contractors and those involved in environmental permitting may also find the document to be a useful resource. Towns and municipalities may also use the document for design and maintenance of local roadways.

Background

In recent years, tremendous improvements have occurred in the breadth and quality of scientific research in the many landscape topics that appear in this guide. The access to information has also expanded due to the ease of using the internet. Much of the information in the ***Technical Landscape Guide*** is a compilation of the best available data from other sources. We have received permission to present this information when appropriate as the most suitable at this time for implementation in Vermont. The goal of this guide is to put the most relevant, technical information for landscape improvements in one place for quick and easy reference. In order to stay up to date, the manual will need occasional updates. The ***Technical Landscape Manual*** will help to demystify the landscape process while providing sound, scientific methods and technical information.

2-a

Grass Seed Establishment: Best Management Practice (BMP 32)

The following excerpts are taken from "Best Management Practice (BMP 32)," U.S. Army Corp of Engineers, Environmental Section.

BMP: Permanent Seeding

Definition

The establishment of perennial vegetative cover on disturbed areas by planting seed.

Purposes

1. To reduce erosion and decrease sediment yield from disturbed areas.
2. To permanently stabilize disturbed areas in a manner that is economical, adaptable to site conditions, and allows selection of the most appropriate plant materials.
3. To improve wildlife habitat.
4. To enhance natural beauty.

Conditions Where Practice Applies

1. Disturbed areas where permanent, long-lived vegetative cover is needed to stabilize the soil.
2. Rough-graded areas which will not be brought to final grade for a year or more.

Planning Considerations

Vegetation controls erosion by reducing the velocity and the volume of overland flow and protecting the bare soil surface from raindrop impact.

Areas which must be stabilized after the land has been disturbed require vegetative cover. The most common and economical means of establishing this cover is by seeding grasses and legumes.

Advantages of seeding over other means of establishing plants include the small initial establishment cost, the wide variety of grasses and legumes available, low labor requirement, and ease of establishment in difficult areas.

Disadvantages which must be dealt with are the potential for erosion during the establishment stage, a need to reseed areas that fail to establish, limited periods during the year suitable for seeding, the potential need for weed control during the establishment phase, and a need for water and appropriate climatic conditions during germination.

There are so many variables in plant growth that an end product cannot be guaranteed. Much can be done in the planning stages to increase the chances for successful seeding. Selection of the right plant materials for the site, good seedbed preparation, and conscientious maintenance are important.

Selecting Plant Materials – The factors affecting plant growth are climate, soils, and topography. In selecting appropriate plant materials, one should take into account the characteristics of the physiographic region in which the project is located.

Soils – Soils can be modified with lime and fertilizer, but climate cannot be controlled. Microclimate, or localized climate conditions, can affect plant growth. A south-facing slope is drier and hotter than a north-facing slope, and may require drought-tolerant plants. Shaded areas require shade-tolerant plants; the windward side of a ridge will be drier than the leeward, etc.

Land Use – A prime consideration in selecting which plants to establish is the intended use of the land. All of these uses –

residential, industrial, commercial, recreational – can be separated into two major categories: high-maintenance and low-maintenance.

High-Maintenance will be mowed frequently, limed and fertilized regularly, and will either receive intense use (e.g., athletics) or require maintaining to an aesthetic standard (home lawns). Grasses used for these situations must be fine-leaved and attractive in appearance, able to form tight sod, and be long-lived perennials. They must be well-adapted to the geographic area where they are planted, because constant mowing puts turf under great stress. Sites where high-maintenance vegetative cover is desirable include homes, industrial parks, schools, churches, athletic playing surfaces as well as some recreational areas.

Low-maintenance areas will be mowed infrequently or not at all; lime and fertilizer may not be applied on a regular basis; the areas will not be subjected to intense use, nor required to have a uniform appearance. These plants must be able to persist with little maintenance over long periods of time. Grass and legume mixtures are favored for these sites because legumes are capable of fixing nitrogen from the air for their own use, and the use of the plants around them. Such mixed stands are better able to withstand adverse conditions.

Sites that would be suitable for low-maintenance vegetation include steep slopes, stream or channel banks, some commercial properties, and "utility turf" areas such as roadbanks.

Seedbed Preparation – The soil on a disturbed site must be modified to provide an optimum environment for seed germination and seedling growth. The surface soil must be loose enough for water infiltration and root penetration. The pH (acidity and alkalinity) of the soil must be such that it is not toxic and nutrients are available, usually between pH 6.0-7.0. Sufficient nutrients (added as fertilizer) must be present. After seed is in place, it must be protected with a mulch to hold moisture and modify temperature extremes, and to prevent erosion while seedlings are growing.

The addition of lime is equally as important as applying fertilizer. Lime is best known as a pH, or acidity, modifier, but it also supplies calcium and magnesium which are plant nutrients. Its effect on pH makes other nutrients more available to the plant. It can also prevent aluminum toxicity by making aluminum less soluble in the soil.

Maintenance – Even with careful, well-planned seeding operations, failures can occur. When it is clear that plants have-not germinated on an area or have died, these areas must be reseeded immediately to prevent erosion damage. However, it is extremely important to determine for what reason germination did not take place and make any corrective action necessary prior to reseeding the area. Healthy vegetation is the most effective erosion control available.

Specifications

Selection of Plant Materials -

Selection of plant materials is based on climate, topography, soils, land use, and planting season. To determine which plant materials are best adapted to a specific site, use Tables 32-1 and 32-2 which describe plant characteristics and list recommended varieties.

Seedbed Requirements—

Vegetation should not be established on slopes that are unsuitable due to inappropriate soil texture, poor internal structure or

internal drainage, volume of overland flow, or excessive steepness, until measures have been taken to correct these problems.

To maintain a good stand of vegetation, the soil must meet certain minimum requirements as a growth medium. The existing soil must have these characteristics:

1. Enough fine-grained material to maintain adequate moisture and nutrient supply.
2. Sufficient pore space to permit root penetration. A bulk density of 1.2 to 1.5 indicates that sufficient pore space is present. A fine granular or crumb-like structure is also favorable.
3. Sufficient depth of soil to provide an adequate root zone. The depth to rock or impermeable layers such as hardpans shall be 300 millimeters (12 inches) or more, except on slopes steeper than 2:1 where the addition of soil is not feasible.
4. A favorable pH range for plant growth. If the soil is so acidic that a pH range of 6.0-7.0 cannot be attained by addition of ph-modifying materials, then the soil is considered an unsuitable environment for plant roots and further soil modification would be required.
5. Freedom from toxic amounts of materials harmful to plant growth.
6. Freedom from excessive quantities of roots, branches, large stones, large clods of earth, or trash of any kind. Clods and stones may be left on slopes steeper than 3:1 if they do not significantly impede good seed soil contact.

If any of the above criteria cannot be met, i.e., if the existing soil is too coarse, dense, shallow, acidic, or contaminated to foster vegetation, then topsoil shall be applied.

Necessary structural erosion and sediment control practices will be installed prior to seeding. Grading will be carried out according to the approved plan.

Soil Conditioners—

In order to modify the texture, structure, or drainage characteristics of a soil, the following materials may be added to the soil:

1. Peat is a very costly conditioner, but works well. If added, it shall be sphagnum moss peat, hypnum moss peat, reed-sedge peat or peat humus, from fresh-water sources. Peat shall be shredded and conditioned in storage piles for at least six months after excavation.
2. Sand shall be clean and free of toxic materials. Sand modification is ineffective unless you are adding 80 to 90% sand on a volume basis. This is extremely difficult to do on-site. If this practice is considered, consult a professional authority to ensure that it is done properly.
3. Vermiculite shall be horticultural grade and free of toxic substances. It is an impractical modifier for larger acreage due to expense.
4. Raw manure, is more commonly used in agricultural applications. However, when stored properly and allowed to compost, it will stabilize nitrogen and other nutrients. Manure, in its composted form, is a viable soil conditioner; however, its use should be based on site-specific recommendations offered by a professional in this field.
5. Thoroughly rotted sawdust shall have 3.5 kilograms of nitrogen added to each cubic meter (6 pounds per cubic yard) and shall be free of stones, sticks, and toxic substances.
6. The use of treated sewage sludge has benefitted from continuing advancements in its applications in the agricultural

community. When composted, it offers an alternative soil amendment. Limitations include a potentially undesirable pH (because of lime added during the treatment process) and the possible presence of heavy metals. This practice should be thoroughly evaluated by a professional and be used in accordance with any local, state, and federal regulations.

Lime and Fertilizer

Lime and fertilizer needs should be determined by soil tests. Soil tests may be performed by a reputable commercial laboratory.

Under unusual conditions where it is not possible to obtain a soil test, the following soil amendments will be applied:

LIME

4,480 kg/ha (2 tons/acre) pulverized agricultural grade limestone (448 kg/1000 m^2 - 90 lbs/1000 ft^2)

Note: An agricultural grade of limestone should always be used.

FERTILIZER

Mixed grasses and legumes:

1,120 kg/ha (1000 lbs/acre) of 10-20-10 or equivalent nutrients (112 kg/1 000 m^2 - 1000 23 lbs./l 000 ft^2).

Legume stands only:

1,120 kg/ha (1000 lbs/acre) 5-20-10 (112 kg/ 1000 m^2 -23 lbs/1000 ft^2) is preferred; however, 1,120 kg/ha (1000 lbs/acre) of 10-20-10 or equivalent may be used.

Grass stands only:

1,120 kg/ha (1000 lbs/acre) 10-20-10 or equivalent nutrients, (112 kg/1000 m2 - 1000 23 lbs./l000 ft^2).

Other fertilizer formulations, including slow-release sources of nitrogen (preferred from a water quality standpoint), may be used provided they can supply the same amounts and proportions of plant nutrients.

Incorporation – Lime and fertilizer shall be incorporated into the top 100-150 millimeters (4-6 inches) of the soil by disking or other means whenever possible. For erosion control, when applying lime and fertilizer with a hydroseeder, apply to a rough, loose surface.

Seeding

1. Certified seed will be used for all permanent seeding whenever possible. Certified seed is inspected by the state certifying agency. The seed must meet published state standards and bear an official "Certified Seed" label.
2. Legume seed should be inoculated with the inoculant appropriate to the species. Seed of the Lespedezas, the Clovers and Crownvetch should be scarified to promote uniform germination.
3. Apply seed uniformly with a broadcast seeder, drill, culti-packer seeder, or hydroseeder on a firm, friable seedbed. Seeding depth should be ¼ to ½ inch.
4. To avoid poor germination rates as a result of seed damage during hydroseeding, it is recommended that if a machinery breakdown of 30 minutes to 2 hours occurs, 50% more seed be added to the tank, based on the proportion of the slurry remaining in the tank. Beyond 2 hours, a fill rate of new seed may be necessary.

Often hydroseeding contractors prefer not to apply lime in their rigs as it is abrasive. In inaccessible areas, lime may have to be applied separately in pelletized or liquid form. Surface roughening is particularly important when hydroseeding, as a roughened slope will provide some natural coverage of lime, fertilizer and seed.

Legume inoculants should be applied at five times the recommended rate when inoculant is included in the hydroseeder slurry.

Mulching

All permanent seeding must be mulched immediately upon completion of seed application.

Maintenance of New Seedlings

In general, a stand of vegetation cannot be determined to be fully established until it has been maintained for one full year after planting.

Irrigation: New seedlings should be supplied with adequate moisture. Supply water as needed, especially late in the season, in abnormally hot or dry weather, or on adverse sites. Water application rates should be controlled to prevent excessive runoff. Inadequate amounts of water may be more harmful than no water.

Re-seeding: Inspect seeded areas for failure and make necessary repairs and re-seedings within the same season, if possible.

a. If vegetative cover is inadequate to prevent rill erosion, over-seed and fertilize in accordance with soil test results.

b. If a stand has less than 40% cover, re-evaluate choice of plant materials and quantities of lime and fertilizer. The soil must be tested to determine if acidity or nutrient imbalances are responsible. Reestablish the stand following seedbed preparation and seeding recommendations.

Fertilization: Cool season grasses should begin to be fertilized 90 days after planting to ensure proper stand and density. Warm season fertilization should begin at 30 days after planting.

Apply maintenance levels of fertilizer as determined by soil test. In the absence of a soil test, fertilization should be as follows:

Cool Season Grasses (per 1000 m^2 per year)

20 kg nitrogen (N) (4 lbs/1000 ft^2)

5 kg phosphorus (P) (1 lbs/1 000 ft^2)

10 kg potash (K) (2 lbs/1 000 ft2)

Seventy-five percent of the total requirements should be applied between September 1 and December 31st. The balance should be applied during the remainder of the year. **More than 5 kg, of soluble nitrogen per 1000 m^2 should not be applied at any one time (1 lb per 1,000 ft^2)**

Warm Season Grasses

Apply 20-25 kg (4-5 lbs/1 000 ft^2) nitrogen (N) between May 1 and August 15th per 1000 m^2 per year.

Phosphorus **(**P) and Potash (K) should only be applied according to soil test.

Note: The use of slow-release fertilizer formulations for maintenance of turf is encouraged to reduce the number of applications and the impact on groundwater.

TABLE 32-1 CHARACTERISTICS OF COMMONLY SELECTED GRASSES

	Common Name *(Botanical Name)*	Life Cycle	Season	pH Range	Germination Time in Days	Optimum Germination Temperature (°F)	Winter Hardiness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seed Per Pound	Maintenance Requirements	Remarks
	Tall Fescue *(Festuca arundinacea)*	Perennial	Cool Season Plant	5.5 -6.2	10-14	60-85	Fair	Fair	Medium	Somewhat Poorly Drained	225K	Low when used for erosion control; high when used in lawn.	Better suited for erosion control and rough turf application.
	Tall Fescues (Improved)	Perennial	Cool Season Plant	5.5 -6.2	10-14	60-85	Fair	Good	Medium	Somewhat Poorly Drained	220K	Responds well to high maintenance	Excellent for lawn and fine turf.
	Kentucky Bluegrass *(Poa pratense)*	Perennial	Cool Season Plant	6.0 -6.5	14	60-75	Good	Poor	Medium	Somewhat Poorly Drained	2.2M	Needs fertile soil, favorable moisture. Requires several years to become well established.	Excellent for fine turfs; takes traffic, mowing. Poor drought, heat tolerance.
	Perennial Ryegrass *Lolium perenne)*	Perennial	Cool Season Plant	5.8 -6.2	7-10	60-75	Fair	Fair	Medium-High	Somewhat Poorly Drained	227K	Will tolerate traffic.	May be added to mixes. Improved varieties will perform well all year.
FINE FESCUES	Hard Fescue *(Festuca ovina duriuscula)*	Perennial	Cool Season Plant	5.0 -6.2	10-14	60-80	Very Good	Good	Low	Moderately Well Drained	400K	Grows well in sun or shade and will tolerate infertile soils; improved for disease resistance.	Exceeds all fine fescues in most tests. Excellent low-maintenance situations.
FINE FESCUES	Chewings Fescue	Perennial	Cool Season Plant	5.0-8.2	10-14	60-80	Very Good	Good	Low	Moderately Well Drained	400K	Tolerates shade, dry infertile soils.	Poor traffic tolerance, less thatch than other fine fescues.
FINE FESCUES	Creeping Red Fescue *(Festuca rubra)*	Perennial	Cool Season Plant	5.0-8.2	10-14	60-80	Very Good	Good	Low	Moderately Well Drained	400K	Low to medium fertility requirements. Requires well drained soil.	Spreads by rhizomes, tillers and stolons. WIll not take traffic - very shade tolerant.

TABLE 32-1 CHARACTERISTICS OF COMMONLY SELECTED GRASSES

Common Name *(Botanical Name)*	**Life Cycle**	**Season**	**pH Range**	**Germination Time in Days**	**Optimum Germination Temperature (°F)**	**Winter Hardiness**	**Drought Tolerance**	**Fertility**	**Soil Drainage Tolerance**	**Seed Per Pound**	**Maintenance Requirements**	**Remarks**
Redtop *(Agrostis alba)*	Perennial	Cool Season Plant	5.8 - 6.2	10	65-85	Good	Fair	Low	Poorly Drained	5M	Will tolerate poor, infertile soils; deep rooted	Does well in erosion control mixes-not for lawns
Weeping Lovegrass *(Eragrostis curvula)*	Perennial	Warm Season Plant	4.5 -6.2	14	65-85	Fair -Poor	Good	Low - Medium	Somewhat Poorly Drained	1.5M	Low-fertility requirements; tolerance.	Fast-growing, warm-season Excellent cover for erosion control.
Berrnuda grass *(Cynodon dactylon)*	Perennial	Warm Season Plant	5.8-6.2	21	70-95	Poor	Good	Medium - High	Somewhat Poorly Drained	1.8M hulled	High nitrogen utilization, excellent drought tolerance.	Common varieties used for erosion control. Hybrids used for fine turf.
Orchardgrass *(Dactylis glomerata)*	Perennial	Cool Season Plant	5.8-6.2	18	60 -75	Fair	Fair	Medium	Somewhat Poorly Drained	625K	Does best on well-drained, loamy soil	Good pasture selection -may be grazed.
Annual Ryegrass *(Lolium multiflorum)*	Annual	Cool Season Plant	5.8-6.2	7	60-70	Good	Poor	Medium - High	Somewhat Poorly Drained	227 K	Do not use in fine-turf areas.	May be added into mixes or established alone as temporary cover in spring and fall.
Rye Grain *(Secale cereale)*	Annual	Cool Season Plant	5.8-6.2	7	55-70	Very Good	Good	Low - Medium	Somewhat Poorly Drained	18K	Do no use in fine-turf areas.	May be added into mixes or established alone for late fall/ winter cover.
Foxtail Millet *(Setaria italica)*	Annual	Warm Season Plant	5.8-6.2	10	65-85	Very Poor	Good	Medium	Moderately Well Drained	220K	Establishes well during summer. Very low moisture requirements.	May be added to erosion-control mixes or established alone.

TABLE 32-2 CHARACTERISTICS OF LEGUMES APPROPRIATE FOR EROSION CONTROL

Common Name *(Botanical Name)*	**Life Cycle**	**Season**	**pH Range**	**Germination Time in Days**	**Optimum Germination Temperature (°F)**	**Winter Hardiness**	**Drought Tolerance**	**Fertility**	**Soil Drainage Tolerance**	**Seed Per Pound**	**Maintenance Requirements**	**Remarks**
Sericea Lespedeza *(Lespedeza cuneata)*	Perennial	Warm Season Plant	5.8 -6.2	21 -28	70-85	Fair	Very Good	Low	Moderately Poorly Drained	335K	Grows in most well-drained soils, Low fertility requirements. Inoculation is essential.	Use hulled seed in spring; unhulled in fall. Very deep rooted legume.
Lathco Flatpea *(Lathyrus sylvestris)*	Perennial	Cool Season Plant	5.0-7.0	14-28	65-75	Good	Good	Low	Poorly Drained	15K	Needs lime and high phosphorus, Good shade tolerance.	Tolerates acidic and wetter soils better than other legumes.
Birdsfoot Trefoil *(Lotus corniculatus)*	Perennial	Cool Season Plant	6.0 -6.5	7	65-70	Good	Fair	Medium	Somewhat Poorly Drained	375K	Inoculation is essential. Grows in medium-fertile, slightly acid soils.	Grows better on poorly drained soils than most legumes. Poor drought/heat tolerance.
Annual Lespedezas *(Lespedeza striata, L. stipulacea)*	Annual	Warm Season Plant	5.8 -6.2	14	70-85	Fair	Very Good	Low	Moderately Well Drained	200K	WIll grow on almost any well-drained soil.	Needs almost no nitrogen to survive.
Red Clover *(Trifolium pratense)*	Perennial	Cool Season Plant	6.0-8.5	7-14	70	Good	Fair	Medium	Somewhat Poorly Drained	275K	Needs high levels of phosphorus and potassium. mixes.	Acts as a biennial. Can be added to low-maintenance
White Clover *(Trifolium repens)*	Perennial	Cool Season Plant	6.0-8.5	10	70	Good	Poor	Medium	Poorly Drained	700K	Requires favorable moisture, fertile soils, high PH.	Spreads by soil surface stolons, white flowers.

2-b

Grass Seed Establishment: Critical Area Planting

The following excerpts are modified with permission from "Critical Area Planting," the United States Department of Agriculture (U.S.D.A.) and the Natural Resource Conservation Service (N.R.C.S.)

Definition

Establishing permanent vegetation on sites that have or are expected to have high erosion rates, and on sites that have physical, chemical or biological conditions that prevent the establishment of vegetation with normal practices.

Purpose

- Stabilize areas with existing or expected high rates of soil erosion by water.
- Stabilize areas with existing or expected high rates of soil erosion by wind.
- Restore degraded sites that cannot be stabilized through normal methods.

Conditions where practice applies

On areas with existing or expected high rates of erosion or degraded sites that usually cannot be stabilized by ordinary conservation treatment and/or management, and if left untreated, could be severely damaged by erosion or sedimentation or could cause significant off-site damage.

Criteria

General Criteria Applicable To All Purposes

Species selected for seeding or planting shall be suited to current site conditions and intended uses. Selected species will have the capacity to achieve adequate density and vigor within an appropriate time frame to stabilize the site sufficiently to permit suited uses with ordinary management activities.

Species, rates of seeding or planting, minimum quality of planting stock, such as PLS or stem caliper, and method of establishment shall be specified before application. Only viable, high quality seed or planting stock will be used.

Site preparation and seeding or planting shall be done at a time and in a manner that best ensures survival and growth of the selected species. What constitutes successful establishment, e.g. minimum percent ground/canopy cover, percent survival, stand density, etc. shall be specified before application.

Fertilization, mulching, or other facilitating practices for plant growth shall be timed and applied to accelerate establishment of selected species. If the recommended fertilizer rate exceeds the criteria in Conservation Practice Standard (590) Nutrient Management, appropriate mitigating practices will be installed to reduce the risk of nutrient losses from the site.

Comply with all applicable federal, state, and local laws, rules, and regulations.

Where possible, grade the area to make planting and maintenance feasible. Slopes must be stable to achieve successful establishment. A slope stability analysis shall be performed where slopes are steeper than 3:1 where other practices and near by structures and facilities could be affected by an unstable slope. Slopes shall not exceed 1.5:1 (1.5 horizontal feet for 1 vertical foot) to achieve stability. A final slope of 3:1 or flatter is preferred to facilitate equipment use.

Install water control practices such as diversions and waterways as needed.

Perform cultural practices as near to contour as practicable. Remove all large stones and other debris.

Apply lime to attain a pH of 6.0, if required by the selected seed mixture. Where possible, incorporate lime and fertilizer into the top two inches of soil.

Additional Criteria Applicable To Temporary Grass or Grain Cover

Select a temporary seeding recommendation from Table 1. Cover grass seed with 1/4 inch of soil. Cover rye or other grain seed with one to two inches of soil.

Fertilize temporary grass or grain cover according to soil test. In lieu of soil test, fertilize as follows:

Fertilizer	Grass Mixture (lbs.)	Grass/Legume Mixture (lbs.)
Nitrogen (N)	60	30
Phosphorous (P_2O_5)	30	30
Potassium (K_2O)	30	60

On sites within 50 feet of a water source use half this rate or none at all if there is potential for runoff to enter the water.

Apply mulch to establish adequate ground cover and reduce erosion. Apply hay or straw mulch at a rate of two tons per acre. In areas with a plan to restore a threatened or endangered plants use only weed free straw.

Additional Criteria Applicable To Permanent Grass and/or Legume Cover

Topsoil should be stockpiled in the early stages of the project. This topsoil should be later used to spread a cap (preferably 3 to 4 inches) over the area to be permanently vegetated. The use of topsoil for establishing vegetation in these areas will greatly enhance the seeding efforts. Use topsoil where a good, vigorous sod is needed, such as an auxiliary spillway, or where percent fines are less than 25%.

Seeding should be done immediately after construction or site preparation. Fertilize and lime according to a soil test. In lieu of soil test, fertilize with 10-20-20 at a rate of 500 lbs. per acre (11 lbs. per 1000 square feet). Use caution with this high rate of fertilizer where surface waters may be impacted by storm event before seedling establishment. Lime shall be applied at a rate of 2 tons per acre. Site specific conditions will determine if manure or other biosolids may be used as an alternative source of nutrients.

Table 1 - Temporary Seeding Recommendations by Rate and Site Adaptation

Species/Mixture Adaptation	Rate in LBS/Acre (LBS/1000 Sq. Ft.)	Recommended Cut-Off Date for Seeding	Site	Notes
Annual Ryegrass	20 (0.5)	September 15	A	Not always winter hardy
Perennial Ryegrass	20 (0.5)	June 1	A	
Oats	96 (2.25)	June 1(Aug 15)	A	Winter Kills
Cereal Rye	90 (2.0) 120 (if not drilled)	October 15	A	Known as "Winter Rye"
Annual Ryegrass & Oats	10 (0.25) 64 (1.5)	June 1	A	Oats Winter Kill
Weeping Lovegrass	5 (0.1)	June 1	B	

A - Well drained to somewhat poorly drained
B - Droughty and excessively drained

Select a permanent seeding recommendation from Table 2 or 3. Cover grass and/or legume seed with 1/4 inch of soil unless seeded by hydroseeder. Cultipacking or tracking the site with a dozer will improve seed to soil contact and enhance uniformity of germination.

Seeding should be done as early as possible in the spring and no later than June 1. Seeding in late summer or fall can be done between August 15 and September 15. These late season plantings are not recommended for mixes 12, 15a, 15b, 18 and 19 in Table 3.

Table 2 - Permanent Seeding Recommendations by Use and Mowing Level

PRINCIPLE USE (A)	MIX NUMBER (MOWED)	MIX NUMBER (NOT MOWED)
Borrow Areas (A)	1,2,6 or 9	Any Mix except 4
Dikes, Levees, Dams & Pond Banks	1,2,6,9 or 13	3 or 7
Drainage Ditches & Channel Banks	1,2,6 or 9	1,2,3,6, or 9
Diversion (B)	2,6 or 9	2
Diversion	2,6 or 9	2
Effluent Disposal Area	Not Recommended	7 & 13
Gravel Pits (A&C)	Not Recommended	10 or 12
Gullied & Eroded Areas	Not Recommended	2,9,11 or 13
Reclaimed Landfill with Liner	Not Recommended	10,11, or 12
Mine, Waste & Other Spoil Banks (A)	Not Recommended	3,10, or 12
Recreation Seeding (D)		
Not Shaded	1,2,4, or 14	Not Recommended
Shaded	1,2,4, or 5	Not Recommended
Road Side & Other Slopes and Banks (A)	1,2,6, or 9	2,3 or 10
Shoreline & Fluctuating Water Levels	Not Recommended	7 & 13
Ski Slopes	Not Recommended	2 or 8
Sod Waterways & Spillways	1,2,3,6 or 9	1,2,3,6 or 9
Sod Waterways & Spillways (B)	1,2,3,6 or 9	1,2,3,6 or 9
Staging Areas	Not Recommended	6
Streambanks	6 or 13	2,7,9, or 13
Utility Rights-of-Way (A)	Not Recommended	1,2,10 or 12
Woods, Road & Skid Trails		
Not Shaded	Not Recommended	1,2,6 or 9
Shaded	Not Recommended	1,5 or 6

(A) - If suppression of woody growth is desired, and site conditions allow use mix number 18, 19 or 20

(B) - For detail on vegetating sandy and gravelly areas, see Vermont NRCS Publication “Vegetating Vermont Sand and Gravel Pits” in Vermont Conservation Planning Technical References.

(C) - Designed for bare ground velocity.

(D) - Select mix based on percent fines.

TABLE 3 - Permanent Seeding Recommendation by Rate and Site Adaptation

Soil Site Adaptation (A)	Mix#	Seed Mixture	Variety	Rate in LBS/ Acre (LBS/ 1000 Sq. Ft.)
Well to Mod. Well Drained	1	Kentucky Bluegrass	Adelphi/Barron	20 (0.5)
		Creeping Red Fescue	Ensylva	20 (0.5)
		Ryegrass or	Pennfine	5 (0.1)
		Redtop	Common	2 (0.1)
	2	Creeping Red Fescue	Ensylva	20 (0.5)
		Redtop and	Common	2 (0.1)
		Birdsfoot Trefoil	Empire	8 (0.2)
	3	Smooth Bromegrass	Saratoga	15 (0.33)
		Ryegrass	Pennfine	5 (0.1)
		Birdsfoot Trefoil	Empire	
	4	Tall Fescue	KY-31	20 (0.5)
Well to Poorly Drained	5	Creeping Red Fescue	Ensylva	40 (0.9)
		Kentucky Bluegrass	Adelphia/Barron	20 (0.5)
	6	Creeping Red Fescue	Ensylva	20 (0.5)
		Redtop	Common	2 (0.1)
		Tall Fescue or	KY-31	20 (0.5)
		Smooth Bromegrass	Saratoga	20 (0.5)
	7	Reed Canarygrass **(B)**	Palaton/Venture	15 (0.33)
		Creeping Foxtail	Garrison	5 (0.1)
		Redtop	Common	5 (0.1)
		White Clover	Dutch type	2 (0.1)
	8	Tall Fescue	KY-31	10 (0.25)
		Redtop	Common	2 (0.1)
		White Clover	Ladino type	7 (0.2)
Excessively to Mod. Well Drained	9	Creeping Red Fescue	Ensylva	20 (0.5)
		Tall Fescue or	KY-31	20 (0.5)
		Smooth Bromegrass	Saratoga	20 (0.5)
		Birdsfoot Trefoil	Empire	8 (0.2)
	10	Switchgrass	Shelter/Blackwell	4 (0.1) **PLS**
		Big Bluestem	Niagara	4 (0.1) **PLS**
		Little Bluestem	Aldous/Camper	2 (0.05) **PLS**
		Sand Lovegrass	NE-27/Bend	1.5 (0.05) **PLS**
		Birdsfoot Trefoil	Viking	2 (0.05) **PLS**
	11	Switchgrass	Shelter/Blackwell	20 (0.5) **PLS**
	12	Tall Fescue	KY-31	10 (0.25)
		Redtop	Streaker/Common	2 (0.05)
		Birdsfoot Trefoil	Viking/Empire	5 (0.1)
Not Specific	13	Tall Fescue	KY-31	20 (0.5)
		Reed Canarygrass **(B)**	Palaton/Venture	10 (0.25)
		Redtop	Common	3 (0.1)
	14	Tall Fescue	KY-31	100 (2.5)

(A) -For details on vegetating sandy or gravelly areas, see FOTG Number Technical Reference CPA #10 – "Vegetating Vermont Sand and Gravel Pits."

(B) -Reed Canarygrass - Use only seed with germination rate of 70% or better that has been tested within the past four of five months. **Do not seed in wet areas where it may become invasive to natural habitats.**

(PLS) -Pure Live Seed - Warm season grass seed is sold and planted on the basis of pure live seed (PLS). An adjustment is made to the bulk pounds of seeded to compensate for inert materials and dead seed.

Inoculate legume seed at two times the rate prescribed by the seed dealer immediately prior to the seeding. Inoculate legume seed four times the prescribed rate if hydroseeding.

Hay or straw mulch shall be applied at a rate of two tons per acre (50 lbs. per square foot). When using mixes 12 and 15a in Table 3, apply "weed free" mulch at a rate of 500 to 750 lbs. per acre.

During the second growing season all areas without adequate plant cover shall be scarified (if necessary), fertilized and reseeded. Where required in the plan, mow annually. If ground nesting bird populations are of concern, refrain from mowing until July 15 or later. Caution is needed if warm season grasses are to be mowed. They should be mowed prior to August 15 and not closer than eight inches to the ground surface. Once a good cover is established, topdress in early spring to maintain good plant growth. Typical topdress applications would include:

Fertilizer	Grass Mixture (lbs.)	Grass/Legume Mixture (lbs.)
Nitrogen (N)	60	30
Phosphorous (P_2O_5)	30	60
Potassium (K_2O)	30	60

Mow, lime and fertilize as needed to maintain adequate growth.

Additional Criteria Applicable To Shrubs and Ground Cover Plantings

Use good planting stock, adapted to soil and site conditions. Special plants require special handling and care. See http://plants.usda.gov/ and pull up plants fact sheets, and contact the State Resource Conservationist for assistance in selecting appropriate plant type and species.

Keep plants moist and cool until planted. Dormant stock should not have initiated growth. Plant in early spring and some species in early fall. The density of cover and species type will govern plant spacing.

Check plants in the spring of the second year of growth. Replant if necessary.

Additional Criteria To Restore Degraded Sites

If gullies or deep rills are present, they will be treated, if feasible, to allow equipment operation and ensure proper site and seedbed preparation.

Soil amendments will be added as necessary to ameliorate or eliminate physical or chemical conditions that inhibit plant establishment and growth. Required amendments, such as compost or manure to add organic matter and improve soil structure and water holding capacity; agricultural limestone to increase the pH of acid soils; or elemental sulfur to lower the pH of calcareous soils shall be included in the site specification with amounts, timing, and method of application.

Considerations

Native species or mixes that are adapted to the site and have multiple values should be considered.

Avoid species that may harbor pests. Species diversity should be considered to avoid loss of function due to species-specific pests.

Some seed mixtures contain KY-13 tall fescue that contains an endophyte harmful to grazing animals.

In using perennial ryegrass within a mixture it is critical to select only those varieties with a known adaptation in Vermont, such as Yorktown II, Manhattan, Diplomat, Omega and Pennfine. Do not use Tetraploid varieties.

Some site locations and conditions may require more innovative approaches to

establish adequate cover. For these sites the State Resource Conservationist may elect to refer the site directly to the Plant Materials Specialist.

If mature tree cover is the ultimate goal of a plan, use a temporary herbaceous seeding recommendation listed in Table 1. These may also be used when herbicide residue is likely to preclude successful establishment of perennial species.

plans and Specifications

Specifications for applying this practice shall be prepared for each site and recorded and filed using the approved specification sheets or narrative statements in the conservation plan.

Operation and Maintenance

Use of the area shall be managed as long as necessary to stabilize the site and achieve the intended purpose.

Control or exclude pests that will interfere with the timely establishment of vegetation.

Inspections, reseeding or replanting, fertilization, and pest control may be needed to insure that this practice functions as intended throughout its expected life.

Mowing of vegetation shall be done only at specified times.

If required to maintain the vegetative stand remove trees, brush and other woody vegetation.

Grazing in areas of Critical Area Planting shall not be permitted and livestock shall be excluded at all times.

Inspect and repair water control practices as needed.

Vegetation used on streambanks is subject to considerable damage. The site should be inspected annually in the spring and after heavy run-off to check for needed repairs. Gaps should be filled in by replanting, or laying down and covering the branches with soil of nearby plants. Any structural measures used to control the bank, such as stone riprap, must be kept in repair in order to maintain the effective willow cover.

References

http://plant-materials.nrcs.usda.gov/technicalpublications/critical.html

2-c

Vegetating with Native Grasses in Northeastern North America

The following excerpts are taken from "Vegetating with Native Grasses in Northeastern North America", USDA-NRCS and Ducks Unlimited Canada:

John Dickerson*
Dave Burgdorf
Tony Bush
Chris Miller

Brent Wark*
Ron Maher
Bill Poole**

*Senior Authors ** Editor

Natural Resources Conservation Services Ducks Unlimited Canada

First printing November 1997
Second printing March 1998

Acknowledgements

The information contained in this document was assembled from cited references and from personal experience in the field establishing native grasses on the landscape. We have also drawn on the experience of colleagues in Ducks Unlimited Canada and in the USDA-NRCS Plant Materials Program. Their willingness to share that experience has improved this document.

The format and approach follows the previous manuals jointly published by NRCS and DUC; *Revegetating with Native Grasses* (1995) and the *Native Grass Seed Production Manual* (1997). Information contained in the 1995 revegetation manual was especially useful during the preparation of this publication.

Encouragement and support for the initiation of this project was received from Dr. Terry Neraasen, then chief biologist with Ducks Unlimited Canada, and from Dr. Rick White, program leader, NRCS Plant Materials Program and from Dr. Billy Teels, director, NRCS Wetland Science Institute.

The senior authors also wish to acknowledge the singular efforts of Lynne Miller, who spent countless hours typing the many drafts which preceded the document you now hold, and Bill Poole, who edited the text and combined the input of six authors into a useful publication.

Finally, we would like to say "thank you" to the following companies who provided financial support for the printing of this manual:

- Ag Renewal Inc.
- Blight Native Seeds
- Newfield Seeds
- Pickseed Canada Inc.
- Prairie Farm Rehabilitation Administration
- Truax Inc.
- Wind River Seeds

John Dickerson
Plant Materials Specialist
NRCS, Syracuse, NY

Brent Wark
Plant Materials Specialist
Ducks Unlimited Canada

What is Native?

When applied to plant species, the word **native** often means different things to different people. In this manual, native is used to refer to the species indigenous to a region at the time of European settlement.

The grasses brought to North America by our forefathers were imported primarily from agriculture. These plants were so highly adapted to northeastern conditions and planted so extensively that they have outcompeted native grasses in many of the ecosystems of the region. Those grasses have long been naturalized in the eastern regions of North America. A **naturalized** plant is one that is known to have originated outside of a particular region, but currently exists in the wild in self perpetuating populations.

While there are specific characteristics common to a species – regardless of place of origin – that distinguish it from other species, there are also adaptations within a species that separate it into **ecotypes**. One ecotype differs from another in specific morphological and physiological traits such as height, hardiness or growth rate.

An ecotype grown out of its area of adaptation is not likely to perform well and may not even survive. However, the opposite may also be true; a species brought into an area may be overly competitive to other desirable plants. Either of these situations could be costly and time consuming to correct. Experience has shown that ecotypes moved too far north tend to have hardiness problems, while those moved too far south are likely to have disease problems.

A **cultivar**, or variety, is an ecotype that has been selected for specific characteristics such as rate of growth, disease resistance, forage yield or seedling vigor. Most are developed through planned breeding programs with selections from diverse initial plant collections. As with other ecotypes, cultivars have specific areas of adaptation.

The selection of species for reclamation plantings should be based on a combination of criteria including the nature of the land base, purpose of seeding, likely management regimes, seed availability, seed costs, longevity, ease of stand establishment and the attributes of available plant species[25]. Many of these same criteria are also likely to influence decisions regarding potential seed sources for each species used in a planting mixture. Seed of a species that could be used in relatively small amounts to increase the diversity of a planting may only be available from suppliers of locally harvested ecotypes. Conversely, the seed of another species may

only be available in sufficient quantity from the producer of an adapted cultivar.

Plant/Cover Types

The discussion in this manual will focus primarily on large scale, long-lived plantings which create diverse, easily managed cover that is attractive to a wide range of wildlife. This objective is often best accomplished by revegetation with native grass, forb and shrub species. Unlike introduced species, adapted native species are virtually permanent – given effective management – making it unnecessary to reseed after several years. The additional cost of reseeding is avoided as is the risk of exposing the land to further erosion during subsequent stand reestablishment.

For sites where nonpermanent cover is the objective, mixtures of introduced grasses and legumes may be more cost effective than native species. In addition, adapted native species may not be available to match the specific conditions found on some sites. In both of these cases, a list of recommended introduced species should be obtained locally.

Cool Season (C3) and Warm Season (C4) Plants

Native grasses are divided into two main categories: cool season and warm season. They are also referred to as C3 and C4 plants because of their particular photosynthetic pathways. Cool season grasses produce most of their growth during the spring and late fall when the soil and air temperatures are cooler. In extremely cold climates, they are forced into dormancy by the cold weather. In temperate climates they generally go dormant or nearly so in midsummer. For this group of plants, the minimum air temperature for active shoot growth is 40 to 42°F (4 to 5°C). Most of the commercially available turn and forage grasses used in the northeast are introduced cool season grasses.

Conversely, the warm season grasses produce most of their annual biomass during the hot summer months from July through September. Growth of this group of plants does not begin until the minimum daily air temperature reaches 60 to 65°F (15 to 18°C) and soil temperatures reach 50°F (10°C). Optimum biomass production occurs when temperatures average 85°F (29°C). At higher temperatures C4 grasses have a greater potential photosynthetic rate and use nitrogen and phosphorus more efficiently than do C3 grasses[7]. They also survive and adapt better than many C3 species under conditions of high water stress, high temperature, high oxygen concentration, low carbon dioxide concentration and high irradiance.

Big bluestem, indiangrass and switchgrass are among the dominant tall warm season grasses of this region. They are best adapted to sites which have deep, moist, fertile soils, but will also grow well on many droughty sites in the northeast. Good seed supplies of these species are available. Many other warm season native grasses can also thrive on drier sites in this region. Locally important species with good drought tolerance include little bluestem, prairie sandreed, sideoats, grama, and sand dropseed.

Due to the recent interest in native plant material, the availability of local and adapted species is constantly increasing. Check current information before making your selections.

Though the establishment of cool season grasses is relatively easy throughout the region, there are droughty, acid or low nutrient sites where long-term maintenance of these grasses is a challenge. This aspect of their use is discussed elsewhere in this manual.

Geographic Considerations for Warm Season Grasses

In addition to the factors that affect cool season grasses, there are specific concerns for warm season grasses. Warm season grasses grow well under conditions that are generally warmer than the best performance range for cool season grasses. This creates some significant challenges for the successful use of warm season grasses throughout the northern states in our region.

These challenges are most often encountered during the establishment year and the following spring. In the geographic region covered by this manual there are two primary concerns due to climate and microclimate that affect warm season grass establishment and growth, and one major concern due to climate and soil interaction. Specifically, these are:

- length of growing season.
- warmth (heat units) received during the growing season.
- frost heaving during the fall, winter and spring after planting.

The length of the growing season and heat units received can be thought of together as growing degree days. Either factor alone can limit seed germination and seedling growth to the point that stand density is too low for effective erosion control or adequate nesting cover. In the northeastern states and eastern Canada these factors combine to challenge success; a relatively high incidence of cloudy days and the high evapotranspiration rates of forest cover moderate summer temperatures compared to those commonly experienced in the prairie/plains states and provinces.

It has been previously estimated that a minimum growing season of 140 days is necessary for success with native warm season grasses in the east. Field planting experience has shown this to be a conservative estimate. Successful plantings have been made in well drained soils at locations with about 100 day growing seasons. These plantings utilized eastern and Kansas and Nebraska cultivars. Stand development and seedling growth were slowed at these locations, from the typical two years to four years for full establishment. Contrast this growth response with that experienced in North Dakota, where equally short growing seasons have more solar radiation and growing degree days. Larimore, in northeastern North Dakota, receives 2,000 GDDs in a 120 day growing season while Roscoe, in the southeast part of New York, only receives 1,600 GDDs in a 120 day growing season. In North Dakota, it is common for good stand density and plant growth to be achieved in the second or third season.

In the mid-Atlantic and southern New England states, warm season grasses generally occupy an ecological niche where the dominant introduced cool season grasses have little physiological adaptation. These sites are generally sandy, sterile, acidic sites that only the C4 plants can tolerate for the long term. The common dominant species on these sites include switchgrass, little bluestem, broomsedge, deertongue and, to a lesser extent, big bluestem and indiangrass.

Specifications for warm season grass establishment must reflect regional characteristics. The user is strongly advised to contact regional USDA-NRCS plant material specialists or DUC staff for information on proper seeding regimes, variety selection, seeding rates, planting dates and fertilizer treatments. For example, clear regional differences are seen in seeding rates, with

much lower rates used for the same species mix in the Great Plains than in the northeast.

Local residents can give the best estimate of growing season length for microclimates. Frost pockets, north and east aspects with poor air drainage and higher elevations all tend to make the site more limiting for warm season grass success by reducing soil and air temperatures through the growing season. When these conditions are combined with soils that tend to be somewhat poorly drained or wetter (even if only seasonally) then warm season grass use becomes a low success project. Even on sites with 140 or more days in the growing season, poorly drained soils are a problem in the upper northeast and eastern Canada.

These sites are prone to a condition known as frost heaving. Frost heaving occurs primarily during the spring after the planting year, when marginally developed plants are literally jacked out of the ground by ice crystals that alternately form and thaw along the roots. This action can totally ruin an otherwise promising grass stand. The best defense is to avoid soils prone to frost heaving, and try to develop the biggest, most robust plants possible during the first growing season. Plants with 10 or more stems are much less vulnerable than those with fewer stems.

When identifying frost pockets, local farmers, especially those who plant alfalfa, know where young plants have been lost to frost heaving. It is wise to be wary of soils that have caused frost heaving with alfalfa when planning warm season grass plantings. Sometimes this may be a risk on only part of a field, allowing for the use of two different seed mixes (cool and warm season mixes) to be strategically placed. The soils map (printed by county in the US) is an excellent resource in predicting where this problem is likely because it identifies soil types by drainage class and landscape position. Soil survey maps may not show “inclusions”, areas of a soil type which are five acres or smaller in size. As a result, they should not be used as a substitute for on-site evaluation. In general, frost heaving is more likely to occur

How Growing Degree Days Are Calculated

Growing degree day (GDD) calculations incorporate both the effective length of the growing season for a particular crop and the amount of heat received each day into one measurement. For corn production, GDDs are based on the adjusted mean daily air temperature within the range of 50°F to 86°F.

$$\text{Corn GDDs} = \frac{[\text{Max. temperature } (\leq 86°) + \text{Min. temperature } (\geq 50°\text{F})] - 50}{2}$$

If the minimum air temperature for a particular day was 60°F and the maximum was 90°F, 23 corn GDDs would have been accumulated: **(86 + 60) ÷ 2- 50 = 23 GDDs**

If the minimum and maximum temperatures on the following day were 56°F and 80°F respectively, that would represent a further 18 GDDs for an accumulated total of 41 corn GDDs for the two days.

Corn GDD values are readily available from agricultural extension agencies for most areas in the northeast. They may also serve as a useful initial indicator of the prospects for success with warm season grass plantings. Based on field experience in the region, 1,400 corn GDDs should be considered a tentative lower practical limit for warm season plantings.

on soils which have poor surface or internal drainage. Soils of this type are often classified as "poorly" or "somewhat poorly" drained on soil maps.

Slopes with north and northeast aspects are easy to spot. Where these occur in USDA plant hardiness zone 4 and especially zone 3 (Figure 5), at elevations above 1,000 feet, reduced growth should be expected with warm season grasses. A pair of sites near Montpelier, Vermont illustrate the effects of aspect. These two sites had the same history of gravel pit use, were on opposite slopes of the same hill, and were planted with the same warrn season grass mixes and rates using the same amendments and planting technique, on the same day. The result, after three years, had the south facing slope covered in three to five foot tall, robust growth, while the north facing slope, which was steeper, had eight to 15 inches of growth, very marginal for wildlife use.

Long, narrow fields with tall trees along the sides increase the potential for problems on north-facing slopes. Shading from the trees further reduces incoming light, making

North aspect, September of the seeding year

North aspect, One year after seeding

South aspect, September of the seeding year

South aspect, Two years after seeding

marginal sites a poor bet for warm season grasses. On other aspects, especially southwestern exposures, bordering trees will have little affect.

This series of photographs from a gravel pit reclamation planting at Montpelier, Vermont, illustrates the influence of aspect on the growth of warm season grasses on some sites. In the seeding year, plants were about six inches tall on the north facing slope (upper left) and 10 to 12 inches tall on the south facing slope (lower left). In July of the year following seeding (upper right), plants on the north facing slope were still only averaging ten inches. By July of the second year (lower right), the plants on the south facing slope were averaging 30 inches tall and were maintaining their height advantage over the plants on the north aspect.

Planting Considerations

It is often recommended that warm season grasses be sown in late winter to early spring at roughly the same time as cool season grasses. If this is done, there is a risk that the warm season grasses will be subject to severe competition from cool season weeds. In those parts of the country where warm season grasses dominate, this competition may not be a problem. Where cool season grasses and weedy herbaceous plants are aggressive and persistent, the cool season species can dominate a newly sown site before the warm season grasses even germinate.

In steeply sloping areas where erosion control is essential or on soils which tend to crust, a cool season companion grass may be necessary. It is imperative that noncompetitive species be used for this purpose. Many regional NRCS Plant Material Specialists and USDA Plant Material Researchers are cautious of mixing warm season and cool season grasses because of repeated failures with the warm season component of the mix.

Ducks Unlimited frequently uses mixtures of warm and cool season grasses in plantings in the Canadian prairie provinces. To offset the apparent competitive advantage enjoyed by cool season seedlings during early stand establishment, DUC attempts to favor the warm season plants in two different ways. Very competitive cool season species like slender wheatgrass are only included in the mixtures at very low rates (0.1 to 0.5 PLS pounds per acre). If seed of a less competitive early successional cool season grass like Canada wildrye is available, it is often used in place of slender wheatgrass in the planting mixture. In addition, wherever possible, the stands are managed with a late spring controlled burn timed to favor the warm season grasses in the year following planting. While those techniques have been successful in retaining the warm season component in those plantings on the Great Plains, they have not yet been adequately tested under the soil and climatic conditions found in the northeast. This approach may be particularly useful on heat deficient sites, sites which are prone to frost heaving or droughty, erosion prone sites. In those situations, the inclusion of cool season grasses may provide improved vegetative cover. It will become more feasible as regionally adapted plant material becomes more readily available.

If a companion crop is absolutely necessary, an annual such as oats (at a rate of 20 lb/acre) or a noncompetitive perennial such as redtop (1 lb/acre) or one of the fine fescues (15 lb/acre) should be used. It may also be possible to use an early successional cool season native species like Canada wildrye (0.5 lb/acre) or slender wheatgrass

(0.25 lb/acre). One should be aware that using these species may limit the selection of herbicides that can be used for postplanting grassy weed control.

Nitrogen fertilizer should not be applied until midsummer on warm season plantings and then only on sites with very low fertility that have very low populations of weeds or cool season grasses. Earlier application will favor the cool season plants. A second application of nitrogen fertilizer is highly desirable during the second growing season. In most instances, if a starter fertilizer is applied with the seed, it should contain a high proportion of phosphorus to stimulate root development. On very coarse soils, it may be appropriate to apply nitrogen with the initial fertilizer.

Warm season native grass plantings are a relatively recent development in much of the northeast. A wide variety of establishment techniques have been attempted with equally variable degrees of success. Given the fact that conditions vary greatly within relatively small distances, it is likely to be some time before standardized successful establishment techniques are identified for all the conditions found in the region. Revegetation practitioners, who test new methods, keep detailed records and then share the information they gain with others can help hasten the development of successful seeding techniques for the northeast.

The importance of keeping detailed records cannot be overemphasized. In their absence, there is no way to determine the reasons for the success or failure of any individual planting or seeding technique.

Until successful methods are identified for areas in which they are not presently known, all plantings should attempt to meet certain basic standards. Seed placed into a firm, moist, weed free seedbed by equipment which ensures good seed to soil contact has a much better chance to establish than does seed which is planted without ensuring that any or all of these standards are met.

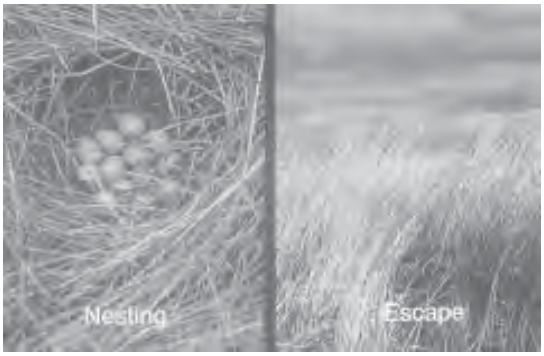
Stands of warm season grasses are generally much slower to develop that cool season stands. The success of the seeding is often difficult to judge until midseason of the second year. Judgement after the first growing season may lead to the false conclusion that the seeding has been a failure. The low amounts of first year cover may lead to problems in determining compliance with establishment criteria and cover requirements.

Most specialists in warm season grasses strongly favor the use of a native seed drill or a range drill equipped with chaffy seed boxes to handle awkward seed shapes. The normal lawn or landscape seed drill will not be able to properly sow the varied seed shapes of the warm season grasses and seed boxes may clog. All these seed drills are difficult to use on wet soils because of soil sticking to the packers. It is not impossible to manufacture a wet ground native seed drill, but such drills are very rare.

If warm season establishment is so troublesome, why provide specifications for

Drills specially designed to plant native grasses can seed into many different types of seedbeds.

Seed box agitators help to maintain an even flow of native grass seeds to the furrow openers.



Native grass plantings can provide both nesting and escape cover for wildlife.

The addition of adapted forbs to the seed mixture increases the diversity and beauty of a planting.

Incorporating lime to adjust soil pH prior to making a native grass planting at Londonderry, NH,

its use? The answer is straightforward. If successfully established, native warm season grasses offer superb wildlife habitat regardless of the season. They are also among the most esthetically pleasing habitats.

Seed

Purchasing quality seed is an essential first step for a successful planting. The purchase of Certified seed will assure quality and proper seed identity. Certified seed provides the maximum possibility for a successful planting, because it assures the buyer about three key seed variables:

- The seed you are buying is certified by an independent organization to be of the genetic makeup you desire.
- The germination percentage of the seed lot meets the quality standards for certified seed. Poor germinating seed will not be certified and the frustration of planting dead seed can be avoided.
- The weed seed content of the certified seed lot also meets quality standards. There will be few weed seeds and no noxious weed seeds. The embarrassment (and potential legal responsibility) of planting noxious weeds can be avoided and failure due to weed competition is less likely.

Bags of certified seed will have a certified identification tag attached. Certified seed tags from some US states also list some of the parameters found in seed analysis reports - percent pure seed, percent inert (dead materials including leaf and stem pieces), percent germination, and percent dormant seed. Bags without a certified tag contain common seed.

If certified seed of adapted cultivars is not available, it may be necessary to purchase common seed. In Canada these bags

generally display a tag marked Canada # I or Canada #2 which refers to the level of weed seed contamination. While common seed cannot be sold by cultivar name in Canada**,** it can in the United States. The best the purchaser can do is to attempt to determine the genetic origin of the seed lot. Note that this is different than the source of the seed lot. A seed lot may contain genetic material that was originally collected in West Virginia (the origin) but grown in Michigan (the source). The marketplace sometimes confuses origin and source. As a safeguard, seed buyers should request that the point of origin be stated on the seed analysis report for common seed.

It is recommended that native seed not be moved more than 300 miles (480 km) north or 200 miles (320 km) south of its point of origin. These limitations serve to minimize problems with hardiness and disease susceptibility. These guidelines were developed after decades of experience in testing cultivars in the plains region. In the region covered by this manual, east-west movement is not critical because precipitation variation is not a limiting factor. Elevation is important, however, because an increase in elevation of 1000 feet is equivalent to a move of roughly 175 miles (280 km) north.

The number of native grass cultivars that have been selected for use in the northeast is limited compared to the number for the plains region. Efforts are underway to improve the situation. In the interim, some mid-western cultivars have proven to be useful and adapted in the northeast, and these are listed along with the eastern cultivars in Appendix C.

Seed Purchase

When purchasing seed, request that the dealer provide a seed analysis report. The seed analysis report is the buyer's only opportunity to exercise quality control on seed lots. This report will identify the laboratory where the analysis was performed, the data listed on the certified seed tag plus percent hard seed, percent of other crop seed (a big bluestem seed lot might contain some switchgrass seed, etc.) and a list of weeds seeds and their amounts. Ask the dealer to report the data at the 0.01 percent level. Avoid dealers who will not provide this information prior to the sale. A call to the test lab can clarify the information if there appear to be problems.

To ensure access to suitable seed, purchases should not be delayed. Seed procurement activities should begin at least three months before the seed is required.

Seed should not be purchased as mixtures. Buy seed of individual species and create the mix that you require. Mix the seed only when the planting is sure to be done. Once the seed is mixed, it cannot he separated except at great expense.

Ducks Unlimited Canada has established a zero tolerance for weed species such as downy brome, hairy chess, rattailed fescue, Japanese brome, smooth brome, quackgrass, purple loosestrife and other invasive species in seed lots. These weeds present management challenges in plantings and may escape to neighboring land. DUC has a clear understanding with distributors and dealers that all seed lots containing objectionable weeds will be rejected.

There are many desirable native species which are valuable in plantings for which no tested and released cultivars are available. For these, seed from native stand harvests may be all that is available in the marketplace. This seed is useful, provided it was harvested in the vicinity (within 150 miles/240

km) of the area proposed for planting and has acceptable quality.

The NRCS' Plant Materials Program developed many of the native species which are now available for revegetation work in the United States. Traditionally, plant material was released as a cultivar (i.e. named variety) which had been extensively selected and tested.

Since 1993, the NRCS and others have also adopted some alternative methods to release plant materials. These new methods have helped to address two major needs. Firstly, plant material which has undergone testing can be released for commercial production and be on the market in just two to four years, rather than the six to ten year testing period that is common for cultivars. Secondly, plants which are adapted to a limited area or need can be released in a cost effective manner.

Plant releases can now fall into one of two groups: natural, where no intentional manipulation of the original germplasm has occurred or manipulated, where purposeful genetic manipulation (multiple crosses, selection for superior traits) has taken place. Within each of these groups, four levels of release would be possible (Table 1). With the exception of bulk populations, each release level could be certified.

Bulk Populations are not usually released to the public, but may be made available to individuals for further research and development.

Source Identified material is seed or plants from a naturally growing population in a known or defined geographic area. It has had no selection or testing. Seeds for commercial sale may be collected from the wild or grown under cultivation. It may be certified by the seed certification agency in the source state.

Table 1. Levels of release for manipulated and natural plant material

Manipulated	Natural
1. Bulk Populations (F1's)	1. Source Identified Class
2. Selected Class	2. Selected Class
3. Tested Class	3. Tested Class
4. Cultivar / Variety	4. Cultivar / Variety

Selected material, as the name implies, has been through some testing and shows some desirable superior trait or promise of performance when compared to other plant material of the same species at a common site. It has not been tested at multiple sites or for more than one year, so its performance has not been proven.

Tested material has been through additional testing - multiple sites, replicated plots - to verify performance and the heritability of desirable traits. Its complete range of adaptation may not be known.

Cultivars have been through replicated tests at multiple sites for two or more generations. That testing will prove and document the heritability of traits, the superiority and/or performance and the range of adaptation.

Table 2 lists the species presently under development at Northeastern Plant Materials Centers. The cultivars which have already been released by Plant Material Centers in this region are shown in Table 3. (Please contact the NY State Big Flats Plants Material Center for an updated list of species in selection and development along with species and cultivars selected for the Northeast.)

As part of its seed mix development program, DUC planted a 42 cultivar, nine species warm season grass test plot in southern Ontario in 1994. Located on moderately heavy soils in plant hardiness

TABLE 2 Native and Naturalized (*) herbaceous species in selection and development processes at northeast Plant Materials Centers

Species	Origin	PMC	Goal of Cultivars
GRASSES			
beaked panicum	md-Atlantic	MD	yes
bitter panicgrass	mid-Atlantic	NJ	no
big bluestem	WI, MI, IN	MI	yes
	mid-Atlantic	MD	yes
bushy bluestem	VA	MD	yes
eastern gamagrass	KS, MD, others	NY	yes
	mid-Atlantic	MD	yes
Florida paspalum	mid-Atlantic	MD	yes
Indiangrass	NY and mid-Atlantic	NY	yes
	mid-Atlantic	MD	yes
little bluestem	mid-Atlantic	MD	yes
poverty oatgrass	ME	NY	no
prairie sandreed	Great Lakes shoreline	MI	yes
prairie cordgrass	NY and N. England	NY	yes
prairie sandreed	Great Lakes shoreline MI	yes	
purple lovegrass	mid-Atlantic	MD	yes
purpletop	KY, WV, NC, OH	KY	yes
	mid-Atlantic	MD	yes
red fescue*	ME	NY	no
redtop	NY MI	NY	yes
sea oats	mid Atlantic and SE	NJ	yes
shortbeard plumegrass mid Atlantic	MD	yes	
splitbeard bluestem	mid Atlantic	MD	yes
sugarcane plumegrass mid Atlantic	MD	yes	
slender woodoats	mid Atlantic	MD	yes
sweetgrass	MI	MI	no
switchgrass	VA NY	NJ	yes
	NC	NJ	yes
	mid Atlantic	MD	yes
Virginia wild rye	mid Atlantic	MD	yes
FORBS			
New England Aster	ME	NY	no
New York Aster	ME	NY	no
Seaside goldenrod	mid Atlantic	NJ	no
Stiff goldenrod	ME	NY	no
LEGUMES			
Tickclover (3)	Great Lakes	MI	yes

Table 3. Native herbaceous species and cultivars selected for northeastern conditions at Plant Materials Centers

Species	Cultivar	Origin	PMC
GRASSES			
American Beachgrass	'Cape'	MA	NJ
big bluestem	Niagra	NY	NY
coastal panic grass	'Atlantic'	mid- Atlantic	NJ
deertongue	'Tioga'	PA,NY	NY
saltmeadow	'Avalon'	NJ	NJ
smoothcordgrass	'Bayshore'	NJ	NJ
switchgrass	'Shelter'	WV	NY
FORBS			
black-eyed susan	'Golden Jubilee'	VT	NY

Table 4. Varieties of warm season grasses with potential value as wildlife cover in southern Ontario

SPECIES	CULTIVAR (ORIGIN)
Big bluestem	'Bison'(ND), 'Bonilia' (SD), 'Chainp' (KS), 'Kaw' (KS), 'Niagara' (NY), 'Pawnee' (KS), 'Rountree' (MO), 'Sunnyview' (SD/MN)
Little bluestem	'Aldous' (KS), 'Blaze' (NE) ''Camper' (NE), IND4115' (ND)
Sand bluestem	'Garden' (NE), 'Goldstrike' (NE)
Indiangrass	'Holt' (NE),'Oto' (KS), 'Rumsey' (MO),'Tomahawk' (NDISD)
Sideoats grama	'Mideer' (ND), 'Pierre' (SD), 'I)ragway' (NE)
Prairie cordgrass	'PMK-686' (NE)
Switchgrass	'Blackwell' (KS), 'Cave-In-Rock' (MO/IL), 'Dacotah' (ND), 'Nebraska 28' (NE), 'Shelter' (NY), 'Summer' (SD), 'Sunburst' (SD), 'Trailblazer' (NE)

zone 6a, the plot was designed to **examine** the performance of varieties from a range of origins in a region typical of DUC's eastern nesting cover plantings. The varieties were assessed for plant vigor, viable seed production and resistance to lodging. Assessment of the plot is still ongoing, but to date several varieties (bolded in Table 4) have performed well enough to be included in DUC seed **mixes** for Ontario.

Preparing a Seed Mix

Pure Live Seed

Native warm season grass seed has been specified and sold for many years as pure live seed (PLS). This methodology was developed to compensate for the wide variation in quality of the seed of chaffy grasses like big and little bluestem, indiangrass and sideoats grama. The PLS approach is spreading to other types of seed as people understand the method and the importance of buying and selling on a uniform system. One way to approach the PLS concept is to compare it to net weight. When we buy most products by weight, we think in terms of the price of the actual product. The corn flakes box has a net weight printed on it and we compare one brand with another by

how many ounces of flakes we get per dollar. We can do the same thing with seed by using the PLS system to factor out the weight of dead seed, sticks and stems, and weed seeds. We only want to pay for the viable seed of the species or cultivar we are buying. To do that we calculate the PLS percentage from the information on the seed analysis report for a given lot of seed.

To determine pure live seed (PLS) percentage, use this calculator:

PLS % = (purity % x viable seed %) divided by 100

Where:

Purity = 100% - (weed seed % + inert matter % + other crop seed %)

Viable seed % = germination % + dormant %

Viable seed % can also be determined by the use of a textrazolium (TZ) test rather than a standard short term germination test.

The percent viable seed is a combination of the seed that is dormant and the easily germinated seed. Dormant seed may not germinate during the first year of planting, but it can add to the stand later. Therefore, one usually adds the percentage of dormant seed to the percent germination to find the total percentage of viable seed which is used in the PLS calculation.

Seed Processing

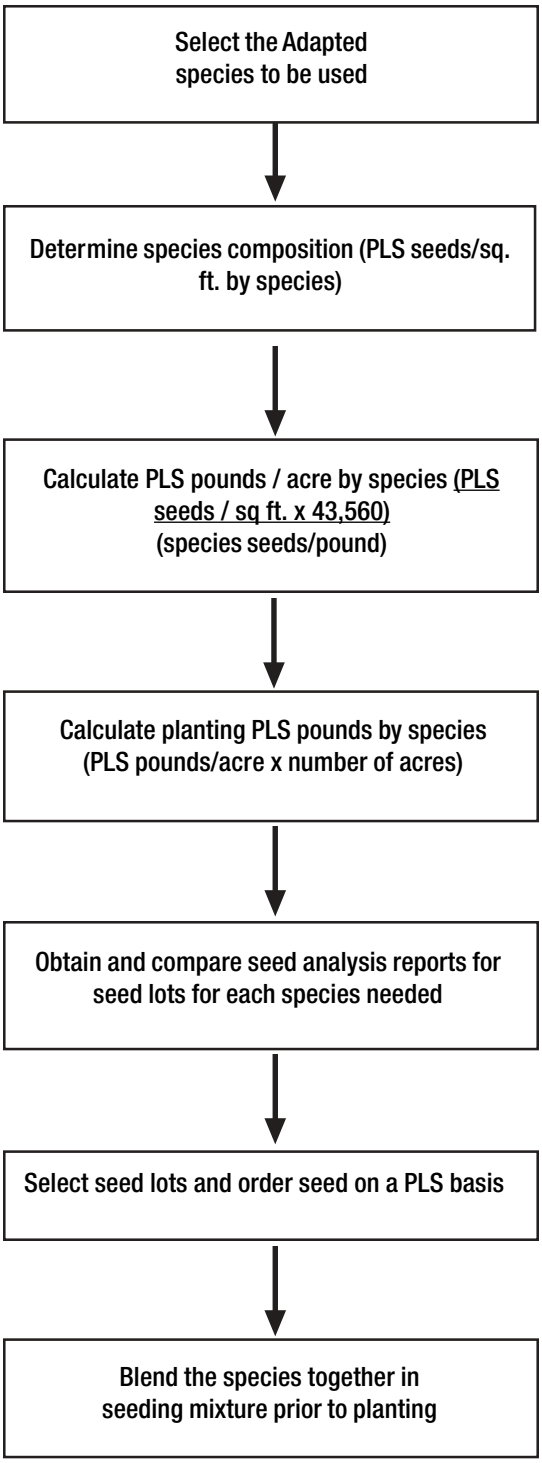
Chaffy seeds like the bluestems, indiangrass and others, can be processed to rub off some of the appendages that make the seed difficult to plant. Debearded big bluestem is the species most commonly available from this process. While debearding adds to the cost of the seed and may be more or less successful on different lots of seed, it can help to improve seed flowability. Debearded seed may not be necessary when native grass drills are used. Another seed processing technique called seed coating can also help improve flowability, particularly for species like little bluestem which have light, chaffy seeds.

Typical seeding rates for warm season grass mixtures range from 10 to 15 PLS pounds per acre, which should provide over 30 pure live seeds per square foot. Compared to cool season grass seeding rates, this recommendation seems low. However, the native warm season grass plants are much larger, and a healthy two to three year old plant can easily occupy a square foot of space. Also, most cool season seeding rates are based upon the likelihood of seeding with a hydroseeder, a far inferior method of planting to those recommended in this manual. If satisfactory populations are not obtained with 10 to 15 PLS pounds of warm season grass seed, then the fault lies in technique or unsuitable site conditions, not the seeding rate. Figure 11 presents a flow chart of activities to follow when planning and obtaining a seed mixture for a specific planting.

Seed mix options for native grass plantings in the east are currently limited due to the modest number of cultivars that are available commercially. There is seed of native forbs and legumes that can be added to the basic warm season grass mix to add diversity.

The most extensive work in the northeast on establishment of warm season grasses has been done on sand and gravel pits in New England. The researchers based their planting recommendations on the percentage of fines in a soil sample. If fines, soil particles passing a 200 mesh sieve (fine sands or finer), were below 15 percent, warm season grasses were the best choice for long term

Figure 11.
Planning and Obtaining a Seed Mixture



stability of the site. If fines were between 15 percent and 20 percent, a warm season grass/legume mix is recommended. As the percentage of fines increased above 20 percent, the flexibility of recommended mixes increased and could include a drought tolerant cool season mix.

Ducks Unlimited Canada usually designs their seed mixtures based on PLS seeds per square foot. Due to relatively poor seedling vigor, native grass seedling establishment is normally estimated at 20 to 25 percent of the PLS seeding rate. To achieve an establishment rate of eight or ten seedlings per square foot, for example, a PLS planting rate of approximately 40 seeds per square foot is required.

The species composition of the planting is determined by assigning relative proportions of the total of 40 seeds to each of the species being included in the mixture. If a **five** species planting was intended to present each species in equal amounts, the mixture would include eight PLS seeds of each per square foot. If the planting objective were different, the mixture might still contain the same **five** species, but each would be present in differing amounts.

Once the species composition and proportions have been determined, the number of PLS pounds of each species needed for an acre of the planting are calculated by multiplying the number of PLS seeds of that species per square foot by 43,560 (the number of square feet in an acre) and dividing the product by the number of seeds per pound for the species (Table 5). Multiplying the PLS pounds of the species required for an acre by the number of acres in the planting determines the total PLS pounds needed for each species. The seed is then ordered on a PLS basis.

After examination and approval of the seed analysis reports for each species, the seed is shipped to the facility which will blend the lots of each species into the planting mixture. To facilitate the seed blending process, DUC prepares mixing instructions for each seed mixture. Those instructions specify the number of bulk pounds of each seed lot required for the mixture. Since all the specifications to this point have been based on PLS values, a conversion factor (CF) is calculated to make it easier to determine bulk amounts from the PLS values.

After the seed mixture has been thoroughly blended, it is re-bagged. Special tags are attached to each bag which show the mix number and name, the number of bulk seeds to be planted per square foot and the number of acres that a bag of that seed mixture will cover. The latter two numbers are especially useful when the operators doing the actual seeding are calibrating their drills. The number of bulk seeds per square foot are equal to the number of seeds per linear foot of row for a drill with 12 inch row spacing.

The process of securing quality seed supplies should begin as early as possible, preferably no later than midwinter before the proposed planting date. By this time, growers will have most seed lots tested and prices established. Waiting until April or May virtually guarantees a reduced number of suppliers with suitable seed still available and may lead to late shipments and subsequent planting delays. US Farm Bill programs have led to increased demand and prices for seed in 1997. Early ordering is vitally important.

Appendix D presents examples of several native species mixtures which have been used in this region.

To calculate a PLS: Bulk conversion factor (CF):

CF* = 100 divided by PLS %

*to minimize the effects of rounding, the CF should be calculated to four decimal places.

Using the CF:

CF x PLS pounds = Bulk pounds

CF x PLS seeds/sq. foot = Bulk seeds/sq. foot

Bulk pounds divided by CF = PLS pounds

Bulk seeds/sq. foot divided by CF = PLS seeds/ sq. foot

Planting Year Activities

In addition to the planning and preparation that occurs during the preplanting year, a number of decisions must be made in the planting year before the seed actually goes into the ground. These include planting date, seedbed condition, preseeding weed control, seeding rate and equipment and fertilization.

Planting Date

Except for dormant seedlings, all grasses should be seeded when soil moisture and temperature conditions are optimal for germination. Cool season grasses will germinate and emerge at about 40°F (4.5° C) or higher. Optional seeding times within this region are spring, late summer or after dormancy occurs in the fall.

Warm season grasses require soil temperatures of at least 50°F (10°C) before they will germinate. The optimal seeding time, whether alone or with cool season grasses, usually occurs between mid-spring and early summer. Later plantings of warm season grasses may reduce problems with weed competition. Early plantings allow more time for stand establishment. Because of the possibility of fall germination and frost heave, seed loss to wildlife through the winter and early week competition in the spring, dormant seeding of warm season species is not recommended.[18]

All plantings should be made into a seedbed that has a high probability of having adequate moisture after seeding. Moisture

conditions are considered to be ideal if the soil can be readily formed into a ball in the palm of the hand and the ball breaks easily when dropped.

Specific date ranges for both warm and cool season grasses will vary, depending on local climate. The window of opportunity will obviously vary from year to year. Seeding dates may be extended two or three weeks past normal when moisture conditions are favorable. In years when slow growing conditions cause a delay in preseeding week control, it may be necessary to delay seeding until after the normal date.

Seedbed Condition

A firm seedbed is important when seeding native grasses. It helps conserve moisture and ensures good seed to soil contact, a factor which is critically important for warm season grasses. Recently tilled ground should be packed with a coil or roller packer prior to seeding. Packing can also be accomplished by traversing the field once or twice with an empty press drill. The seedbed is considered firm enough when a footprint penetrates ¼ to ½ inch deep. Packing is rarely necessary when seeding into standing stubble as soil compaction is usually adequate.

It can be especially challenging to prepare a suitable seedbed on heavy clay soils. If they are tilled when they are too wet, the surface can become very cloddy. No-till planting into the residue left from a previous crop can often result in a more uniform seedbed.

Preseeding Weed Control

Though weed control procedures during the site preparation year should eliminate most of the major weed problems from a field, the effectiveness of these measures should be evaluated again prior to seeding and a control plan developed accordingly. Weeds or volunteer cereal grains present at seeding time will have a competitive advantage over the slower developing native seedlings, so they must be controlled before seeding.

Non selective herbicides can be used in the spring immediately prior to seeding or up to four days after seeding. Applications later than four days after planting may cause seedling damage. In no-till fields where annuals are a concern, use Roundup or paraquat when weeds reach two to six inches in height. A tank mix of Roundup with one pound per acre of atrazine can provide effective week control prior to planting warm season grasses.

Planting Equipment

The equipment used to seed native plants should provide a uniform distribution of seed, place seed at the proper depth and provide for good seed to soil contact. Given suitable moisture levels and temperatures, meeting all three of those conditions should result in optimum germination and emergence. The characteristics of some native grass seeds require the use of specialized equipment or modifications to standard agricultural equipment or seeding practices to accomplish that objective.

Seeds of some species are awned or have sharply pointed tips. Others are light and fluffy. Any of those characteristics can result in uneven rates of seed flow in standard gravity fed grain drills and undesirable skips within seed rows. To overcome that problem, a light rate of oats (five to ten pounds per acre) or, preferably, an inert carrier like cracked wheat, cracked corn, oat groats or vermiculite at half the bulk seed rate can be mixed with the grasses to improve seed flow. If the inert carrier and seed are to be mixed in the drill box, first mix some of the carrier

and seed in a separate container. The seed cups should be full of this mixture before filling the drill box.

Although seeding a companion crop is generally not recommended, the use of oats as a carrier can be valuable on soils subject to erosion or crusting. In drier areas, however, native plant seedlings may have difficulty competing with oats and an inert carrier should be used. Fertilizer is generally not recommended as a carrier due to the possibility of damaging the seed or seedling.

Specialized grass seeding drills usually have seed box agitators and/or specially designed seed cups to help ensure a uniform flow without carriers. These adaptations are particularly useful when seeding mixtures containing more than 50 percent warm season grasses.

Equipment used for seeding native grasses must be capable of operating at a consistent, shallow depth. Seed should be placed at ¼ and ½ inch depths in fine to medium textured soils and ½ to ¾ inch deep in sandy soils. The depth is about right when some seed is occasionally visible on the soil surface after seeding. Do not seed deeper than one inch in an attempt to see to moisture.

Incorrect seed placement can significantly reduce stand establishment. Depth bands or gauge wheels linked to the openers provide positive see depth control on disc type seeders. Packer/gauge wheels are used to ensure depth control on seeders which use hoe or knife openers.

If the seeding machine does not provide adequate on row packing after the seed has been placed, the site should receive an additional packing operation to ensure good soil to see contact.

Tilled seedbeds and standing residue are the most common surface condition encountered when undertaking a revegetation planting. Occasionally, plantings are also made into existing sod.

Tilled Seedbeds

Sites which have been tilled during the pre-planting year are normally in suitable condition for seeding with all types of equipment. The minimal amount of surface residue remaining should not interfere with the operation of seed drills with disc, knife or hoe openers. In areas where the lack of surface residue may increase the risk of wind erosion, it is preferable to seed into standing residue.

Herbicide treatments should replace tillage for weed control immediately prior to planting. Avoiding tillage at that time will leave a firmer seedbed, making depth control more precise. Also tilling may accelerate the rate at which the surface soil dries out, making conditions less suitable for rapid germination. If tillage cannot be avoided, the site should be packed prior to seeding.

Standing Residue

Planning for planting into standing residue must include the management of the harvest from the preceding crop. Purely from the standpoint of seedbed preparation, removal of the crop as green feed, either in bales or as green feed, either in bales or as silage represents the ideal situation. That treatment will remove most of the seed from weeds which may have escaped the in crop herbicide program and removes the potential problem created by heavy crop residues. It also provides sufficient time for any remnant week population to reach a growth stage where it can be further controlled by post harvest herbicide application.

In many cases the preceding crop will be harvested for grain rather than green feed. When that occurs, both the straw and chaff must be managed to minimize potential problems at seeding time. Straw should be baled and removed from the field or finely chopped and spread uniformly throughout the field. The chaff can also be collected and removed, a practice which also remove weed seeds and waste grain coming through the harvesting machinery. Chaff can also be spread on the field. If the straw or chaff has not been spread satisfactorily, harrowing after harvest can help solve the problem. All of these techniques will help to reduce the risk of straw hairpinning into the seed slot during seeding.

Distributing the chaff as widely as possible is very important. If not done properly the resulting chaff row can interfere with seed placement as well as germination and emergence.

Disc, knife or hoe openers can all seed into standing stubble. To optimize their performance, especially in heavy residue, the openers are often preceded by a coulter or trash plow. These implements, respectively, cut through or clear a narrow strip of residue preventing the residue from hairpinning. A narrow band of blackened ground directly over the seed row can hasten germination and emergence by creating somewhat warmer soil temperatures near the seed.

Provided residue is properly managed and the seed is well placed, clean standing stubble is an excellent seedbed for revegetation plantings on agricultural soils. The soil is firm, allowing good depth control. The standing stubble reduces wind speed and evaporation at the soil surface, provides erosion protection to the soil and may provide some partial shade to tender, newly emerged seedlings and cover for ground nesting birds.

Existing Sod

Seeding into existing sod presents some special challenges.While the roots and top growth of the old vegetation provide excellent soil erosion protection, they can make it difficult to achieve good seed placement. Removal of the above ground biomass is very important before attempting to plant into existing sod.

Standard knife and hoe openers tend to tear existing sod, leaving a rough surface. Because of that tearing action, seed depth and soil seed contact can be extremely variable resulting in uneven seedling establishment.

Proper seed placement into existing sod requires the use of specialized equipment. Sod seeders usually have disc openers or very narrow knives and cutting coulters. The coulter makes a slot in the sod for the opener to follow. It is important for sod seeders to provide good on row packing to ensure the slot is closed and the soil is firmed around the seed.

Existing sod will compete very strongly with new seedlings for moisture and nutrients. For that reason, a non selective herbicide should be applied prior to planting to suppress competition. If the planting site contains a significant remnant native plant population, serious consideration should be given to a management program that would favor remnant plants rather than eliminating them with an herbicide and then reseeding.

Sod seeding, particularly with native species, is still not well understood. This technique, therefore, represents the highest risk of the options considered. Since research into sod seeding is a continuing activity,

anyone considering this technique is urged to seek the most current information available.

Seeding Rate and Equipment

Seeding rates for native grass stands usually vary from ten to fifteen pounds PLS per acre. The lower rates are normally used in drier prairie regions, with rates in the northeast near the high end of the range.

Prior to planting, the seed drill must be serviced and repairs carried out. Regular maintenance such as greasing, checking seed cups and seed tubes for obstructions as well as removing old seed from the seed box, cups and tubes should be done before each planting. It is advisable to disassemble and clean the distribution manifolds on an air seeder or aid drill before each planting as they tend to be somewhat prone to blockages, resulting in seeding misses. The seed delivery system on all drills should be checked periodically during seeding to ensure that it is operating properly.

To ensure the desired PLS seeding rate is achieved, the drill must be calibrated for each seed mixture to be planted. Once planting is underway, the operator should stop several times in the first acre or two to ensure that the seeding depth is appropriate. A quick look in the seed box during those stops can also give an indication that all seed cups are feeding.

There are two methods of drill calibration, one based on the bulk weight of seed and the other on seeds per row foot. The following alternative method can be a time saver on a windy day when drill calibration using the seeds per row foot method may be difficult.

a) Jack up the drive wheel end of the drill and measure the drive wheel circumference in feet. Mark the side of the tire as a reference point.
b) Place containers under three or more seed spouts.
c) Rotate the drive wheel one half turn or one full turn and calculate the distance traveled by the circumference of the wheel.
d) Count the number of seeds in each container and divide by the number of feet of wheel travel to determine the number of seeds delivered per linear foot.
e) If all the spouts are not delivering the same amount of seed, adjust them to feed uniformly.

Broadcast seeding is not a recommended practice if site conditions allow the use of a drill. If conditions dictate that it is the only possible method, however, there are some techniques which will improve the prospects for success. The site should be harrowed prior to broadcast seeding, then harrowed and firmly packed after seeding. Good success has also been experienced when broadcasting is followed by tracking – driving a bulldozer up and down slope to completely cover the side with cleat marks. While broadcast seeding rates double those used for drill plantings are usually recommended, those elevated seeding rate have not been necessary on tracked sites in New York, Vermont, New Hampshire and Maine.

Fertilizing

Fertilizer applications are not usually required for native species in the establishment year. The results of the soil test taken in the fall of the pre-planting year will give an accurate picture of the nutrient status of the planting site.

Sites which have infertile soils or those which have been cropped in the pre-planting year may benefit from Fertilizer. In those cases, it is particularly important to ensure

that adequate phosphorus levels are provided since it promotes root development.

Potassium and phosphorus may be applied either prior to or when planting. If the application is a separate operation in late fall or early spring prior to seeding, it should be made with equipment that creates a minimum of soil disturbance. A spring preseeding application may loosen the seedbed to such an extent that a repacking operation is required prior to seeding. However, repacking at that time may pulverize the soil surface and increase the risk of wind erosion.

Nitrogen should not be applied to warm season grasses until the second growing season. Earlier applications will stimulate weed growth and encourage encroachment of cool season grasses. Generally, excessive rates of nitrogen will not result in higher yields.

If fertilizer of any type is applied at seeding time, ensure that there is sufficient separation between the seed and fertilizer to minimize the risk of seedling injury.

When established stands of big bluestem or switchgrass are subject to annual use for hay or pasture, they may require fertilizer applications to maintain there productivity. Apply the nitrogen and phosphate in a 3:1 ratio based on soil test result. For a nitrogen application of 90 pounds per acre for example, it is recommended to apply 30 pounds of phosphate. Applications should not be made until spring grass growth has reached four to six inches or the soil temperature reaches 60 ºF (15º C).

Special Considerations

Most warn season native grasses grow best on moderately deep to deep, well drained, medium to moderately fine textures soils with moderate permeability and high to

Clean standing crop stubble can provide a suitable seedbed for native grass plantings

With proper seeding equipment, plantings can be established in chemically suppresed sod.

Depth control bands ensure uniform, shallow seed placement.

Grass seeding drills can be calibrated by counting the seeds delivered per measured length of row.

very high water holding capacity. Many sites lack these or other ideal conditions; some may merit special consideration.

Coarse Textured, Droughty Soils

On sandy sites where droughty conditions prevail, attention should be given to species or ecotype selection. As previously mentioned there are several drought tolerant species available. Even species typically not tolerant may have adapted ecotypes that are less susceptible to moisture stress. Since competition for moisture between species, as well as with weeds, will be keen, use the lower end of the prescribed seeding rate. Planting an annual grain crop for one year then seeding directly into the standing stubble without further tillage will help conserve moisture and protect the merging grass from wind and blowing sand. Drilling into suppressed existing sod has also show great promise under these conditions.

Fine to Medium Textured Soils

When an adequate herbicide program is not an option and erosion is not a problem, one method of combating heavy weeds is to plant as late as possible but before mid-season. Since weeds germinate as soon as the soil warms a late planting allows time to eliminate the weeds through light, shallow cultivation; deep cultivation will only bring up more weed seeds. Discing or harrowing at two to three week intervals will eliminate much of the problem. The danger with late plantings is the possibility of not receiving enough precipitation to germinate the seed or having insufficient plant size to overwinter successfully.

Floodplains or Muck Soils

Cool, wet springs many delay access to floodplains or muck soils until mid-June. If seeding is scheduled on these soils the seedbed should be worked the previous late summer or fall. Some native grasses tolerate some spring flooding or high water tables but grow best on organic soils that dry out mid-spring and remain dry during the growing season.

Stand Evaluation

To determine the overall success of the planting a monitoring program should evaluate the number of seedlings, distribution of seedlings across field gradients, seedling vigor, height and growth stage and overall diversity of seeded plants. Preliminary evaluation of fall and spring planted native grasses should be made four to six weeks after germination. For spring planting, this would normally occur six to eight weeks after planting. This inspection of seedling density and distribution can easily be combined with an inspection for postplant weed control requirements. A second inspection late in the summer of the planting year will be necessary to evaluate stand adequacy based on density of established plants and their stage of development. However, the final establishment inspection should ideally be made after the stand has gone through at least one winter.

It is often difficult to decide when establishment occurs following grass seeding. A grass seedling should be completely autotrophic (not reliant on seed reserves) before being considered established. Successful establishment of grass seedlings also requires the formation of adventitious roots.

Sampling Techniques

The systematic collection of stand establishment data is especially important when an individual or organization first become involved with native grass revegetation or when new seed mixtures are being tested. As part of a comprehensive system of field records, establishment data can play a key

role in determining the reason for the ultimate success, or failure, of a planting.

Several methods can be used to collect stand establishment data. Density measurements, taken by counting the number of individual plants and species within a standard on square foot quadrant, are the most commonly used. The accuracy and usefulness of the data collected will depend on the number of location of the sites sampled. As a general rule, there should be a least one sample site per acre in fields of 40 acres or less. A minimum of 50 sites is required on fields larger than 40 acres.

The location of the sites within the field deserves special attention. Sample locations should reflect the nature of the field. If 25 percent of the field has sandy soil, the same percentage of samples should be taken from the sandy areas. If the sculptured seedling approach has been used, it would be advisable to sample each part of the field which received a different seed mixture separately.

At the time of the first inspection, species with high rates of seed dormancy may not have emerged. Experienced personnel can usually determine by visual observation if plant emergence has been satisfactory.

Postplanting Weed Control

Planting Year

Prompt attention to postplant weed control is required on all sites during the establishment year. Weed control options and strategies will vary depending on the type of planting (cool season warm season or mixed grasses), the weed species present, whether forbs or legumes have been included and whether the stand will be harvested for forage.

There are four basic methods that can be used to control weeds in developing grass stands: clipping, herbicides, grazing and fire. Of these only the first two are normally used during the planting year.

Clipping is the simplest method of assisting establishment of new grass stands, especially warm season grasses. The goal is to reduce the shade pressure that the weeds are exerting, and secondarily to keep the weeds from producing seeds. The best equipment to use for this method is a sickle bar mower that can operate horizontally within an elevation range of 6 to 12 inches (15 to 30 cm). Sickle bars are preferred over rotary mowers because they cut and drop each stem individually. Weeds are spread evenly over the entire swath and do not clump as tends to happen with the rotary machine. If at all possible, clipping should be delayed until July to allow ground nesting birds to complete incubation.

The height of cut is not critical if clipping cool season grasses. Cool season grasses generally have good seedling vigor and the growing point (meristem) is near the soil where it is not likely to be cut off. It is acceptable to cut off some of the grass leaf with the weeds. Leaving two thirds or more of the leaf length uncut is a good policy. Plants need leaf surfaces to capture light and generate food for growth so cutting half or more of the leaf off can have a retarding effect on growth.

When first year warm season grass stands care clipped, one has to account for the weaker seedling vigor of the plants and the elevated growing point. With these grasses, only the leaf tips should be cut. Clipping either grass type has the effect of promoting stooling out of the plant, which is the stimulation of basal bud to produce more stems and leaves.

Herbicides, used correctly, can provide effective control of many weeds in a timely and cost-effective manner. As with other weed control methods, the development of an herbicide use strategy should begin with a field inspection four to six weeks postplanting to identify the weed species present.

As mentioned in preplanting preparations, herbicides should be used to target problem weeds during the year or two before planting native grass stands. Not only does this allow for greater flexibility and opportunity for effective control, but it avoids the potential problem of herbicides not being labeled for us with species that you wish to plant. These herbicide applications can be especially valuable for controlling weedy cool season grasses and persistent broadleaf perennials like Canada thistle.

In the past, very few herbicides were specifically tested for their efficacy on native plant materials. The cost of testing, combined with the relatively small size of the potential market for use on native plants compared to annual agricultural crops, have mitigated against testing being undertaken by the producers of crop protection chemicals. As a consequence, very few herbicides currently carry label recommendations for use on native plants.

The situation has begun to change in recent years. In Canada, DUC has been actively collaborating with weed scientists at Agriculture and Agri-Food Canada and other agencies to undertake the testing required for the granting of what is called a "minor use registration." Such a registration leads to supplement label information which allows the use of the product on specified native plant species. Registration for the use of Achieve to control wild oats and green foxtail in western, northern and slender wheatgrass is one example of a registration which has resulted from that program. A number of other herbicides are currently being tested on a wide range of native grasses. As the testing is completed, those products which have demonstrated acceptable performance will be put forward for minor use registration.

Some of the new crop protection products which have been released in recent years carry registered uses for native plant species, either on the original labels or on supplemental labels which were issued soon after the products were released. In the United States, for example, some members of the imidazolinone family of herbicides carry such labeled uses. A comparison of three of those products –Arsenal, Plateau and Pursuit – versus Atrazine as part of an integrated weed management strategy to establish or restore warm season grasses in the Great Plains has been reported.

Some references to specific herbicides and rates of application in this section are based on preliminary research and field experience. Unless stated otherwise, they should not be construed as recommendations for herbicide use under differing conditions and label recommendations. For example, the effect of a particular herbicide on seedlings can vary with the level of weed infestation. In addition, an herbicide may not have an impact on vegetative growth or biomass production, but may significantly reduce seeds yields. For specific recommendations for local conditions, refer to state or provincial week control publications, herbicide label information and experienced local personnel.

Each herbicide controls or suppresses a range of annual grassy and broadleaf weeds as well as some broadleaf and cool season grass perennials, but they do differ in their effects on specific warm season species. Plateau, for example, is labeled for use on big bluestem, little bluestem, indiangrass, sideoats grama, blue grama and buffalograss while the Pursuit label covers big bluestem, little bluestem and switchgrass.

The US label for Plateau also contains tolerance information for a range of seedling and established forbs and legumes, including such species as black-eyed susans, yellow coneflower and partridge pea. As a result, it may be a useful weed control product in plantings which include forbs and legumes or on degraded sites where restoration work is being undertaken. Consult the product label for complete specific information.

Even after a diligent weed control program in the preplanting year(s), additional control measures are often required in the establishment year. Annual broadleaf weeds are fairly easy to control in warmer or cool season grass stands by using chemicals like 2,4-D or Banvel. If annual grassy weeds are also present, other products or tank mixes of products, may control them both in on application.

In special problem situations like cool season grasses in a warm season stand, the herbicide options become more limited. In some situations, it may be possible to use products like atrazine of Plateau. It may also be possible to apply Roundup to growing cool season grasses while the warm season grasses are dormant in early springs or late fall. If the warm season grasses are dormant to the soil (green does not show) and the cool season plants are actively growing, this treatment can provide some control.

Wick applicators can be used to apply Roundup to susceptible broadleaf weeds and grasses if they have grown above the desired plants, but this method is not very effective if the weed population is high. Unless the wick method can be used, cool season grass weeds in a stand of native cool season grasses are essentially untouchable with herbicides.

Grazing can be used to advantage, but has several potential pitfalls. It must be carefully controlled or the stand can be destroyed by over grazing, hoof damage or physically uprooting the seedling as the animals bit and tear off the forage.

In the second year and beyond, risk from hoof damage and the dislodging of plants is greatly reduced. Grazing can be used to reduce weed pressure early in the season where cool season grasses are invading a warm season grass stand. Livestock are attracted to the tender new growth of the cool season grasses before the warm season grasses begin to grow. Intense grazing at this time can weaken the cool season grasses significantly. The animals' feed intake may need to be supplemented as grass growth slow. They should be removed as soon as the warm season grass starts to grow. Sheep or goats can be used to selectively graze broadleaf weeds early in the season. If a planting is grazed, it is sometimes useful to build an enclosure to leave a small plot ungrazed so one can monitor plant growth.

Fire is an excellent tool to use to stress weeds in a warm season grass stand, but great care must be used to control the fire and not allow it to escape. Smoke, in the wrong place, will be a hazard to road traffic and airplanes as well as being bothersome to neighbors. Local regulations must be met. Enlisting the aid of fire control experts,

perhaps to use your controlled burn as a training exercise, is a good idea. Standing warm season grass residues burn fast and this is the effect that you want without losing control at the downwind end of the field. Slow backfires are not desirable because they can create hotter soil temperatures than fast moving fire does and can damage the crowns of the plants. If local authorities insist that you backfire all the way through the stand, abandon the plans to burn. Generally, controlled burns should be spring events that are timed to take advantage of dry fuel and winds around 10 miles per hour from a favorable direction. The warm season grasses should have one to three inches of new growth. After the burn, the black ash will absorb solar radiation, warm the soil rapidly and in turn cause more rapid grass growth. The warm season grasses gain some advantage at the same time the weeks and cool season grasses are set back.

Fire may be a less useful tool for managing cool season grass stands in the northeast. The native cool season grasses of the northeast probably did not evolve in a frequent fire environment, as did the warm season grasses.

Cool season grasses can be used as an effective firebreak around warm season stands, but they will carry a fire if not raked free of death material and thatch. If in doubt, wetting the firebreak with water immediately before a burn is good insurance. **Before any use of fire is attempted, a plan must be in effect, necessary permits arranged, the right equipment and sufficient personnel to control the fire must be on hand. As well, effective preparation of firebreaks must be achieved and the weather and timing must be favorable.**

Stand maintenance

While native plantings may be considered permanent, periodic management is required. Management interval will vary with soil, climate, plant species and other factors. In the northeast, management may be required every three years. It is important that management occurs before stand vigor declines dramatically or competitive invasive species overrun a planting. A program of systematic monitoring of systematic monitoring of stand vigor is recommended to guide management decisions.

Management treatments on either planted or naturally occurring native sites may be undertaken for a variety of reasons. Chief among these is the removal of accumulated plant litter which can impede light penetration. Experience indicates that a two to three inch (6 to 8 cm) continuous layer of plant litter can reduce seed culm and total culm densities. These features are indicators of stand vigor. Exposing growth points to sunlight and recycling nutrients tied up in old plant growth with a controlled burn generally stimulates vigorous new growth.

Properly timed management, especially a properly timed burn, can stimulate tillering in new plantings, accelerating the establishment of newly seeded native grasses. In a warm season grass planting, a burn in the spring of the second or third year after establishment when the grasses have one to three inches of new growth is strongly recommended as an initial management treatment. Fire management also serves to reduce the risk of large and potentially damaging wildfires by removing accumulations of old growth. Haying a grazing are also accepted management techniques on seeded native areas.

Planned well controlled fire is a useful and inexpensive management technique in warm season grass stands. Unplanned, uncontrolled

fire is obviously dangerous and becomes more likely as the number of public users is increased. Few people have experience with tall grass fires that involve stands with several years of fuel built up. Therefore it is wise to manage the hazard with planned cool season grass firebreaks and consider the relative need for these in the site selection process.

Controlled burns are a valuable stand management technique in both seeded plantings and prairie remnants like this one in Illinois.

Spot mowing can provide weed control and stand management benefits.

Even livestock as exotic as bison can be used to supply managed grazing treatments on plantings.

Although these burns may and should be supervised by qualified personnel, distances considered safe for fire may be shorter than for associated smoke. Smoke damage to property or smoke inhalation by humans or livestock could be a costly situation. This is equally true if one is considering a roadside site. Traffic management, posting and permits need to be addressed before burning.

Timing, weather, moisture conditions and firing techniques are important factors influencing the effectiveness of a managed burn. If the burn is intended to control shrubs and saplings, timing is critically important. Research at several universities has shown that the most effective time to injure woody plants with fire is just as they reach full leaf. At that stage, they have expended large energy reserves to create new growth and have not yet been able to replenish their carbohydrate store through photosynthesis and respiration. Warm season grasses will likely have achieved more than one to three inches of new growth – the stage at which fire is most beneficial to them – when woody plants reach full leaf. However, warm season grass vigor will not be seriously affected as long as late burns are not frequent occurrence. Careful management is required if controlled burns are being used to maintain a savanna type plant community where shrubs and/or trees are interspersed throughout the grassland. Before undertaking a burn, consultation with experts and a review of the literature is recommended.

Mowing and grazing can provide many benefits similar to burning. If mowing is used we recommend waiting until after June 30 when most ground nesting birds have completed incubation and left their nest sites. Cut as low as possible with a mower conditioner or a flail type mower. Remove as much of

the old plant litter as possible to stimulate new growth. Experience suggests that mowing does not provide a long lasting treatment effect if the lower letter layer is not removed. If mowing or haying don't provide sufficient impact on old plant litter, scarification of the soil surface with heavy harrows or similar equipment may enhance the treatment effect.

Grazing is also a management option. On wildlife priority areas, we recommend that grazing be well regulated, infrequent and intended to provide maximum benefits to the grass stand. Grazing should be designed to maximize stand vigor, with secondary agricultural benefits. Extensive reclamation areas or areas of existing pasture revegetated with native plant materials can be maintained in a productive state and provide nutritious long lived forage under a managed grazing system. Local pasture experts should be consulted to set up a system that is appropriate for your sold and climate zone.

Where it can be practiced, controlled fire is the most effective technique for maintaining warm season grass stands in the northeast. We know that vegetation can shift rapidly from grassland to shrub and tree communities when no management occurs. When that happens, broard scale herbicide application, chain saws or bulldozers may become the only remaining management alternative.

APPENDIX C

Native Grass Cultivars Adapted for Use in Northeastern North America

Cultivar Recommendations for the Northeastern States and Eastern Canada

SPECIES	CULTIVAR	SELECTED IN	GEOGRAPHIC USE AREA	USDA PLANT HARDINESS ZONE
Bluestem, big	'Bison'	ND	northern MI to central MN & n	2, 3, 4
	'Bonilla'	SD	central MI to central MN	4, 5
	'Champ'	IA/NE	southern WI south	5, 6
	'Kaw'	KS	Southern VT/NH & south	5, 6, 7
	'Niagara'	NY	all	3,4,5,6
	'Pawnee'	NE	southern WI south	5, 6
	'Rountree'	MO	southern MN to central MI & s	4, 5, 6
	'Sunnyview'	SD/MN	central MI to central MN	4, 5
Bluestem, little	'Aldous'	KS	southern WI, NY & south	4, 5, 6
	'Blaze'	NE	southern MN, WI, MI	4, 5
	'Camper'	NE	central MN south, NY & north	4, 5
Bluestem, sand	'Goldstrike'	NE	NY & north	3, 4, 5
Cordgrass, salt meadow	'Avalon'	NJ	VA/NH	4, 5
Smooth	'Bayshore'	NJ	VA/NH	4, 5
Deertongue	'Tioga'	NY	all	3, 4, 5
Gamagrass, eastern	'Pete'	KS	all	4, 5, 6
Grama, sideoats	'Butte'	NE	central MN to southern MI	4, 5
	'El Reno'	KS	NY & south	4, 5, 6
	'Killdeer'	ND	northern MI & north	2, 3
	'Pierre'	SD	central MN to central MI	4, 5
	'Trailway'	NE	southern New England & north	3, 4
Indiangrass	'Cheyenne'	OK	VA & south	6, 7
	'Holt'	NE	central MN & south	4, 5
	'Lometa'	TX	VA & south	6, 7
	'NE-54'	NE	NY & north	3, 4, 5
	'Osage'	KS/OK	central PA & south	6, 7
	'Oto'	KS/NE	southern MN & south	4, 5
	'Rumsey'	MO	PA & north	4, 5, 6
	'Tomahawk'	ND/SD	central MI, northern WI & n	2, 3, 4
Lovegrass, sand	'Bend'	KS	central VT, NH & south	5, 6
	'NE-27'	NE	NY & north	3, 4, 5
Panicgrass, coastal[1]	'Atlantic'	NJ	all	3,4,5,6
Switchgrass	'Alamo'	TX	southern MD & south	6, 7
	'Blackwell'	KS	southern WI to NY & south	5, 6, 7
	'Cave-in-Rock'	IL/MO	southern WI to NY & south	5, 6, 7
	'Dacotah'	ND	central MN to northern MI & north	2, 3, 4
	'Forestburg'	KS	central MN to central MI	4, 5
	'Kanlow'	KS/OK	Long Island & south	6, 7
	'Nebraska 28'	NE	central MN to central MI	4, 5
	NJ-50[2]	NJ	PA & south	6, 7
	'Pathfinder'	KS/NE	southern MN to southern MI	4, 5
	'Shelter'	NY	WV to southern NH	5, 6
	'Sunburst'	SD	central MN to central MI	4, 5
	'Trailblazer'	NE	southern MI, MN; central VT & north	3, 4

[1]This is the only cultivar of coastal panicgrass. It is not reliably winter hardy north of central Pennsylvania. However, it is often used as a temporary companion throughout the region due to its good seedling vigor, especially on droughty sites.

2**NJ-50** seed may have been formally released and available in 2000.

APPENDIX D

Because of the wide range of conditions encountered in the northeast, a correspondingly wide range of native species mixtures have been and are being used in the region. Those shown here have been selected to represent that range. They should not be construed as being recommended mixtures for all parts of the Northeast. To get recommendations for specific conditions and/or cultivar selection, contact your local NRCS office or other knowledgeable local personnel.

Basic warm season grass mixture. (See Appendix C for cultivar recommendations).

SPECIES	PLS LB/AC	SEEDS/LB	PLS SEEDS/SQ FT
Switchgrass	2	389,000	17.8
big bluestem	3	165,000	11.4
indiangrass	1	175,000	4.0
eastern gamagrass	2	7,500	0.3
little bluestem	2	240,000	11.0
coastal panicgrass	1	300,000	6.9
sideoats grama	1	191,000	4.4
purpletop (PA south)*	1	161,000	3.7
Option 1. On droughty sites with less than 10 percent fines passing 200 mesh sieve, add and subtract:			
sand lovegrass	add 2	1,550,000	71.2
sand bluestem	add 2	125,000	5.7
deertongue	add 1	400,000	9.2
coastal panicgrass	add 1	300,000	6.9
eastern gamagrass	sub 2	7,500	0.3
prairie sandreed	add 2	274,000	12.6
sideoats grama	sub 1	191,000	4.4
Option 2. On wetter sites add and subtract:			
prairie cordgrass*	add 1	197,000	4.5
little bluestem	sub 2	240,000	11.0
coastal panicgrass	sub 1	300,000	6.9
Option 3. To the above mix add some genera of the following forbs and legumes. This list presents a cross section of bloom dates, flower color and seed shape to attract native pollinators and birds. Other species worthy of consideration may also be available.			
butterfly milkweed	.01	50,000	0.01
New England aster	.01	1,216,000	0.3
New York aster	.01	4,600,000	1.0
heath aster	.01	800,000	0.2
blue false indigo	.01	63,140	0.01
partridgepea	.1	3,500	0.008
oxeye daisy	.1	2,063,000	4.7
lanceleaved coreopsis	.05	210,000	0.2
purple coneflower	.1	97,000	0.2
sunflower heliopsis	.01	126,000	0.03
roundhead lespedeza	.01	144,000	0.03
spiked gayfeather	.01	162,000	0.04
perennial lupine	.05	18,800	0.02
wild bergamot	.01	1,418,000	0.3
grey-head coneflower	.01	410,000	0.09
blackeyed susan	.01	1,750,000	0.4
cup rosinweed	.01	12,000	0.003
Canada goldenrod	.01	1,000,000	0.2

*these species are only available from wild harvest at this time.

APPENDIX D-5

Basic Warm Season Grass Mixture (See Appendix C for cultivar recommendation) and New England States/ Mid Atlantic

Warm season grass mixture

Species	PLS lbs/ Acre	Seeds / Pound	Seeds/ Acre	PLS Seeds/ Sq. Ft.
Big Bluestem	1.0	165,000	165,000	3.8
Switchgrass	1.0	389,000	389,000	8.9
Indiangrass	3.0	175,000	525,000	12.0
Little bluestem	1.0	240,000	240,000	5.5

(Adapted forbs may be added)

Purple prairie clover, black-eyed susan, round-headed brush clover and stiff goldenrod were mentioned as possible or core forbs in all four states. Yellow coneflower, Maximilian sunflower and coreopsis are also specified in one or more states. Purple coneflower, showy goldenrod, Canada tick trefoil, wild bergamot, lead plant, butterfly weed and ox-eye (false) sunflower were listed as optionals in three of four states.

New England States/Mid-Atlantic Mixture

Species	PLS lbs/ Acre	Seeds/ Pound	Seeds/ Acre	PLS Seeds/ Sq. Ft
Deertongue	*15*	400,000	6,000,000	137.7
Broomsedge	10	—	—	—
Bush clover	2	144,000	288,000	6.6
Redtop	I	4,990,000	4,990,000	114.5

2. For sand and gravel pits, wildlife areas, landfill cover seeding

Species	PLS lbs/ Acre	Seeds/ Pound	Seeds/ Acre	PLS Seeds/ Sq. Ft
Big bluestem	10	165,000	1,650,000	37.9
Indiangrass	10	175,000	1,750,000	40.2
Switchgrass	10	389,000	3,890,000	89.3
Little bluestem	10	240,000	2,400,000	55.1
Redtop or	1	4,990,000	4,990,000	114.5
*Perennial **ryegrass***	10	*227,000*	*2,270,000*	*52.1*

Seed Mixes

Introduction

The Vermont Agency of Transportation has developed two seed mixes to be used in highway projects throughout the State. These two mixes, a Rural Areas Conservation Mix and Urban Areas Conservation Mix, have been formulated to provide a rapid starting, low maintenance vegetative cover that is tolerant of Vermont's climate and salt conditions along roadways. The annual ryegrass found in both mixes germinates quickly and will help reduce the potential for erosion. The urban mix has a high percentage of Kentucky Blue Grass, which is popular as a lawn grass and, therefore will blend better with neighboring lawns.

Both of these mixes are readily available from most agriculture or feed stores. Though it is not kept on hand in its mixed form, the individual components of each mix are usually in stock and can be blended upon request.

VTrans Seed Mixes

Urban Areas Conservation Mix

% WT.	Lbs./A.	NAME	Pur%	Germ%
42.5	34.0	Creeping Red Fescue	98	85
10.0	8.0	Perennial Rye Grass	95	90
42.5	34.0	Kentucky Blue Grass	85	85
5.0	4.0	Annual Rye Grass	95	85
100.0	80.0			

RATE: Double if hydroseeding

Rural Areas Conservation Mix

% WT.	Lbs. / A.	NAME	Pur%	Germ%
37.5	22.5	Creeping Red Fescue	98	85
37.5	22.5	Tall Fescue	95	90
5.0	3.0	Red Top	95	90
15.0	9.0	Birdsfoot Trefoil	98	85
5.0	3.0	Annual Rye Grass	95	85
100.0	60.0			

RATE: Double if hydroseeding

The following grass mixes are recommended for low maintenance and poor soil sites.

Low Grow/Fine Fescue Mix:

% WT.	NAME	Pur%	Germ%
38	Creeping Red Fescue	98	90
29	Spartan Hard Fescue	95	85
15	Azay Sheep's Fescue	95	87
15	Annual Ryegrass	95	90
3	Inerts		
100.0			

RATE: Double if hydroseeding

How Fine Fescues Cut Roadside Maintenance Costs

(Source: *Better Roads Magazine*, Sept. 92)
Author: Larry J. Kuhns

Fine fescues including creeping red, chewings, sheeps, and hard fescue have always been available for use as low-maintenance grasses but they are not well-known or used.

Where used, fine fescues have proven to be extremely effective. They grow under a wide variety of soil texture, fertility, and moisture conditions. They are drought tolerant; well-adapted to acidic, infertile soils; and will grow in clay soils or soils with a high sand content. They grow from coast-to-coast

in the temperate regions of the United States and Canada. They develop a deep, extensive root system and a dense sod that will provide support for vehicles that leave the road. They tolerate shade and grow well in full sun. They survive and thrive better than any of the other cool-season grasses under low maintenance conditions which include little or no mowing, irrigation, fertilization, or pesticide use.

Once established, fine fescues are extremely competitive with weeds and brush species. They may have allelopathic effects on other vegetation, either totally excluding it or severely stunting it. They are tolerant of many selective broadleaved weed killers and are even resistant to two selective grass killers. This means brush and weeds of all types can selectively be removed from fine fescue plantings without damaging them.

In a roadside situation, fine fescues require little or no mowing. Sheeps and hard fescue grow very slowly, and the leaf blades of the taller-growing red and chewings fescue lay over and mat as they grow. The only reasons to mow fine fescues along roadsides are to cut weeds or their seed heads, of which hard and red fescue produce very few.

Fine fescue difference

There are some distinctions between the fine fescue species. Creeping red fescue is distinct from the other fine fescues in that it spreads by small, short rhizomes. Improved varieties develop a stronger rhizome system and can spread faster. It has a medium establishment rate and will provide a cover faster than hard or sheeps fescue. However, it does not complete excessively with them during establishment. While leaf blade lengths of 20 in. are common for many of the turf varieties of red fescue, canopy height of an unmowed area will be considerably less because the leaves lay over. Other varieties have been developed that produce leaf blades of only 12 to 14 in. It typically produces very few seed heads and would not require mowing for seed head control. Red fescue is not as tolerant of wet soils and salt as hard fescue.

Chewings fescue is very similar to creeping red fescue except that it lacks rhizomes. It is a bunch-type grass with a rate of establishment and vertical shoot growth comparable to that of red fescue. As with red fescue, lower-growing varieties are available. The climatic adaptations of chewings fescue are similar to those of red fescue. However, it does produce more seed heads and they would need to be mowed once a year to maintain a neat appearance.

Hard fescue has a bunch-type growth habit, excellent drought and heat tolerance, and will survive higher soil moisture and salt levels than red fescue. Its germination and establishment rate is distinctly slower than that of red or chewings fescue. It produces few seed heads and would not need to be mowed for seed head removal. Hard fescue has reasonably good winter color, but they are slower to green up in the spring than some chewings and red fescue.

Sheeps fescue is a bunch-type grass that germinates and establishes at about the same rate as hard fescue, but grows slower and remains lower. It is extremely drought resistant, but its heat tolerance is lower than the other fine fescues. It produces more seed heads than hard fescue and they would need to be mowed.

Though they are well-adapted for roadside use, the fine fescues have several limitations. They are usually weedy during establishment because they have a slow (hard and sheeps)

to medium (red and chewings) germination and establishment rate. Establishment is especially poor during hot summer months. Also, their lateral spread is slow, even for creeping red fescue. This could be a problem on unevenly prepared sites or areas where the seeding pattern was not uniform.

Why use them?

If fine fescues are so good, why haven't they been used more along roadside? Though used, they have been a small part of the market. Few people were aware of their desirable characteristics and most people were totally unfamiliar with any fine fescue except red fescue.

Research is continuing with all of the fine fescues, and industry and university personnel are conducting active selection and breeding programs to develop new varieties. The improved varieties are not only extremely adaptable to a variety of sites, but they receive turf quality ratings as high as or higher than those of Kentucky bluegrass and perennial rye grass. At this time, many varieties of all the fine fescue species are available, while more are being developed, tested, and introduced.

This creates a major problem for anyone writing specifications for seed mixes, especially since almost all the testing is done under more typical turf conditions—annual fertilizer applications and close mowing. Differences between varieties include texture, growth rate, color, seed head development, disease and insect resistance, and the presence of endophyte (a beneficial fungus associated with the grass that makes it resistant to some common insect problems). To further complicate the issue, the relative performance of two particular varieties may be reversed in different parts of the country. Yet improved varieties should be specified because they are superior to the common, old varieties.

There are other grasses than can be combined with the fine fescues either to aid in establishment or to provide some other characteristics that may be important in the long term. Colonial bentgrass is a fine-textured, sod-forming grass that is adapted to northern, humid climates and will tolerate acid, infertile, and droughty soils. This grass has very fine seeds and should not exceed 5% by weight in seed mixture. The improved variety is recommended.

Kentucky bluegrass is a sod-forming grass that is adapted to northern climates and to better soils in the roadside environment or to areas that receive some fertilizer, such as urban zones.

Perennial rye grass is a bunch grass that establishes rapidly and is useful for initial stabilization. It is short-lived under roadside conditions and because it is highly competitive during establishment, should be a minor component of roadside seed mixes. No more than 15 lbs. /acre should be included in a mix with fine fescues.

Establishing and maintaining a low maintenance fine fescue turf is no more difficult than any other turf. However, a few more steps can be added to speed the establishment of a weed-free stand:

1. Select a seed mix. The textures of the hard fescues and red fescues are compatible; both are well-adapted to a variety of roadside conditions, and neither produces enough seed heads to require mowing. If there is a need for immediate soil stabilization, add 5 to 10% improved perennial rye grass. In Preliminary trials on Pennsylvania roadsides, red fescue germination and establishment were not far behind that of perennial rye grass.

2. Eliminate all weeds from the areas. If the site is new construction, the soil will be bare following grading. If the site is being renovated or converted from a high-maintenance cover, spray the area with a translocated, postemergence, non-selective, non-residual herbicide such as Roundup to kill all perennial weeds and grasses.
3. Run over the soil with disk to form shallow (1 in. or less) grooves. This should be done on bare ground or after sprayed vegetation has had time to absorb and translocate the herbicide to its roots.
4. The seed can be broadcast, dropped, or hydroseeded. Research conducted at Penn State showed that rolling or dragging following seeding was not necessary. Steps 3 and 4 can be combined with seeding equipment that is currently available.
5. Apply 40 lbs. of nitrogen/acre to increase growth during establishment.
6. When the grass reaches a height of 2 in., an application of selective herbicides can be made to control competing vegetation. Mowing will also work but will not be quite as effective.
7. A broadcast application of selective herbicides every two to five years should be sufficient to prevent the establishment of perennial broadleaved weeds or brush species. Little or no mowing should be needed. If mowed it should not be cut closer than four inches and there is really no need to cut lower than 6 inches, since it does not regrow fast.

Though a well-established fine fescue planting would present a neat and attractive appearance along a roadside, it could become monotonous. Some of the money saved on maintenance costs should be put into landscape plantings. These plantings should be designed into groupings of trees and shrubs instead of being planted as individuals. The growth and development of individual trees and shrubs surrounded by fine fescue will be stunted by their competitive and allelopathic nature. The trunks of trees planted individually are also often damaged by mowers. By planting the trees and shrubs in groups they can provide a canopy dense enough to keep the grass and mowers away from them.

Sand and Gravel Sites Conservation Mix

Gravel Sites Conservation Mix

%Wt	Lbs./A	Species	*Preferred Variety	Pur% Germ%
32.0	4.0	Switch grass	Blackwell	(varies on crop harvest)
32.0	4.0	Big Bluestem	Niagra	(varies on crop harvest)
16.0	2.0	Little Bluestem	Camper	(varies on crop harvest)
12.0	2.0	Sand Lovegrass	NE27	(varies on crop harvest)
8.0	1.0	Blackeyed	Golden Susan	(varies on Jubilee crop harvest)
100.0	13.0			

*Substitute preferred varieties if not available

Actual lbs/A, will be higher than 13.0 lbs. Seed rate is based on a pure live seed formula (P.L.S.) An adjustment is made to the bulk weight of the seed to compensate for inert material and dead seed. The supplier will formulate seed mixture according to (P.L.S.) formula and bag seed mixture in quantities of one acre bags.

This seed mixture is designed for borrow areas, gravel banks and gravel pits. It is a mixture of 4 “warm season grasses” and 1 wildflower that is best suited for these areas. Rural or urban conservation mixes will not survive in these areas. This mixture requires

specific seeding preparation different from the other mixes.

Further seed information for gravel sites can be found in the NRCS Critical Area Section of this Technical Guide.

Site Preparation for Gravel Sites Conservation Mix

Use of this seed mix can be determined by obtaining 6 to 8 small samples (1 or 2 handfuls) of soil from the upper 4 inches of soil material from the area to be seeded. Mix the small samples to obtain one composite sample.

Send soil sample to an approved soil laboratory for analysis. Where percent by weight passing a 200 sieve is less than 15, use the Sand and Gravel Sites Conservation Mix.

The seeding must be done by the use of a hydroseeder and dozer combination. Incorporate lime at the rate of 1 ton per acre, fertilizer at the rate of 500 lbs. per acre of 19-19-19 and seed at the rate of 13.0 lbs (P.L.S.) per acre into the hydroseeder.

Use dozer to "Track" the site. If on a slope, slope must be "Tracked" up and down rather than across. It is not necessary to have the slope perfectly smooth.

If the erosion hazard is low, mulching is not necessary for seeding success. If mulch is required, weed-free mulch is a must. Clean straw is recommended. Mulch at the maximum rate of 500 – 750 lbs. per acre. Higher mulching rates and mulch with weed content will inhibit seeding success significantly.

The primary seeding window begins as soon as the snow is gone in the spring and ends May 15. The importance of early seeding cannot be over emphasized. Substantial failure can be expected if seeding is done later, depending on weather conditions.

Maintenance for Gravel Sites Conservation Mix

The plant species germinate and grow slowly. Complete cover may not occur for 2 – 3 years. Follow-up seeding may be needed to establish vegetation on the more difficult parts of some sites. The need to do follow up seeding can be determined the year after seeding.

Substantial stand vigor can be achieved if the site is top dressed with a "Slow Release" fertilizer one year after planting. Fertilize between June 15 and July 15. The time of this top dressing is important. Top dress with a balanced fertilizer; apply 50 lbs. of nitrogen per acre.

If mowing is desired to suppress woody growth, mow about mid-July.

The following seed mixes are "native plants" recommended for specific site conditions.

Source with permission: Ernst Conservation Seeds, Meadville PA

Wet Area Mix

Wet areas are usually adjacent to rivers and waterways. Some examples of typical wet areas are: road ditches; retention basins that catch runoff water, pond areas and wetland edges. The soil will contain clay, a high amount of organic matter or saturated sands.

Wet Area Seed Mix

Common Name	Latin Name	% Mix
Virginia Wild Rye Grass	*Elymus virginicus*	20%
Fox Sedge	*Carex vulpinoidea*	10%
American Mannagrass	*Glyceria grandis*	20%
Giant Bur-Reed	*Sparganium eurycarpum*	10%
Common Three-Square	*Scirpus americanus*	20%
Soft-Stem Bulrush	*Scirprus validus*	10%
Canada Rush	*Juncus canadensis*	10%

Rate of Application: 10# per acre (up to15# per acre if hydroseeded)

Site Preparation

Spray Glyphosate (Rodeo) or a similar wetland aquatic only with the Agency of Agriculture permit formulation to control undesirable vegetation. Caution: Some persistent species such as Purple Loosestrife, Phragmites, or Reed Canarygrass may need multiple applications of Glyphosate. Before seeding, excess dead vegetation should be burned or turned under providing it is not too wet. Newly constructed wet meadows, retention basins, and wet construction sites should be seeded as soon after construction as possible. Fertility: Due to the potential for water contamination we do not recommend the use of lime or fertilizer in wetlands. We do recommend the addition of organic materials when topsoil has been depleted or removed.

Seeding Methods

Broadcast Method: Broadcast by hand or knapsack seeder using the proper seeding rate, carefully proportioning seed for the entire area. Sometimes filler such as kitty litter, sawdust, or sand is added to help proportion the seed. Increase accuracy by seeding half of the seed in one direction (horizontally) and the remaining seed in the other direction (vertically). Follow by rolling or tracking seed into the top ¼ inch of the soil to achieve good seed to soil contact. Do not roll or track the seed if soil is wet. Cover with a light layer of straw mulch.

Hydro-seeding: Hydro-seeding is typically used on areas too wet to work. Apply seed and a small amount of hydro-mulch for good seed placement. Follow up with straw mulch or hydro-mulch seed. Rate: 25#/acre.

Maintenance

Grassy weeds or persistent perennials can reestablish in this type of soil. Monitoring weeds and mowing is very critical in the first and second years. Burning about every three years in early spring can prevent shrub invasions.

Upland Native Mix for Dry Sites

Source with permission: Ernst Conservation Seeds, Meadville PA

% Wt	Lbs./ Acre	Botan. name	Common name	Pur% Germ%
40.0	10.0	*Echinochloa crus-galli*	Japanese Millet	(varies by source)
	OR	*Hordeum vulgarel*	Barley	(varies by source)
26.0	6.5	*Andropogon gerardii*	Big Bluestem	(varies by source)
14.0	3.5	*Andropogon scoparius*	Little Bluestem	(varies by source)
14.0	3.5	*Sorghastrum nutans*	Indiangrass	(varies by source)
6.0	1.5	*Panicum virgatum*	Switchgrass	(varies by source)
100.0	25.0 Bulk Pounds per Acre			

Application Rates:

Seed	20 bulk lbs. / acre
Lime	2 ton/ acre
Mulch	2/ton/ acre
Fertilizer	500 lb/acre

The seed mixture shall not have a weed content exceeding 0.40 % by weight and shall be free of all noxious weed seed.

Seed to be applied per seeding formula as directed by the Resident Engineer.

Upland Sites are characterized by being dry most of the time, with very little sandy shale –like top-soil they are subject to drought. Upland sites are generally exposed to full sun and have good air circulation. Examples include: naturally rocky soils that have been subject to erosion or steep road cuts, abandoned building sites and industrial sites.

Upland Native Mix for Dry Sites —Seeding establishment Guide

Site Preparation

Removing and controlling existing weedy growth is the first step in creating a natural habitat. The primary way to control weeds is spraying them with Glyphosate (Roundup) or tilling them into the soil. Deep-rooted perennials and woody species may require special removal and/or control measures. High potential for erosion exists after removing the existing vegetation. Soil should be tilled to a depth of two inches followed by rolling or tracking to create a firm seed-bed as light, fluffy soil will dry out rapidly. Return any available topsoil to the site. Fertiltiy: Adding organic matter is most important to improve soil fertiltiy. Lime and fertilizer should be added per soil test.

Seeding Methods

BROADCAST: Broadcast by hand or knapsack seeder using the proper seeding rate, carefully proportioning seed for the entire area. Sometimes filler such as kitty litter, sawdust, or sand is added to help proportion the seed. Increase accuracy by seeding half of the seed in one direction (horizontally) and the remaining seed in the other direction (vertically). Follow by rolling or tracking seed into the top ¼ inch of the soil to achieve good contact. Cover with a light layer of straw mulch or erosion control blankets.

HYDROSEEDING: Hydroseeding is typically used on steep slopes and roadside cuts. Apply seed and a small amount of hydromulch for good seed placement. Follow up with erosion control blankets, straw mulch, or hydromulch to cover seed.

DRILL SEEDING: Native grasses and wildflowers require a drill with a seed box developed for light, fluffy seed. These drills are generally only practical for several acres or more where slopes are not too steep for operation. The use of a drill can promote good seed-to-soil contact and can reduce the need for mulch.

First Year Maintenance

Observation of the growth of desired species and weed competition is essential to making maintenance decisions. When vegetation reaches 12 to 18 inches tall, mow to no less than six inches by rotary mowing or weed eater to prevent the weeds from going to seed. Most native plants will grow deeper root systems in the first year than tops, and mowing to six or eight inches will not hurt them. This allows sunlight to reach desired species. DO NOT MOW WITH A LAWN MOWER. Mowing too close encourages weedy species.

Second Year Maintenance

Mow one time as close to ground as possible in early spring. This allows the soil to warm more quickly and young native plants to emerge. During the winter birds and other wildlife can enjoy your native site if you postpone mowing until early spring.

Retention Basin Mix

% Weight	LBS/Acre	BOTANICAL NAME	COMMON NAME
20.0	5.0	*Agrostis alba*	Red Top
20.0	5.0	*Agrostis stolonifera*	Creeping Bentgrass
20.0	5.0	*Elymus riparius*	Riverbank Wild Rye
20.0	5.0	*Poa palustris*	Fowl Bluegrass
20.0	5.0	*Puccinellia distans*	Alkaligrass
100.0	25.0	Bulk Pounds per Acre	

Application Rates:

Seed	20 bulk lbs./acre
Lime	2 ton/acre
Mulch	2/ton/acre
Fertilizer	500 lb/acre

The seed mixture shall not have a weed content exceeding 0.40 % by weight and shall be free of all noxious weed seed.

Seed to be applied per seeding formula as directed by the Engineer.

Sites for this seed include retention basin floors that catch runoff water, and wet meadow and riparian sites that are adjacent to rivers and waterways. Examples of these sites include: road ditches, retention basin floors that catch runoff water, pond areas, and wetland edges.

SITE PREPARATION: Newly constructed wet meadows retention basins and wet construction sites should be seeded as soon as possible after construction. Spray Glysophate (Rodeo) or a similar wetland aquatic formulation to control undesirable vegetation. CAUTION: Some persistent species such as Purple Loosestrife, Phragmites, or Reed Canarygrass may need multiple applications of Glysophate. Before seeding, excess dead vegetation should be burned or turned under providing it is not too wet. Newly constructed wet meadows, retention basins and wet construction sites should be seeded as soon as possible.

FERTILITY: Due to the potential for water contamination, we do not recommend the use of lime or fertilizer in wetlands. We do recommend the addition of organic materials when topsoil has been depleted or removed.

Seeding Methods

BROADCAST: Broadcast by hand or knapsack seeder using the proper seeding rate, carefully proportioning seed for the entire area. Sometimes filler such as kitty litter, sawdust or sand is added to help proportion the seed. Increase accuracy by seeding half of the seed in one direction (horizontally) and the remaining seed in the other direction (vertically). Follow by rolling or tracking seed into the top ¼ inch of the soil to achieve good seed to soil contact. Do not roll or track the seed if soil is wet.

HYDROSEEDING: Typically used in areas too wet to work. Apply seed and a small amount of hydromulch for good seed placement. Follow up with straw mulch or hydromulch to cover seed.

MAINTENANCE: Grassy weeds or persistent perennials can reestablish in this type of soil. Monitoring weeds and mowing is very critical in the first and second years. Burning about every three years in early spring can prevent shrub invasions.

3

Wildflowers

Introduction

For many years VTrans has experimented with wildflower planting statewide. VTrans is involved with three wildflower programs: One is the federal program where wildflowers are planted as part of landscape projects undertaken on the federal-aid highway system.

Wildflower Planting , I-89. Hartland, VT.

The second program is conducted by the VTrans Operations Division. Over fifty wildflower plots have been planted in over twenty towns throughout the state along Interstate and other limited access highways. These plots are maintained by the VTrans Operations Division. If funding is available new beds are added and older ones are refurbished each year.

The third program is a cooperative effort between VTrans and the Vermont Heritage Program to protect rare, endangered and threatened native species within highway rights-of-way.

a. What is Native?

Source: Vegetating with Native Grasses in Northeastern North America,

United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS) and Ducks Unlimited, Canada

"Wildflower species should be those that are adaptive to the Northeast. Selection of seed mixes will be determined by a number of technical factors and the user's primary objective."

What is Native?

When applied to plant species, the word **native** often means different things to different people. In this manual, native is used to refer to the species indigenous to a region at the time of European settlement.

The grasses brought to North America by our forefathers were imported primarily from agriculture. These plants were so highly adapted to northeastern conditions and planted so extensively that they have out competed native grasses in many of the ecosystems of the region. Those grasses have long been naturalized in the eastern regions of North America. A **naturalized** plant is one that is known to have originated outside of a particular region, , but currently exists in the wild in self perpetuating populations.

While there are specific characteristics common to a species – regardless of place of origin – that distinguish it from other species, there are also adaptations within a species that separate it into **ecotypes**. One

ecotype differs from another in specific morphological and physiological traits such as height, hardiness or growth rate.

An ecotype grown out of its area of adaptation is not likely to perform well and may not even survive. However, the opposite may also be true; a species brought into an area may be overly competitive to other desirable plants. Either of these situations could be costly and time consuming to correct. Experience has shown that ecotypes moved too far north tend to have hardiness problems, while those moved too far south are likely to have disease problems.

A **cultivar**, or variety, is an ecotype that has been selected for specific characteristics such as rate of growth, disease resistance,

Wildflower Planting, I-89 Hartland, VT

forage yield or seedling vigor. Most are developed through planned breeding programs with selections from diverse initial plant collections. As with other ecotypes, cultivars have specific areas of adaptation.

The selection of species for reclamation plantings should be based on a combination of criteria including the nature of the land base, purpose of seeding, likely management regimes, seed availability, seed costs, longevity, ease of stand establishment and the attributes of available plant species. Many of these same criteria are also likely to influence decisions regarding potential seed sources for each species used in a planting mixture. Seed of a species that could be used in relatively small amounts to increase the diversity of a planting may only be available from suppliers of locally harvested ecotypes. Conversely, the seed of another species may only be available in sufficient quantity from the producer of an adapted cultivar.

b. Wildflowers and the Federal-Aid Highway Program:

source: US Department of Transportation, Federal Highway Administration / FHWA website titled Roadside Vegetation Management http://www.fhwa.dot.gov/environment/wildflwr.htm

Wildflowers and other native plants provide visual character that enhances the natural scenic beauty of our nation's landscape. The growing concern for our natural heritage has generated an increasing interest in their restoration, preservation, and appreciation.

Our nation's highways provide access to the splendors of nature as well as offer opportunities for natural beauty within their rights-of-way. Under the program provisions of "Operation Wildflower" and the Surface Transportation and Uniform Relocation Assistance Act of 1987 (STURAA), native wildflowers are being planted in the rights-of-way to add natural character to the highway environment. These programs are the framework of all State Department of Transportation wildflower programs.

The Surface Transportation and Uniform Relocation Assistance Act of 1987/ STURAA became effective on April 1987. It contains a mandatory requirement that native wildflower seeds or seedlings be planted as

part of landscaping projects undertaken on the Federal-aid highway system. At least one-quarter of one percent of the funds expended for a landscaping project must be used to plant native wildflowers (and grasses) on that project. A landscaping project involves any action taken as part of a highway construction project or as a separate action to enhance the aesthetics of a highway through placement of plant material consistent with a landscape design.

Wildflowers are being grown and protected on highway roadsides under other program initiatives instituted by States. The reduced mowing policies of Michigan, Wisconsin, and Minnesota allow the natural establishment of wildflowers and protection of natural remnants. Additionally, native wildflowers and grasses are being customarily included in plantings undertaken as part of erosion control and vegetation management methods. They are also being planted under State's continuing efforts like Adopt-a-Highway, Roadsides-for-Wildlife, and Intermodal Surface Transportation Efficiency Act (ISTEA) enhancement projects. Watch for wildflowers on your next summer Sunday afternoon drive.

Role of the Federal Highway Administration:

The Federal Highway Administration oversees State programs on interstate and State highways that use federal funds. We also act as a technical resource and information clearinghouse for these programs. Each State's program is unique. Therefore the highway traveler will view different interpretations of STURAA and Operation Wildflower in each State. Within each State, natural regions vary and so do the roadside solutions used.

Roadside Use of Native Plants

Native Wildflower Requirement Agreement

In 1995 an exemption was granted the California Department of Transportation (Caltrans) by the Federal Highway Administration. Because the planting of native wildflowers might not be appropriate on all projects, especially urban sites, a type of banking alternative was developed by Caltrans. In 1998 the Wisconsin Department of Transportation (WisDOT) used the Caltrans exemption as a model for their own native wildflower banking system, viewed by the Federal Highway Administration (FHWA) as a commitment to establish and/or protect more native wildflowers than the U.S.C. 319(b) landscaping requirement. Their example demonstrates the flexibility of FHWA. Furthermore, as Wisconsin's FHWA Division Administrator wrote upon signing the agreement, "the new program should lend great support to WisDOT's strategic landscaping objectives including: safety enhancement, effective erosion control, reduction in the use of herbicides, pesticides, and fertilizers, and reduction of overall roadside vegetation maintenance costs." The WisDOT programmatic waiver is possible when certain stipulated conditions are met (shown below). **This agreement may be handled through each State's FHWA Division Office.**

1. Native wildflowers shall be used on Federal-aid highway planting projects as required by existing Federal law wherever it is practical, appropriate, and cost effective.
2. WisDOT shall establish a fund to which Federal-aid highway planting project moneys may be deposited or combined for use with other native wildflower plantings to achieve larger scale plantings.

3. WisDOT shall use an established method to identify a number of high-quality sites on Federal-aid highway rights-of-way in the State to preserve or establish native vegetation that will serve as native wildflower banking areas. The banking sites shall be developed in sufficient area to compensate for the locations where wildflower plantings are found to be inappropriate.
4. WisDOT shall develop a policy and guidance regarding the use and preservation of native wildflowers for use by landscape (and maintenance) staff that reflects the terms and conditions of this agreement.
5. WisDOT may determine that it is inappropriate to use native wildflowers where any of the following conditions exist:
   a. Where the adjacent urban landscape demands a compatible formal planting design inconsistent with the use of native wildflowers
   b. Where the required native wildflowers would result in poor planting design, regardless of adjacent landscape, or
   c. Where cultural practices necessary to sustain the rest of the planting would lead to the decline of the native wildflowers.
6. WisDOT shall determine that it is inappropriate to use non-native wildflowers whenever such species are perceived as a threat to the genetic integrity of similar native species in the region or whenever such species are considered invasive to natural areas, or competitive with native plantings.

c. Wildflowers and Federal Funding

source: Federal Highway Administration, *Code of Federal Regulations http://www.access.gpo.gov/nara/cfr/waisidx_03/23cfr752_03.html*

Federal funding for wildflower planting as a part of larger transportation projects is explained by the following regulation taken from the *Code of Federal Registration* ***CFR –Title 23 Volume 752.11 (b)*** *as follows:*

(b) Federal-aid highway funds may participate in any landscaping project undertaken pursuant to paragraph (a) of this section provided that at least one-quarter of one percent of funds ex pended for such landscaping project is used to plant native wildflower seeds or environmental impact seedlings or both. The Administrator statements may, upon the request of a State highway agency, grant a waiver to this requirement provided the State certifies that:

(1) Native wildflowers or seedlings cannot be grown satisfactorily; or

(2) There is a scarcity of available planting areas; or

(3) The available planting areas will be used for agricultural purposes.

(c) Subject to the requirement of removed paragraph (b) of this section, Federal-aid highway funds may participate plant establishment periods in or associated with landscape development.

(d) Notwithstanding the provisions of paragraph (b) of this section, Federal- aide highway funds may participate in the planting of flowering materials, including native wildflowers, donated by private garden clubs and other organizations or individuals.

(e) The value of donated plant materials shall not count toward the one quarter of one

percent minimum expenditure required by paragraph (b) of this section.

(f) Federal-aid funds may not be used for assemblage, printing, or distribution of information materials; for temporary or portable information facilities; or for installation, operation, or maintenance of vending machines.

4-a

New England Green Invasion

by William Brumback,
Conservation Director of the New England Wildflower Society.

from Conservation Notes of the New England Wild Flower Society-5; Vol.2, No.3—1998
Conservation Notes may be found at http://www.newfs.org/conserve/docs/wfn98.pdf

I have always thought that endangered species should be added to religion and politics on the list of topics unsuitable for dinner conversation. As we approach the millennium, I would now add invasive exotic plants. to the list of unmentionables. Plant professionals usually have strong opinions on this subject, and the views of some gardeners about these thugs of the plant world are unprintable in this journal. It seems that almost everybody has had some personal experience with changes caused by an invasive plant, either in the garden or in the larger landscape. These experiences instill deeply held convictions, which tend to polarize our conversations.

The published statistics on the potential impact of invasive plants are indeed frightening:

- Invasive plants already cover over 100 million acres and continue to increase by 8 to 20 percent annually, an annual increase in area equal to twice the size of the state of Delaware.
- Our public natural areas are being lost at an estimated rate of 4,600 acres per day to invasive species.
- The Nature Conservancy estimates that 42% of the declines of threatened and endangered species in the U.S. are partly due to the effects of invasive species.

Yet there is little unanimity over the scope of the problem or the solutions. Perhaps this is because the exotic species controversy is really about ourselves—about humans and our role in shaping the landscape of the earth —a subject with which many of us are uncomfortable.

In this issue of *New England Wild Flower: Conservation Notes*, we have tried to present a primer on the topic of Invasive Non-Native Species, complete with the biology of invasiveness (traits that made invasive species so successful), a "Rogues Gallery" of important invasive species in our area, and personal anecdotes from workers in the field and senior naturalists who have watched the pace of change increase over the years. We will discuss the controversies surrounding this very divisive topic and, we hope, present some possible solutions.

Defining The Problem

Native plants. are generally thought of as those species existing here (assuming that *here* is the U.S.) before the advent of the Europeans. Invasive exotic species are those non-native species that invade and alter both natural and managed areas. By these broad definitions, which are themselves disputed, there are many exotic species in this country, but only a few of them are considered invasive. For example, although one-third of the 3000 species listed in Seymour's (1969) *Flora of New England* are not native to our region, most, even if ubiquitous in the landscape, cause little concern among biologists. On the other hand, a few species, when released from the natural controls present in their region of origin (usually Europe or Asia) threaten to overwhelm our landscape, alter

our ecosystems, and change the face of New England.

Controversy In A Capsule

Here is a brief summary of some of the dialog from both sides of the issue, and, from my perspective, the fundamental reasons for trying to stem the tide of exotic invasions.

Controversy 1: Native vs. Non-native?

Native plant enthusiasts argue that native plants are better adapted, more appropriate, and more ecologically suited to our area than exotics. Supporters of horticulturally useful invasive exotic species have argued that these plants were brought here by people and, like people, can be considered part of the natural evolutionary spread of a species. They also argue that some exotic species are filling gaps where native plants are not able to thrive—urban streets being a prime example. But as long as our landscape is green, most people don't care whether the plants they see are "native" or "exotic." And what about native plants anyway? Aren't some of them invasive too?

Although some native species have invasive tendencies, few native species are considered troublesome in the long-run within their own range. Natural succession—the progress of meadow to woodland or pond to marsh—by changing conditions and fostering competition, is enough to prevent one species from dominating a habitat.

Relatively few natives from one region of the contiguous U.S. have become problems in other regions where they are not native. There are exceptions, such as Black Locust (*Robinia pseudoacacia*), a native of the southern U.S. that has escaped from cultivation and become a problem in parts of New England. Or a native New England cord grass, *Spartina alterniflora,* that was intentionally planted by the Army Corps of Engineers in California to hold sand dunes in place, but has apparently been so successful that it eliminates other species in that dune community.

But it would be difficult to name a dozen native U.S. species that are problems in other regions of the country. It's a lot easier to name exotic problem plants, especially Asian plants, which may be successful here due to the climatic similarities and biogeographic relationships of the east coasts of Asia and North America. And, to be fair, we have no idea how many U.S. plants are problems in other parts of the world, especially Japan.

Controversy 2: Personal Experience vs. The Larger Picture

When my brother-in-law first arrived in New England from Louisiana, he commented on the beauty of Purple Loosestrife in the wetlands, but by the end of his weekend trip he was saying, "You've got a problem."

The same plant that is a devastating invasive in your region may not even be noticed in mine. When I look through lists of species purported to be invasive exotics in a New England state or the region as a whole, I almost always see one or two names that cause me to think, "That's not a problem; why is it on this list?"

Recently, when a specialist on invasive plants of the northwestern United States was telling me about the aggressive acts of Herb Robert *(Geranium robertianum)* in the natural areas of that region, I tried to defend the plant, which is listed in *Gray's Manual of Botany* as a native species. Countering my arguments, the northwest specialist informed me that, in Gleason and Cronquist's (1991) *Manual of Vascular Plants,* the plant is described as an introduced species. Even if

it is introduced, I pleaded, it isn't a problem where I live. In New England it's a well-behaved denizen of rich, rocky woods, and shady ledges. I even view it as a good indicator of a rich, diverse natural habitat where rare species can also be found. It all depends on point of view.

Controversy 3: Ecology vs. Economy

Because nurseries and botanic gardens originally introduced, promoted, or currently make their living from selling many of the plants that are now considered pests, they tend to become defensive when the topic of invasiveness arises. Some even deny that any problem exists, especially when the suggestion is made that only native plants be used in modern landscaping. If you had 10,000 of a certain plant species growing in your nursery, you too might be a trifle irritated to be told that your investment was a terrible weed and shouldn't be sold. Understandably, some nursery owners demand proof that an exotic plant is a problem before ending its sale.

Either intentionally or unintentionally, humans have been moving plants all over the world for millennia, and I don't think that our innate desire for the new, the improved, or the unusual is going to end anytime soon. Yet, it is time to take a look at the issues posed by exotic species in the horticultural trade. One source states that 50% of the problem plant species invading this continent were brought here to beautify our gardens. Should we screen all plants coming into this country for invasive tendencies? Should we regulate which species can be sold in an at-risk area?

Controversy 4:Act Now or Wait for All the Facts?

It's a basic principle of nature that there are just so many niches in a habitat. When one species starts to dominate, something else is being lost, but hard data on both the abundance and effects of invasive exotics in natural areas is difficult to find. For this reason, some argue that conservationists are overreacting to the effect of invasive species.

Herbarium specimens, which form a permanent record of our flora collected over many years, should be the perfect resource to track the spread of invasive species to a new area, but unfortunately this record is often incomplete. Curators note that specimens of invasive exotics are greatly underrepresented in proportion to their abundance on the landscape. This is probably because many botanists never think to collect these abundant invaders.

Invasive exotic plant species may cause many changes in a habitat, but we still lack full information on these changes. For example, Purple Loosestrife apparently makes poor nesting habitat for many birds, but we do not yet know what specific effects Purple Loosestrife infestation may have on individual plant or animal species. You don't need a PhD in Conservation Biology though, to see the Purple Loosestrife in a swamp that turns the color of Barney the Purple Dinosaur in July and August. Though more research is clearly needed, the pace of change and the potential for damage is too great to justify extended delay in beginning to take preventive measures.

The Bottom Line

Biodiversity

Although we do not know how many native species we need in order to maintain viable communities and ecosystems, it is important to maintain as much resilience and stability as possible by maintaining as much natural diversity as possible. This is essential for adaptability and a harmonious, fully

functional ecology. Diversity protects whole systems from the potentially disastrous effects of disruption, both human and natural. As invasive plants take over, many of our natural communities are apparently becoming less diverse. Although documentation of these changes is lacking, and our ability to understand the effects to ecosystems is still very limited, we should not take the threat posed by invasive exotics lightly. History is full of ecological disasters caused by human neglect or hubris.

Because we understand so little of the long-term effects of invasive exotics on our ecosystems, we need to maintain natural areas that are minimally affected as reference points for native flora and for continued maintenance of basic ecosystem functions. In general, we must try to keep as many natural areas as possible free of invasive exotics. In some instances, the areas we have set aside as "conservation lands," including many state parks and town properties, are already too compromised in terms of species integrity to be included in a list of natural areas. For many of these lands, the expenditure of time, money, and effort to reclaim the property from exotic plants would be too great to warrant the attempt.

Don't get me wrong; these lands are certainly worth preserving as open space or for other public interests, but in terms of "natural areas" the biomass of the invasive exotic species can far outweigh the native plants. There are still some relatively pristine places, however, and it is in these areas, where the first skirmishes for the landscape are now underway, that we must be particularly vigilant. With invasive exotic plants, knowing when to fight and when to walk away is not only smart, but vital if we are to conserve the limited conservation resources we have.

Landscape

What do we want our landscapes to be? What types of vegetation should surround us, in our own backyards, our towns, our states, or our regions? Does it matter if New England's vegetation looks like Japan's? To me, the varied landscapes of New England are signatures of the underlying local diversity—a source of vitality that deserves protection. Unfortunately, we are seeing more and more of the botanical equivalent of monoculture—the same kinds of trees, shrubs, and perennials, some of which are thought to be highly invasive, used over and over again in home or business landscapes throughout a region. Similarly, natural areas are being invaded by many of the same exotic species used in horticulture. The pictures introducing this article dramatically illustrate the contrast between a diverse natural woodland and a woodland dominated by an invasive, exotic plant species.

There can be little doubt that invasives are changing the face of our landscapes on a large scale. They may even be affecting our major native vegetation types, which are based on the dominant species typically found there. In New England, for example, the Oak-Hickory forest and the Beech-Maple woodland are two of the most prevalent vegetation types. If the course of these changes continues, we may have to add a couple of new types: the Oak-Hickory-Japanese Barberry forest or the Beech-Maple-Bush Honeysuckle woodland. Or how do you feel about a Buttonbush-Purple Loosestrife swamp?

Some scientists have dubbed our current geologic epoch the "Homogocene," a humorous play on words that makes a serious point —the homogenization of the world's flora and fauna is a very real possibility. As

humans have spread to occupy most of the earth, many plants used for horticulture and agriculture have spread with them, often with unintended effects on the native vegetation. It is time to examine these effects, come to grips with the real and potential threats to our ecosystems, and, if possible, develop a consensus to deal with the issue. We should learn how to identify non-native invasive plants. We must begin the documentation process that has been neglected. We must develop methods of control, and refine procedures for determining which new species may become invasive problems in the future. We must examine the effects of our horticulture programs, especially large-scale planting by towns, highway departments, and other governmental agencies, because this is where our decisions may have the strongest impact. Although there may be no cumulative difference between 1,000 homeowners each planting a single specimen of an invasive exotic species, and one highway department planting 1,000 of the same species, it seems like a good beginning to consider using only native species (or exotics that have shown no invasive tendencies over decades of use) for any large scale public landscaping project.

As you read this publication, and others on the same topic, you will encounter differing opinions, definitions, and positions, as well as some contrasting statistics. This sort of divergence is only to be expected when a subject first enters the public spotlight. The views contained here are intended to reflect that diversity and make no claim to fully reconcile the differences. While it's too soon to draw final conclusions, now is the right time to start studying this important and costly problem and examining the alternatives. I hope that, in these pages, you will find the information you need to begin to draw your own conclusions about the problems and potential solutions surrounding invasive exotic plant species in your own "native landscape."

4-b

The Problem with Invasive Plant Species

by Bonnie Harper-Lore
Source:* Greener Roadsides*, A Federal Highway Administration Quarterly Newsletter for Roadsides Decision-Makers, Vol. 6, No 3, Fall 1999

The Many Conflicts and Constraints for Highway Rights-of-Way

Or should I have said problems? Here is my top ten list of problems each State Department of Transportation is faced with, when dealing with invasive plant species.

1. **No single definition embraced** - For Federal dollars purposes, all agencies have agreed to the following definition: "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health." It is the best definition we have at this time. Although some native plants can act invasively, they are not considered invasive species. That does not mean we give a free pass to the use of all native plants. There are some that are toxic to animals and humans, as well as troublesome to agriculture. Choose plants carefully.
2. **State policy differences** - Because some DOTs give the control of invasive plants a higher priority than their neighbors, conflicts will arise. State DOTs do complain about one another's lack of weed control, and/or planting of noxious weeds. State DOTs need to talk to one another; share their experiences; and consider border partnerships.
3. **Lack of funding** - Key to the rapid spread of invasive plants is the lack of funding at every level, in every agency. Many State legislatures, Congress, and federal agencies are exploring ways of making funds available across the country. Beyond prevention and control, some of this funding needs to be directed towards public awareness and research efforts.
4. **Needed training** - Eradicating a new invader avoids years of maintenance efforts needed to control a large, well-established population. Trained crews can identify and stop threats like yellow star thistle in its tracks. Arm them with the tools they need to fight this biological wildfire.
5. **Other agencies** - Although 16 federal agencies signed a Memorandum of Understanding (MOU) in 1994 to encourage communication and cooperation, the reality in the field is not always consistent with the MOU. Our roadways cross those agencies' lands. Increased partnerships will be mutually beneficial.
6. **Public awareness** - State DOTs are under various levels of public pressure over this issue. States like Tennessee are well organized under the Tennessee Pest Plant Council. More and more States are establishing such Councils. DOTs need to become members to learn the public and agency concerns. The public is likely to be surprised by many DOT efforts already in place.
7. **In the name of safety**, maintenance methods can actually increase invasive plants. Most States bare-ground the areas around guardrail, inviting invasions. Frequent and low mowings stress grasses and allow weed invasion. If

methods like blading expose soils, revegetate with natives quickly.

8. **One weed list** - Complicating DOT and other agency cooperation is the absence of a list of key invasive plant species. Recognizing that different weed species require different control tactics, how can we pull together, if our efforts are not aimed at the same plants? Controlling your State's noxious weed list is only part of the answer. Focusing on already established invasives ignores new threats.
9. **Erosion control/water quality** - Another constraint that DOTs face is law that requires quick establishment of vegetative cover to stop erosion and protect water quality. In our history of accomplishing quick cover, we have often chosen aggressive introduced grasses and legumes to do the job. They overdid the job! Careful selection of erosion control and wildflower mixes is important.
10. **Construction practices** - Soil disturbances caused by construction, create new populations of weeds. Here are some best management practices (BMPs):

a. Minimize soil disturbances to avoid future costly weed control,
b. Inspect and wash equipment before moving to another site,
c. Provide a construction pay item for cleaning, and other on-the-site work, and
d. Avoid importing soils or mulches that contain weed seed.

4-C

Vermont Department of Agriculture Creates Noxious Plants Rule to Combat Invasive Plant Problem

MONTPELIER- As warmer weather brings us back into our re-enlivened gardens, fields, and forests, The Nature Conservancy and the Vermont Department of Agriculture are asking Vermonters to check for plants that can escape cultivation and cause tremendous damage to the natural environment and the working landscape.

Beautiful But Harmful

Plants such as purple loosestrife, Japanese knotweed, common buckthorn, Japanese barberry, and some varieties of honeysuckle have been used widely in horticulture, landscaping and erosion control, and can be found in backyards, wetlands and forest edges throughout the state. At first glance these plants may look pretty, but their beauty is deceptive.

Known as invasive species, plants like these are typically transplants from distant places. Once free from the natural checks and balances that kept them under control in their native realms, these plants can establish themselves in new areas and proliferate to the detriment of native species.

They often hoard light, water and nutrients, and can even alter entire ecosystems by changing soil chemistry or hydrological processes. As a result, invasive plants can overtake native plants and, in turn, displace the animals that had relied on the native plants for food and shelter. With intentional and unintentional assistance from people, these problematic plants are spreading at an alarming rate, infecting natural areas across the United States.

"There are a number of invasive upland species that create serious problems for our landscape. Gardeners and any other Vermonters with an interest in the ecological health of our state can make a big difference in controlling these threats to our state's natural landscape."

The Vermont Department of Agriculture, Food & Markets has recently promulgated a quarantine rule related to what it refers to 'noxious weeds.' The purpose of this regulation is to stop the sale, transportation, and propagation of a selected list of invasive species that have been identified as present or potential threats in Vermont.

"This quarantine action is unprecedented nationally," said Scott Pfister, VT Department of Agriculture Plant Pathologist.

"No other state has taken such action, but we are fortunate to have a responsive nursery and landscape industry in Vermont whose leaders wish to be proactive on this issue."

John Padua of Cobble Creek Nursery in Monkton keeps track of the invasive species issue and works with customers to focus on those species that are genuine threats.

"Clearly there are some species that are a real problem," he says. "We support efforts to control and eliminate these plants and to find attractive and appropriate alternatives."

In Vermont, five plants stand out as examples of how serious the situation can be when a plant intended for limited use escapes its intended purpose:

- **Purple loosestrife**, also known as the "purple plague," an ornamental plant promoted for its purple flowers, has the ability to produce millions of seeds which spread easily by wind or water. Once limited to gardens in the Northeast, it now chokes wetlands across the country.
- **Japanese knotweed** is a fast-growing herbaceous perennial that frequently forms dense bamboo-like patches along waterways. This plant has escaped cultivation and been naturalized throughout eastern North America, actively reducing species diversity and wildlife habitat.
- **Common and glossy buckthorn**, deciduous perennial shrubs that reach up to 20 feet in height, can establish dense stands and choke out native shrubs and herbaceous plants. Native to Europe and Asia, these shrubs were originally introduced for hedges, forestry uses, and wildlife habitat.
- **Honeysuckle**, with its tubular flowers and many-seeded berries, can alter native woody and herbaceous plants by decreasing light availability. Honeysuckle berries are readily eaten by birds which spread them across the landscape. Troublesome varieties include Morrow, Tatarian, and Hybrid.
- **Japanese barberry** grows along roadsides, in old fields and open woods. Tolerant of sun, shade and a variety of habitat types, this spiny, woody shrub is a particular threat to open, second-growth forests where, once established, it can crowd out other understory plants.

For more information on these invasive species, you can contact The Nature Conservancy of Vermont, 27 State Street, Montpelier, VT 05602, Phone: (802) 229-4425 or Scott Pfister at the Vermont Department of Agriculture at (802) 828-2431.

4-d

Vermont Agency of Agriculture Food & Markets Quarantine #3 — Noxious Weeds

Section I: Statement of Concerns

Whereas, the Vermont Department of Agriculture, Food & Markets having found that certain noxious weeds out compete and displace plants in natural ecosystems and managed lands; and

Whereas, competition and displacement of plants by certain noxious weeds has significant environmental, agricultural and economic impacts; and

Whereas, it has been determined to be in the best interest of the State of Vermont to regulate the importation, movement, sale, possession, cultivation and/or distribution of certain noxious weeds;

Therefore, the State of Vermont is hereby establishing this noxious weed quarantine regulation by the authority of 6 V.S.A., Chapter 84, Pest Survey, Detection and Management.

Section II: Definitions

"Class A Noxious Weed" means any noxious weed on the Federal Noxious Weed List (7 C.F.R. 360.200), or any noxious weed that is not native to the State, not currently known to occur in the State, and poses a serious threat to the State.

"Class B Noxious Weed" means any noxious weed that is not native to the state, is of limited distribution statewide, and poses a serious threat to the State, or any other designated noxious weed being managed to reduce its occurrence and impact in the State.

"Commissioner" means the Commissioner of Agriculture, Food & Markets, or his or her designee.

"Noxious Weed" means any plant in any stage of development, including parasitic plants whose presence whether direct or indirect, is detrimental to the environment, crops or other desirable plants, livestock, land, or other property, or is injurious to the public health.

"Plant and Plant Products" means trees, shrubs, and vines; forage, fiber, and cereal plants; cuttings, grafts, scions, buds and lumber; fruit, vegetables, roots, bulbs, seeds and wood; and all other plants, parts of plants, and plant products.

"Possession" means to grow, manage or cultivate through planting, pruning, watering, fertilization, weeding, propagation, or any other means that promotes the growth of the noxious weed. This does not include the incidental occurrence of a noxious weed on wild or managed land.

Section III: Designation as a Noxious Weed

(A) The following conditions shall be met for a plant or plant product to be designated as a Class A or B Noxious Weed:

(1) As determined by a pest risk assessment, a quarantined noxious weed must pose an actual or anticipated threat to a substantial agricultural, forestry or environmental interest and/or the general public.

(2) Establishment of a quarantine for a specified noxious weed is likely to

contribute to the objective of preventing introduction or for limiting the spread and/or severity of the noxious weeds impact to the agricultural, forestry or environmental interest.

(3) No substitute or alternative mitigating action will accomplish the same pest prevention purpose.

(4) The economic and/or environmental benefits of quarantining a specified noxious weed outweigh the economic and/or environmental benefits associated with the noxious weed.

(B) The following biological factors shall be used to evaluate whether or not a plant or plant product has satisfied the conditions for designation as a Class A or Class B Noxious Weed:

(1) Native origin of the plant;
(2) Known distribution;
(3) Mechanism and potential for spread to and within Vermont;
(4) Past, current and potential environmental, economic and human health impacts;
(5) Regional and national perspective;
(7) Designation as a federal noxious weed; and/or
(8) Other pertinent factors.

(C) Designation as a Class A or Class B Noxious Weed shall occur through the Administrative Rule procedure as outlined in 3 V.S.A., Chapter 25.

Section IV: Designated Noxious Weeds

(A) Class A Noxious Weeds.

(1) All weeds listed in 7 C.F.R. 360.200 as amended, which is hereby incorporated by reference including subsequent amendments and editions.
(2) Cabomba caroliniana (fanwort)
(3) Egeria densa (Brazalian elodea)
(4) Hydrilla verticillata (hydrilla)
(5) Hygrophila polysperma (Roxb.) T. Anderson (E. Indian hygrophila)
(6) Myriophyllum aquaticum (Vell.) Verdc. (Parrot feather)
(7) Myriophyllum heterophyllum (variable-leaved milfoil)
(8) Salvinia auriculata (giant salvinia)
(9) Salvinia biloba (giant salvinia)
(10) Salvinia herzogii (giant salvinia)
(11) Salvinia molesta (giant salvinia)
(12) Vincetoxicum hirundinaria Medikus. (pale swallow-wort)

(B) Class B Noxious Weeds.

(1) Aegopodium podagraria L. (goutweed)
(2) Ailanthus altissima (tree-of-heaven)
(3) Alliaria petiolata (A. officinalis) (garlic mustard)
(4) Butomus umbellatus (flowering rush)
(5) Celastrus orbiculatus Thunb. (Oriental bittersweet)
(6) Fallopia japonica (Polygonum cuspidatum) (Japanese knotweed)
(7) Hydrocharis morsus-ranae L. (frogbit)
(8) Lonicera x bella (Bell honeysuckle)
(9) Lonicera japonica (Japanese honeysuckle)
(10) Lonicera maackii (Amur honeysuckle)
(11) Lonicera morrowii (Morrow honeysuckle)
(12) Lonicera tatarica (Tartarian honeysuckle)
(13) Lythrum salicaria (purple loosestrife)
(14) Myriophyllum spicatum (Eurasian watermilfoil)
(15) Nymphoides peltata (Gmel.) Ktze. (yellow floating heart)
(16) Phragmites australis (common reed)

(17) Potamogeton crispus L. (curly leaf pondweed)
(18) Rhamnus cathartica (common buckthorn)
(19) Rhamnus frangula (glossy buckthorn)
(20) Trapa natans L. (water chestnut)
(21) Vincetoxicum nigrum L. (black swallow-wort)

Section V: Prohibitions

(A) The movement, sale, possession, cultivation, and/or distribution of Class A Noxious Weeds designated in Section IV of this quarantine regulation is prohibited.

(B) The movement, sale, and/or distribution of Class B Noxious Weeds designated in Section IV of this quarantine regulation is prohibited.

(C) Violation of any of the prohibitions listed in Section V of this regulation may result in:

(1) The issuance of cease and desist orders; and/or,
(2) Temporary or permanent injunctions; and/or,
(3) Administrative penalties not to exceed $1,000 per violation, as specified in 6 V.S.A., Chapter 84, Sections 1037 and 1038.

Section VI: Exemptions

(A) Scientific, economic and educational exemptions may be granted by the Commissioner to allow for the movement, possession and field experimentation of noxious weeds for scientific and educational purposes under such conditions as may be prescribed by the commissioner. When granting exemptions, the commissioner shall take into consideration the value of the scientific, economic or education purpose and the risk to Vermont's environment, economy and citizens.

(B) Transportation of any Class A or B Noxious weed on any road or highway of the state is exempt if any of the following is true:

(1) It is for disposal as part of a management control activity; or
(2) It is for the purpose of identifying a species or reporting the presence of a species, and the Class A or B Noxious weed is in a sealed container; or

(C) Preserved specimens in the form of herbaria or other preservation means are not subject to this regulation.

(D) Varieties, cultivars, hybrids and/or subspecies that have been shown through scientific research and analysis not to be invasive.

Adopted on 4/22/02

4-e

Explaining the Executive Order on Invasive Species

by Bonnie Harper-Lore

Source:* Greener Roadsides*, A Federal Highway Administration Quarterly Newsletter for Roadsides Decision-Makers, Vol. 6, No 3, Fall 1999

What Does EO 13112 Mean To Roadside Programs?

Consider how you have controlled weeds on rights-of-way (ROW) in the past.

When you had another outbreak of Canada thistle, did you have what you needed to make it a priority ... interagency cooperation, internal support, or funding (personnel or materials)? This Executive Order (E.O.) does not guarantee, but strongly encourages those three ingredients in a vegetation management program. Let's examine the Federal Highway Administration guidance sent to the field on August 18, 1999. Just in case a copy has not reached your desk, check the center spread. For your reference, E.O. 13112 is found on page two. What follows is some of the support you asked for.

Use of Federal Funds: 1. This piece of E013112 deserves your close attention. Federal-aid and Federal Lands Highway Program funds cannot be used for construction, revegetation or landscaping activities that include the use of known invasive species. At this time, "known invasive plants" are defined as your State's official noxious weed fist. Please check that list. Some State DOTs are indeed planting some of the listed weed species. A national list of invasive species (the worst of the worst) is likely to be defined by the National Invasive Species Council sometime in the future so that all agencies are fending off the same weed species. It is time to check your general seed mixes used in erosion control and landscaping! **2.** The FHWA recommends use of Federal-aid funds for new and expanded invasive species control efforts under each State DOTs' roadside vegetation management program. That's pretty clear!

FHWA NEPA Analysis: Determining existing, adjacent and potential invasive species along with a description of measures to minimize their impact will now become a part of the NEPA process. Here we take advantage of the environmental process to spot trouble before design, and plan ahead to ward off increased weed problems that naturally come with disturbance. Some States have already come up with ideas like: certified weed-free mulches, soils, sods, and seed mixes. A weed prevention and control strategy now becomes part of every project.

Here is your chance to begin statewide vegetation inventory, to have on hand when future decisions are made regarding construction, maintenance, etc. A Statewide vegetation management plan can be built on this inventory. Some States are already using botanists and Geographic Information Systems (GIS) to inventory their rights-of-way. We suggest you do your own plan, because part of this EO calls for a national management policy in the year 2000. A plan that suits your State should come from you.

State DOT Activities and Funded Facilities: 1. The FHWA encourages the States to implement the Executive Memorandum (E.M.) on Beneficial Landscaping at every

opportunity (landscaping, rest area, scenic overlooks, State entrances, and TEA-21 enhancement activities. Because the intent of the E.O. is to prevent and control weeds, followed by restoration of native plants wherever possible, the 1994 E.M. is part of the answer. **2.** The FHWA recommends that State/District roadside maintenance programs be given the necessary support to control and prevent invasive species. This one's for you! While traveling with many of you "on the road" discussing what works and what does not, you asked for greater support.

Innovative Design: The FHWA encourages the selection/invention of construction and landscaping techniques and equipment to accomplish the intent of the E.O. More details are explained in the guidance.

Coordinated Research: The FHWA environmental research program will promote studies on invasive plant control methods, and restoration of native species. The results will be shared in an effort to manage roadside vegetation more effectively and efficiently. We encourage State research partnerships and other cooperative efforts.

Training: Increased training of vegetation managers in maintenance districts, landscape units, and erosion control sections is suggested. Take advantage of your State's weed experts. The FHWA will provide training materials for identification of invasive plants, State weed law, and restoration of native plants. Region-specific vegetation workshops are already being offered by the FHWA and will be expanded in 2000. In addition, the majority of States already have strong herbicide applicator workshops. integrating other tools into the workshops would be useful in this war on weeds. We will also support increased public education efforts, because if the public understands this war, we are convinced we will gain their support.

Interagency Cooperation: This is a new day for cooperating with federal, State, local, and tribal governments. Each State DOT will be able to participate in a State Invasive Species Council with connections to the National Invasive Species council. The benefits of "puffing together" (with our neighbors on the other side of the ROW fence) will be numerous. Sharing solutions with adjacent States in your region is always encouraged.

Interagency Committees: The FHWA itself will network with related agency committees to find new answers aimed at pubic awareness, training, policy, funding, and research on invasive plant issues, in an effort to avoid "reinventing the wheel" or losing time as weeds continue to spread. For example, Tennessee DOT's success with biocontrol of Musk Thistle is largely unknown. The Minnesota interagency committee, including the DOT, has existed since 1988. We need to find new and rediscover old answers that are applicable to roadside environments.

In my search for answers to vegetation management problems, I have reviewed agendas from the ol' Ohio Short Course Days ... when folks like us met to solve current highway issues. The maintenance issues have not changed much since then ... this could be a turning point. The E.O. and the FHWA guidance is proactive, practical, and on target. It is important that all of us in the transportation ROW management business, do our part. Like many, I have attended weed meetings for twenty years. The Executive Order is the first meaningful national response I have seen. It should go

down in history as a turning point in our "war on weeds." State DOTs are definitely part of the solution to gaining control of invasives. I have traveled with too many State vegetation managers who do not have the resources to do what is needed. This "do more with less" situation can now change. Although some invasive plants may be beyond control, all agencies united at every level should be able to stop or contain some alien invaders, especially new invaders. We will have done our part.

Note- The original Executive Order on Invasive Species 13112 is included as Appendix A of this document.

5

Establishment of Wet Area Vegetation Along Highways — Guidelines

Source: Ontario Ministry of Transportation, Ontario, Canada

Summary

The following guidelines have been reproduced with permission from Ontario Ministry of Transportation. Some of the content relative to plant selection has been revised to match local conditions in Vermont.

This manual provides a design methodology based on the type of wet area in question. Criteria for placement of plant material and seeding are based on wetness zones within the area. Information is provided on species selection to be used in association with surveys of the vegetation found in local wet areas.

The degree of wetness adjacent to a highway determines the extent and types of wetland plants which will grow. Five zones are identified:

Zone 1 represents the sloped area adjacent to the pavement, which is a compacted substrate and is not normally moist.

Zone 2 is the part of the sideslope which may be inundated during major storm events and is influenced by moisture in Zone 3.

Zone 3 is the lowest level (often a ditch) and, if not permanently wet, is subject to periodic flooding during and after rain events.

Zone 4 is the backslope, which may be permanently wet where the road is adjacent to a wetland, river, lake or stream.

Zone 5 is the region beyond the highway right-of-way

Eight different wet area situations are identified:

1) open water adjacent to highway,
2) treed wet area adjacent to highway,
3) open wet area adjacent to highway,
4) watercourse parallel to highway,
5) watercourse perpendicular to highway,
6) highway interchange,
7) stormwater facility adjacent to highway, and
8) ditch associated with highway.

Suggested placement of wet area seed mixture and herbaceous and woody plant material is indicated on plan views and crossections for each of the eight wet area situations.

Species selection for planting in wet areas should be based on information from biological inventories in surrounding wet areas. The guide concludes with lists of herbaceous and woody species which would be suitable for planting in wet areas along highways. A wet area seed mix has been proposed for use in wet areas which are too wet to support a standard seeding mixture.

Expected benefits

This information will assist planners and landscape architects in selecting plant material for wet areas and making decisions on plant placement as part of the design process. Improved plant selection will result in better plant survival and reduced maintenance in these areas. This information wi11 allow staff to provide suitable plantings for erosion control, fish habitat enhancement, vegetative compensation and to improve aesthetic quality in environmentally sensitive wet areas that are impacted by highway construction activities.

Glossary

Aggressiveness (rate of spread), is an important characteristic when using plant material as it relates to the spacing required in planting, whether the species will tolerate other species, and whether it may invade neighboring habitats.

Anoxic, conditions in the soil which are devoid of oxygen.

Bioengineering, the use of plants to strengthen or stabilize soil materials as on slopes and the banks of watercourses or lakes.

Biological Oxygen Demand (BOD), the amount of oxygen required to degrade the organic material and oxidize reduced substances.

Bog, an area of wet, peaty substrate, rich in organic debris but low in mineral nutrients, low in pH, with a vegetation of mosses, sedges and ericaceous shrubs.

Chemical Oxygen Demand (COD), the amount of oxygen required to degrade inorganic and organic material and oxidize reduced substances.

Diversity, the absolute number of species in an assemblage, community or sample. A measure of the number of species and their relative abundance in a community.

Drought Tolerance, some plants can tolerate water shortage better than others. While this is generally not a problem for water-associated plants, species that dry out in unusually dry summers and/or die, are obviously not useful species.

Ease of Establishment, some species are relatively easy to establish while others require very specific conditions

Emergent, an aquatic plant having most of its vegetation parts above water.

Fen, a habitat which is generally dominated by trees and/or shrubs, has restricted drainage, and is mineral rich. This results in a species-rich community.

Growth Form, the general size and shape of a plant. The classifications used in this guide are: T = tree; SH = shrub; HB = herbaceous plant; GR = grass (in Lists I-IV).

Heavy Metal, one of a group of metals of high specific gravity including: antimony, bismuth, cadmium, copper, gold, lead, mercury, nickel, silver, tin and zinc. They are a concern in the environment as pollutants which are toxic to living organisms and bioaccumulate.

Hydroseeding, the use of water as a carrying medium to carry and spread seeds and mulch on a site.

Height Class, for convenience three height classes have been used in Lists I-IV: 1 = < 2 m; 2 = 2-5 m; 3 = > 5 m.

Legume, a family of plants including peas, clover and vetches which have symbiotic bacteria capable of converting atmospheric nitrogen to a form that can be used by plants. These bacteria are associated with root nodules.

Littoral Zone, the aquatic zone in a water body which is influenced by the terrestrial zone and in which plants may grow.

Marsh, this habitat is associated with usually water-logged conditions and the presence of marshland plants. These species are primarily emergent species which have vegetative parts extending above the water level.

Mulching, the use of organic or synthetic materials on the ground to prevent the growth of undesirable plants and/or to control water loss and erosion.

Persistence, this relates to the persistence of the plant through the winter. Some herbaceous plants retain above-ground parts which

affects aesthetics, runoff and the general appearance.

pH Requirements, soils range in pH from approximately 2.5-3.0 to around 8.0. Many plants have a preference for soils of a certain pH, particularly bog plants which can tolerate the most acidic conditions.

Planting Type, refers to the preferred type of propagule used for introducing a plant to an area. It may be with whole plants, parts of plants (cuttings, rhizomes etc.), dormant propagules (bulbs) or seed.

Problem Species, many plant species may present a problem. They are either weed species in agricultural areas, or non-native species, such as purple loosestrife, which may detrimentally affect native plant communities throughout the province.

Riparian, the terrestrial zone adjacent to a water-body, watercourse or wetland area which is influenced by the presence of surface water.

Rodent, a family of mammals including mice, voles, muskrat and beaver. These mammals are herbivorous and may eat riparian and wetland vegetation causing potential problems in the establishment of vegetation.

Safety Clear Zone, the zone adjacent to a highway which is kept clear of immovable objects such as trees and posts. Also called “hazard setback zone.”

Salt Tolerance, some plants are halophytes. They can tolerate relatively high salt levels in the ground water or are tolerant to salt spray. These plants are well adapted for highways exposed to high salt loadings.

Seral Stage, a stage in the process of succession from one community type to another. Some wetlands may exhibit seral stages while others may not.

Soil Saturation, the relative duration of saturation of soils with water during the growing season is indicated as a value between 0 and 100%.

Soil Stabilizer, some species develop a network of roots or rhizomes which stabilize the soil and prevent erosion.

Stratification, the process of breaking seed dormancy to encourage germination. It may include scarification, cool temperatures or chemical treatment.

Succession, the process of one plant community changing to another, through time.

Swamp, this is a habitat which is inundated for a part of the year, usually in the spring and early summer, and dries out sufficiently so that at least the surface soil becomes oxygenated. Swamps are characterized by having trees as the dominant vegetation.

Vegetative Reproduction, plants use various methods of reproduction, usually separated into sexual reproduction and types of vegetative reproduction. Plants vary considerably in their ability to spread by vegetative means and this ability should be considered during the selection process.

Wet Meadow/Swale, this is a primarily grassy habitat associated with pastures, riverine meadows and roadside ditches. Standing water is usually absent but may occur for a relatively short period i.e. several days following periods of heavy rain.

1. Introduction

Particular concerns associated with highway wet area plantings include: erosion control, provision of wildlife habitat, maintenance of water quality, and management of landscapes. Highway designers need to know which species should be planted or seeded, where they will grow well, and how maintenance costs can be minimized. This must be accomplished without interfering with highway function or negatively impacting existing wetland form and function.

Wet area vegetation is considered for the purpose of this report as vegetation occurring in areas of ample water availability. The vegetation may be either herbaceous or woody and is influenced by the presence of water, either from highway runoff or from wetlands outside the right-of-way (ROW). These adjacent wetland areas may be streams, creeks, rivers, lakes, ponds, marshes, swamps, fens and bogs.

Roads are designed so that water, snow and ice are shed as soon as possible from the pavement and subgrade, and water is generally directed to roadside swales, ditches and streams (Monet 1992). Space along the ROW may be provided for storage of snow, which provides additional water to these areas. New wet areas may develop as a result of road construction, being either narrow roadside strips or backwater areas which can cover several hectares. They usually become colonized with cattails *(Typha* spp.), reedgrass *(Phragmites* spp.) and other wet area species such as purple loosestrife *(Lythrum salicaria).* There is currently a need to reduce maintenance costs in terms of mowing, ditching and weed control while at the same time maintaining ecological function and increasing the diversity and aesthetic appearance of highway riparian landscapes. The planting of appropriate wetland species may reduce the invasion of undesirable species and in so doing, reduce maintenance costs.

1.1 Purpose of wet area planting project

The objectives of planting wet area vegetation within highway ROWs can be summarized as follows:

- to cover exposed hydric soils with suitable vegetation;
- to minimize sedimentation to adjacent wetlands;
- to protect contiguous wetlands from road contaminants such as salt, oil, grease, deicing compounds and heavy metals;
- to provide an aesthetic and distinctive vegetation compatible with existing wetland form and function; and
- to provide a vegetation cover which does not impair the structural integrity of the road bed, impede sight lines, or otherwise reduce the safety of the highway for users.

The function of highway wet areas in providing wildlife habitat is not considered a major part of this project because of the potential for animals to use highway-associated wet areas and then venture onto roads, resulting in vehicle/animal accidents. Information relevant to the attractiveness of roadside vegetation to wildlife is included where appropriate.

1.2 Wetlands in Vermont

Wetlands can be found in all eight biophysical regions of Vermont. There are many wetland natural communities. These communities include: flood plain forests, hardwood swamps, softwood swamps, seeps, and vernal pools, open or shrub wetlands, marshes and sedge meadows, wet shores and shrub swamps.

1.3 Wetlands and Roads

Roadbed material is often rock, which may require the addition of topsoil or organic matter if wet area vegetation is to be established rapidly. The short growing

season provides less time for plant material to become established in any one growing season. Roadside ditches and wet areas are used by moose and deer as a source of browse, as travel corridors and as sources of salt which is often deficient in the natural vegetation. This leads to an increased number of vehicle animal accidents.

1.4 Characteristics of highway-associated wet areas

A number of general characteristics of wet areas associated with highways are:

1. Highway-created wet areas are usually linear and may act as corridors for plant species dispersal and travel routes for animals.
2. These wet areas may permit the dispersal of less desirable plant species such as purple loosestrife *(Lythrum salicaria)* and common reed-grass *(Phragmites communis)*.
3. Highways may break otherwise continuous wetlands into two or more parts and potentially affect the integrity and functioning of the wetlands.
4. Natural vegetation is often replaced with a few aggressive herbaceous species which are often non-native.
5. The periodicity and volume of water flows is different from natural wetlands.
6. Highway-associated wet areas are generally exposed to contaminants such as motor oils, grease, antifreeze, heavy metals and salts such as sodium chloride.
7. The effectiveness of wet vegetated areas for pollutant removal from runoff varies by type of wetland and site-specific parameters. Pollutant removal efficiencies are influenced by hydraulic retention time, slope, fetch, surface area, salinity, pH, water level fluctuations, depth of standing water versus channel flow, loading and other factors. However, some general conclusions can be made. There is a consistent reduction of Biological Oxygen Demand (BOD), suspended solids (SS), and heavy metals in runoff. The removal of organic material is good and nitrogen removal is consistently high. Phosphorous removal is variable due to eventual saturation of the soils. Suspended solids removal is satisfactory but can vary significantly with loading. Oils and greases trapped by roadside vegetation may volatilize or be broken down by microbial decomposition.

1.5 How to use this Manual

- After a general examination of the document, determine what type of wet area situation is to be dealt with using the list of wet area situations listed in Table 1 (page V-8) and determine the situation which most closely describes the site under consideration.
- If the area is adjacent to an existing wetland, conduct a vegetation survey to determine the common trees, shrubs and herbaceous material in the area.
- If the area is not adjacent to a wetland, identify the nearest wetland and conduct a brief vegetation survey to assist in plant species selection.
- Use the tables at the back of this document to determine which of the locally occurring species are recommended for planting in the situation at hand and that occur at or near the site. Check availability and type of material (seed, cuttings, rhizomes, bare root, peat pots, balled and burlap) for each species.
- Use the general outline provided in the “situation guidelines” and develop detailed specifications for the wet area site, listing species and zones in which they are to be planted.

2. Review of Wetland Communities and Issues

The topography, climate, soils and hydrology in an area determine what type of wetland will develop.

The purpose of recognizing their distinctions will lead to a better understanding of the rationale for species selection, nutrient requirements and propagation methods. This should avoid planting species in areas where they may not survive. Further information about the maturity of a wetland can be obtained from an examination of soil cores and detailed plant community analysis.

2.1 Wetland types

Five wetland types are most commonly found:

Swamp - Swamps usually contain a mix of herbaceous and woody species with the latter forming the dominant vegetation. The soil is wet with seasonal inundation. Nutrients are generally available and the water level drops below the surface of the soil at some time during the growing season. Frequently there are channels and pools indicating slow water flow within the swamp. The accumulation of an organic layer is usually restricted to a few inches. Trees may be either deciduous or coniferous and may be of commercial value. Swamp thickets are dominated by shrubs, usually willow, dogwood or alder.

Fen - Fens are peatlands which are characterized by surface layers of poorly to moderately decomposed organic material (peat). They are mineral rich and nutrients are available for growth. There is usually high species richness. Sphagnum is usually subordinate or absent and other genera of mosses are present. Often there is a low-to medium-height shrub layer and sometimes a sparse layer of trees. Fens usually develop where there is restricted drainage and oxygen concentrations are relatively low.

Bog -The most common species in bogs is *Sphagnum* rnoss, which often forms raised hummocks, separated by low wet spaces. Ericaceous shrubs such as Labrador tea *(Ledum groenlandicum),* leatherleaf *(Chamaedaphne calyculata),* blueberry and cranberry *(Vaccinium* spp.) and sedges (Carex spp.) are usually common. Trees such as black spruce (*Picea mariana)* and larch *(Larix laricina)* may represent up to 25% of vegetation cover.

Marsh - Marshes are wet areas which are inundated with standing or very slowly moving water most of the time. They are characterized by the presence of emergent vegetation such as sedges (Carex spp.), cattails (Typha spp.), bur-reeds *(Sparganium* spp.) and bulrushes *(Scirpus* spp.). Some shrubs such as willows (Salix spp.) may be present on higher areas. Water is usually close to neutral in pH and has adequate nutrient levels. Marshes may include patches of open water, but this fluctuates depending upon the time of year and the hydrology of the area.

Shallow Open Water - It is characterized by having rooted aquatic plants such as water lilies *(Nuphar variegatum and Nymphaea odorata),* milfoils (*Myriophyllum* spp.) and pondweeds *(Potamogeton* spp.) which may or may not reach the surface. The water is generally less than two meters deep. Shallow water habitats are important fish nursery habitats, and are also extensively used by other wildlife including waterbirds such as coot *(Fulica americana)* and sora *(Porzana carolina),* amphibians and reptiles, and semi-aquatic mammals such as muskrat *(Ondatra zibethicus)* and beaver *(Castor canadensis).*

2.2 Successional stage

Plant communities which establish in newly exposed soil may undergo a period of succession in which colonizer species first establish themselves. As the conditions of the site change due to the accumulation of organic matter and nutrients and weathering

of the substrate, other species replace the colonizers. Several distinctive plant communities may occur at a single site before the plant communities become relatively stable through time. Such a community is often referred to as a climax community. Communities which develop in wet areas may also go through successional transitions, although some situations appear to stabilize rapidly and then remain relatively constant, while others fluctuate in response to environmental conditions.

The occurrence and composition of a wetland is dependent upon a dynamic balance between the normal presence of water to establish and maintain a wetland situation and the accumulation of organic matter which raises the organic soil level above the water table. Periodic dry spells may alter the community for several years allowing the wet area to become vegetated with terrestrial species and filling in. Early successional species are often annual and perennial herbaceous species, while climax stages are dominated by long-lived woody species. This has an effect on the frequency of maintenance activities which may be required to control roadside vegetation in some situations.

There is also a balance between rates of sedimentation and erosion, and a balance in nutrient accumulation and nutrient loss which affects what happens to a wet area in the long term. Some wet areas may dry out due to the slow accumulation of organic matter, while others may remain wet.

2.3 Rare and/or endangered species

There is no intent in establishing wet area plantings to introduce rare and/or endangered species adjacent to highways. In light of the disturbed nature of these wet areas and the potential contamination from highway associated chemicals, revegetation of wet areas is focused on providing a vegetated cover in which common wetland species are introduced. Such plantings are to be characteristic of adjacent wetlands recognizing the influence that the modified hydrology of the highway will have.

2.4 Invasive and non-native species

There is considerable concern over the spread of noxious agricultural weeds and certain invasive non-native species. Therefore, native species are recommended for all situations because they present less of a threat to existing wetland areas which are already markedly reduced. Likewise, as native elements of the flora, they are generally not a problem to agricultural operations.

3. Wet Area Planting Situations

3.1 Wet area planting situations typically found along highways

Highways intersect or are aligned adjacent to many types of wet areas, each of which may require different treatments. The construction of a highway often causes a change in the hydrology of an area resulting in the development of wet area communities where none previously existed. Roadside wet area conditions were grouped to enable the prescription of generic guidelines for their revegetation. Table 1 lists eight generic situations involving wet area habitat, each of which is referenced to example graphics, description of habitat characteristics and proposed treatments.

3.2 Highway planting zones

Five zones have been identified along the margin of a highway. These are helpful in understanding the physical conditions that may affect plant growth and survival and illustrating the relationship between the highway and the surrounding landscape. The zones are also essential in that they reflect different hydrologic conditions, and it is the hydrologic gradients which mainly control the

distribution of wetland species (Keddy and Ellis 1984). The zones can best be understood in relation to a standard cross-section of a highway (Figure 1).

Zone I

Zone 1 is immediately adjacent to the paved roadway or the gravel or paved shoulder. The subsurface of this zone comprises structural granular material used for the road bed. Because this zone has a uniform specification determined by the engineering requirements for the road it is only wet temporarily due to rainfall events, and will not support a vegetation characteristic of wetland areas. In most cases the surface should be scarified and topsoil added prior to seeding. The lower slope, which interfaces with Zone 2, may be suitable for planting other species.

Zone 2

Zone 2 is the transition between the roadway embankment (Zone 1) and the wet area of the ROW (Zone 3). Zone 2 extends from the foot of Zone 1 to the edge of the riparian area. In some cases, Zones 1 and 3 may be adjacent and Zone 2 absent. It is an area which will usually be disturbed during construction activities but its substrate is the parent soil of the area. It may be sloped or flat. It may be influenced by water either during heavy rain events or due to the influence of water in Zone 3, especially during flood events. It may be planted with herbaceous or woody wet area vegetation.

Zone 3

Zone 3 is the wet zone within the ROW and approximately one meter on either side of that. It is often located in parent soils and is variable in width. It may be continuously inundated with standing or moving water or intermittently inundated with standing or moving water. The zone may be restricted to a narrow ditch or it may extend from the edge of Zone 1 to the edge of the ROW. Zone 3 may be continuous with wetlands outside the highway ROW or it may be completely encircled by road, as in a cloverleaf or interchange, and have no surface hydrologic connection with the surrounding landscape.

Table I *List of wet area situations*

Wet Area Situation	Explanation	See Page ...
Open water adjacent to highway	Lakes, ponds or other open standing water in which there is no obvious water flow.	5-10, 5-11
Treed wetland adjacent to highway	A treed swamp or fen in which there is a predominance of woody vegetation.	5-12, 5-13
Open wetland adjacent to highway	Usually a marsh, but also a bog, fen or seasonally flooded meadow in which the predominant vegetation is herbaceous or low woody species less than a metre in height.	5-14, 5-15
Watercourse flows parallel to highway	This may be a river, stream or culvert flowing parallel to the highway. Water flow may have erosive potential.	5-16, 5-17
Watercourse flows perpendicular to highway	This may be a river, stream or culvert which flows beneath the highway.	5-18, 5-19
Wet area within highway interchange	The wet area is surrounded by roads and it is not directly adjacent to any other wet area.	5-20, 5-21
Wet area is a stormwater management facility	The area within or adjacent to the highway is designed as a stormwater facility.	5-22 5-23
Wet area is a ditch	The area conducts water away from the road bed	5-24, 5-25

Zone 4

Zone 4 extends from Zone 3 to the edge of the ROW. It may represent the least disturbed area of the ROW. It may be intermittently inundated or dry. It provides the area of junction between the road, its associated grading and drainage, and the surrounding landscape and is the area where the most natural planting can occur. It may not be disturbed during road construction and may, therefore, be left unmanaged. Zone 4 may be absent if Zone 3 extends through to Zone 5.

Zone 5

Zone 5 is the property outside of the ROW. It is not directly impacted by the highway ROW, but it may be modified hydrologically by the construction of a highway or from the effect of wind or aerosol sprays (salt etc.).

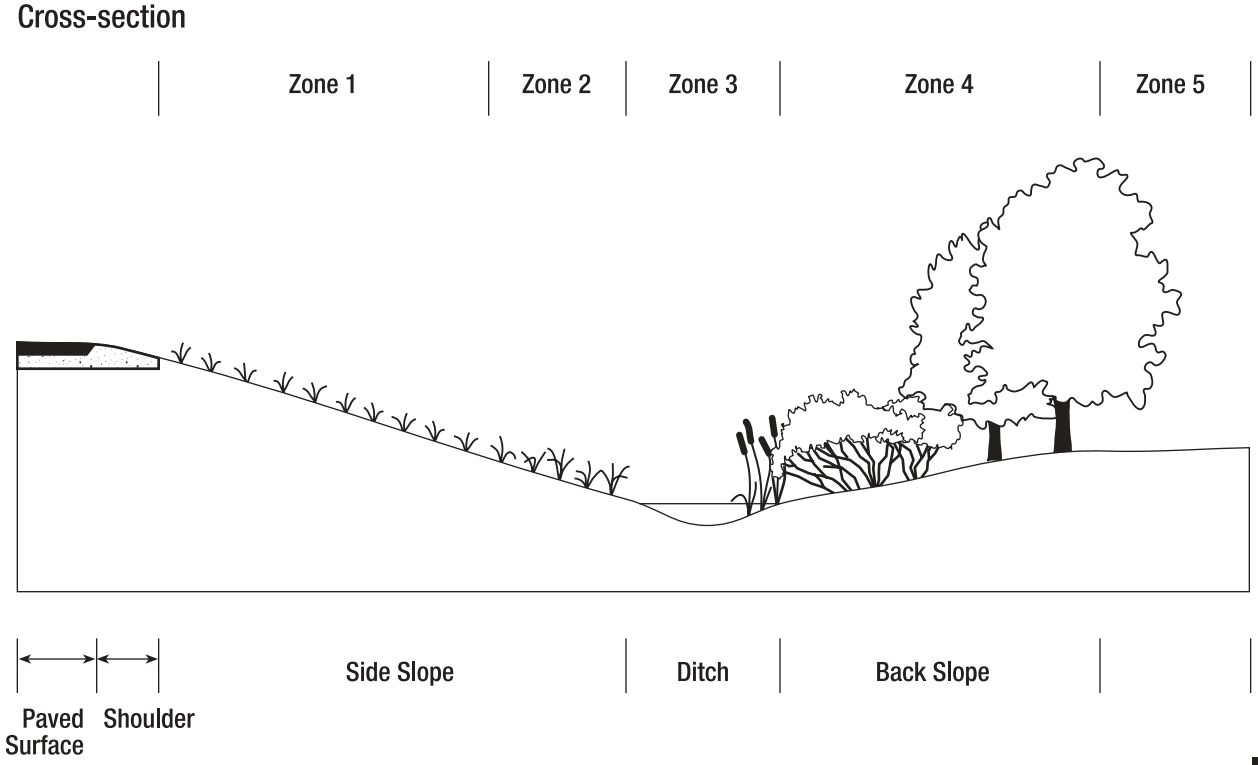
It should be emphasized that these zones do not imply the delineation of homogeneous plant communities. The zones represent physical conditions which will determine the selection of plants and the type of community that evolves. Designers should treat the boundaries of these zones with some degree of flexibility allowing plant communities to mix across boundaries wherever possible and using a variety of vegetation within each zone to ensure a diverse plant community.

3.3 Wet area situations

Based on an examination of sites, highway design drawings, literature review and discussion with Transportation staff, it was determined that eight types of wet area situations typically occur (Table 1). Each of these situations are described and illustrated on the following pages.

Figure I.

Cross-section at highway showing hydrologic zones



3.3.1 Open Water Adjacent to Highway

The open water situation occurs where a highway runs adjacent to a body of water, for example a pond, bay or lake. The major factors to consider in the treatment are the type of soil or bedrock, the degree of water level fluctuation through the season, and the amount of wave energy in the beach zone.

If the highway ROW is exposed to wave action, it may require protection with some form of erosion control device or armoring. The nature of this armoring will depend upon the wave height and energy which may have erosive forces on the road bed. This is also related to the degree of slope in the littoral zone. The water level may fluctuate by 50-100 cm in a year and in this case there is likely to be a natural beach which will develop at the interface between water and land.

If the water levels do not fluctuate significantly, then establishing vegetation to the water's edge is appropriate. Overhanging shrubs and trees provide cover for wildlife to move along the shoreline, as well as habitat for nesting birds and shading for fish. Emergent vegetation may be required in places to help stabilize the beach zone. The selection of the appropriate treatment will be based upon detailed biological surveys of existing vegetation communities in the area. Where armoring is required it would be advantageous for aesthetic and wildlife purposes to fill the interstices with sand/soil mix and allow this to become vegetated. Some shrub planting could be undertaken during construction. These latter techniques will soften the appearance of long stretches of large rocks or stone gabions.

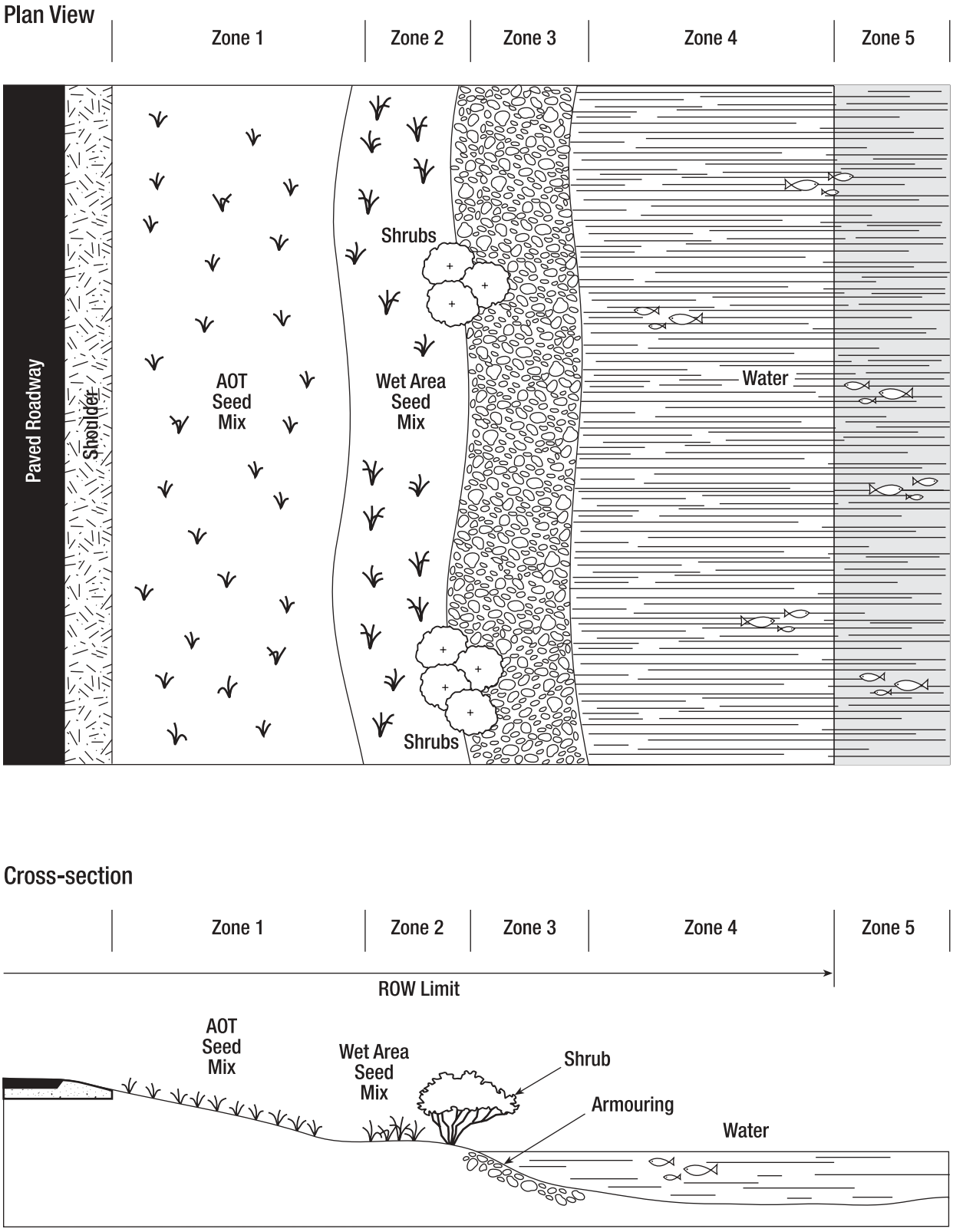
Table 2 *Open water adjacent to highway*

Zone	Condition	Prescription
1	< 5 m Wide	Use standard AOT seed mix.
	> 5 m wide	
	2:1 slope or greater	Use standard AOT seed mix.
	4:1 slope or less	Use standard AOT seed mix. Plant shrubs from list 11 beyond 5 m zone.
2	Within safety setback zone (< 5 m from pavement).	Use wet area seed mix (List IV)
	Beyond safety setback zone (> 5 m from pavement).	Use wet area seed mix (List IV). Plant shrubs (List II) and trees (List III) in occasional clumps for aesthetics and to provide shade and cover for wildlife.
3	High energy area, waves can develop.	Plant shrubs (List II) above shoreline protection.
	Low energy area, waves do not develop.	No shoreline protection; plant shrubs (List II) and occasional trees (List III).
4	Open water	Leave as is.

Notes:

- When using trees and shrubs use those characteristic of the area, based on inventory nearby. There is no intent to provide continuous cover along shoreline, but rather clumps of shrubs, with open areas between.
- The use of overhanging deciduous trees can provide wildlife habitat, and be used for aesthetics.
- Shrub planting at the water's edge is encouraged where wave action is minor. If armoring is used, fill crevices with sand prior to planting shrub material. This will allow invasion and consolidation of a natural shoreline.
- Where wave action can be severe, plant above the shoreline protection.
- Emergents can be planted in sand in gaps between shoreline armoring.
- The safety setback is generally considered to be between 5 and 10 metres from the pavement depending upon posted speed.
- The choice between deciduous and coniferous trees should be related to aspect of slope, with conifers being planted on north facing slopes and deciduous trees on south facing slopes.

Figure 2.
Open water adjacent to highway



3.3.2 Treed Wetland Adjacent to Highway

Treed wetlands are characterized by the presence of standing water for a portion of the growing season.

The major concern with highways passing through or adjacent to treed wetlands is the impact that the highway will have on the hydrologic regime of the wetlands. There may also be secondary concerns with relation to changes in water temperature impacting cold water streams.

As trees in wetlands are typically shallow rooted, the cutting of trees along the edge or through a treed wetland will often result in an increase in windthrow (falling trees) in the vicinity of the highway. It is suggested, therefore, that planting native trees and shrubs in Zones 4, 3 and 2 (where possible) will provide a better buffer between the wetland and the highway.

Table 3 *Treed wet land adjacent to highway*

Zone	Condition	Prescription
I	< 5 m wide	Use standard AOT seed mix.
	> 5 m wide	
	2:1 slope or greater	Use standard AOT seed mix.
	4:1 slope or less	Use standard AOT seed mix. Plant shrubs from List II beyond 5 m zone.
2	Within safety setback zone (< 5 m from pavement).	Use wet area seed mix (List IV).
	Beyond safety setback zone (> 5 m from pavement).	Use wet area seed mix (ListIV). Plant shrubs (List II) and trees (list III) to provide edge of existing wooded wetland.
3	Zone is flooded for more than 50% of growing season.	Leave for natural regeneration
	Zone is only periodically flooded and was disturbed during construction.	Plant with shrubs (List II) and trees (List III) if area was disturbed.
4	Zone is flooded for more than 50% of growing season.	Leave for natural regeneration
	Zone is only periodically flooded and was disturbed during construction.	Plant with shrubs (List II) and trees (List III) if area was disturbed.

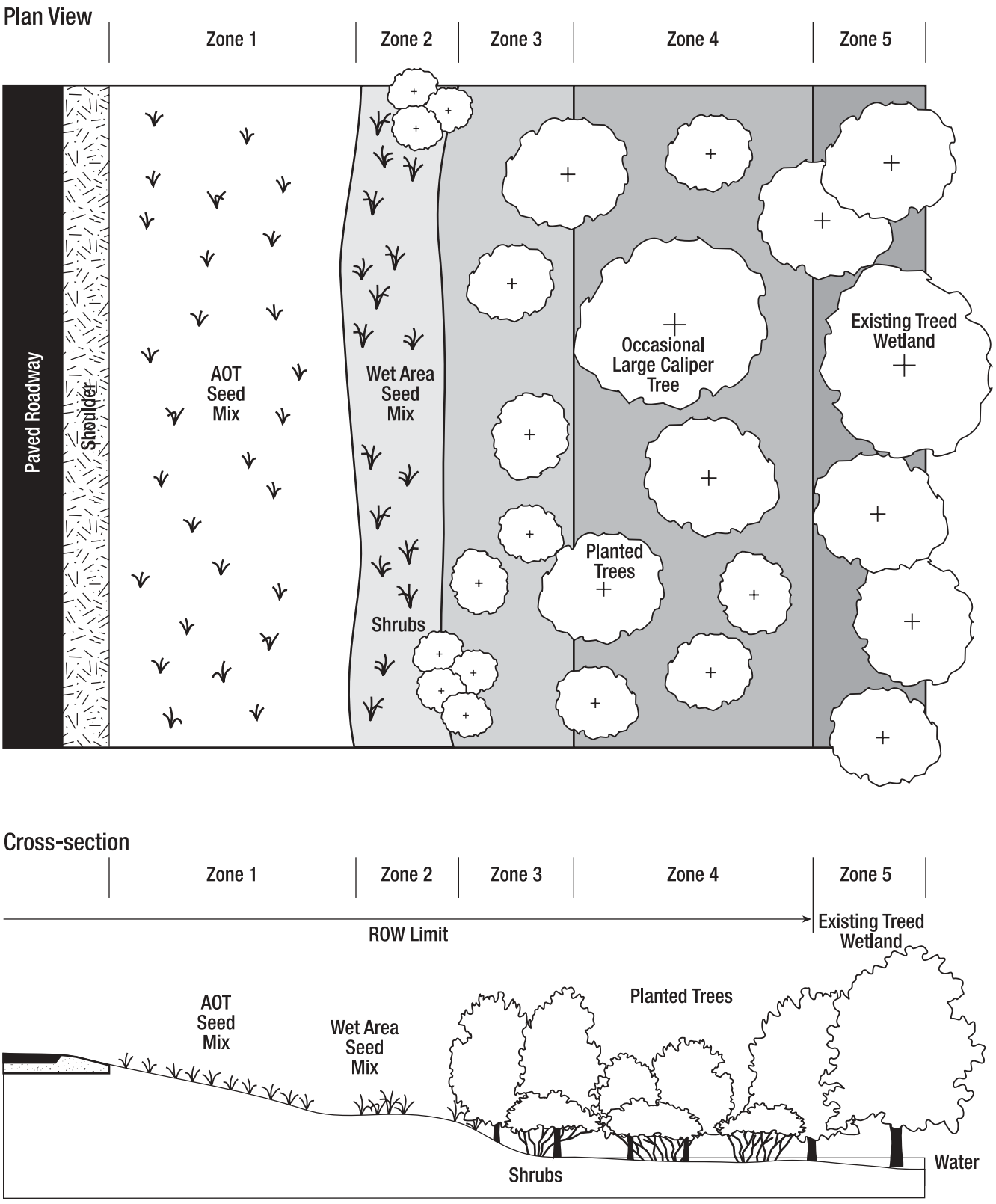
Notes:

Use wet area seed mix for erosion control,

Utilize trees and shrubs based on inventory of species in adjacent treed wetland.

- The use of shrubs in Zone 2 will provide a softening of the edge and buffer the impact of the open ROW on the treed wetland.
- Zone 3 and 4 may be continuous and indistinguishable.

Figure 3.
Treed wetland adjacent to highway



3.3.3 Open Wetland Adjacent to Highway

Open wetlands are generally dominated by glass-like plants such as cattails, sedges and reeds.

The major concern is to provide a vegetation cover to the interface between road and wetland which reduces the spread of weed or non-native species and utilizes local species where possible.

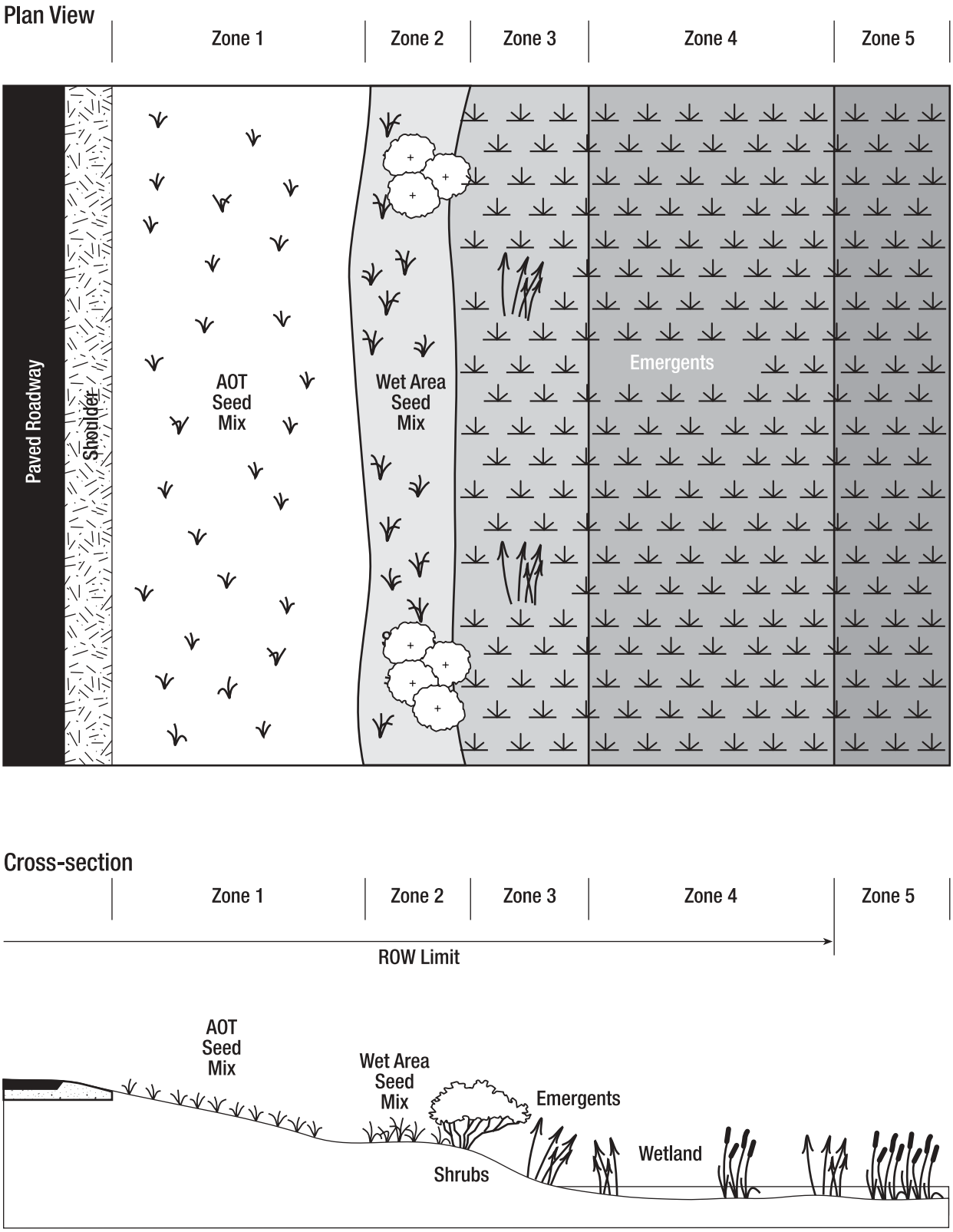
Table 4 *Open wet land adjacent to highway*

Zone	Condition	Prescription
I	< 5 m wide	Use standard AOT seed mix.
	> 5 m wide	
	2:1 slope or greater	Use standard AOT seed mix.
	4:1 slope or less	Use standard AOT seed mix. Plant occasional shrubs from List II beyond 5 m zone
2	Within safety setback zone (< 5 m from pavement).	Use wet area seed mix (List IV).
	Beyond safety setback zone (> 5 m from pavement).	Use wet area seed mix (ListIV). Plant well spaced shrubs (List II) to provide wildlife cover at edge of wetland.
3	Zone is flooded for more than 50% of growing season.	Leave for natural regeneration
	Zone is only periodically flooded and was disturbed during construction.	Use wet area seed mix (List IV). Plant with occasional clumps of shrubs (List II).
4	Zone is flooded for more than 50% of growing season.	Leave for natural regeneration
	Zone is only periodically flooded and was disturbed during construction.	Use wet area seed mix (List IV). Plant With shrubs (List II).

Notes:

- The use of shrubs in Zone 2 will create some natural cover as often occurs at the edge of an open wetland. It will also provide cover and nesting sites for wildlife.
- Planting of clumps of emergents within elevated areas of Zone 3 will provide diversity of plant species.
- The proportion of the growing season during which Zones 3 and 4 are flooded affects the potential treatment of the area. If flooded a large proportion of the time, only occasional plantings of emergents should be required. If flooding is primarily seasonal, shrub planting may also be used at the margin of the wetland.
- Cattails will invade naturally and do not need to be planted.

Figure 4
Open wetland adjacent to highway



3.3.4 Watercourse Parallel to Highway

Highways may be built or already exist alongside streams or rivers. The watercourse, if small, may lie within the highway ROW, or, if the river is large may extend outside the highway ROW. The water velocity and variation in water depth during flood events is a major consideration in re-establishing wet area vegetation. This affects the shoreline treatment; the shoreline may have to be armoured against erosion. If the flow rate is low the shoreline can be protected with shrubs and herbaceous vegetation.

Where the watercourse is a cold water stream or river, the provision of adequate shade is a determining factor in the selection of vegetation to be used. For rivers, planting of trees along the banks is recommended. Shrubs can be used for streams.

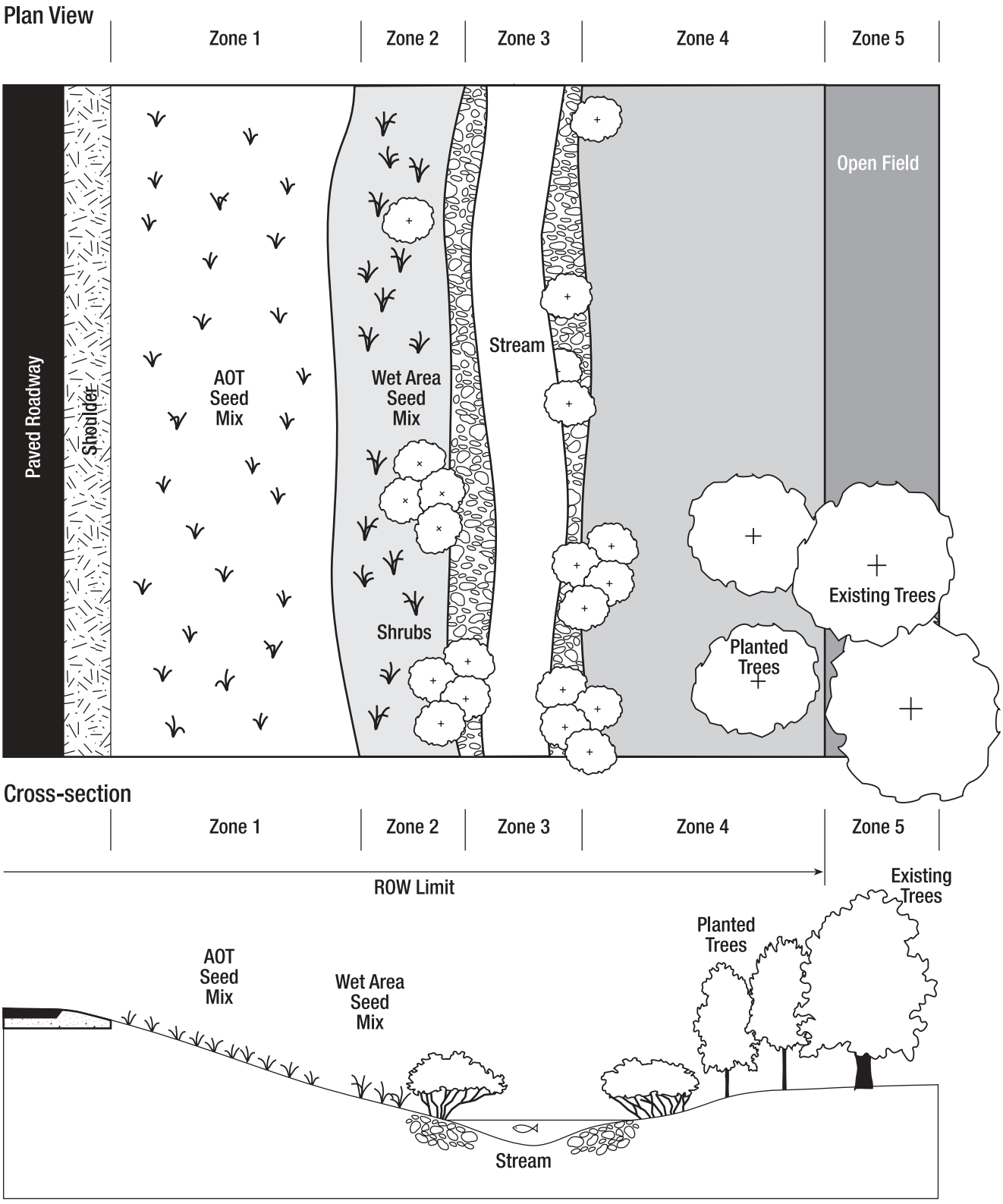
Table 5 *Watercourse parallel to highway*

Zone	Condition	Prescription
1	< 5 m wide	Use standard AOT seed mix.
	> 5 m wide 2:1 slope or greater 4:1 slope or less	 Use standard AOT seed mix. Use standard AOT seed mix. Plant occasional shrubs from List II beyond 5 m zone.
2	Within safety setback zone (< 5 m from pavement).	Use wet area seed mix (List IV).
	Beyond safety setback zone (> 5 m from pavement).	Use wet area seed mix (List IV). Plant shrubs (List II) for 3 m from edge of Zone 3 to provide wildlife cover: if watercourse > 3 m across also use trees (List III).
3	Potential for high velocity water flow, with armouring.	Plant shrubs from edge of armouring to Zone 2 and 4
	Low velocity water flow, without armouring.	If area was disturbed, use wet area seed mix (List IV). Plant with occasional clumps of shrubs (List II).
4	Zone is dry	Use standard AOT seed mix and/or plant with upland species if area was disturbed.
	Zone is wet	If area was disturbed, use wet area seed mix (List IV). Plant shrubs (List II) for 3 m from edge of Zone 3 to provide wildlife cover: if watercourse > 3 m across also use trees (List III).

Notes:

- If watercourse is a cold water stream or river, then continuous planting with trees and shrubs is required in Zones 2, 3 and 4 to provide shading for fish and wildlife cover.
- If watercourse is a warm water stream or river, discontinuous use of shrub and tree planting is sufficient.
- If water velocity is high, use armouring on banks. If the watercourse is narrow (< 2 m wide), armour the channel bottom.
- Use of trees in Zone 4 is dependent on land use in Zone 5.
- There is the opportunity for bioengineering along stream/river banks, and for using combinations of live staking and stone materials.
- Where continuous planting is required along a water- course, the initial planting may be spaced at 2-4 m on centre to permit invasion of other native species and to allow the planted shrubs to fill in.

Figure 5
Watercourse parallel to highway



3.3.5 Watercourse Perpendicular to Highway

Watercourses perpendicular to highways may be small streams diverted or flowing through culverts beneath the road or large rivers which are spanned by the highway. The general treatment is to provide erosion control where there is potential for erosive forces, and to provide the connection of the water and riparian zones as they pass under the highway.

For cold water streams and rivers, the installation of shrubs and trees along the water's edge is the major target, with continuity in Zone 2 where practical. Along warm water streams and rivers, wet area seed mixes can be used with erosion control measures incorporated as required.

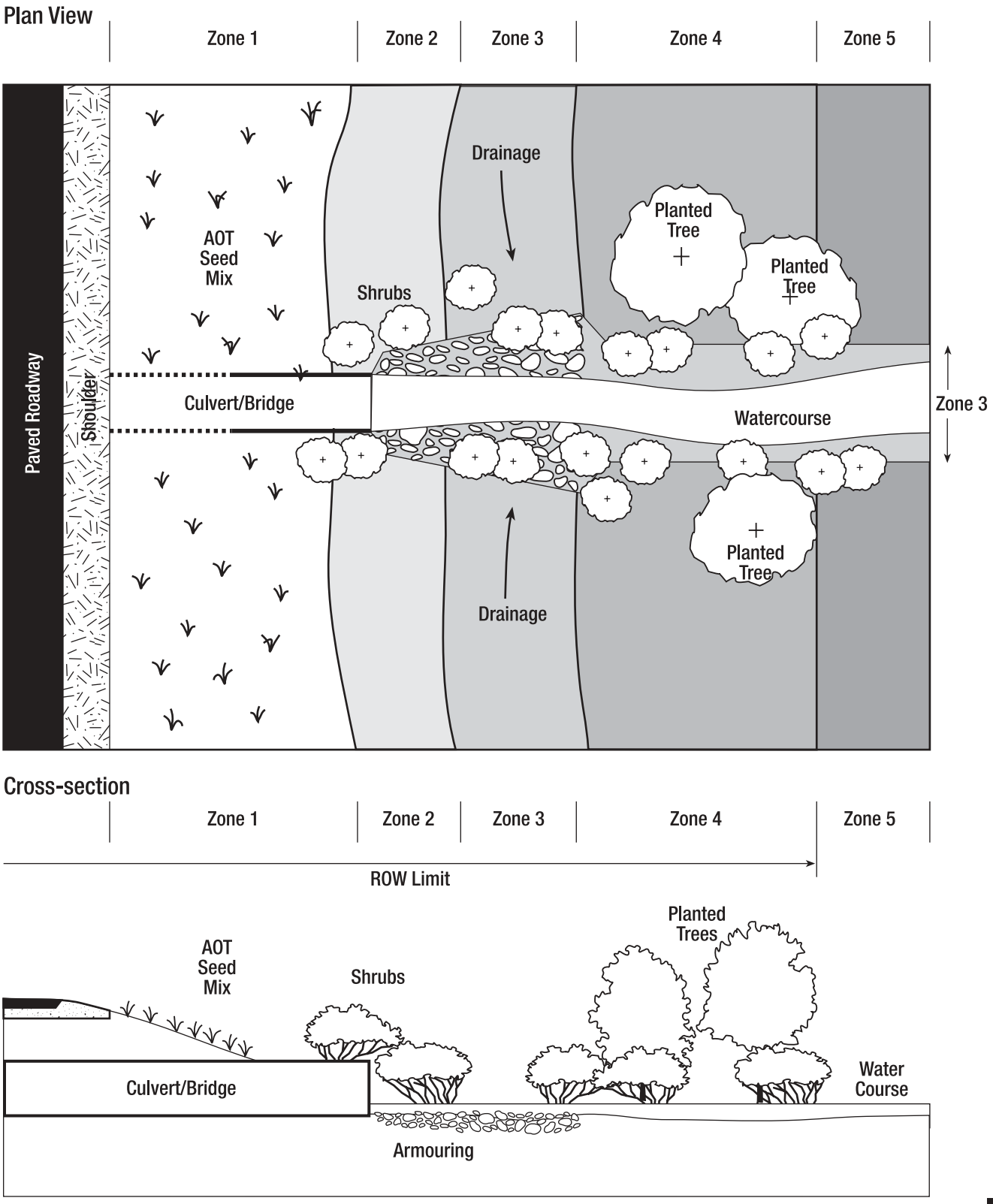
Table 5 *Watercourse perpendicular to highway*

Zone	Condition	Prescription
1	< 5 m wide	Use standard AOT seed mix.
	> 5 m wide 2:1 slope or greater 4:1 slope or less	 Use standard AOT seed mix. Use standard AOT seed mix. Plant occasional shrubs from List II beyond 5 m zone.
2	Within safety setback zone (< 5 m from pavement).	Use wet area seed mix (List IV).
	Beyond safety setback zone (> 5 m from pavement).	Use wet area seed mix (List IV). Plant shrubs (List II) for 3 m from edge of Zone 3 to provide wildlife cover: if watercourse > 3 m across also use trees (List III).
3	Potential for high velocity water flow, with armouring.	Plant shrubs from edge of armouring to Zone 2 and 4
	Low velocity water flow, without armouring.	If area was disturbed, use wet area seed mix (List IV). Plant with occasional clumps of shrubs (List II). If area was not disturbed, leave as is.
4	Zone is dry	Use standard AOT seed mix and/or plant with upland species, if area was disturbed.
	Zone is wet	If area was disturbed, use wet area seed mix (List IV). Plant shrubs (List II) for 3 m from edge of Zone 3 to provide wildlife cover: if watercourse > 3 m across also use trees (List III).

Notes:

- Ensure that bottom of the culvert is at same level as the stream bottom. If the water velocity is high, use armouring where necessary on channel bottom and banks.
- Shrubs should be planted along stream banks and above the culvert to provide shade and fish and wildlife habitat.
- Use wet area seed mix and trees and shrubs within a 3 to 10 m band on either side of stream/river, depending on size of watercourse and width of zones.

Figure 6
Watercourse perpendicular to highjway



3.3.6 Wet Area Within a Highway Interchange

The occurrence of wet areas within highway interchanges can be seen in many parts of the country. The size of such wet areas is quite variable depending on the local topography and land availability, but may be several hectares for major interchanges on controlled access highways. The interchange will have a ditch running along the inside perimeter to collect drainage from the highway, but the central area may be at or below the level of the ditch (Zone 3). In this case revegetation of wet areas in Zone 3 may be required.

General prescriptions for the area depend upon its overall elevation, size and the periodicity of any flooding events. If an area of the interchange is waterlogged for more than 50% of the growing season then the use of wet area plants is justified. It is advisable to alter the grading of the central area to create some zone of permanent water; vegetation can then adjust to the modified hydrologic gradients over the space of several years.

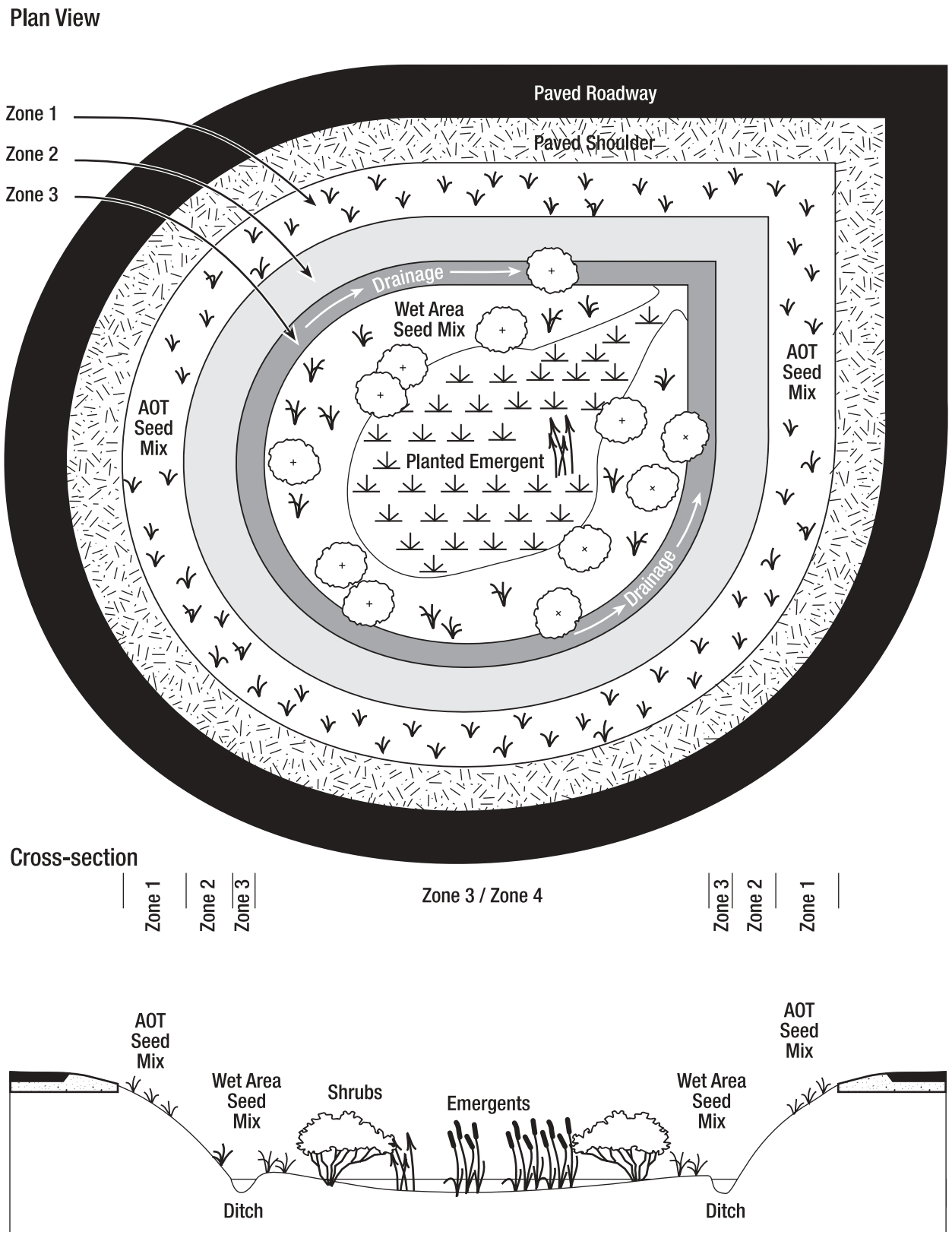
Table 7 *Wet area within a highway interchange*

Zone	Condition	Prescription
I	< 5 m wide	Use standard AOT seed mix.
	> 5 m wide	
	2:1 slope or greater	Use standard AOT seed mix.
	4:1 slope or less	Use standard AOT seed mix. Plant occasional shrubs from List II beyond 5m zone
2	Within safety setback zone (< 5 m from pavement).	Use wet area seed mix (List IV).
	Beyond safety setback zone (> 5 m from pavement).	Use wet area seed mix (List IV). Plant shrubs or trees (List II) for 3m from edge of Zone 3.
3	Zone is below level of Zone 2	Use wet area seed mix (List IV). Plant shrubs (List II) to edge of normal water level. If standing water occurs for 50% of growing season select herbaceous wetland plants (List I).
	Zone is above Level of Zone 2.	Use AOT seed mix and/or plant with upland species if area was disturbed.
4	Zone is dry.	Use AOT seed mix and/or plant with upland species, if area was disturbed.
	Zone is wet	If area was disturbed use wet area seed mix (List IV). Plant shrubs (List II) for 3 m from edge of Zone 3 to provide wildlife cover: if watercourse > 3 m across also use trees (List III).

Notes:

- The central depressed area does not have to have a regular shape.
- If the area is large enough, it may be possible to create an island within the wet area, thus providing visual and biotic interest and diversity.
- If there is the potential for wet areas to develop because of hydrologic conditions, then a representative planting of wet area species should be included.

Figure 7
Wet area within a highway interchange



3.3.7 Stormwater Management Facility Adjacent to Highway

The distinguishing features of a stormwater management facility are an inflow water stream and an outflow water stream which may be controlled by design structures or control devices. The periodicity of flood events and use of the facility for storing water must be known prior to design. The general intent of such facilities is to attenuate water flow and improve water quality at the outflow.

General design criteria will influence wet area plantings but, providing that the water catchment basin has shallow sloping sides and is not channelized, a planting zonation based on water depth and frequency of inundation can be designed. It is also important to dissipate water energy as it flows into the facility to promote settling of suspended sediments. This can be accomplished by opening up the channel as it enters the wet area and providing islands or other baffles which will spread the water flow out over a large area. Slowing of water velocity will increase settling of suspended particles.

Table 8 *Stormwater management facility adjacent to highway*

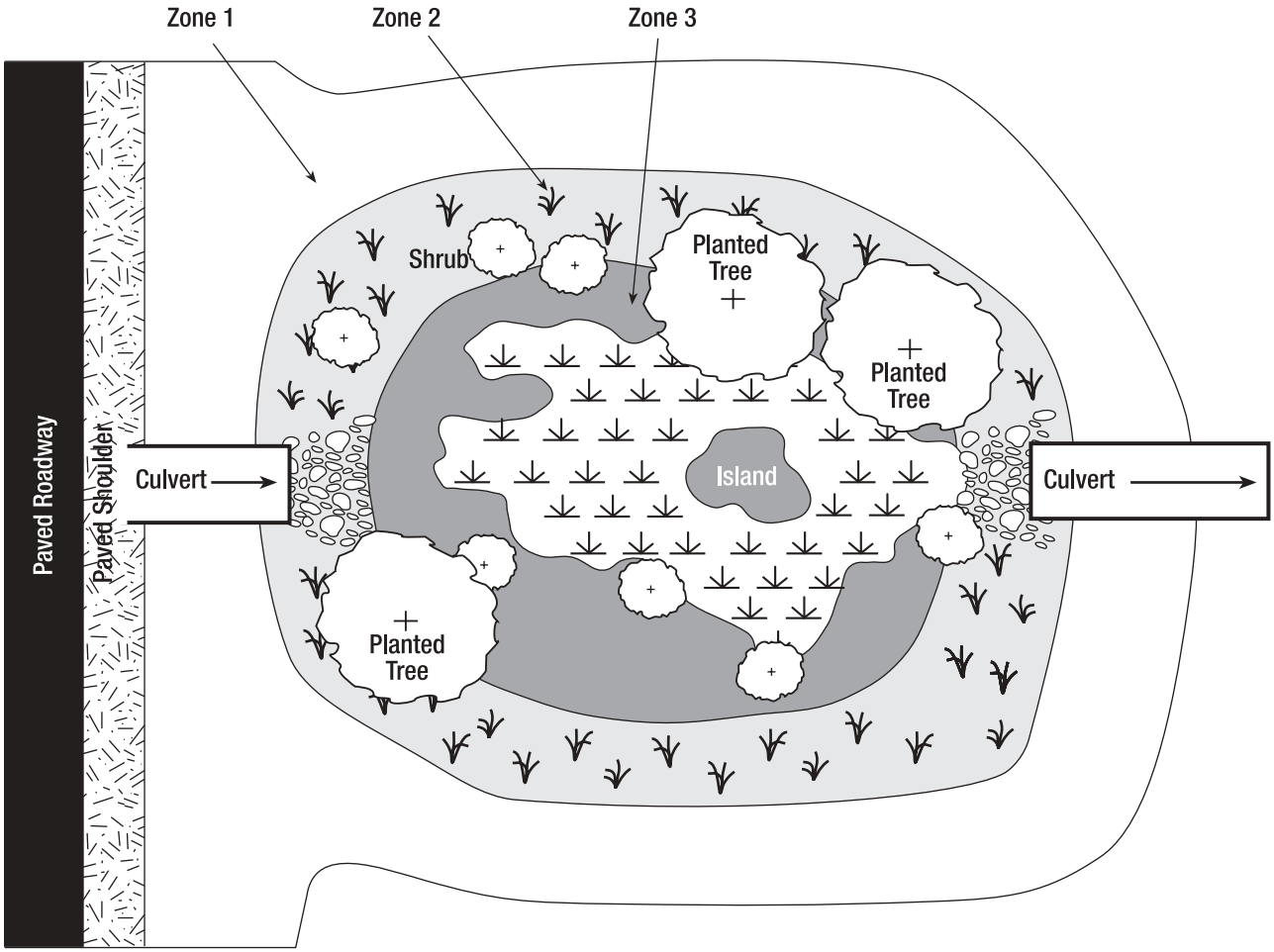
Zone	Condition	Prescription
I	< 5 *m wide*	Use standard AOT seed mix.
	> 5 m wide	
	2:1 slope or greater	Use standard AOT seed mix.
	4:1 slope or less	Use standard AOT seed mix. Plant occasional shrubs from List II beyond 5 m zone
2	Within safety setback zone (< 5 m from pavement).	Use wet area seed mix (List IV).
	Beyond safety setback zone (> 5 m from pavement).	Use wet area seed mix (List IV). Plant shrubs (List II) for 3 m from edge of Zone 3.
3	Zone is flooded more than 25 % of growing season.	Use wet area seed mix (List IV). Plant with emergents (List I) and shrubs (List II).
	Zone is rarely flooded and detention time for flood events is less than 3 days.	Use wet area seed mix (List IV). Plant shrubs (List II) and trees (List III) to edge of normal water level. If standing water occurs for 50% of growing season select herbaceous wetland plants (List I).
4	This zone is absent.	Not applicable.

Notes:

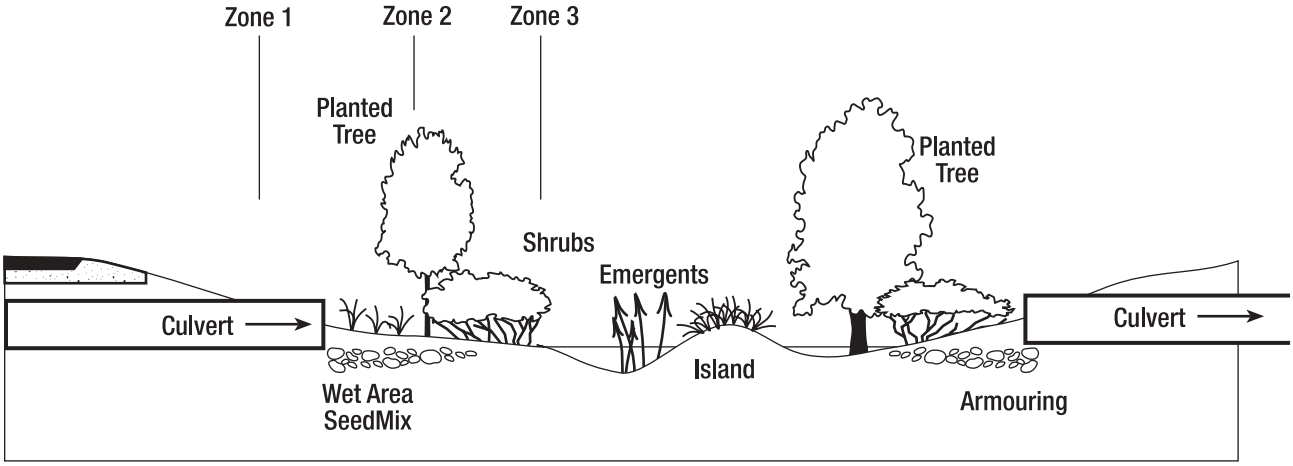
- Ensure that culvert bottoms have connection with the wet area. Plant edges of inlets and outlets with shrubs so that waterway to stormwater facility is protected and shaded. Plantings will encourage animals to use culverts to move in and out of the wet area rather than trying to cross the road.
- Zone 3 may be wide or narrow depending upon the configuration of the facility, periodicity of storm events and detention time.
- If the site is large enough, an island can be created to reduce water velocity and increase sediment deposition.
- If possible, ensure that the deepest part of the wet area maintains some water most of the growing season and that the bottom. slopes of facility are gently sloping (1:10) towards deepest area.
- Trees may be planted in occasional clumps within Zone 2 and upper Zone 3 when appropriate.

Figure 8
Stormwater management facility adjacent to highway

Plan View



Cross-section



3.3.8 Ditch Adjacent to Highway

The primary function of drainage ditches is to transfer water away from the highway as quickly as possible. In order to function effectively, drainage ditches require periodic maintenance. Sediment loadings of drainage water is increased after ditch creation and maintenance activities and may have detrimental effects on fish, amphibians, reptiles and aquatic plants in receiving waters.

The growth of wetland vegetation in ditches is ubiquitous and, where sufficient moisture is present, cattails, purple loosestrife, or common reed-grass may invade within a one or two year period. The purpose of revegetating ditches with wet area species is to stabilize the banks and bottoms with species which will survive wet conditions, reduce the frequency of maintenance, provide effective water conveyance, and dissipate water energy during major rain events. A zoned approach is undertaken and, while grass may be suitable for many swales and ditches where water collects, other wet area vegetation which can tolerate long periods of immersion or are more compatible to surrounding wet areas may be preferable.

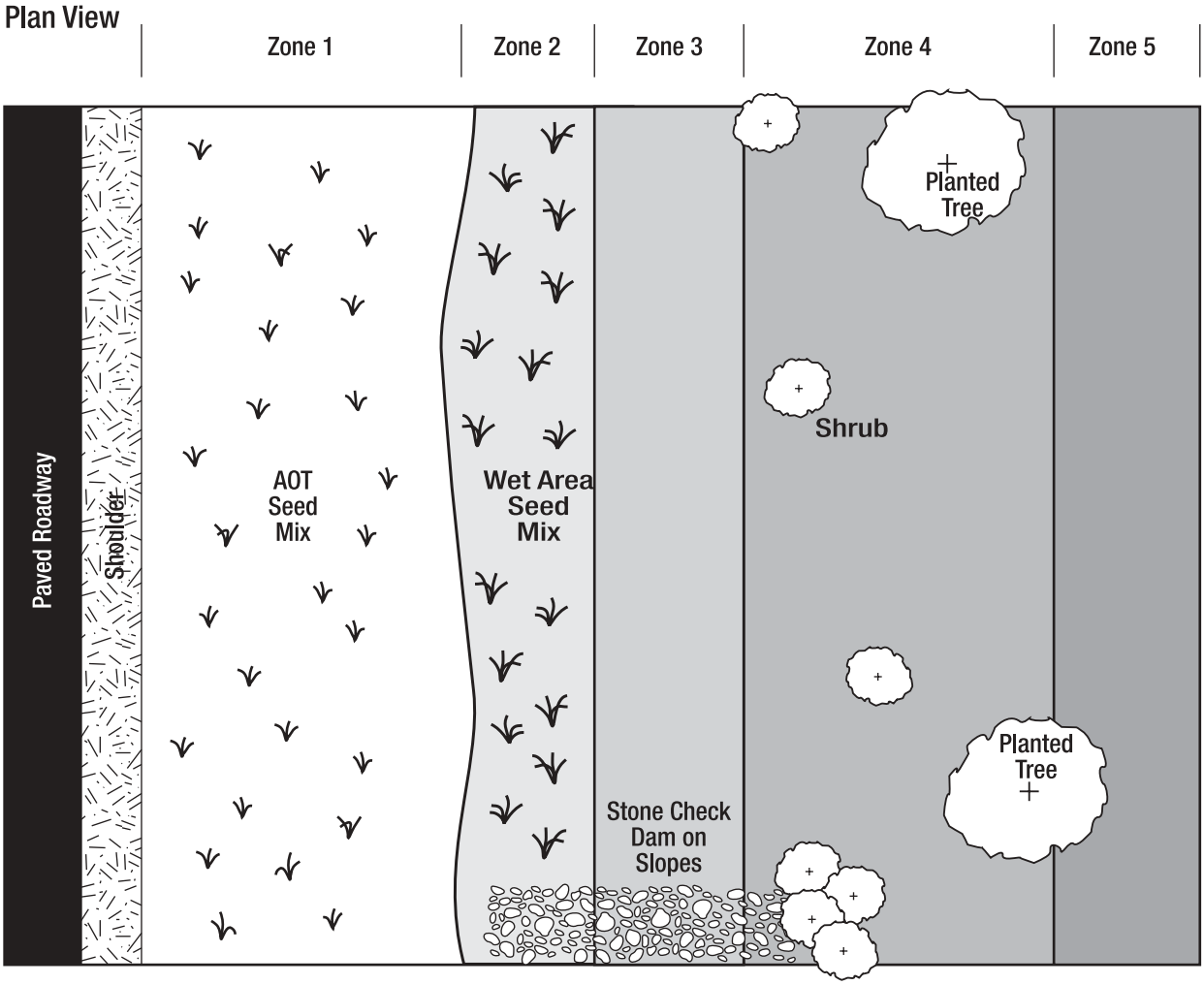
Table 9 *Ditch adjacent to highway*

Zone	Condition	Prescription
I	< 5 m wide	Use standard AOT seed mix
	> 5 m wide	
	2:1 slope or greater	Use standard AOT seed mix.
	4:1 slope or less	Use standard AOT seed mix. Plant occasional shrubs from List II beyond 5 m zone.
2	Within safety setback zone (< 5 m from pavement).	Use wet area seed mix (List IV).
	Beyond safety setback zone (> 5 m from pavement).	Use wet area seed mix (List IV). Plant occasional shrubs (List II).
3	Potential for high velocity water flow, with armoring.	Use wet area seed mix (List IV) with geotextile and armoring to Zone 2 and 4.
	Low velocity water flow, without armoring.	Use wet area seed mix (List IV). Plant slopes with occasional clumps of shrubs (List II).
4	Zone is dry	Use AOT seed mix and/or plant with upland species, if area was disturbed.
	Zone is wet	If area was disturbed, use wet area seed mix (List IV). Plant shrubs (List II) for 3 m from edge of Zone 3 to provide wildlife cover; if watercourse > 3 m across also use trees (List III).

Note:

- ff the slope of ditch warrants, use stone check clams to capture sediment and reduce water velocity.

Figure 9
Ditch adjacent to highway



4. Implementation

4.1 Site evaluation

Site evaluation involves identifying and analyzing the conditions of a site to determine if appropriate characteristics exist for the establishment of wet area vegetation. Ideally, sites would be evaluated using conditions adjacent to the ROW where existing plant communities remain which were not disturbed by highway construction.

Site evaluation can be completed at three levels of investigation:

1. *map analysis* - potential wet area areas can be identified from topographic mapping, mapping, environmental assessment studies, and vegetation appraisal studies. Analyzing potential wet sites from existing mapped information will focus field studies on candidate areas and avoid extensive field investigation.
2. *general site analysis* - having identified candidate sites from map analysis, investigators can review specific sites in the field to eliminate areas with unsuitable or difficult conditions.
3. *detailed site analysis* - having screened sites through general site surveys, investigators can analyze specific sites to confirm that appropriate conditions exist for the establishment of wet area vegetation.

Final site evaluation should consider analysis of the following characteristics:

- can existing hydrological conditions support wet area or hydrophytic vegetation?
- will the soils support appropriate species or plant communities?
- will water quality (due to high salinity etc.) hinder the establishment of appropriate plant communities?
- will excessive shade prevent the successful establishment of a new plant community?
- is an incompatible land use potentially limiting to the successful establishment of wet area communities?
- will high water or excessive water velocity prevent the establishment of wet area vegetation?
- will access problems limit or make planting prohibitively expensive?
- does the size of the planting area warrant special planting techniques?
- are the species selected for planting compatible with or representative of the composition of plant communities adjacent to the ROW?
- will the depth to bedrock limit certain types of planting (i.e., are the soils too shallow for plant establishment)?
- how will existing or proposed erosion control devices (e.g., rip rap, geotextiles, gabions, gro-block) influence planting options?
- will high frequency of salt as spray or in runoff during winter months damage plants?
- will wind and exposure conditions limit the choice of plant material or increase the failure rate of plant material during establishment?

4.2 Plant selection

The species of shrubs, trees and herbs adjacent to a roadway are usually a combination of native and non-native species. Owing to their impacts on surrounding landscapes, and typically aggressive nature, non-native species should not be used except for providing temporary cover while native species become established. It is recommended that when the site survey is undertaken, native plant species adjacent to the disturbed ROW, or remaining in the ROW, be used as a basis

for establishing plant lists for planting of wet areas. This will avoid the potential for spreading unwanted or weed species and promote the use of locally adapted species which will have a high probability of successful establishment.

A mix of species should be selected to maximize the likelihood of success and to provide a diverse ground cover. Species that occur in similar habitats should be used, thus bog species and marsh species should not be mixed in the same planting scheme. A mix should include grass-like species (grasses, sedges, spike-rushes, bulrushes) and flowering forbs (herbaceous perennials) along with trees and shrubs as indicated in the situation diagrams and tables.

Special considerations that may be required by review agencies (i.e., preservation of cold water streams, erosion control or recharge and discharge areas) should be accounted for when selecting species for planting.

The selection of species for wet area planting is based on:

- conducting a plant inventory adjacent to the site;
- checking the species against plant Lists I-IV;
- making a list of preferred species for planting, ensuring variety of herbaceous, shrub and tree material where appropriate; and
- checking the availability of plant material from nurseries or other suppliers, and, if possible, arranging for material to be custom grown.

4.3 Propagation methods

There are a number of forms of planting material that can be used for wet area planting. Availability depends upon plant types, geographical area and the sophistication of local growers.

Potential propagation methods include:

Seeding

Seed mixes - premixed or custom seed mixes through seed suppliers.

Vegetative Propagules

- *rhizome or root cutting* - underground stems or roots which store food to be used by a new plant, sends out roots into the soil and shoots to soil surface.
- *tubers* - a solid, thickened portion or outgrowth of an underground stem, of a more or less rounded form, bearing modified auxiliary buds from which new plants may arise (Thunhorst 1993).
- *bulb* - a round underground modified bud which serves as a storage organ.
- *cuttings* - whole branches or live stakes cut from nursery stock or natural plants.

Transplanted Material

- *plug* - entire and usually young plant with sediment still on roots.
- *bare root* - spring dug or cold storage (fall dug) dormant plants; usually young plants with sediment removed from roots.
- *potted* - spring dug plants potted for less than a complete growing season, usually in fibre pots.
- *container grown* - plants grown in containers (Mastic, FIVC, fibre, or peat pots) for a minimum of two growing seasons, with well established root systems.
- *balled and burlapped* - trees or shrubs where root ball has been removed from the ground and enclosed in burlap and string for delivery.
- *wire basket* - tree or shrub that has been machine dug, and placed in a wire basket with biodegradable woven fabric to contain rooting soil.

All of the above forms of planting can be used in upland conditions as well. The choice

of plant material will depend on availability, budget and the desired results. Seeding will generally be the least expensive route but is not very successful in many wet situations. For example, sedges are difficult to establish from seed. Seed for many species may not be readily available and seed quality can be poor.

Vegetative propagules and especially transplanted material will allow faster establishment, and larger plants will provide more immediate results than seeding. Availability may vary considerably and the cost may be prohibitive for large areas. The planting of bare root trees and shrubs has not been very successful in wet conditions (Thunhorst 1993).

4.4 Cover (nurse) crops

The value of nurse or cover crops for wet area seeding has yet to be determined. In upland situations, the use of nurse grasses such as Italian annual rye grass, fall wheat or rye grain provide initial, quick cover to control erosion and compete with weeds. Short-lived perennials such as perennial rye grass provide medium term cover while the seeded species establish.

4.5 Options for revegetating wet areas

There are three basic options for dealing with wet area sites. They include:

- Do nothing.
- Provide a seed pool for the colonization of the area.
- Re-establish plant communities.

The 'do nothing' approach may be appropriate on small sites or where the sites do not have a high public profile. This approach should only be used in areas where colonization can occur from existing plant communities adjacent to the ROW. Plant communities in the early stages of succession such as wet meadows, old fields, etc., will colonize an area more quickly than mature communities such as established deciduous swamps.

The second option of providing a seed pool requires planting selected species in anticipation that they will colonize the site. This is appropriate in low-profile locations where public exposure is limited and where there are plant communities outside the ROW that will contribute to the process.

The third and final approach is to replant with the intent of providing the complete structure of a wet area community. This would include planting early and late successional species and other species which are part of the indigenous plant community. The intent is to facilitate establishment such that mature plant communities are established in a short time period. This would include not only planting a wide variety of species but using large sized stock. The advantage of developing a later successional stage is that typical species are generally slower growing and require less maintenance once established.

4.6 Site preparation

There are a variety of possible conditions that may be found within the ROW that would require special remedial work before planting can occur. These could include:

- *Compacted Soils* - Areas within the ROW may be compacted from construction, particularly in Zones 1, 2 and 3. Topsoil and in some cases the substrate should be scarified prior to seeding or placement of large beds of plant materials. Tree pits in compacted sites should be dug in such a way as to ensure proper drainage where planting stock requires well-drained soils.
- *Lack of Topsoil* - Some areas of the ROW may have very thin layers of topsoil. Where trees and shrubs are part of the wet area vegetation, adequate topsoil must

be supplied as part of the installation to ensure proper establishment.

- *Poor Topsoil* - Even if topsoils are available in adequate quantities, the soil may require amendment to provide sufficient nutrients and ensure proper establishment of wet area vegetation. Lack of organic matter may require special remedial steps during installation.
- *Erosion Potential* - Steep slopes may require special consideration in the restoration of wet area communities. Some sites may require the installation of erosion control products such as erosion control fabrics, mulches or fast growing cover or nurse crops.
- *Competition* - Sites with already established vegetation may require removal or control of existing plant communities to ensure proper establishment of proposed wet area vegetation. New planting may require mulching with combinations of woven fabrics, bark mulch or other mulches to control competition from ground cover and other vegetation. Selective spraying and mechanical removal may also be means of controlling competition from existing plant communities.

4.7 Sources of plant material

There are sources of native seed and herbaceous and woody plant nurseries available in the Northeast. Contact your local nurseryman for information.

4.8 Seeding

The standard Vermont Agency of Transportation mix is:

VTrans Rural Areas Conservation Mix.

37.5% creeping red fescue
37 % tall fescue
5% red top
15% birdsfood trefoil
5% annual ryegrass

Rate of Mix Application: 60# per acre.
Double if hydroseeding

Wet Area Seed Mix:

Common Name	Latin Name	%Mix
Virginia Wild Rye Grass	Elymus virginicus	20 %
Fox Sedge	Carex vulpinoidea	10%
American Mannagrass	Glyceria grandis	20%
Giant Bur-Reed	Sparganium eurycarpum	10%
Common Three-Square	Scirpus americanus	20%
Soft-Stem Bulrush	Scirpus validus	10%
Canada Rush	Juncus canadensis	10%

Rate of Mix Application: 10# per acre (up to 15# per acre if hydroseeded)

4.9 Wildlife control

In some cases there may be the need for wildlife control where animals may pull up, graze or otherwise destroy wet area plantings.

4.9.1 Birds

Control of birds involves using bird scarers, fencing and various chemical sprays (Timm 1983).

- Canada geese may represent a problem by grazing on vegetated wet areas, and by pulling out newly planted wetland plants.
- Ducks may pull out wetland plants and graze heavily on suitable planted areas. When traffic densities and speed are high, they tend to avoid highway wet areas.

4.9.2 Mammals

- Deer are a problem when grazing close to or crossing major roads. Factors which influence their presence are the provision of suitable forage, particularly early in the year, together with the presence of salt in roadside ditches. The provision of good sight lines for traffic is the best strategy

for avoiding vehicle-deer incidents (Lintack pers. comm.).

- Muskrat are a potential problem in cattail stands adjacent to highways. They may eat recently planted material and may use the road bed to burrow for dens. They can be controlled by trapping (Novak et al. 1987).
- Beaver present a problem when they dam up ditches, culverts and watercourses adjacent to highways. Control is generally recommended and involves trapping by authorized personnel and the destruction of dams (Novak et al. 1987).
- The major impact of mice and voles is girdling of trees and shrubs. Large populations in grass and meadow situations can effectively kill all wooded material. Woody material can be protected by maintenance around trees, bait stations and the use of tree guards (Ker and Wilson 1989. Timm 1983).

5. Literature Cited

Country Wetlands Ltd. 1992. Nursery catalogue. Country Wetlands Nursery & Consulting Ltd., Muskego, Wisconsin.

Crum: H.A. 1992. A focus on peatland and peat mosses. University of Michigan Press, Ann Arbor, Mi., 306 pp.

Keddy, P.A. and T.H. Ellis. 1984. Seedling recruitment of 11 wetland plant species along a water level gradient: shared or distinct responses. Can. J. E3ot. 63:1876-1879.

Ker, K.W. and K. Wilson. 1989. Rodent and deer control in orchards. Ontario Ministry of Agriculture and Food. Toronto, ON. AGDEX 210/681. Order No. 89-122. 4 pp.

Lintack, W.M. 1993. Personal communication. Owen Sound Area Office, Ontario Ministry of Natural Resources.

National Wetlands Working Group. 1988. Wetlands of Canada. Ecological Land Classification Series No. 24. Sustainable Development Branch, Environment Canada, Ottawa, ON, and Polyscience Publications Inc., Montreal, OU.

Novak, M., J.A. Baker, M.E. Obbard and S. Malloch.

(Eds.). 1987. Wild forbearer management and conservation in North America. Ontario Trappers Association and the Ministry of Natural Resources, Toronto, ON. 1 1 50 pp.

Ontario Ministry of Natural Resources. 1993. Ontario wetland evaluation system: Southern manual. Toronto, ON. 3d edition. 1.33 pp.

Ontario Ministry of Natural Resources and Ontario Ministry of Municipal Affairs. 1992. Manual of implementation guidelines for the Wetlands Policy Statement. Toronto, ON. 116 pp.

Thunhorst, G.A. 1993. Wetland planting guide for the northeastern United States: Plants for wetland creation, restoration and enhancement. Environmental Concern, Inc. St. Michaels, MD.179 pp.

Timm, R.M. 1983 (Ed.). Prevention and control of wildlife damage. Nebraska Cooperative Extension Service. University of Nebraska, Lincoln. NB.

Watson, G. (Ed.). 1991. Selecting and planting trees. The Morton Arboretum, Lisle, IL. 24 pp.

Wildlife Nurseries, Inc. 1992. Nursery catalogue. Wildlife Nurseries Inc., Oshkosh, Wisconsin.

Appendix I/ Plant Lists

Natural Habitats; Moisture Requirements/ Tolerance

Natural habitats are broken into a few broad wetland habitats to provide some guidance as to the preferred use for each species. Each of these habitats is defined in Section 2.1 starting on page 7. Plants found in marsh habitats will also suit lake and river shoreline habitats. Several species listed have special characteristics. For instance, grass of Parnassus *(Parnassia glauca)* is a calciphile that prefers lime rich soils with a high pH. It is necessary for the landscape architect or biologist working on a particular project to determine if these requirements are present at a particular site.

Rate of Spread

An attempt was made to indicate the rate at which each species is expected to spread. There is little information available for most of the species listed. The guidance in the table is largely based on our own experience with these species and knowledge of their behavior in natural settings. When planted in artificial settings, where competition may be reduced, hydrology changed, etc., these plants may behave quite differently, thus the information should be used as a guide only.

Propagation Method

There is little information on the propagation methods used for the majority of native species. We have drawn on information from nursery catalogues for some of the information and relied on our own familiarity with the species for the balance. It should be noted that local nursery operators and specialists may have additional information.

Herbaceous Perennials

Species	Common Name	Natural Habitat; Moisture Requirements/Tolerance	Rate of Spread	Propagation Method
Caltha palustris	Marsh-Marigold	Meadow, marsh, Swamp; wet to mesic	slow	rhizome
Carex lacustris	Lake Sedge	Marsh; hydric, wet	moderate	seed, bareroot, peat pot
Carex lasiocarpa	Slender Sedge	Marsh, Meadow, Fen, Bog; wet to mesic, can withstand temp. drought		
Carex vulpinoidea	Fox Sedge	Meadow, Marsh; wet to mesic	slow	rhizome
Dulichium arundinaceum	Three-way Sedge	Marsh; wet	moderate	rhizome, seed
Eleocharis acicularis	Needle Rush	Meadow, Marsh; wet	slow	seed
Eleocharis palustris	Marsh Spike-Rush	Marsh, Meadow; wet to hydric; tolerant of submergence and temporary drought	moderate	rhizome
Glyceria striata	Fowl Manna Grass	Marsh, Meadow, Swamp; wet to hydric	moderate	rhizome, seed
Iris versicolor	Wild Blue Flag	Meadow, Swamp; wet, tolerant of temporary drought		bulb, seed
J*uncus effusus*	Common Rush	Marsh, Swamp, Meadow; wet to Hydric		rhizome
Juncus tenuis	Slender Rush	Meadow; wet	slow	
Juncus torreyi	Torrey's Rush	Meadow; wet	slow	

Herbaceous Perennials, continued

Species	Common Name	Natural Habitat; Moisture Requirements/Tolerance	Rate of Spread	Propagation Method
Lobelia cardinalis	Cardinal Flower	Marsh, Swamp; wet to mesic	slow	rhizome
Lycopus americanus	American Water-Horehound	Swamp, Marsh; wet		seed
Onoclea sensibilis	Sensitive Fern	Marsh, Meadow, Swamp; wet to Mesic	moderate	rhizome
Osmunda cinnamomea	Cinnamon Fern	Swamp; wet	slow	rhizome
Osmunda regalis	Royal Fern	Swamp, Marsh; wet	slow	rhizome
Polygonum hydro-piperoides	Mild Waterpepper	Marsh, Meadow; wet		rootstocks
Pontederia cordata	Pickerelweed	Marsh; hydric, intolerant of emergence		
Thelypteris (Dryopteris) palustris	Marsh Fern	Marsh, Swamp; wet	moderate	rhizome
Triadenum fraseri	Marsh St. Johnswort	Marsh, Meadow; wet		stolons
Typha latifolia	Common Cattail	Marsh, Meadow; wet to Hydric, tolerant of submergence	invasive	rhizome
Scirpus fluviatilis	River Bulrush	Marsh; wet	moderate	rhizome
Scirpus validus; Scirpus tabernaemontanii	Softstem Bulrush	Marsh; wet to hydric, tolerant of emergence	rapid	rhizome
Sium suave	Water-parsnip	Marsh, Meadow; wet, tolerant of Submergence	slow	
Smilacina trifolia	Three-leaved False Solomon's-Seal	Swamp, bog; wet		
Sarracenia purpurea	Pitcher Plant	Bog; wet		
Scirpus acutus	Hard-stemmed Bulrush	Marsh; wet to hydric		rhizome
Sparganium eurycarpum	Giant Bur-Reed	Marsh; wet to hydric	rapid	rhizome

Shrubs

Species	Common Name	Natural Habitat; Moisture Requirements/Tolerance	Propagation Method
Andromeda glaucophylla	Bog-rosemary	Bog; wet	
Cephalanthus occidentalis	Buttonbush	Swamp; wet	
Chamaedaphne calyculata	Leather-leaf	Bog, wet	
Cornus stolonifera Cornus sericea)	Red-osier Dogwood	Swamp, Meadow; wet to mesic	fall seed sowing, cuttings and layering
Gaultheria hispidula	Creeping Snowberry	Swamp, Bog; wet to mesic	seed, hardwood and soft-wood cuttings, division, layering
Gaylussacia baccata	Black Huckleberry	Swamp; wet to mesic	seed, hardwood and soft-wood cuttings, division, layering

Shrubs, continued

Species	Common Name	Natural Habitat; Moisture Requirements/Tolerance	Propagation Method
Ilex verticillata	Winterberry	Swamp; wet	planting stock, seed, cuttings
Kalmia angustifolia	Sheep-laurel	Bog; wet	seed, cuttings and layering
Kalmia polifolia	Bog-laurel	Bog, Swamp; wet	
Ledum groenlandicum	Labrador-tea	Bog, Swamp; wet to mesic	
Lindera benzoin	Spicebush	Swamp; wet to mesic	stratified seed when available
Myrica gale	Sweet Gale	Swamp, Bog; wet	
Nemopanthus mucronata	Mountain Holly	Swamp, wet	
Potentilla fruticosa	Shrubby Cinquefoil	Bog, Fen, Marsh, Swamp; wet to mesic	
Rosa palustrus	Swamp Rose	Marsh; wet	scarified seed, cuttings
Salix candida	Hoary Willow	Swamp, Marsh; wet-mesic	seed, cuttings
Salix pedicellaris	Bog Willow	Bog, Fen, Marsh, Swamp: wet	seed, cuttings
Sambucus canadensis	Common Elder	Swamp; wet-mesic	seed, rooted cuttings
Spiraea alba	Meadowsweet	Marsh: wet	softwood and hardwood cuttings
Spiraea tomentosa	Steeple-bush	Marsh; wet	
Vaccinium corymbosum	Highbush Blueberry	Swamp; wet to mesic	stratified seed and stock, cuttings
Vaccinium macrocarpon	Large Cranberry	Swamp; wet	
Vaccinium myrtilloides	Velvet-leaved Blueberry	Swamp; mesic	
Vaccinium oxycoccos	Small Cranberry	Bog; wet	
Viburnum cassinoides	Witherod	Swamp; wet	two stage stratification of seed

Trees

Species	Common Name	Natural Habitat; Moisture Requirements/Tolerance	Propagation Method
Acer rubrum	Red Maple	Swamp; wet to mesic	Seed
Acer saccharinum	Silver Maple	Swamp; wet to mesic, tolerant of submergence	Seed
Fraxinus pennsylvanica	Green Ash	Swamp; wet to mesic	Seed
Larix laricina	Tamarack, Larch	Swamp, Bog, Fen; wet to mesic	Seed
Picea mariana	Black Spruce	Swamp, Bog;	Seed
Populus balsamifera	Balsam	Swamp; mesic	Suckers, Cuttings
Ouercus bicolor	Swamp White Oak	Swamp; wet to mesic	Seed
Salix nigra	Black Willow	Swamp; wet to mesic, tolerant of submergence	Cuttings
Thuja occidentalis	White Cedar	Swamp; wet to mesic	Seed
Ulmus Americana	American Elm	Swamp; wet to mesic	Seed

Species Suitable for Wet Area Seed Mix

Species	Common Name	Natural Habitat; Moisture Requirements/Tolerance	Rate of Spread
Bidens spp	Beggarticks	Marsh, Meadow; wet	moderate
Carex annectens (C. vulpinoidea)	Fox Sedge	Marsh; Meadow	
Carex lacustris (C..riparia)	Lake Sedge	Marsh; wet to hydric	moderate
Carex lasiocarpa	Slender Sedge	Marsh, Meadow, Fen, Bog; wet to mesic, can withstand temporary drought	
Carex limosa	Mud Sedge	Marsh, Fen, Bog; hydric to mesic	
Carex stricta	Sedge	Meadow, Marsh; wet to mesic	moderate
Dulichium arundinaceum	Three-way Sedge	Marsh; wet	moderate
Eleocharis palustris	Marsh Spike Rush	Marsh, meadow; wet to hydric, tolerant of submergence and temporary drought	moderate
Juncus atroviens	Rush	Meadow	
Scirpus cyperinus	Wool grass	Marsh; Pond, Bog; wet to mesic	moderate
Scirpus validus	Softstem Bulrush	Marsh, wet to hydric, tolerant of emergence	rapid

Appendix 2/ Contact list

Environmental Protection Agency Hotline
Washington, D.C.
1-800-832-7828

Mr. Ellis J. Clairain, Jr.
Leader, Wetlands Research Team Wetlands and Terrestrial Habitat Group
U.S. Army Corp of Engineers Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, Mississippi 39180-6199
(601) 634-3774

Mr. Paul Garrett
Wetlands Research Group
Office of Environmental Planning and Analysis
U.S. Federal Highway Administration
Washington, D.C.
(202) 366-2067

Mr. Crawford Jinks
Transportation Research Division
U.S. Federal Highway Administration
Washington, D.C.
(202) 334-2379

Ms. Mary E. Kentula
Wetlands Research Program
Environmental Research Laboratory
U.S. Environmental Protection Agency
200 S.W. 3.5th Street
Corvallis, Oregon 97333
(503) 754-4478

How to Take a Soil Sample

Reprinted from University of Vermont Agricultural Testing Lab

The reliability of a soil test is only as good as the sample you submit. The small amount of soil in the sample bag you send to the Agricultural Testing Lab must represent the entire area to be fertilized. Avoid unusual areas such as those where fertilizer or lime has spilled. Take samples before lime, fertilizer, or manure are added. Use only clean equipment for collecting soil samples.

Where to sample:

The area to be sampled should be as uniform as possible in terms of soil type and cropping and fertilizing history. For practical purposes it should be an area you expect to fertilize as a unit. This means separate samples for annual mixed vegetables and a strawberry patch, for golf green and fairway, and for different major crops in a commercial nursery or vegetable operation. If you have a problem on part of a lawn, garden, or commercial production field, you may wish to determine if soil fertility is the cause by taking one sample to represent the "good" and the other to represent the "poor" area.

Take a good sample:

Collect a number of cares or slices by walking in a zig-zag pattern over the area. Mix cores thoroughly in a clean pail for a composite lab sample. The greater the number of collected cores mixed together, the better the sample will represent the average condition of the sampled area. Consider 10 cores as the minimum for home gardens and lawns up to 10,000 square feet in size. Larger areas should be represented by at least 15 to 20 samples.

Choose one of the following tools:

Soil Probe or Auger - A soil probe or auger, available from mail order catalogs and garden or farm supply outlets, is the best tool for sampling. An auger will be needed if the soil is very stony or gravelly. Simply push the probe (or push and turn the auger) into the soil to the desired depth, lift up to remove the core, and place it in the clean pail. Sampling depth should be 4 to 6 inches deep for lawns, turf, or other perennial sod, or tillage depth (usually 6-10 Inches) for annually tilled crops.

Garden Trowel or Shovel - If a soil probe or auger is not available, collect your sample by pushing the blade of a garden trowel, shovel, or spade into the soil to the desired depth. Cut out a triangular wedge of soil and set it aside (to be replaced after sampling). Now slide your blade into the soil again taking a thin (half inch) slice from one side of the hole. With a knife, trim the slice to about a 1-inch strip of soil down the center of the spade—top to bottom. Save this "core" as part of your composite lab sample.

Mix the sample and fill the sample bag.

Make sure that all the cores are thoroughly mixed together. Wet clay soils may first require setting aside to dry. Your soil test mailer contains a plastic bag intended for one lab sample. Fill this bag about 1/2 full (approximately 1 cup) with the mixed sample. Mail or deliver the samples to:

University of Vermont Extension System
& University of Vermont Agricultural
Testing Lab

Soil Test Report

Reprinted from Soil Test Report, UVM Agricultural & Environmental Testing Laboratory

SAMPLE DESCRIPTION

Crop/planting: lawn/turfgrass to be planted
soil texture: sandy
soil drainage: good
size of area: > I acre

COMMERCIAL AGRICULTURAL & ENVIRONMENTAL TESTING LABORATORY AND UVM EXTENSION

UNIVERSITY OF VERMONT

527-5448 LAB NUMBER L990942 DATE 11/22/99

REPORT FOR:
Craig Dusablon/Agency Trans. 133 State St
Montpelier, VT 05602

SOIL TEST RESULTS			LOW	MEDIUM	OPTIMUM
Avail. Phosphate	(ppm P)		7.1	**********	
Potash	(ppm K)	123	**********	**********	
Magnesium	(ppm Mg)	79	**********	**********	
pH	6.8				
Calcium	(ppm (Ca)	1051			
Effective CEC	(meq/100g)	6.2			
Ca: Mg: K ratio		17:2.1:1			
Aluminum	(ppm Al)	44			

Please refer to the back side for a more detailed description of the test.

Maintaining a high quality lawn usually requires multiple applications of fertilizer, especially nitrogen (N). Frequency and timing depend on your choice of management level (see below). A “good” or “high” management level is recommended for most vigorous growth.

Management Level	Application Times			
	Early Spring	Early June	September	Late Fall (Nov.)
High	X	X	X	X
Good	X		X	X
Adequate	X			X
Minimum				X

All fertilizers should be broadcast evenly and watered in.
No lime additions are necessary.
Your soil tested OPTIMUM in phosphorus and OPTIMUM in potassium.
Routine fertilization should supply enough nutrients. Use a high-N analysis lawn fertilizer and follow manufacturer’s instructions.
If you wish to add nitrogen (N) at other times, use a high-N analysis lawn fertilizer and follow manufacturer’s instructions.

The above recommendations were designed for normal lawns. If you have a special application and need more specific recommendations, please contact Jim Leland.

If you have questions about your soil test, please contact:

Jim Leland 802-828-2431
VT Department of Agriculture
Division of Plant industry

UVM Agricultural Testing Lab Analysis Results

Reprinted from University of Vermont Extension System & UVM Agricultural Testing Lab

L 990942 11/22/99
LAB # Date Completed

PACKAGE 1 MICRONUTRIENTS *
(ppm in soil)

		Your Results/	Avg. levels in Vermont soils
Sodium	(Na)	25.0	20.0
Iron	(Fe)	4.1	7.0
Boron	(B)	0.2	0.3
Manganese	(Mn)	6.4	14.0
Copper	(Cu)	<.2	0.4
Zinc	(Zn)	0.7	1.0

*Micronutrients are not usually deficient in Vermont soils. The average levels are provided for comparison only and are not necessarily optimum levels for plant growth. Additions of micronutrient fertilizers should be done with caution because of the narrow range between deficiency and toxicity. Organic residues such as manure are usually good sources of micronutrients.

% Organic Matter: 3. 5

Estimating Soil Moisture by Feel and Appearance

Reprinted from The Natural Farmer, Fall 2003

By USDA Natural Resources Conservation Service

Evaluating soil moisture is one of an irrigator's most important management tools. Determining the status of the soil moisture reservoir guides the decision of not only how much to irrigate, but also when to irrigate. The "appearance and feel" method of monitoring soil moisture using a soil probe is still a valid procedure no matter how sophisticated the irrigation scheduling system. A measurement of soil moisture is essential to update knowledge of the need for and timing of irrigation and the "appearance and feel" method can be used to obtain that information.

In addition to indicating how much moisture is in the soil, this method also reveals where that moisture is located in the profile. This information is important to the irrigator as well as the dryland farmer. The depth of water penetration from irrigation or rainfall is useful in planning and making management decisions. For example, problem areas with compacted soil layers that restrict water penetration may be detected with the soil probe.

Soil texture, the relative amount of sand, silt or clay contained in a soil, is an indicator of the amount of water a soil will hold. Available water capacity is the maximum amount of moisture the soil will hold that plants can use. The values of available water for four basic textural classes are given in *Table 1*.

The textural classification of a soil is important not only for knowing how much water potentially can be held for crop use, but also for visual inspection. Different soil types respond differently to the methods described in this guide, which is one of the keys to making the soil moisture determination. The county soil survey, which can be obtained through your Cooperative Extension Service office or the Soil Conservation Service, includes discussions on soil texture and available water capacity of your soils.

Sampling and Evaluation Procedures

A soil probe, soil auger, or spade can be used to extract a soil sample. Evaluate the soil moisture at one foot intervals from the surface to the bottom of the active root zone. The active root zone for most irrigated crops is approximately 3 feet deep. When checking for water penetration or soil moisture for dryland crops, probe to the depth of 4 to 5 feet.

To begin learning the appearance and feel of your soil at particular moisture contents, start early in the spring, one or two days after a heavy rain. At this point the soil moisture level should be near field capacity, or holding 100 percent of the water that it can naturally retain. Likewise, probe the soil at the end of the growing season when the profile is likely to be dry. Knowing the appearance and feel of your soil at the wet and dry ends of the spectrum will help make determinations during the midseason. Use the photos and description in the following section when assessing soil moisture. The number and location of sampling sites depends on both the uniformity of the soils in the field and the irrigation procedures.

Check problem areas in the field in addition to the starting and stopping areas of your particular irrigation system. Sample a minimum of four sites in different parts of the field.

Guides for Estimating Soil Moisture

When using a soil probe to extract the samples, the following procedures will make the job easier:

a. Scrape a clean, level area on the soil surface before inserting the probe.

b. Insert the probe to the desired depth (at one foot increments) and turn the probe once clockwise before pulling it back to the surface.

c. After inspecting the soil, remove all of the soil from the tube, including the tip. A fitted dowel may help. Soil left in the tip may tend to compact the next sample.

d. Clean the probe after each use to prevent rust and hard caked soil.

e. Replace or sharpen the tip as needed.

Procedure for evaluating soil moisture using photo guides and descriptions:

1. Determine texture of soil.
2. Squeeze small handful of soil firmly.
3. Observe the condition of the ball and your hand.
4. Attempt to form a ribbon of the soil between your thumb and forefinger.
5. Observe what happens.
6. Compare your observations with the photos and descriptions in the guides.

   (Photo guides and soil moisture descriptions for four soil types are provided.)

Calculating Soil Moisture Status

After estimating the soil moisture, the amount of water in the soil reservoir can be calculated using *Table I.* The following example illustrates the calculation:

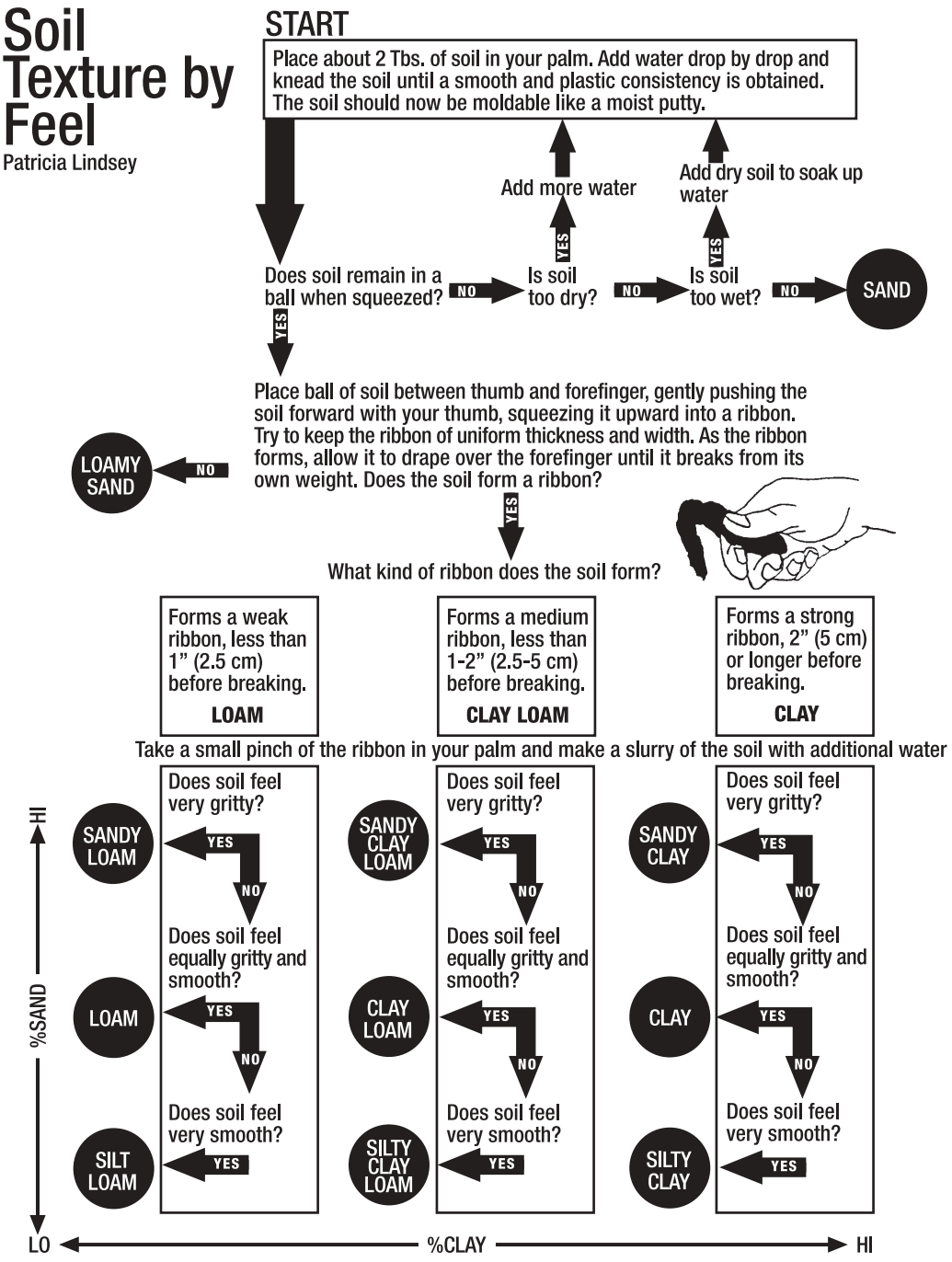
1. Soil: Silt loam (from soil survey classification).
2. Available moisture at field capacity = 2.4 inches/foot.
3. Current soil moisture status = 50% available soil moisture remaining (from appearance and feel method evaluation).
4. Amount of soil in sample = 1 foot.

Table I. Available water capacity for soils.

Soil Texture	Available water (inches/foot)
Fine sand or loamy sand	1.0 to 1.1
Sandy loam	1.4
Loam or silt loam	2.0 to 2.5
Silty clay or clay loam	1.8

Soil Texture by Feel

Patricia Lindsey



Mycorrhizal Management

By Michael P. Amaranthus, PhD

Reprinted from Land and Water, September/October 2001

A look beneath the surface at plant establishment and growth

Little things run the world. This is especially true when it comes to getting plants established. Under natural conditions plants live in close association with soil organisms called mycorrhizal fungi. These fungi colonize plant roots and extend the root system into the surrounding soil. Estimates of amounts of mycorrhizal filaments present in healthy soil are astonishing. Several miles of filaments can be present in less than a thimbleful of soil associated vigorously growing plants. The relationship is beneficial because the plant enjoys improved nutrient and water uptake, disease resistance, and superior survival and growth. Nearly all commercially produced plants form mycorrhizae and require the association for maximum performance in outplanted environments. This not-so-glorious association between plants and mycorrhizal fungi is fundamental to plant establishment and growth.

Depending on the environment in which they are growing, plants may divert up to 80% or more of the net energy fixed as sunlight to below-ground processes. Some of this energy goes into root growth; but, a high proportion may be used to feed mycorrhizal fungi and other soil organisms. This is not energy that is lost to the plant. On the contrary, soil organisms living in the root zone greatly influence the ability of plants to establish through effects on nutrient cycling, pathogens, soil aeration, and soil water uptake. Of the various soil organisms that benefit plant establishment, the most is known about mycorrhizal fungi. Roughly 90% of plant species are thought to form mycorrhizae; the combination of fungal and root tissue is called the mycorrhiza and the fungal partner is termed a mycorrhizal fungus.

Commercial production of mycorrhizal fungi for practical use has been available in the last decade; however, the importance of mycorrhizal fungi has been evident for some 400 million years. The earliest fossil records of the roots of land plants contain evidence of the fossil remains of mycorrhizal fungi. Scientists now believe that the “marriage” of mycorrhizal fungus and plant played an essential role in the evolutionary step which brought aquatic plants from sea to land. At some point in the evolutionary process, a filament penetrated into the outer cells of a primitive plant root. Once there, it accommodated itself so nicely that a new, more complex entity emerged, the mycorrhiza. The increased absorbing area, provided by an elaborate system of fungal filaments, allowed aquatic plants to leave the marine environment and exploit a relatively harsh soil environment.

In today’s man-made environment plants can be greatly stressed and the relationship between fungus and root is critical. Unnatural conditions such as concrete, asphalt, roadsides, sidewalk cut outs, trenching, drain fields, air pollution, shopping malls, business districts, and suburban developments adversely effect the presence and abundance of mycorrhizal fungi. Man-made environ-

ments often suffer from compaction, top soil loss, and the absence of quality organic matter, conditions which reduce the habitat necessary for the mycorrhizal fungus to survive and thrive. Artificial landscapes effect the mycorrhizal relationship in two fundamental ways. First, they isolate the plant from beneficial mycorrhizal fungi available in natural settings and, secondly, they increase plant stress and the need for water, nutrients, and soil structure mediated by their below-ground "partners".

Fortunately, recent advancements in mycorrhizal research and application have made landscape applications with mycorrhiza easy and inexpensive. New products and knowledge result in increased transplant survival and lower long-term maintenance.

However, to be successful the landscape contractor requires an appreciation of fungi beyond itchy toes and moldy bread. How do mycorrhizal fungi work? Mycorrhizal root systems increase the absorptive area of roots 10 to 1000 times thereby greatly improving the ability of the plants to utilize the soil resource. Mycorrhizal fungi are able to absorb and transfer all of the 15 major macro and micro nutrients necessary for plant growth. Mycorrhizal fungi release powerful chemicals into the soil that dissolve hard to capture nutrients such as phosphorous, iron and other "tightly bound" soil nutrients. This extraction process is particularly important in plant nutrition and explains why non mycorrhizal plants require high levels of fertility to maintain their health. Mycorrhizal fungi form an intricate web that captures and assimilates nutrients conserving the nutrient capital in soils. In non-mycorrhizal conditions much of this fertility is wasted or lost from the system.

Mycorrhizal fungi are involved with a wide variety of other activities that benefit plant establishment and growth. The same extensive network of fungal filaments important to nutrient uptake are also important in water uptake and storage. In non-irrigated conditions, mycorrhizal plants are under far less drought stress compared to non mycorrhizal plants. In a recent study, true fir seedlings treated with mycorrhizal inoculum had 43 percent less plant moisture stress than non-treated control seedlings on a droughty, difficult to revegetate site. Tree vigor, color and needle retention were improved with the mycorrhizal treated plants. Rhizopogon mycorrhizae were abundant on the roots systems of the treated plants. Numerous studies have shown Rhizopogon spp. is an aggressive colonizer in non-irrigated and harsh field conditions. Disease and pathogen suppression is another benefit for a mycorrhizal plant. Mycorrhizal roots have a mantle (a tight, interwoven socklike covering of dense filaments) that acts as a physical barrier against the invasion of root diseases. In addition, mycorrhizal fungi attack pathogen or disease organisms entering the root zone. For example, excretions of specific antibiotics produced by mycorrhizal fungi immobilize and kill disease organisms. Some mycorrhizal fungi protect pine trees from Phytophora, Fusarium and Rhizoctonia diseases. In a recent University study, pine trees were purposefully inoculated with the common disease organism- Fusarium. Over 90% of the pine trees died. Only the pine trees inoculated with the mycorrhizal fungus Rhizopogon survived. Survival rates for Rhizopogon treated pines exceeded 95%.

Mycorrhizal fungi also improve soil structure. Mycorrhizal filaments produce humic compounds and organic "glues" (extracellular polysaccharides) that bind soils

into aggregates and improves soil porosity. Soil porosity and soil structure positively influence the growth of plants by promoting aeration, water movement into soil, root growth, and distribution. In sandy or compacted soils the ability of mycorrhizal fungi to promote soil structure may be more important than the seeking out of nutrients.

Does my sod already contain mycorrhizal fungi?

Soils in natural settings are full of beneficial soil organisms including mycorrhizal fungi. Research indicates, however, many common practices can degrade the mycorrhiza-forming potential of soil. Tillage, fertilization, removal of topsoil, erosion, site preparation, road and home construction, fumigation, invasion of non native plants, and leaving soils bare are some of the activities that can reduce or eliminate these beneficial soil fungi. In many man-made landscapes we have reduced or eliminated the soil organisms necessary for plants to function without high levels of maintenance.

Nursery grown plants available to landscape contractors are often deficient in mycorrhizae. Plants raised in most nurseries receive intensive care and feeding. The artificial conditions, high levels of water and nutrients and sterile soils at the nursery, keep certain soil born diseases to a minimum and produce vast quantities of plants for sale. Unfortunately, the high levels of water and nutrients and the lack of mycorrhizae discourage the plant to produce the extensive root system it will need for successful transplantation. The result are plants poorly adapted to the eventual out-planted condition that must be weaned from intensive care systems and begin to fend for themselves. Application of mycorrhizal inoculum during transplanting can encourage plant establishment and set the plant on track to feed for itself Research studies document the need of plants to generate a mycorrhizal roots system in order to become established. Maintaining intensive inputs is necessary until the extensive root system is achieved. There are practical solutions to some of the mycorrhizal deficiencies in man-made environments and reintroducing mycorrhizal fungi in areas where they have been depleted can dramatically improve plant establishment and growth.

What types of mycorrhizal products are available?

A landscape contractor can enhance plant root growth and transplant success and improve many problems that result from intensive care practices at the nursery. Plants grew and thrived on this planet for millions of years without intensive care. Nature provides the template. A more sustainable approach to plant establishment and growth includes using mycorrhizal fungi. Certain mycorrhizal spores or “seeds” of the fungus have been selected for their establishment and growth-enhancing abilities. The goal is to create physical contact between the mycorrhizal inoculant and the plant root. Mycorrhizal inoculant can be sprinkled onto roots during transplanting, worked into seed beds, blended into potting soil, watered in via existing irrigation systems, applied as a root dip gel or probed into the root zone of existing plants. The type of application depends upon the conditions and needs of the applicator. Generally, mycorrhizal application is easy, inexpensive and requires no special equipment. Typically for small plants the cost ranges from less than a penny to a few cents per seedling. For larger plants more inoculum is needed and costs are higher.

Mycorrhizal products often contain other ingredients designed to increase the effectiveness of the mycorrhizal spores. For example, organic matter is often added to encourage microbial activity, soil structure and root growth. Stress vitamins improve nutrient uptake and builds root biomass. Water absorbing gels help "plaster" beneficial mycorrhizal spores in close proximity to feeder roots and encourage favorable soil moisture conditions for mycorrhizae to form and grow. Organic biostimulants, in general are effective ingredients in mycorrhizal products. By promoting field competitiveness, stress resistance and nutrient efficiency biostimulants reduce barriers for rapid mycorrhizal formation especially during the critical period following transplanting.

Mycorrhizal diversity is important

Natural areas generally contain an array of mycorrhizal fungal species. The proportions and abundance of mycorrhizal species often shifts following any disturbance. Not all mycorrhizal fungi have the same capacities and tolerances. Some are better at imparting drought resistance while others may be more effective in protecting against pathogens or have move tolerance to soil temperature extremes. Because of the wide variety of soil, climatic, and biotic conditions characterizing man-made environments, it is improbable that a single mycorrhizal fungus could benefit all host species and adapt to all conditions. For example, the types and activities of mycorrhizal fungi associated with young plants may be quite different from those associated with mature plants. Likewise, mycorrhizal fungi needed to help seedlings establish themselves on difficult sites may differ from those which sustain productivity over a long-lived plant. Diversity Rely provides a buffering capacity not found on sites with only one or few species. The diversity of mycorrhizal fungi formed by a given plant may increase its ability to occupy diverse below ground niches and survive a range of chemical and physical conditions.

Conclusions

The lack of mycorrhizal fungi on plant root system is a leading cause of poor plant establishment and growth in a variety of forest, restoration, agricultural, suburban and urban landscapes. As we develop holistic approaches to understanding man-made environments we must factor in the inseparable connections to soil organisms. Mycorrhizal fungi are one of the more important groups of soil organisms and play a critical role in nutrient cycling, mediating plant stress and protecting against pathogens. They are also cornerstones in the ability of plants to survive transplant shock. Plants have co-evolved mutualistic relationships with symbiotic mycorrhizal fungi such that their survival and fitness depends upon the healthy functioning of these fungi and vice versa, just as plants invest tremendous capital in the form of energy to fuel below ground sod organisms, so too we must "look below the surface" to understand and utilize these beneficial fungi.

L&W *Reprint from Mycorrhizal Applications Inc. website: www.mycorrhizae.com*
For more information, contact Dr. Michael P. Amaranthus, Mycorrhizal Applications Inc., P.O. Box 1181, Grants Pass, OR 97528, (541)476-3985, fax (541)476-1581, e-mail.- info@mycorrhizae.com

Dr. Mike Amaranthus spent 20 years with Oregon State University and the USDA Forest Service where he authored over 50 research papers on mycorrhizae. He is a recipient of the USDA Department of

Agriculture Highest Honors Award for scientific achievement and has been featured on several major national and international television programs. He is president and chief scientist for Mycorrhizal Applications Inc.

Compost and its Use for Highway Applications

Source: Field Guide to Compost Use, U.S. Composting Council, 1996

Compost: The Scientific Definition

Compost shall be free of weed seeds and comply with EPA Chapter 40 CFR Part 503 (e.g. pathogens, metals). The compost shall have a loose and granular texture with the following characteristics or properties: 30-60% organic matter content, 0.5-2.0% total kjeldahl nitrogen content, 6.5-7.5 pH, maximum particle size less than 1 inch, a soluble salt content of less than 5 mmhos/cm, and a percentage of human inerts less than 1.0% (by dry weight). Compost shall comprise 1/4 of the backfill material.

Source – Bill Stack, Woodlot Alternatives, Topsham, Maine

There are many sources of quality compost. The following website is a good place to look for information: www.anr.state.vt.us/dec/wastediv/compost/vtcompostingcomp.htm

Compost Use on State Highway Applications

U.S.Composting Council, 1924 N. Second Street, Harrisburg, PA 17102

Project Background

Thanks to funding provided by a United States Environmental Protection Agency (USEPA) cooperative agreement (number X82826301), The Composting Council Research and Education Foundation (CCREF), in conjunction with the United States Composting Council (USCC) has completed the enclosed document in order to promote compost use on state and local 'roadside' applications. Aside from helping to assure healthy plant growth and reduced plant loss, the use of compost in roadside applications, can also reduce the production of greenhouse gases. This is accomplished in two ways. First, by promoting the use of composting as an alternative waste management strategy to landfilling and lagooning of organic by-products, known sources of methane production, and secondly, through the use of compost itself. The use of compost has demonstrated the ability to sequester carbon within the soil. For additional information on USEPA programs, go to their website at www.epa.gov.

Through this grant, the CCREF has completed various data collection efforts, in order to develop a tool that may allow State Departments of Transportation (DOT), as well as other roadside management organizations, specify the use of compost with greater ease and confidence. Further, this information package will assist these organizations to better locate potential suppliers of compost, foster communications between related highways organizations and allow compost use with greater success.

Overall Objectives

1. Assist States in incorporating the use of compost in landscape building specifications in building, construction, highway seeding, planting, erosion control and other applicable projects.
2. Educate State and local DOT's about the various methods of compost utilization, as well as its many economic, agronomic, and environmental benefits.
3. Broaden the definition of *compost* in the list of landscape products recognized by

the transportation industry to include a wider range of organic feedstocks.

Project Management

CCREF/IJSCC
1924 N. Second Street Harrisburg, PA 17102
717-238-9759
717-238-9985 fax
www.compostingeouncil.org

1.0 Introduction

This document has been developed to assist those individuals and organizations involved in the maintenance and management of roadsides and highways. It is understood that the proper and sustainable management of 'roadsides' relies on professionals that possess varying and specific skill sets. Today, with greater emphasis being placed on environmental sustainability, as well as reducing the environmental impacts of roadways, the growth of compost utilization in landscape, erosion/sediment control and other environmental applications is imminent. Through the development and distribution of this document, the United States Environmental Protection Agency (USEPA) and the United States Composting Council (USCC) hopes to provide the 'transportation' industry, which encompasses roads and highways staff, policy makers, product specifiers, project designers and engineers, environmental officers, landscapers, and other interested parties, with the tools necessary to use composted products to meet their specific project requirements.

Although composted products are manufactured from 'recycled' materials, and many agencies are promoting the use of recycled products, its usage has actually grown because of its functionality and cost effectiveness. Compost is often less expensive than other soil amendments. With this said, it should be understood that the use of compost in specific applications may actually increase the construction costs on certain projects. However, the maintenance costs related to that same project would be reduced. For example, experience and research has proven that by using compost in roadside planting projects, an acceptable vegetative stand can be developed much faster, and the survival rate of landscape plants is improved. So, although the initial cost of installation may have been greater, long-term costs are no doubt lower. Therefore, in some cases, the life cycle cost (analysis) of project must be considered. In cases like these, it is important that both DOT design/construction and maintenance staff be in communication, and understands the longer-term benefits of using compost on the project. Besides, in many cases, innovative applications for compost simply out perform standard practices and products used today.

What is Compost?

Compost is the product resulting from the controlled biological decomposition of organic material that has been sanitized through the generation of heat and stabilized to the point that it is beneficial to plant growth. Compost bears little physical resemblance to the raw material from which it originated. Compost is an organic matter resource that has the unique ability to improve the chemical, physical, and biological characteristics of soils or growing media. It contains plant nutrients but is typically not characterized as a fertilizer.

How is Compost Produced?

Compost is produced through the activity of aerobic (oxygen-requiring) microorganisms. These microbes require oxygen, moisture, and food in order to grow and multiply. When these resources are main-

tained at optimal levels, the natural decomposition process is greatly accelerated. The microbes generate heat, water vapor, and carbon dioxide as they transform raw materials into a stable soil conditioner. Active composting is typically characterized by a high-temperature phase that sanitizes the product and allows a high rate of decomposition, followed by a lower-temperature phase that allows the product to stabilize while still decomposing at a lower rate. Compost can be produced from many feedstocks.

Why Use Compost?

Compost is an extremely versatile product, possessing a variety of innate benefits. Today, these benefits are better understood, and measurable. Compost has the unique ability to improve the properties of soils physically (structurally), chemically (nutritionally), and biologically. But aside from its technical benefits, the simple fact is that both research and field experience have documented that vegetation and other plants established with compost grow healthier and faster, and are able to better persist in harsh conditions. Although many equate the benefit of compost use to lush green growth, caused by the plant-available nitrogen, the real benefits of using compost are long-term and related to its content of living-organic matter.

2.1 Benefits to Compost Use on Roadside Applications

As mentioned earlier, there are a variety of benefits to using compost on roadside applications (Figure 1). In this section these benefits are discussed in greater detail.

Improved Structure: Compost can greatly enhance the physical structure of soil. In fine-textured (clay, clay loam) soils, the addition of compost will reduce bulk density, improve friability (workability) and porosity, and increase its gas and water permeability, thus reducing erosion. When used in sufficient quantities, the addition of compost has both an immediate and long-term positive impact on soil structure. It resists compaction in fine-textured soils and increases water-holding capacity and improves soil aggregation in coarse-textured (sandy) soils. The soil-binding properties of compost are due to its humus content. Humus is a stable residue resulting from a high degree of organic matter decomposition. The constituents of the humus act as a soil "glue," holding soil particles together, making them more resistant to erosion and improving the soil's ability to hold moisture.

Moisture Management: The addition of compost may also provide greater drought resistance and more efficient water utilization. Therefore, the frequency and intensity of irrigation may be reduced. Since compost can hold many times it own weight in moisture, its use can greatly assist the establishment of roadside plantings. Recent research also suggests that the addition of compost in sandy soils can facilitate moisture dispersion by allowing water to more readily move laterally from its point of application.

Modifies and Stabilizes pH: The addition of compost to soil may modify the pH of the final mix. Depending on the pH of the compost and of the native soil, compost addition may raise or lower the pH of the final mix. Therefore, the addition of a neutral or slightly alkaline compost to acidic soil will increase soil pH if added in appropriate quantities. In specific conditions, compost has been found to affect soil pH even when applied at quantities as low as 10-20 tons per acre. The incorporation of

compost also has the ability to buffer or stabilize soil pH, whereby it will more effectively resist pH change.

Increases Cation Exchange Capacity: Compost will also improve the cation exchange capacity of soils, enabling them to retain nutrients longer. It will also allow crops to more effectively utilize nutrients, while reducing nutrient loss by leaching. For this reason, the fertility of soils is often tied to their organic matter content. Improving the cation exchange capacity of sandy soils by adding compost can greatly improve the retention of plant nutrients in the root zone.

Provides Nutrients: Compost products contain a considerable variety of macro and micronutrients. Although often seen as a good source of nitrogen, phosphorous, and potassium, compost also contains micronutrients essential for plant growth. Since compost contains relatively stable sources of organic matter, these nutrients are supplied in a slow-release form. On a pound-by-pound basis, large quantities of nutrients are not typically found, in compost in comparison to most commercial fertilizers. However, compost is usually applied at much greater rates; therefore, it can have a significant cumulative effect on nutrient availability. The addition of compost can affect both fertilizer and pH adjustment (lime/sulfur addition). Compost not only provides some nutrition, but often makes current fertilizer programs more effective.

Provides Soil Biota: The activity of soil organisms is essential in productive soils and for healthy plants. Their activity is largely based on the presence of organic matter. Soil microorganisms include bacteria, protozoa, actinomycetes, and fungi. They are not only found within compost, but proliferate within soil media. Microorganisms play an important role in organic matter decomposition which, in turn, leads to humus formation and nutrient availability. Microorganisms can also promote root activity as specific fungi work symbiotically with plant roots, assisting them in the extraction of nutrients from soils.

Suppresses Plant Diseases: Disease incidence on many plants may be influenced by the level and type of organic matter and microorganisms present in soils. Research has shown that increased population of certain microorganisms may suppress specific plant diseases such as pythium and fusarium as well as nematodes. Efforts are being made to optimize the composting process in order to increase the population of these beneficial microbes.

Binds Contaminants: Compost has the ability to bind heavy metals and other contaminants, reducing both their leachability and absorption by plants (bioavailability). Therefore, sites contaminated with various pollutants may often be improved by amending the native soil with compost. The same binding affect allows compost to be used as a filter media for storm water treatment and has been shown to minimize leaching of pesticides in soil systems.

[Much of the information in section 2.1 has been adapted from 'The Field Guide to Compost Use' published by the US Composting Council 1996]

Benefits of Using Compost

Figure 1

1. Improves the soil structure, porosity, and bulk density, thus creating a better plant root environment.
2. Increases infiltration and permeability of heavy soils, reducing erosion and runoff.
3. Improves water holding capacity in sandy soils, reducing water loss and leaching.

4. Supplies a variety of macro and micronutrients.
5. Controls or suppresses certain soil-borne plant pathogens and nematodes.
6. Supplies significant quantities of organic matter.
7. Improves cation exchange capacity (CEC) of soils, improving their ability to hold nutrients for plant use.
8. Supplies beneficial microorganisms to soils.
9. Improves and stabilizes soil pH.
10. Can bind and degrade specific pollutants.

Adapted from The Field Guide to Compost Use, *US Composting Council 1996.*

2.2 Compost Applications

Although unable to be discussed in detail, there are a variety of potential roadside applications for compost (Figure 2). Today, the use of compost on roadsides has grown past the more typical landscape applications, discussed in later sections of this report, and now includes a variety of 'high tech' applications which include erosion and sediment control, reclamation, bioremediation, storm water management and wetland mitigation. It should be understood, however, that this document focuses on the use of compost in typical landscape applications. As mentioned in the previous section, the benefits of using compost in these applications are well understood and have been documented over a long period of time.

Figure 2 Potential 'Roadside' Applications for Compost

- Soil Incorporant
  - Turf establishment
  - Garden Bed Preparation
  - Reclamation / Remediation
  - Roadside Vegetation
  - Wetlands Establishment
- Growing Media Component
  - Landscape (e.g., rooftop, raised planters)
  - Backfill Mixes (tree and shrub planting)
  - Golf Course (e.g., tee, green, divot mixes)
  - Manufactured Topsoil
  - Wetland Establishment
- Surface Applied
  - Garden Bed Mulch
  - Erosion Control Blanket
  - Silt/Sediment Control Berm
  - Turf Topdressing

With so much interest in environmental sustainability in the proximity of roadsides, as well as 'low impact' design, we would be remiss to mention specific environmental applications where compost has shown great promise.

Erosion and Sediment Control

A very promising, and rapidly expanding, application for compost is as an erosion and sediment control material. Various research, as well as, field trials, has shown that compost can often out perform conventional slope stabilization methods, such as hydroseeding, hay/straw mulching, geotextile blankets, etc. Compost, composted mulches and compost blends are used as a soil 'blanket' or 'cover', and typically placed on up to a 2:1 slopes at an application rate of 2 to 4 inches. Lesser application rates are possible in areas of lower flow and on less severe slopes. This compost layer not only absorbs the energy of the rainfall, which causes the movement of soil particles, but can also absorb a substantial volume of moisture, as well as reduce its flow velocity, improving moisture percolation into the soil. These organic 'soil blanket' products are typically applied using a bulldozer, grading blade or pneumatic blower. The courser or woodier composts used in erosion control are often not seeded following application, but

may be seeded at a later time, once the product stabilizes. Research performed for Portland Metro, an environmental regulatory body based in Portland, Oregon, further showed that yard trimmings compost was capable of not only controlling erosion, but also of filtering, binding and degrading contaminants from the storm water passing through the organic layer.

Research and field experience has also shown that the use of compost filter berms, which can be placed at the base of slopes and around construction sites, are very effective in sediment control. These filter berms are typically 1 to 2 feet tall by 3 to 4 feet wide. They act as excellent sediment filters and can even be used in conjunction with silt/sediment fences in areas of heavy flow. Research completed by the New England Transportation Consortium found that even certain wood waste materials can be effective as mulch for erosion control or as a filter berm at construction sites, (used) to prevent eroded soil from leaving the site. Equipment now exists which can apply these products efficiently, and typically at a cost equal to or less than traditional methods (sediment fencing). The Portland Metro research also documented that compost filter berms (83% reduction) can be twice as effective as sediment fences (39% reduction) in reducing total solids (TS) in runoff.

Reclamation

Compost has been used extensively in revegetation and reclamation of marginal and low quality soils. These problem sites benefit through improving soil quality, reducing erosion, enhancing plant establishment, immobilizing toxic metals and supplying microbes. In research performed by Dr. William Sopper of Penn State University, compost (and biosolids) were applied to a gravely site, possessing a low pH and organic matter content, and contaminated with zinc. Within fifteen months of the application, the hillside was covered by a combination of orchard grass, tall fescue and crown vetch. Newly planted trees showed a survival rate of over 70%. In this example, the compost not only supplied plant nutrition and moderated soil pH, but also established a nitrogen and organic matter cycle in the soil and immobilized heavy metals, by both reducing their leachability and absorption by plants. By establishing vegetation on soils contaminated with heavy metals, water erosion can be minimized, thus reducing the transfer of pollutants. The physical structure of the compost amended soil is also improved, increasing soil porosity and moisture infiltration, thus reducing run-off. This benefits both the environment and plant growth. Compost used is this application is often applied at soil inclusion rates of 20 to 50%, or at rates of 25 to 175 tons per acre.

Wetlands

Organic matter in the soils of wetlands in the United States has decreased steadily over the last three decades. According to Dr. Donald Hey, an expert in flood plain management, over 100 million acres of U.S. wetlands have been drained, and our wetlands now contain only about half the amount of organic matter they contained in the 17th century. As a result, annual floods have worsened, ground water quality has deteriorated, and wildlife diversity has declined. Compost, with its high organic matter content, can absorb up to four times its weight in water and can replace essential organic material in wetands. As urbanization continues to expand, wetlands are often destroyed in the construction of roads and other structures. Today, environmental regulations are in

place which require the re-establishment of wetlands as a means of improving water quality. The goal of any wetlands mitigation project is to develop a wetland that functions well in terms of hydrology, soil properties and plant community composition. Thereby, a highly organic, microbially active soil must be developed which possesses similar physical and chemical properties to those of native wetland soils.

Compost is an excellent component to manufactured wetland soils because of its high organic matter content, water holding capacity and microbial activity. Although used effectively throughout the country in wetland mitigation, to develop an effective wetlands media using compost, it is important to understand the soluble salt and nutrient levels of the compost and their relationship to the wetland plants being established. When developing wetland construction mixes, it is important to develop a blend which has similar characteristics to the surrounding soils, and for that reason, manufacturing wetlands mixes must be done on a case by case basis

Much of the information in section 2.2 has been adapted from the 'Compost Markets Grow With Environmental Applications' article first published in the April, 1999 Biocycle Magazine, published by JG Press, Emmaus, PA.

Structural Soil: An Innovative Medium Under Pavement That Improves Street Tree Vigor

Landscape Architecture Technical Information Series, LATIS, 1998

"Structural Soils, A New Medium to Allow Urban Trees to Grow in Pavement," American Society of Landscape Architects, 636 Eye Street, N.W., Washington, DC 20001-3736

Nina Bassuk, Jason Grabosky, Peter Trowbridge, FASLA, James Urban, ASLA

Introduction

The major impediment to establishing trees in paved urban areas is the lack of an adequate volume of soil for tree root growth. Soils under pavements are highly compacted to meet load-bearing requirements and engineering standards. This often stops roots from growing, causing them to be contained within a very small useable volume of soil without adequate water, nutrients or oxygen. Subsequently, urban trees with most of their roots under pavement grow poorly and die prematurely. It is estimated that an urban tree in this type of setting lives for an average of only 7-10 years, where we could expect 50 or more years with better soil conditions. Those trees that do survive within such pavement designs often interfere with pavement integrity. Older established trees may cause pavement failure when roots grow directly below the pavement and expand with age. Displacement of pavement can create a tripping hazard. As a result, the potential for legal liability compounds expenses associated with pavement structural repairs. Moreover, pavement repairs which can significantly damage tree roots often result in tree decline and death.

The problems as outlined above do not necessarily lie with the tree installation but with the material below the pavement in which the tree is expected to grow. New techniques for meeting the often opposing needs of the tree and engineering standards are needed. One new tool for urban tree establishment is the redesign of the entire pavement profile to meet the load-bearing requirement for structurally sound pavement installation while encouraging deep root growth away from the pavement surface. The new pavement substrate, called 'structural soil', has been developed and tested so that it can be compacted to meet engineering requirements for paved surfaces, yet possess qualities that allow roots to grow freely, under and away from the pavement, thereby reducing sidewalk heaving from tree roots.

Conventional Tree Pits Are Designed For Failure

Looking at a typical street tree pit detail, it is evident that it disrupts the layered pavement system. In a sidewalk pavement profile, a properly compacted subgrade of existing material often is largely impermeable to root growth and water infiltration and significantly reduces drainage if large percentages of sand are not present. Above the subgrade there is usually a structural granular base material. To maintain a stable pavement surface the base material is well compacted and possesses high bearing strength. This is why a gravel or sand material containing little silt or clay is usually specified and compacted to 95% Proctor density (AASHTO T- 99). The base layer is granular material with no appreciable plant available moisture or nutrient

holding capacity. Subsequently, the pavement surrounding the tree pit is designed to repel or move water away, not hold it, since water just below the pavement can cause pavement failure.

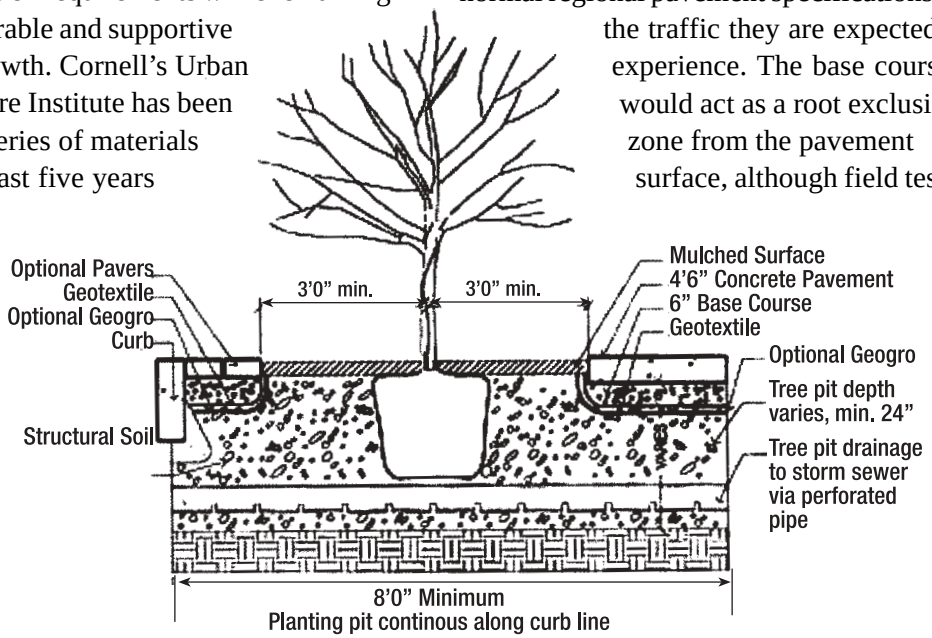
Acknowledging that the above generalizations do not account for all of the challenges below the pavement for trees, it is no mystery why trees are often doomed to failure before they are even planted.

The subgrade and granular base course materials are usually compacted to levels associated with root impedance. Given the poor drainage below the base course, the tree often experiences a largely saturated planting soil. Designed tree pit drainage can relieve soil saturation, but does nothing to relieve the physical impedance of the material below the pavement which physically stops root growth.

A New System To Integrate Trees And Pavement

'Structural soil' is a designed medium which can meet or exceed pavement design and insulation requirements while remaining root penetrable and supportive of tree growth. Cornell's Urban Horticulture Institute has been testing a series of materials over the past five years focused on characterizing their engineering as well as horticultural properties. The materials tested are gap-graded gravels which are made up of crushed stone, clay loam, and a hydrogel stabilizing agent. The materials can be compacted to meet all relevant pavement design requirements yet allow for sustainable root growth. The new system essentially forms a rigid, load-bearing stone lattice and partially fills the lattice voids with soil. Structural soil provides a continuous base course under pavements while providing a material for tree root growth. This shifts designing away from individual tree pits to an integrated, root penetrable, high strength pavement system.

This system consists of a four to six inch rigid pavement surface, with a pavement opening large enough to accommodate a forty year or older tree. The opening could also consist of concentric rings of interlocking pavers designed for removal as the buttress roots meet them. Below that, a conventional base course could be installed and compacted with the material meeting normal regional pavement specifications for the traffic they are expected to experience. The base course would act as a root exclusion zone from the pavement surface, although field tests



show that tree roots naturally tend to grow away from the pavement surface in structural soil. A geotextile could segregate the base course of the pavement from the structural soil. The gap-graded, structural soil material has been shown to allow root penetration when compacted. This material would be compacted to not less than 95% Proctor density (AASHTO T-99) and possess a California Bearing Ratio greater than 40 (Grabosky and Bassuk 1995,1996). The structural soil thickness would depend on the designed depth to subgrade or to a preferred depth of 36 inches. This depth of excavation is negotiable, but a 24 inch minimum is encouraged for the rooting zone. The subgrade should be excavated to parallel the finished grade. Under-drainage conforming to approved engineering standards for a given region must be provided beneath the structural soil material.

The structural soil material is designed as follows. The three components of the structural soil are mixed in the following proportions by weight: crushed stone: I00; clay loam: 20; hydrogel: 0.03. Total moisture at mixing should be 10% (AASHTO T-99 optimum moisture).

Crushed stone (granite or limestone) should be narrowly graded from 3/4 -1 1/2 inch, highly angular with no fines. The clay loam should conform to the USDA soil classification system (gravel<5%, sand 25-30%, silt 20-40% day 25-40 %). Organic matter should range between 2% and 5%. The hydrogel, a potassium propenoate-propenamide copolymer is added in a small amount to act as a tackifier, preventing separation of the stone and soil during mixing and installation. Mixing can be done on a paved surface using front end loaders. Typically the stone is spread in a layer, the dry hydrogel is spread evenly on top and the screened moist loam is the top layer. The entire pile is turned and mixed until a uniform blend is produced. The structural soil is then installed and compacted in 6 inch lifts.

In a street tree installation of such a structural soil, the potential rooting zone could extend from building face to curb, running the entire length of the street. This would ensure an adequate volume of soil to meet the long term needs of the tree. Where this entire excavation is not feasible, a trench, running continuous and parallel to the curb, eight feet wide and three feet deep would be minimally adequate for continuous street tree planting.

There will be a need to ensure moisture recharge and free gas exchange throughout the root zone.

The challenge may be met by the installation of a three dimensional geo-composite (a geo-grid wrapped in textile one inch thick by eight inches wide) which could be laid above the structural soil as spokes radiating from the trunk flair opening. This is currently in the testing stage. Other pervious surface treatments could also provide additional moisture recharge, as could traditional irrigation.

When compared to existing practice, additional drainage systems, and the redesigned structural soil layer represent additional costs to a project. The addition of the proposed structural soil necessitates deeper excavation of the site which also may be costly. In some regions this excavation is a matter of standard practice. However, this process might best be suited for new construction and infrastructure replacement or repair, since the cost of deep excavation is already incurred.

The Urban Horticulture Institute continues to work on refining the specification for producing a structural soil material to make the system cost effective. It is patent pending and will be sold with the trademark 'CU-Soil' to insure quality control. Testing over five years has demonstrated that stabilized, gap-graded structural soil materials can meet this need while allowing rapid root penetration. Several working installations have been completed in Ithaca, NY, New York City, NY, Cincinnati, OH, Cambridge, MA and elsewhere. To date the focus has been on the use of these mixes to greatly expand the potential rooting volume under pavement. It appears that an added advantage of using a structural soil is its ability to allow roots to grow away from the pavement surface, thus reducing the potential for sidewalk heaving as well as providing for healthier, long- lived trees.

References

Grabosky, J. and Bassuk, N. "A New Urban Tree Soil to Safely Increase Rooting Volumes Under Sidewalks". 1995. *Journal of Arboriculture 21(4)*, 197-201.

Grabosky, J. and Bassuk, N. "Testing of Structural Urban Tree Soil Materials for Use Under Pavement to Increase Street Tree Rooting Volumes". 1996. *Journal of Arboriculture 22(6)*, 255-263.

Technical Innovations in Landscape Architecture—1998 Annual Meeting of the American Society of Landscape Architects

7

Vermont Stormwater Management Manual: Introduction to Process

Source: Vermont Agency of Transportation
Drawer 33, 1 National Life Drive, Montpelier, VT 05633

INTRODUCTION

VTrans has in place a standard process for Stormwater Management which is detailed in Volumes I (Stormwater Treatment Standards) and II (Technical Guidance) of The Vermont Stormwater Management Manual. Further, VTrans "has made a commitment to ensure that erosion prevention and sediment control planning and implementation is a priority. Federal and State stormwater regulations have changed and there is a significant nationwide shift in the way stormwater runoff from construction sites is being handled. In Vermont, VTrans will help set the standard for others to emulate." (Dave Scott, former Director of Program Development Division). Starting in 2004, all projects have been required to follow a specific process depending upon which category it falls into regarding size and/or date of construction. These details are outlined in Dave Scott's Memo titled: Guidance for Erosion Prevention and Sediment Control Plan Process, dated March 31, 2004.

DEFINITIONS OF TERMS

The following terms are used in this document:

DTA
District Transportation Administrator

Large Culverts
Culverts having a span greater than (>) 48".

Permanent Erosion Controls
i.e. established vegetation, stone lining, turf reinforcement mats, slope terracing, etc.

Perennial Streams
Watercourses that flow year-round.

Roadside Ditches
Man made swales, which collect and convey runoff away from a transportation facility.

Similar Length
A change in length that is not greater than 10 feet on each end.

Similar Type
Round, Pipe-Arch, Box, Bridge, Open-Bottom Arch.

Small Culverts
Culverts having a span less than or equal to (≤) 48".

Surplus Materials
Excess earthen matter generated during maintenance activities.

Temporary Erosion Controls
i.e. seed and mulch, erosion matting, silt .

Type I Stone
Stone varying in size from 1" – 12", with at least 50% 4" or greater.

Type II Stone
Stone varying in size from 2" – 36", with at least 50% 12" or greater.

VTrans
Vermont Agency of Transportation

OBJECTIVE

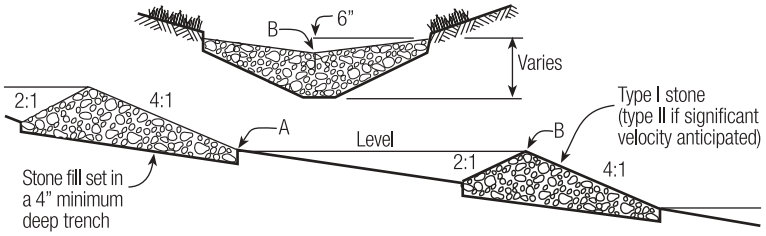
This handbook is intended to assist VTrans maintenance workers in:

- Protecting the natural and cultural resources in the vicinity of transportation facilities.

- Preventing discharge of sediment into waters of the state.

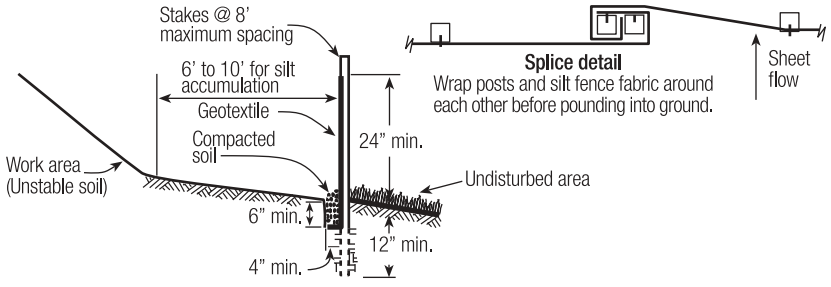
GENERAL GUIDELINES

- Maintenance activities should be performed from the existing road surface, if at all possible.
- All measures shall be taken to minimize the amount of exposed soils during all maintenance activities.
- Surplus materials will not be placed within 100' of any wetland or the top of bank of any river, stream, lake or pond, or in an area that has not been approved by the VTrans Biologist and Archaeologist.
- Temporary erosion control measures shall be properly installed before any soil disturbance occurs on a site. They will be inspected and, if necessary, repaired before the end of each workday and maintained until permanent protection measures are established.
- Geotextile shall be placed under all stone fill.
- Seeding should be completed and ditches stabilized before September 15th. If seeding cannot be done before September 15th, non-vegetative protection measures (i.e. erosion matting) must be used on all slopes.
- If projects must, out of necessity, extend beyond October 15th, special winter erosion and sediment control measures (including but not limited to stone check dams and silt fence) will be required. The DTA will make recommendations for



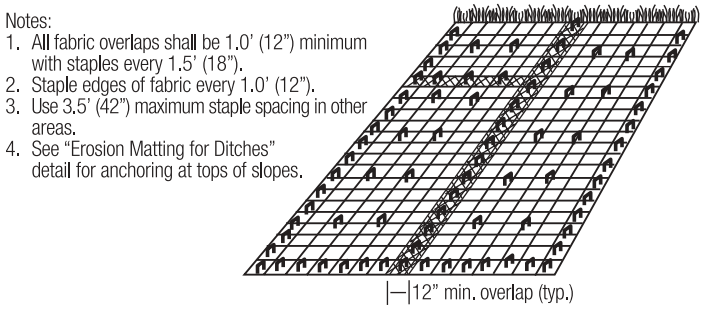
Stone Check Dam Detail

Notes:
1. Check dams to be used during establishment of grass lined drainage ditches
2. Locate downstream structure such that point "B" is approximately level with the lowest ground elevation "A" of the upstream structure



Silt Fence Detail

1. Do not use silt fence in streams, drainage ditches, or areas of concentrated flow.
2. Back with staked-in-place hay bales or wire fence if additiional support is needed.
3 Silt fence must be removed when work area is stabilized. Seed and mulch soil that is disturbed during removal.



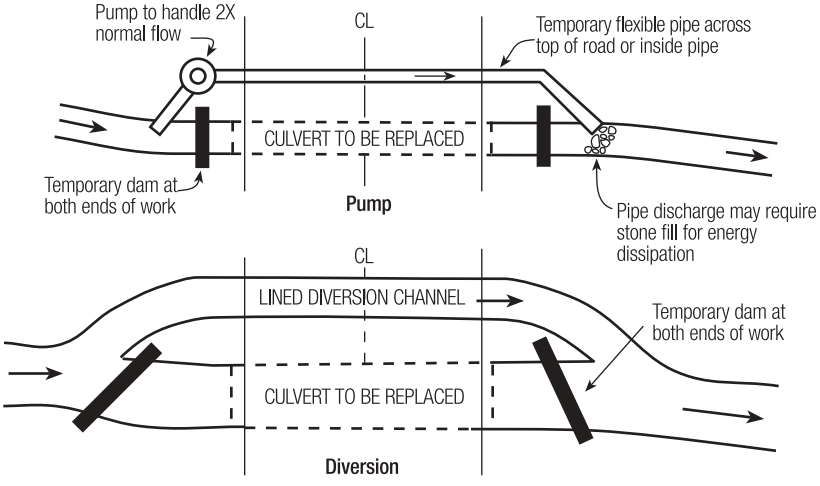
Erosion matting for side slopes steeper than 3:1

winter control measures, which will be approved by the VTrans Environmental Section.

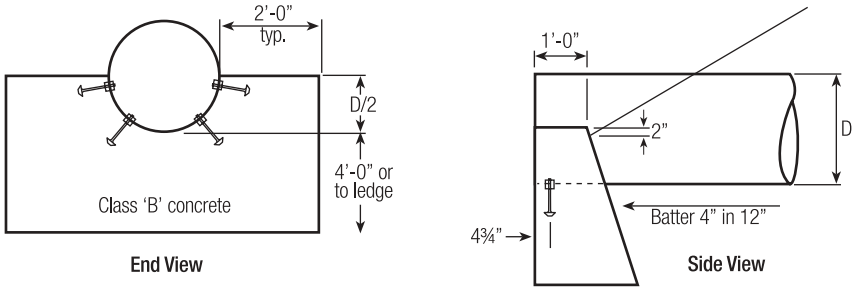
- For side slopes steeper than 3:1 (H:V), erosion matting should be used.

CULVERTS
Installing and Replacing Small Culverts (<48")

- Replacement of culverts that are not of similar length and similar type will require review by the Environmental Section and/or Hydraulics Unit.
- If flows are present, a temporary check dam and bypass system must be used. All downstream flow will be maintained. Pumping may be required.
- All construction activities on culverts carrying perennial streams must not occur before June 1 or after October 1.

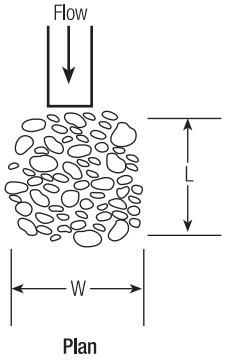


Notes:
1. Downstream end of diversion channel must be opened before upstream end.
2. Upstream dam should be placed before downstream dam.
3. Diversion channels require the road be closed during construction.



Cradle Headwall Details for Small Culverts
Note: Refer to VTrans standard drawing D-2 for additional details

- Headwalls should be considered and constructed where appropriate.
- If a small-corrugated culvert is to be replaced with a smooth lined culvert, it will require a riprap splash pad for energy dissipation. Unless otherwise specified, the following detail can be used:



Stone Pad Requirements

Culvert Size	Fill Type	W	L	Thickness
< 24"	Type I Stone	2X Pipe Rise	4X Pipe Span	12"
24" – 48"	Type II Stone	1.5X Pipe Rise	4X Pipe Span	24"

Note: Geotextile must be placed under all stone fill.

Replacing, Repairing, and Lining of Large Culverts (> 48")

- A separate review process is necessary when working with large culverts. VTrans Environmental Section and/or Hydraulics Unit must be contacted.

MAINTENANCE AND CONSTRUCTION OF ROADSIDE DITCHES

Existing Ditch Maintenance and New Ditch Construction

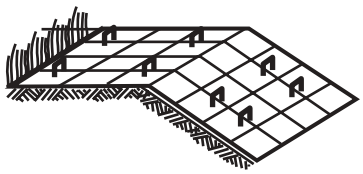
- All temporary erosion control measures will be in place by the close of each construction day.
- If heavy rains wash away seed and mulch, both should be re-applied.
- Temporary erosion control measures will be utilized and inspected, and, if necessary, repaired until final controls are established.
- Permanent erosion control measures will be installed upon completion of the maintenance of each ditch. These measures are dependent on the slope of the ditch as summarized below:

Channel Slope	Ditch Linings	
	Lining	Min. Thickness
0 – 1 %	Seed & Mulch *	4”
1 – 2.5 %	Erosion Control Matting & Seed	—
2.5 – 10 %	Type I (stone)	12”
> 10 %	Type II (stone)	24”

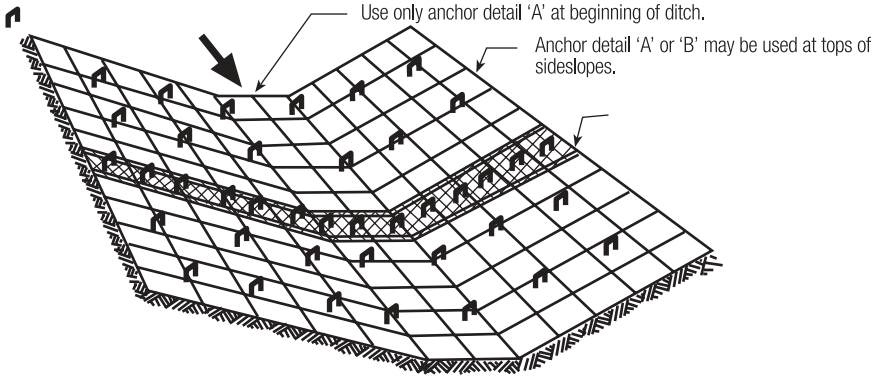
- This table is applicable between May 1 and September 15.
- Slopes that would require only seeding and mulching between May 1 and September 15 will require seed and erosion matting between September 15 and October 15.
- Between October 15 and May 1, all slopes will require winter control measures.

*** Alternative forms of soil stabilization may be utilized as deemed appropriate by the DTA.**

Anchor Detail ‘A’
Insert and staple fabric into 0.5’ X 0.5’ (6” X 6”) trench prior to backfilling and compacting soil. use 3 staple pattern every 1.5’ (18”).



Anchor Detail ‘B’
If the top of slope is relatively flat extend material approximately 2.0’ (24”) and staple every 1.5’ (18”) minimum.



Erosion Matting for Ditches

Notes:
1. Overlaps shall be 1.0’ (12”) minimum in the direction of flow and stapled every 1.5’ (18”) minimum through both fabrics.
2. Use 3.5’ (42”) maximum staple spacing in other areas.

NOTE

This document is intended to suggest practices for protecting cultural and natural resources during culvert and ditching maintenance activities. It is recognized that controlling erosion is site specific and that variations from the recommendations described in this document will occur. These variations should be accepted by the DTA and cleared by the Environmental Section before implementation.

Contacts

John Narowski, P.E.
VTrans Environmental Services Engineer
Phone: 828-5265
E-mail: john.narowski@state.vt.us

Mike Tuttle, P.E.
VTrans Hydraulics Engineer
Phone: 828-5763
E-mail: mike.tuttle@state.vt.us

8

Trees and Shrubs

Introduction

The following subsections are taken from a variety of sources to supply information on the many aspects of tree care including planting and maintenance, tree protection during construction, and hazard elimination and tree evaluation. Much of the information here has been taken from information pamphlets issued by the International Society of Arboriculture, P.O. Box 3129, Champaign, IL 61826. The tree care website is http://www.treesaregood.com/treecare/treecareinfo.asp

VT Urban & Community Forestry Contacts

The Vermont Department of Forests, Parks and Recreation has five district foresters assigned throughout the state to provide technical information for urban and rural sites advising on tree evaluations, tree protection and hazard trees. These names are included at the end of this section. In addition Vermont has an Urban Forestry Program and full-time coordinator as part of a national program to provide assistance to urban and village settings.

Danielle Fitzko
State Program Coordinator
VT Forests, Parks & Recreation
103 South Main St., Bldg. 10 South
Waterbury, VT 05671-0601
(802) 241-3673
danielle.fitzko@anr.state.vt.us

Rick White
District 1 Coordinator (Windham & Windsor)
VT Forests, Parks & Recreation
100 Mineral St., Suite 304
Springfield, VT 05156
(802) 885-8824
rick.white@anr.state.vt.us

Gary Salmon
District 2 Coordinator (Rutland & Bennington)
VT Forests, Parks & Recreation
317 Sanitorium Rd., West
Pittsford, VT 05763
gary.salmon@anr.state.vt.us

Bill Baron
District 3 Coordinator (Addison, Chittenden, Franklin, Grand Isle)
VT Forest, Park & Recreation
111 West St.
Essex Jct., VT 05452
bill.baron@anr.state.vt.us

Dave Wilcox
District 4 Coordinator (Lamoille, Washington & Orange)
VT Forests, Parks & Recreation
324 N. Main St.
Barre, VT 05641
(802) 476-0179
dave.wilcox@anr.state.vt.us

Neil Monteith
District 5 Coordinator (Caledonia, Essex & Orleans)
VT Forests, Parks & Recreation
1229 Portland St., Suite 201
St. Johnsbury, VT 05791
(802) 751-0118
neil.monteith@anr.state.vt.us

a. Benefits of Trees

Adapted from ISA pamphlet ***Benefits of Trees*** and US Department of Agriculture ***Benefits of Urban Trees***

Trees and shrubs are planted to provide beauty or shade. There are many additional benefits from the planting of trees, covered in more detail in the *VTrans Landscape*

Guide for Vermont Roadways & Transportation Facilities, 2002. Benefits are as follows:

Environmental: Trees improve air quality. Leaves give off oxygen absorb other air pollutants - such as ozone, carbon monoxide, and sulfur dioxide.

Trees reduce stormwater runoff and erosion, modify local climate and moderate the effects of sun, wind, and rain. Trees conserve energy due to shading and the effect of evapotranspiration. Trees create habitat for plants and animals.

Radiant energy from the sun is absorbed or deflected by leaves on deciduous trees in the summer and is only filtered by branches of deciduous trees in winter. Trees in cities moderate the heat island effect caused by pavement and buildings in commercial areas.

Economic: Trees increase property value and increase in value as they mature.

Social and Communal: Trees reduce stress for humans, promote a sense of community, and increase the quality of life for community residents. Trees provide visual screening. Most people respond to the presence of trees beyond simply observing their beauty. Trees bring natural elements and wildlife habitats into urban surroundings.

By planting trees and shrubs, we return to a more natural and less artificial environment. The natural cycles of plant growth, reproduction, and decomposition are again present, both above and below ground.

Trees require an Investment: To function well in the landscape, trees may require maintenance such as watering, corrective pruning and mulching.

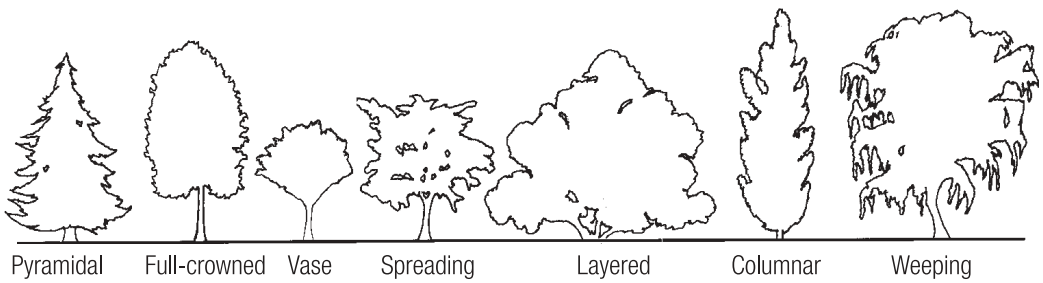
b. Tree Selection and Quality

Source: ISA pamphlet ***Tree Selection and Quality***

Tree selection is covered in greater detail in the 2002, *VTrans Landscape Guide for Vermont Roadways & Transportation Facilities*. Additional resources include *Recommended Trees for Vermont Communities,* April 2001, published by the Vermont Urban and Community Forestry Program of the VT Department of Forests Parks and Recreation, and Landscape Plants for Vermont published by University of Vermont Extension Service, 2002.

Match the tree to the site. The rule “form follows function.” is a good rule when selecting a tree. Selecting the right form (shape) to complement the desired function (what you want the tree to do) can significantly reduce maintenance costs and increase the tree’s value in the landscape. When making a selection about form, also consider mature tree size.

Trees grow in a variety of sizes and shapes, as shown below….Select a form and size that will fit the space.



Selecting a tree that will thrive in a given set of site conditions is the key to long-term tree survival. The following is a list of the major site conditions to consider:

- Soil Conditions
- Exposure (sun and wind)
- Human Activity
- Drainage
- Space Constraints
- Hardiness Zone

c. Selection of High Quality Trees

Source: ISA pamphlet: ***Buying High Quality Trees***

What determines tree quality? Inspect each tree to make certain each tree has no problems with roots, injuries, or form.

High-Quality Trees:

- Adequate-sized root ball with enough sound roots to support healthy growth.
- Trunk free of mechanical wounds and wounds from incorrect pruning.
- Strong form with well-spaced, firmly-attached branches.

Low-Quality Trees:

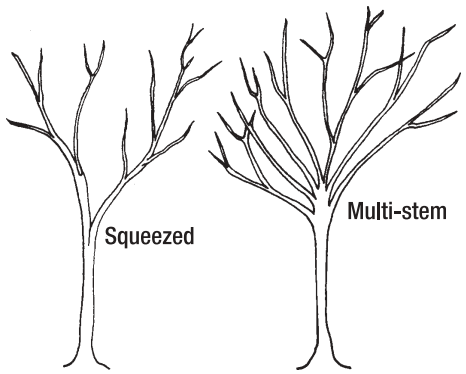
- Crushed or circling roots in a small root ball or small container.
- Trunk with wounds from mechanical impacts or incorrect pruning.
- Weak form where multiple stems squeeze against each other or where branches squeeze against the trunk.

Trunk Flare Should be Obvious - You should be able to see the basal trunk flare. The flare is the spreading trunk base that connects with the roots. Root balls should be flat on top. Be on alert for trees planted too deeply in containers or trees "buried" in fabric bags.

Cut the Wire on Baskets - Place the basket into the planting site**.** Cut away at least the top two wires without disturbing the rootball.

Trunk - Beware of injuries beneath trunk wraps. Never buy a tree without thoroughly checking the trunk. If the tree is wrapped, remove the wrap and inspect the trunk for wounds, incorrect pruning cuts, and insect injuries.

Injuries and Pruning - A correct pruning cut removes the branch just outside of the collar. A ring, or "doughnut", of sound tissues then grows around the cut. Do not make cuts flush to the trunk. The closing tissues may form only to the sides of the flush cuts. Trunk tissues above and below flush cut branches often die. When the heat of the sun or the cold of frost occurs, cracks or long dead streaks may develop above and below the dead spots.



Good, strong form, or architecture, starts with branches evenly spaced along the trunk. The branches will have firm, strong attachments with the trunk.

Squeezed branches signal problems. Weak branch unions occur where the branch and trunk squeeze together. As the squeezing increases during diameter growth, dead

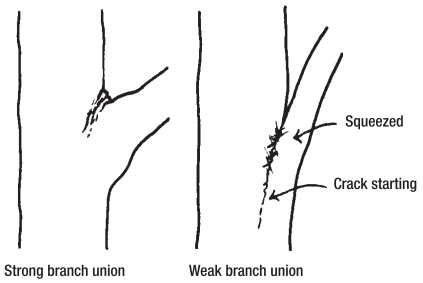
spots, or cracks often begin to form below where the branch is attached to the trunk. Once this problem starts, the weak branch attachment could lead to branches cracking or breaking during mild to moderate storms.

When several branches are on the same position on the trunk, the likelihood of weak attachments and cracks increases greatly. As the branches grow larger and tighter together, the chances for splitting increase.

Avoid trees with two or more stems squeezing together. As stems squeeze together, cracks often form down the trunk. The cracks could start from squeezed multiple leader stems, or where the two trunks come together.

If you desire a tree with multiple trunks, such as a birch clump, make certain that the trunks are well-separated at the ground line.

Remember, trunks expand in diameter as they grow. Two trunks may be slightly separated when small; but, as they grow in girth, the trunks will squeeze together.



Look for early signs of vertical trunk cracks. Examine branch unions carefully for small cracks below the unions. Cracks are major starting points for fractures of branches and trunks. The small cracks could be present for many years before a fracture happens. Always keep a close watch for vertical cracks below squeezed branches and squeezed trunks.

Corrective pruning helps. If your tree has only a few minor problems, corrective pruning may help. Start corrective pruning one year after planting. Space the pruning over several years.

Remove broken or torn branches at the time of planting. After one year, start corrective pruning by removing the branches that died after planting.

d. Prevention and Treatment of Stem Girdling Roots /SGR

Sources: ISA pamphlet: ***Prevention and Treatment of Stem Girdling Roots / SGR***

Stem girdling roots are woody roots that grow and circle the tree and compress stem tissue. Over time these roots can damage and kill trees by cutting off circulation and fluid transport to the trunk. Trees may topple suddenly and decline rather quickly. If trees planted so the root flare is visible and slightly elevated, this problem can frequently be avoided. Removal of SGR's is another option.

Prevention of Stem girding roots begins at planting. *Watson et al. (1990)* speculated that SGR's formed just before or at the time of transplanting with the species they investigated. This speculation has been confirmed with a larger number of species in field studies at the University of Minnesota (Johnson 1999). Therefore, time spent inspecting for and correcting developing SGR problems at planting time is time well-invested and considerably less than that required for a root collar examination after the tree has been in the landscape for several years.

1. For **bare-rooted nursery stock,** closely examine the root system and remove encircling roots or "J" roots that could eventually compress stem tissues (Figure

31). Consider rejecting trees with moderately to severely deformed root systems.

2. For **containerized trees,** inspect the root systems for encircling woody roots and depth to the root collar flare. If woody roots are encircled, straighten or prune them prior to planting (Figures 32 and 33). If the root collar flare is buried more than 1 to 2 inches, remove the excess growing medium to expose the flare areas prior to planting.
3. **Inspect balled-and-burlapped or tree-spaded trees** for soil depth over the root collar flare using a wire probe. If there is more than 1 to 2 inches of soil over the flare/branch root area, plant the tree higher than normal in the landscape, remove the excess soil prior to backfilling the planting hole, and inspect the stem for developing encircling roots or SGRS. Consider rejecting trees that are deeply buried within the root ball. Use the height of the root ball versus the depth within the root ball to the lateral roots as a guide. The more deeply buried the root system, the fewer roots available for tree establishment.

If the root collar flare and stem are above the soil surface, developing SGR's will be easily detectable and treatable long before they cause physiological stress to the tree. **Therefore, prevention of SGR's must include planting trees so that the root collar flare is at or only slightly below the soil or mulch surface.**

3. Treating Trees with SGR's

Removal is the most common treatment of encircling roots or SGR's that have caused minimal stem compression. Roots may be removed with wood gouges, saws, or prunes during the examination process (Figures 34 and 35).

When SGR's have caused extensive stem compression and are fully or partially embedded in the stem, modify the removal treatment to avoid damage to the stem. Embedded and severely compressing SGR's are often left in place when they cannot be safely removed; there is some belief that SGR's reduce the typically short life span of urban trees by only a few years, and the potential damage associated with SGR removal is not justified (Watson et al. 1990; Tate 1981).

A compromise is to prevent the SGR from growing and further compressing stern tissues by severing it at the edges of the stem. Remove the remaining root to a distance where it no longer poses a threat to the stem and allow the severed SGR to decay with time. Annual examination of the stem to assess for decay is recommended.

The season during which SGR's are removed might influence the success of the treatment. Smiley (1999a) found that summer removal resulted in better diameter growth over two years than did fall removal or a combination of summer and fall removal for red maple trees under an irrigation system.

Regardless of treatment, do not backfill the examination area. Lightly mulch the exposed roots but not the root collar flare or stem area (Figure 36). Subsequent examinations will not require the time-consuming removal of soil.

Treat the tree to improve vitality or at least reduce environmental stresses during the recovery period if SGR's are removed, or as long-term maintenance if SGR's are prolific and imbedded.

Maintain optimum soil water through irrigation and surface mulches. Surface mulch as much of the rooting area as pos-

sible, but do not pile mulch against the tree stem or completely bury the exposed root collar examination area. Mulch also helps to remove competition for water and nutrients from turf grass.

Control infectious diseases and insect pests, especially those that defoliate canopies or induce stem cankers. Nutrients may be added if soil and/or a foliar analysis indicates a deficiency.

There are instances where the treatment options include removal. If stem compression from SGR's is severe and extensive (greater than one-third to one-half of the stem circumference), tree stability might be the main issue. Consider removing SGR-affected landscape trees that pose a high risk of failure and are near immobile targets (e.g., sidewalks, buildings, streets). In other instances, planting new trees near SGR-affected trees in anticipation of their death would be appropriate.

Insect and disease organisms affect almost every tree and shrub species. Every plant has its particular pest problems, and the severity varies geographically. These may or may not be life threatening to the plant. You should select plants resistant to pest problems for your area. Your local ISA Certified Arborist, tree consultant, or cooperative extension agent can direct you to information relevant to problem species for your location.

A survey of practicing tree care professionals (Hauer and Johnson 1997) revealed that 88% of the respondents treated trees with SGRs. The two most common treatments were removal of SGRs and treatments to increase tree vitality (e.g., fertilization, irrigation, aeration). Although the practice of removing offending roots has been recommended in countless publications for decades, there is nothing beyond anecdotal evidence that supports this treatment. The most effective "treatment" is prevention.

e. Tree Planting Methods

Source: ISA pamphlet: ***New Tree Planting, 2001***

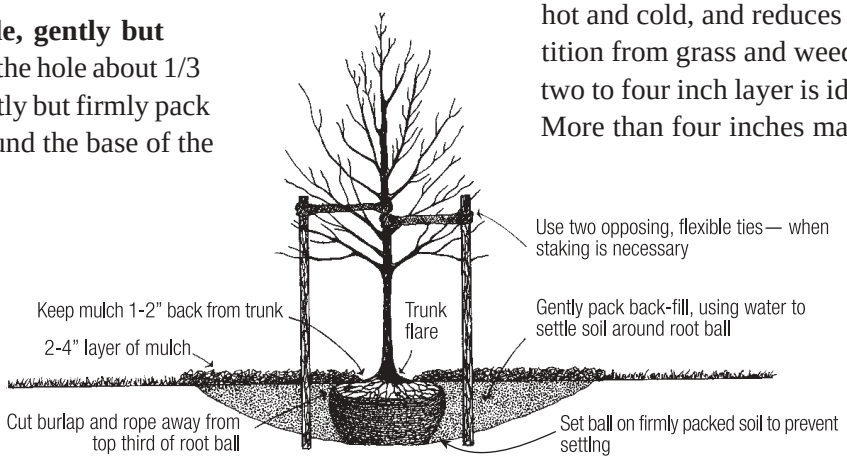
The purchase of a tree is a life time investment. How well it grows depends on the type of tree and location selected for planting as well as the follow up care the tree receives after planting.

The ideal time to plant trees and shrubs is during the dormant season in the fall after leaf drop or early spring before bud-break. Weather conditions are cool and allow plants to establish roots in the new location before spring rains and summer heat stimulate new top growth. *Check all underground utility utilities prior to planting.*

If the tree is balled and burlapped, or bare rooted, 90-95% of its original size root system has been reduced during transplanting. As a result of the trauma caused by the digging process, trees will commonly exhibit what is known as transplant shock, indicated by slow growth and reduced vigor following transplanting. Proper site preparation before and during planting and good follow-up care will reduce the amount of time the plant experiences transplant shock, allowing the tree to quickly establish.

1. **Dig a shallow, broad planting hole.** Make the hole wide, as much as three times the diameter of the root ball, but only as deep as the root ball. Breaking up the soil in a large area around the tree provides the newly emerging roots room to expand into loose soil to hasten establishment. It is better to plant the tree a little high, 2-3 inches above the base of the trunk flare, than to plant it at or below the original growing level.

2. **Identify the trunk flare**. The trunk flare is where the roots spread at the base of the tree. This point should be partially visible after the tree has been planted. If the trunk flare is not partially visible, you may have to remove some soil from the top of the root ball. Find it so you can determine how deep the hole needs to be for proper planting.
3. **Place the tree at the proper height.** Before placing the tree, check to see that the hole has been dug to the proper depth and no more. The majority of the roots on the newly planted tree will develop in the top 12 inches of soil. If the tree is planted too deep, new roots will have difficulty developing due to a lack of oxygen. **It is better to plant the tree a little high, 2-3 inches above the base of the trunk flare, than to plant it at or below the original growing level.** This will allow for some settling (see diagram). To avoid damage when setting the tree, always lift the tree by the root ball, never by the trunk.
4. **Straighten the tree in the hole.** Before you begin backfilling view the tree from several directions to confirm the tree is straight.
5. **Fill the hole, gently but firmly.** Fill the hole about 1/3 full and gently but firmly pack the soil around the base of the root ball. Then, if the tree is balled and burlapped, cut and remove the string and wire from around the trunk and top 1/3 of the root ball. Fill the remainder of the hole taking care to firmly pack soil to eliminate air pockets that may cause roots to dry out. To avoid this problem, add the soil a few inches at a time and settle with water. Continue this process until the hole is filled and the tree is firmly planted. It is not recommended to apply fertilizer at the time of planting.
6. **Stake the tree, if necessary.** Studies have shown that trees will establish more quickly and develop stronger trunk and root systems if they are not staked at the time of planting. However, protective staking may be required on sites where lawn mower damage, vandalism or windy conditions are concerns. If staking is necessary for support, two stakes used in conjunction with a wide flexible tie material will hold the tree upright, provide flexibility, and minimize injury to the trunk. Remove support staking and ties after the first year of growth.
7. **Mulch the base of the tree**. Mulch acts as a blanket to hold moisture, moderate soil temperature extremes, both hot and cold, and reduces competition from grass and weeds. A two to four inch layer is ideal. More than four inches may cause



a problem with oxygen and moisture levels. When placing mulch, care should be taken so that the actual trunk of the tree is not covered, causing decay of the living bark at the base of the tree. A mulch-free area, two inches wide at the base of the tree, is sufficient to prevent decay.

8. **Follow-up care.** Keep the soil moist but not soaked; over watering will cause leaves to turn yellow or fall off. Water trees at least once a week, barring rain, and more frequently during hot weather. When the soil is dry below the surface of the mulch, it is time to water. Continue until mid-fall, tapering off for lower temperatures that require less frequent watering.

Other follow-up care may include minor pruning of branches damaged during the planting process. Prune sparingly immediately after planting and wait to begin necessary corrective pruning until after a full season of growth in the new location.

f Soil Volumes

Introduction

The health and vigor of mature trees is directly proportional to the amount and type of soil available. There has been research to show the relationship of the projected crown size and the amount of soil available to support healthy growth as shown below.

Source**:** ***Journal of Arboriculture***, June 1991, Vol.17, No.6. Patricia Lindsey and Nina Bassuk.

Abstract. The small volume of soil in a typical street tree pit or container often is not capable of supplying adequate water as the tree needs it. As a result, trees can experience severe limitations upon healthy growth and development.

Inadequate soil rooting space can be one of the more important factors in the premature mortality of trees in urban areas. Clearly, there is a basic conflict between the biological needs of trees, whose roots systems are generally near the surface and spread laterally and the small and confined areas they are relegated to in the design of streets in our urban areas. The typical street tree pit, which is inhospitably sandwiched in a narrow strip between the road and sidewalk, places severe limitations upon healthy tree growth and development. The small volumes of soil in these areas often do not hold water sufficient enough to meet transpirational demand, resulting in the tree experiencing periodic to prolonged water deficits.

While the soil serves many functions as a physical and biological medium of root growth, it is in its role as a reservoir for water that is of primary interest in soil volume calculations.

The proportion of summer precipitation that actually becomes available for plant use is the result of complicated interplay between atmospheric evaporative demand, the duration and intensity of rainfall, tree canopy size and structure, and the water holding and drainage capabilities of the soil. As an alternative, summer soil water storage values could be calculated if a soil profile description and textural classification were known for the area of interest. This information is extremely difficult to obtain for disturbed, heterogeneous urban soils. We can therefore use precipitation rates only as a general estimate of the water available for tree uptake for any defined period of time.

It should be emphasized strongly that for these volumes to work, tree pits, extended shared space, and containers all must be mulched. A coarse textured mulch, 3-4

inches deep, with a particle size roughly that of pea gravel, will conserve over 80% of the precipitation that accumulates in the soil. Groundcovers used under the tree canopy, especially turf, quite effectively compete for water with tree roots. Currently, it is hard to predict the amount of this additional water loss, and so these plantings should be avoided unless planted areas are irrigated.

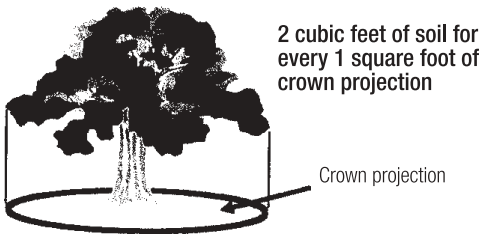
Summary

Street trees live on average 7-10 years with trees in containers living only 2-5 years. In Seattle, 80% of unirrigated newly planted street trees died within two years. Soil, overly wet or too dry, or even more simply, the lack of soil, can account for many tree survival problems. The challenge is to engineer a larger and more suitable soil environment, especially for the inner city street tree. Unfortunately, outdated installation details, planting specifications and procedures are often still being used. Successful urban planting must be properly informed by a new landscape technology based on the broadening body of scholarly urban tree research.

This soil volume methodology, and the subsequent recommendation of 2'cubed of soil for every foot squared of crown projection, is an attempt to transfer a vital part of this burgeoning technology into the hands of interested professional. Hopefully, the resulting applications of this soil volume methodology can enhance current attempts to "green" our cities, making them more aesthetically pleasing, livable, and ecologically sound environments.

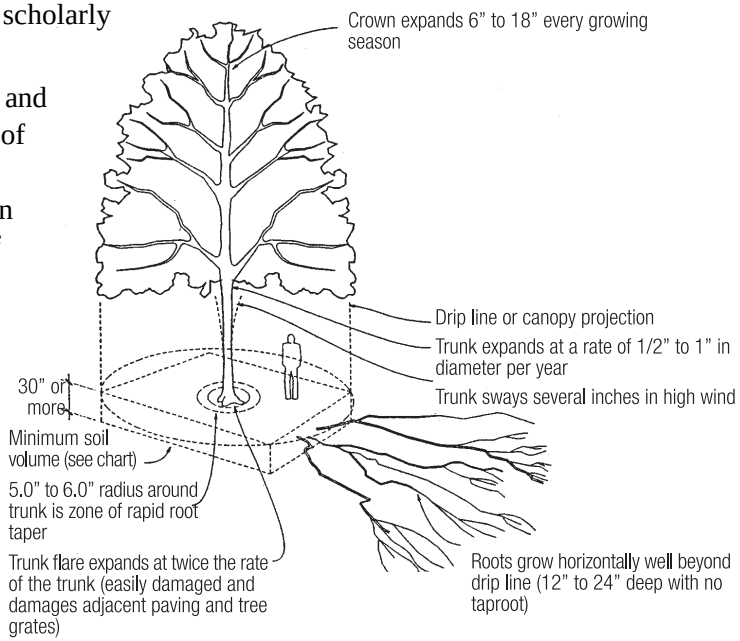
Additional information regarding a new structural medium that can support pavement and sidewalks is referenced elsewhere in this manual- see Section 6 g. CU Structural Soils.

How much soil volume does a tree need?



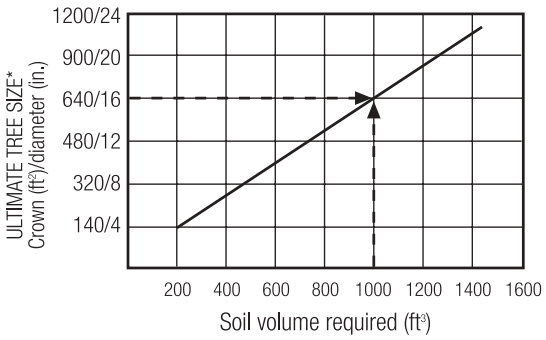
2 cubic feet of soil for every 1 square foot of crown projection

If it is recognized that urban trees are desired and necessary to the health and livability of our cities, how much useable soil is necessary to allow them to fulfill their design functions? Research at Cornell's Urban Horticulture Institute (UHI) has

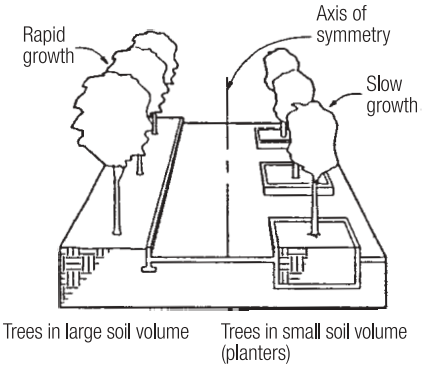


shown that a reasonable 'rule of thumb' for most of the United States, except for the desert southwest, is to plan for two cubic feet of soil per every square foot of crown projection. The crown projection is the area under the drip line of the tree (Lindsey and Bassuk, 1991). If the tree canopy is viewed as symmetrical, the crown projection can be calculated as the area of a circle (Pi x radius squared). For example: for a tree with a canopy diameter of 20 feet the crown projection would be 3.14 (10 squared), or 3.14 (100) = 314 square feet. Using the 'rule of thumb' an estimate can be calculated that the tree needs 628 cubic feet of soil to support it. Assuming a useable rooting depth of 3 feet, one way of dimensioning the space needed for this tree would be 21' x 10' x 3', or 630 cubic feet. It is clear that the typical 4' x 5' tree opening in the sidewalks or the 6' x 6' tree pit is inadequate to allow the tree to fulfill its function in the landscape.

llandscascape.



*The ultimate tree size is defined by the projected size of the crown and the diameter of the tree at breast height.
NOTE:
For example, a 16-in. diameter tree requires 1000 cu ft of soil.



Note: If visually symmetrical tree planting is required, symmetrical soil volumes are also required to produce trees of sumilar crown size.

g. Proper Mulching Techniques

Source: ISA pamphlet: ***Proper Mulching Techniques,*** *updated 2002*

Mulches are materials placed over the soil surface to maintain moisture and improve soil conditions. Mulching is one of the most beneficial things a home owner can do for the health of a tree. Mulch can reduce water loss from the soil, minimize weed competition, and improve soil structure. Properly applied, mulch can give landscapes a handsome, well-groomed appearance. Mulch must be applied properly; if it is too deep or if the wrong material is used, it can actually cause significant harm to trees and other landscape plants.

Benefits of Proper Mulching

- Helps maintain soil moisture. Evaporation and need for watering are reduced.
- Helps control weeds. A 2-4 inch layer of mulch reduces weed germination and growth.
- Mulch serves as nature's insulating blanket. Soils are warmer in winter and cooler in the summer.
- Many types of mulch can improve soil aeration, structure (aggregation of soil

particles), and drainage over time.

- Some mulches may improve soil fertility.
- A layer of mulch can inhibit certain plant diseases.
- Mulching around trees helps facilitate maintenance, and can reduce the likelihood of damage from "weed whackers" or the dreaded "lawnmower blight."
- Mulch can give planting beds a uniform well-cared-for look.

Trees growing in a natural forest environment have their roots anchored in a rich, well-aerated soil full of essential nutrients. The soil is blanketed by leaves and organic materials that replenish nutrients and provide an optimal environment for root growth and mineral uptake. Urban landscapes, however, are typically a much harsher environment with poor soils, little organic matter, and big fluctuations in temperature and moisture. Applying a 2-4 inch layer of organic mulch can mimic a more natural environment and improve plant health.

The root system of a tree is not a mirror image of the top. The roots of most trees can extend out a significant distance from the tree trunk. Although the guideline for many maintenance practices is the **drip line** to the outermost extension of the canopy, the roots can grow many times that distance. In addition, most of the fine absorbing roots are located within inches of the soil surface. These roots, which are essential for taking up water and minerals, require oxygen to survive. A thin layer of mulch, applied as broadly as practical, can improve the soil structure, oxygen levels, temperature, and moisture availability where these roots grow.

Not Too Much!

As beneficial as mulch is, too much can be harmful. The generally recommended mulching depth is 2 to 4 inches. North American landscapes are falling victim to a plague of over mulching. A new term, "mulch volcanoes," has emerged to describe mulch that has been piled up around the base of trees. Most organic mulches must be replenished, but the rate of decomposition varies. Some mulches, such as cypress mulch, remain intact for many years. Top dressing with new mulch annually (often for the sake of refreshing the color) creates an unhealthy buildup to depths that can be unhealthy.

Mulch Wide Not Deep

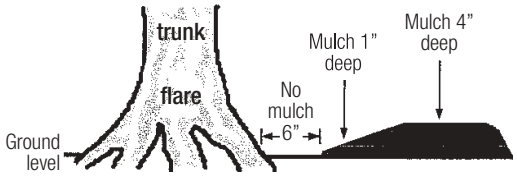
Mulch Volcanoes cause many Problems for Trees

Problems Associated with Improper Mulching

- Deep mulch can lead to excess moisture in the root zone, stressing the plant and causing root rot.
- Piling mulch against the trunk or stems can stress stem tissues and may lead to insect and disease problems.
- Some mulches, especially those containing cut grass, can affect soil pH. Continued use of certain mulches over long periods can lead to micronutrient deficiencies or toxicities.
- Mulch piled high against the trunks of young trees may create habitats for rodents that chew the bark and can girdle the trees.
- Thick blankets of fine mulch can become matted, and may prevent the penetration of water and air. In addition, a thick layer of fine mulch can become like potting soil and may support weed growth.
- Anaerobic "sour" mulch may give off pungent odors, and the alcohols and organic acids that build up may be toxic to young plants.

Proper Mulching:

- **Inspect plants and soil in the area to be mulched**. Determine whether drainage is adequate. Determine whether there are plants that may be affected by the choice of mulch. Most commonly available mulches work well in most landscapes. Some plants may benefit from the use of a slightly acidifying mulch such as pine bark.
- **If mulch is already present, check the depth.** Do not add mulch if there is a sufficient layer in place. Rake the old mulch to break up any matted layers and to refresh the appearance. Some landscape maintenance companies spray mulch with a water soluble vegetable-based dye to improve the appearance.
- If mulch is piled against the stems or tree trunks, **pull it back several inches so that the base of the trunk and the root crown is exposed.**
- Organic mulches are usually preferred to inorganic materials due to their soil-enhancing properties. If organic mulch is used, it should be well aerated, and preferably, composted. Avoid sour-smelling mulch.
- Composted wood chips can make good mulch, especially when they contain a blend of leaves, bark, and wood. Fresh wood chips may also be used around established trees and shrubs. Avoid using non-composted wood chips that have been piled deeply without exposure to oxygen.
- For well-drained sites, apply a 2-4 inch layer. If there are drainage problems, a thinner layer should be used. **Avoid placing mulch against the tree trunks**. Place mulch out to the tree's drip line or beyond.



Remember: if the tree had a say in the matter, its entire root system (which usually extends well beyond the drip line) would be mulched.

h. Pruning

People trained in tree work should be consulted for tree pruning. Pruning large trees can be dangerous. If pruning involves working above the ground or using power

equipment, it is best to hire a professional arborist. An arborist can determine what type of pruning is necessary to improve the health, appearance, and safety of your trees. A professional arborist can provide the services of a trained crew, with all of the required safety equipment and liability insurance. (See sub-section j. Why Hire an Arborist in this Chapter regarding arborist selection.)

Sources: ISA 2001 pamphlets ***Pruning Young Trees*** **and** ***Mature Tree care***

Pruning Young Trees

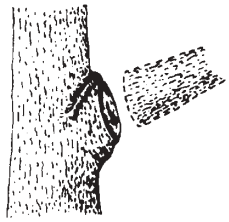
Proper pruning is essential in developing a tree with a strong structure and desirable form. Trees that receive the appropriate pruning measures while they are young will require little corrective pruning when they mature.

There are a few simple principles to be understood before setting out to prune a tree.

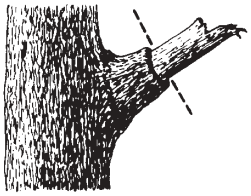
- **Each cut has the potential to change the growth of the tree.** Always have a purpose in mind before a cut is made.
- **Proper technique is essential.** Poor pruning can cause damage that lasts for the life of the tree. Learn where and how to make the cuts before picking up the pruning shears.
- **Trees do not heal the way people do.** When a tree is wounded it must grow over and compartmentalize the wound. As a result, the wound is contained within the tree forever.
- **Small cuts do less damage to the tree than large cuts.** This is why proper pruning (training) of young trees is critical. Waiting to prune a tree when it is mature can create the need for large cuts that the tree cannot easily close.

Pruning of newly planted trees should be limited to corrective pruning. Remove torn or broken branches, and save other pruning measures for the second or third year.

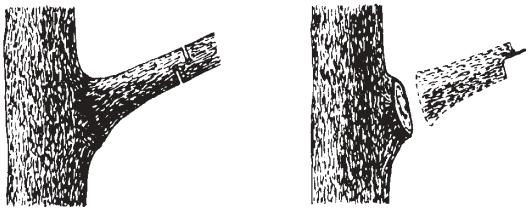
Trees should not be pruned when planted to compensate for root loss. Trees need their leaves and shoot tips to provide food and the substances which stimulate new root production. Unpruned trees establish faster with a stronger root system than trees pruned at the time of planting.



Pruning cuts should be made just outside the branch collar.



On a dead branch that has a collar of live wood, the final cut should be just beyond the outer edge of the collar.



Use the 3-cut method to remove a large limb.

Reasons for Pruning Mature Trees

Since each cut has the potential to change the growth of the tree, no branch should be removed without a reason. Common reasons for pruning are to remove dead branches, to remove crowded or rubbing limbs, and to eliminate hazards. Trees may also be pruned to increase light and air penetration to the inside of the tree's crown or to the landscape below. In most cases, mature trees are pruned as a corrective or preventative measure.

Routine thinning does not necessarily improve the health of a tree. Trees produce a dense crown of leaves to manufacture the sugar used as energy for growth and devel-

opment. Removal of foliage through pruning can reduce growth and stored energy reserves. Heavy pruning can be a significant health stress for the tree.

Yet if people and trees are to coexist in an urban or suburban environment, then we sometimes have to modify the trees. City environments do not mimic natural forest conditions. Safety is a major concern. Also, we want trees to complement other landscape plantings and lawns. Proper pruning, with an understanding of tree biology, can maintain good tree health and structure while enhancing the aesthetic and economic values of our landscapes.

i. Avoiding Tree & Utility Conflicts

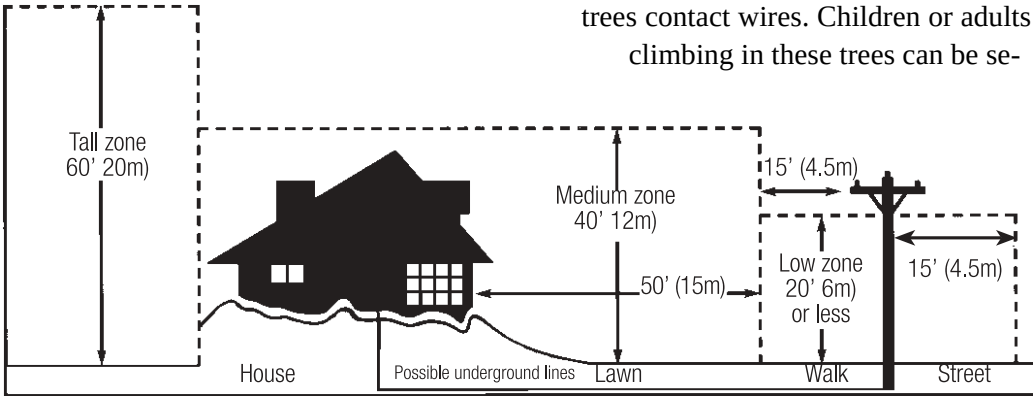
Source: pamphlet International Society of Arboriculture, ***Avoiding Tree & Utility Conflicts***

Determining where to plant a tree is a decision that should not be taken lightly. Many factors should be considered prior to planting. When planning what type of tree to plant, remember to look up and look down to determine where the tree will be located in relation to overhead and underground utility lines.

Often, we take our utility services for granted because they have become a part of our daily lives. These services arrive at our homes through overhead or underground lines. Overhead lines can be either electric, telephone, or cable television. Underground lines include these three plus water, sewer, and natural gas. The location of these lines should have a direct impact on your tree and planting site selection. The ultimate mature height of a tree to be planted must be within the available overhead growing space. Just as important, the soil area must be large enough to accommodate the particular rooting habits and ultimate trunk diameter of the tree. Proper tree and site selection will provide trouble-free beauty and pleasure for years to come.

Overhead Lines

Overhead utility lines are the easiest to see and probably the ones we take most for granted. Although these lines look harmless enough, they can be extremely dangerous. Planting tall growing trees under and near these lines will ultimately require your utility to prune them to maintain safe clearance from the wires. This pruning may result in the tree having an unnatural appearance. Periodic pruning can also lead to a shortened life span for the tree. Trees that must be pruned away from power lines are under greater stress and are more susceptible to insects and disease. Small, immature trees planted today can become problem trees in the future. Tall growing trees near overhead lines can cause service interruptions when trees contact wires. Children or adults climbing in these trees can be se-



verely injured or even killed if they come in contact with the wires. Proper selection and placement of trees in and around overhead utilities can eliminate potential public safety hazards, reduce expenses for utilities and their rate payers, and improve the appearance of landscapes.

The illustration **above** indicates approximately where trees should be planted in relation to utility lines.

Underground Lines

Trees are much more than just what you see overhead. Many times the root area is larger than the branch spread above ground. Much of the utility service provided today runs below ground. Tree roots and underground lines often co-exist without problems. However, trees planted near underground lines could have their roots damaged if the lines need to be dug up for repairs.

The biggest danger to underground lines occurs during planting. Before you plant, make sure that you are aware of the location of any underground utilities. To be certain that you do not accidentally dig into any lines and risk serious injury or a costly service interruption, call your utility company or utility protection service first. Never assume that these utility lines are buried deeper than you plan to dig. In some cases, utility lines are very close to the surface.

2. Scenic Areas, Aerial and Underground Utilities

Source: **Utilities Manual***; 1998 State of Vermont, Agency of Transportation, P.2-13*

New aerial installations, including those needed for highway purposes, are not permitted in areas of scenic enhancement and natural beauty, rest areas, or recreation areas. Nor are they permitted in the right-of-way of adjacent highways or other lands that are acquired or improved with federal-aid or direct federal funds, where there is a feasible and prudent alternative to the use of such lands. Exceptions may be allowed if the following conditions are adhered to:

- Other locations are unusually difficult and uneconomical, or are more undesirable from the standpoint of visual quality.
- Under grounding is not technically feasible or is unreasonably costly as determined by the Agency after the submission of documentation by the applicant.
- The proposed installation will be made at a location, and will employ suitable design and materials, that give the greatest weight to the visual qualities of the area being traversed.

Facility Design

Ground-mounted utility facilities must be designed to be compatible with the visual quality of the specified highway section being traversed.

Underground Utilities

Types/Owners of Facilities

Underground facilities include, but are not limited to, water, sewer, gas, power, telephone, and cable TV. The facilities are owned by a variety of private for-profit companies, as well as municipalities, cooperatives, and fire districts.

Rural Locations

In rural areas, underground facilities must be located between the shoulder point and highway right-of-way boundary line. The preferred location is as close to the boundary line as possible. In cases of ledge cut or other extenuating circumstances, consideration may be given to placing the facilities in the shoulder slopes, but in no case less than 610 millimeters from the roadway.

Urban Locations

In urban areas, underground utilities must be located between the curb line and the highway right-of-way boundary line. They must not disturb the foundations of highway structures. Sewer lines may be retained or installed beneath the roadway where no practical alternative exists, and where the AADT (annual average daily traffic) is less than 750. The preferred location for underground utility facilities is beneath the sidewalk or as close to the boundary line as practical.

Uniform Offset and Consolidation of Like Facilities

At the initial installation, longitudinal facilities should be located at a uniform distance from the highway centerline as far as practical. Where an existing facility is to be replaced, subjected to major repair, or supplemented, all possible consideration must be given to the consolidation—or grouping—of the facilities. The area in which the facilities are consolidated or grouped is called a utility *strip* or *corridor*. Because of increasing demands on space available to accommodate utilities, it is imperative that all proposals be planned to make the most economical use of the available space. A utility's failure to demonstrate a good faith effort in consolidation must be regarded as enough cause for denying a permit, pending receipt of a revised application. In general, all types of utility facilities should be designed for economy of space occupancy.

Relocation Criteria

Facilities existing beneath the traveled way of a proposed highway improvement may be retained in place where either a) sufficient cover will exist to protect the facility from damage during and following construction, or b) it is feasible to adequately protect the facility with insulation and/or encasement, or with construction of a floating structural slab.

Scenic Areas

New underground installations may be permitted within scenic areas, rest areas, etc., where they do not require extensive removal or alteration of trees or other natural features visible to highway users, and where they do not impair the visual quality of the area.

3. Roadside Trees

Source: ***ROADSIDE DESIGN Manual –*** AASHTO, American Association of State Highway and Transportation Officials, 444 North Capitol Street N.W., Suite 249, Washington, D.C. 20001. ww.transportation.org

Section 4.8 TREES ***ISBN: 1-56051-132-X***

Single vehicle crashes with trees account for nearly 25 percent of all fixed-object fatal crashes annually and result in the deaths of approximately 3,000 persons each year. Unlike the roadside hardware previously addressed in this chapter, trees are not generally a design element over which highway designers have direct control. With the exception of landscaping projects where the types and locations of trees and other vegetation can be carefully chosen, the problem most often faced by designers is the treatment of existing trees that are likely to be impacted by an errant vehicle. To promote consistency within a State, each highway agency should develop a formal policy to provide guidance to design, landscape, construction, and maintenance personnel for this situation. This section is intended to provide general guidelines from which a specific policy on trees may be developed.

Trees are potential obstructions by virtue of their size and their location in relation to vehicular traffic. Generally, an existing tree with an expected mature size greater than 100 mm [4 in.] is considered a fixed object. When trees or shrubs with multiple trunks or groups of small trees are close together, they may be considered as having the effect of a single tree with their combined cross-sectional area. Maintenance forces can minimize future problems by mowing clear zones to prevent seedlings from becoming established. The location factor is more difficult to address than tree size. Typically, large trees should be removed from within the selected clear zone for new construction and for reconstruction. As noted in Chapter 3, the extent of the clear zone is dependent upon several variables, including highway speeds, traffic volumes, and roadside slopes. Segments of a highway can be analyzed to identify individual trees or groups of trees that are candidates for corrective measures. County and township roads, which generally have restrictive geometric designs and narrow, off-road recovery areas, account for a large percentage of the annual tree-related fatal crashes, followed by State and U.S. numbered highways on curved alignment. Fatal crashes involving trees along Interstate highways are relatively rare in most states.

Following several years of research by the Michigan Department of Transportation, a *Guide to Management of Roadside Trees* was distributed nationally by the Federal Highway Administration as Report No. FHWA-IP-86- 17. This document contains detailed information on identifying and evaluating higher risk roadside environments and provides guidance for implementing roadside tree removal. It also addresses environmental issues, alternative treatments, mitigation efforts, and maintenance practices. The remainder of this section is basically a summary of the information and recommendations included in that report.

Essentially, there are two methods for addressing the issue of roadside trees. The first is to keep the motorist on the road whenever possible, and the second is to mitigate the danger inherent in leaving a roadway with trees along it. On-roadway treatments include: pavement marking, rumble strips, signs, delineators, and roadway improvements.

Pavement markings are one of the most effective and least costly improvements that can be made to a roadway. Centerline and edge line markings are particularly effective for roads with heavy nighttime traffic, frequent fog, and narrow lanes. Shoulder rumble strips can also be used to warn motorists that their vehicles have crossed the edgeline and may run off the road.

The installation of advance warning signs and roadway delineators can also be used to notify motorists of sections of roadway where extra caution is advised. Typically, these will be used in advance of curves that are noticeably sharper than those immediately preceding it.

Roadway improvements such as curve reconstruction to provide increased superelevation, shoulder widening, and paving are relatively expensive countermeasures that may not be cost-effective in all cases. Off-roadway treatments consist primarily of two options: tree removal, and shielding.

The removal of individual trees should be considered when those trees are determined both to be obstructions and to be in a location where they are likely to be hit. Such trees can often be identified by past crash histories at similar sites, by scars indicating previous crashes, or by field reviews.

Removal of individual trees will not reduce the probability that a vehicle will leave the roadway at that point, but should reduce the severity of any resulting crash. Because tree removal can be expensive and often has adverse environmental impacts, it is important that this countermeasure be used only when it is an effective solution. For example, IV:3H and flatter slopes may be traversable, but a vehicle on a IV:3H slope will usually reach the bottom. If there are numerous trees at the toe of the slope, removal of isolated trees on the slope will not significantly reduce the risk of a crash. Similarly, if the recommended clear zone for a particular roadway is 7m [23 ft], including the shoulder, removal of trees 6m to 7m [20 ft to 23 ft] from the road will not materially change the risk to motorists if an unbroken tree line remains at 8m [26 ft] and beyond. However, isolated trees noticeably closer to the roadway may be candidates for removal. If a tree or group of trees is in a vulnerable location but cannot be removed, a properly designed and installed traffic barrier can be used to shield them. Roadside barriers should only be used when the severity of striking the tree is greater than striking the barrier. Specific information on the selection, location, and design of roadside barriers is contained in Chapter 5.

References

1. AASHTO. *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals.* American Association of State Highway and Transportation Officials, Washington, DC, 2001.
2. Ross, H. E., **Jr.,** D. L. Sicking, and R. A. Zimmer. *National Cooperative Highway Research Pro- gram Report 350: Recommended Procedures for the Safety Evaluation of Highway Features.* Transportation Research Board, Washington, DC, 1993.
3. Federal Highway Administration. *Manual on Uniform Traffic Control Devices.* FHWA, Washington, DC, 2000.
4. AASHTO. A *Policy on the Accommodation of Utilities within Freeway Right-of-Way.* American Association of State Highway and Transportation Officials, Washington, DC, 1989.
5. AASHTO. A *Guide for Accommodating Utilities within Highway Right-of- Way.* American Association of State Highway and Transportation Officials, Washington, DC, 1994.
6. Transportation Research Board .Safety Appurte*nances and Utility Accommodation. Transportation Research Record 970.* Transportation Re- search Board, Washington, DC, 1984.
7. Federal Highway Administration. *Guide to Management of Roadside Trees.* Report No. FHWA- IP-86-17. FHWA, Washington, DC, December 1986.

j. Why Hire An Arborist?

Source: ISA Pamphlet, ***Why Hire an Arborist*** *1995, updated 2003*

An arborist is a specialist in the care of individual trees, knowledgeable about the needs of trees and trained and equipped to provide proper care. The arborist can determine what type of pruning is necessary to maintain or improve the health, appearance, and safety of trees. An arborist can help decide whether or not a tree should be removed. Arborists have the skills and equipment to safely and efficiently remove trees**.** Pruning or removing trees, especially large trees, can be dangerous work. Tree work should only be done by those trained and equipped to work safely in trees.

Some arborists plant trees and most can recommend what types of trees are appropriate for a specific location. The wrong tree in the wrong location could lead to future problems due to limited growing space,

insects, diseases, or poor growth**.** Poorly maintained trees can be a significant liability.

Typical services offered by certified arborists include:

- Practicing Plant Health Care; a concept of preventive maintenance to keep trees in good health, to help the tree's defenses against insects, disease, and site problems.
- Fertilization.
- Cabling or bracing for added support to branches with weak attachment.
- Aeration to improve root growth.
- Spraying or injecting to control certain insect and disease problems.

Certified arborists have achieved a level of knowledge in the art and science of tree care through experience passing a comprehensive examination developed by leading national experts on tree care. Certified arborists must continue their education to maintain their certification. They should be up-to-date on the latest techniques in arboriculture.

When selecting an arborist consider:

- Membership in professional organizations, such as the International Society of Arboriculture (ISA), the Tree Care Industry Association (TCIA), or the American Society of Consulting Arborists (ASCA).
- Certification through the ISA Certified Arborist program.
- Proof of insurance, compliance with any local, state, or national laws that governs their work.
- Ask for references
- Get more than one estimate.
- Be wary of individuals offering bargains for performing tree work.
- Good arborists will only perform accepted practices. Knowledgeable arborists know that topping is harmful to trees and is not an accepted practice.
- Don't always accept the low bid.
- Get it in writing.

k. Professional Evaluation of Trees and Other Plants

Sources: ISA pamphlet: ***Tree Values, Factors in Professional Evaluation of Trees and Other Plants,*** 1995 updated 2003 and ***Workbook-Guide for Plant Appraisal, 9th Edition*** *by* Council of Tree and Landscape Appraisers and ISA, 2000

Plants have a dollar value of their own that can be measured by competent plant appraisers. Seek the advice of professionals in this field who have developed a set of guidelines for the evaluation. These guidelines have been widely adopted in the field and are recognized by insurance companies, the courts, and in some cases, the Internal Revenue Service (IRS).

Four Factors for Professional Evaluation of trees.

1. **Tree size.** Sometimes the size and age of a tree are such that it cannot be replaced. Trees that are too large to be replaced should be evaluated by professionals who use a specialized appraisal formula.
2. **The kind of tree (or its classification).** Choose the species for its utility and adaptability. Tree values vary according to your region, the "hardiness" zone, and even state and local conditions. If you are not familiar with these variables, be sure your advice comes from a competent source.
3. **Condition of the tree, shrub, or plant.** The professional will also consider the condition of the plant. Obviously, a healthy,

well-maintained plant will have a higher value. Roots, trunk, branches, and buds need to be inspected before determining tree condition.

4. **Location of the plant.** There are functional considerations as well as aesthetic. This is where location factors into the evaluation. One standing alone will often have a higher value than one in a group. The site, placement, and contribution of a tree help determine the overall value of the plant attributable to location.

All of these factors can be measured in dollars and cents to determine the value of a tree, specimen shrubs or evergreens, and whether for insurance purposes, court testimony in lawsuits, or for tax deductions.

These are steps to take before and after any casualty loss to trees and landscape:

- Plan your landscaping for both beauty and functional value.
- Protect and preserve to maintain value.

Information for this brochure was taken from the companion publications; *Guide for Plant Appraisal* and *Manual for Plant Appraisers*, available from the ISA, International Society of Arboriculture.

I. RECOGNIZE HAZARDOUS DEFECTS IN TREES

Source: ISA pamphlet ***Recognizing Tree Hazards,*** 2001

Recognizing Tree Hazards

Trees provide significant benefits to our homes and cities, but when trees fall and injure people or damage property, they are liabilities. Taking care of tree hazards makes your property safer and prolongs the life of the tree. Trees are an important part of our world. They offer a wide range of benefits to the environment and provide tremendous beauty. However, trees may be dangerous. Trees or parts of trees may fall and cause injury to people or damage to property. We call trees in such situations hazardous, to signify the risk involved with their presence. While every tree has the potential to fall, only a small number actually hit something or someone.It is an owner's responsibility to provide for the safety of trees on his/her property. This brochure provides some tips for identifying the common defects associated with tree hazards. However, evaluating the seriousness of these defects is best done by a professional arborist. Regular tree care will help identify hazardous trees and the risk they present. Once the hazard is recognized, steps may be taken to reduce the likelihood of the tree falling and injuring someone.

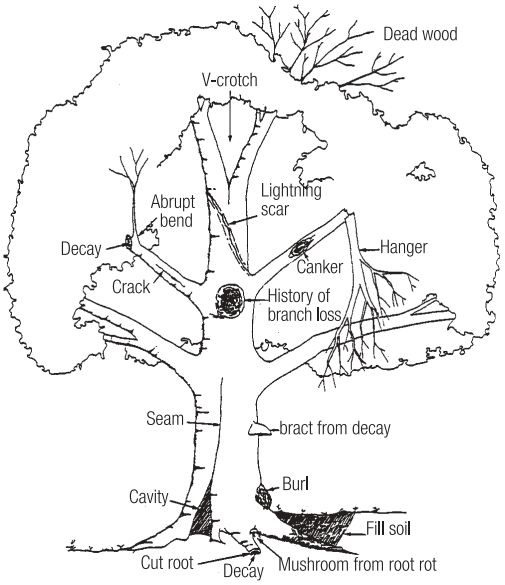
Hazardous Trees & Utility Lines

Trees that fall into utility lines have additional serious consequences. Not only can they injure people or property near the line, but hitting a line may cause power outages, surges, fires, and other damage. Downed lines still conducting electricity are especially dangerous. A tree with a potential to fall into a utility line is a very serious situation.

Tree Hazard Checklist

Consider these questions...

1. Are there large dead branches in the tree?
2. Are there detached branches hanging in the tree?
3. Does the tree have cavities or rotten wood along the trunk or in major branches?
4. Are mushrooms present at the base of the tree?
5. Are there cracks or splits in the trunk or where branches are attached?

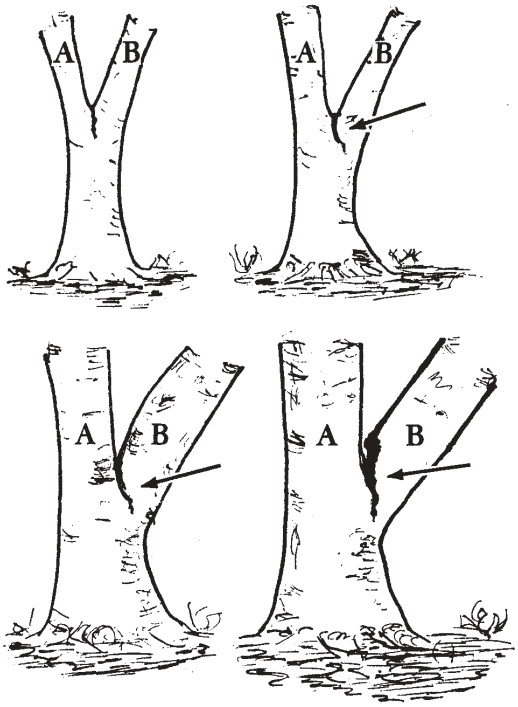


Source: *Hazardous Tree Evaluation & Management*, Bartlett Tree Research Labs, Charlotte, N.C. Authors: E.Thomas Smiley,

6. Have any branches fallen from the tree?
7. Have adjacent trees fallen over or died?
8. Has the trunk developed a strong lean?
9. Do many of the major branches arise from one point on the trunk?
10. Have the roots been broken off, injured, or damaged by lowering the soil level, installing pavement, repairing sidewalks, or digging trenches?
11. Has the site recently been changed by construction, raising the soil level or installing lawns?
12. Have the leaves prematurely developed an unusual color or size?
13. Have trees in adjacent wooded areas been removed?
14. Has the tree been topped or otherwise heavily pruned?

Examples of Defects Present in Urban and Rural Trees...

- Re-growth from topping, line clearance or other pruning
- Electrical line adjacent to tree
- Broken or partially attached branch
- Open cavity in trunk or branch
- Dead or dying branches
- Branches arise at one point on the trunk
- Decay and rot present in old wounds
- Recent change in grade or soil level, or other construction
- Recent site construction, grading and tree removal; clearing of forests for development
- Previous tree failures in the local area
- Tree leaning near target



Crotch failure

When stems A and B grow upward at about the same angle, there is usually a strong attachment between the stems. When stem B grows at about the same rate as stem A and grows away from stem A, the attachment of stem B usually becomes very weak as bark with the crotch turns inward (arrows). Be on guard when stem B begins to grow over streets, walkways, houses, and recreation and picnic areas.

- Forked trunk; branches and stems equal in size (See diagram)
- Wet areas with shallow soil

Managing Tree Hazards

An arborist can help you manage the trees on your property and can provide treatments that may help make your tree safer, reducing the risk associated with hazardous trees. An arborist familiar with hazard tree evaluation may suggest one or more of the following:

- **Remove the target.** While we can't move a home or a nearby power line, we can sometimes move picnic tables, cars, landscape features, etc., to prevent them from being hit by a falling tree.
- **Prune the tree.** Remove the defective branches of the tree. Since inappropriate pruning may also weaken a tree, it is best done by an ISA Certified Arborist.
- **Cable and brace the tree.** Provide physical support for weak branches and stems to increase their strength and stability.
- **Provide routine care.** Mature trees need routine care in the form of water, fertilizer (in some cases), mulch, and pruning as dictated by the season and their structure.
- **Remove the tree.** Some hazardous trees are best removed. If possible, plant a new tree in an appropriate place as a replacement.

Recognizing and reducing tree hazards not only increases the safety of your property and that of your neighbors, but will also improve the tree's health and may increase its longevity!

Ensuring Quality Care for Your Tree

Trees are assets to your home and community and deserve the best possible care. If you answered "yes" to any of the questions in the Tree Hazard Checklist or see any of the defects contained in the illustrations, your tree should be examined by an ISA Certified Arborist.

For a list of ISA Certified Arborists in your area, please visit http://www.treesaregood.org. If your tree is located near a power line, contact your local electrical utility.

Developed by the International Society of Arboriculture (ISA), a non-profit organization supporting tree care research around the world and is dedicated to the care and preservation of shade and ornamental trees. For further information, contact:

ISA, P.O. Box 3129, Champaign, IL 61826-3129, USA.E-mail inquires: isa@isa-arbor.com

Additional information is presented in this document. ***How to Recognize and Prevent Tree Hazards***, USDA report NA-FR-01-96 University of Tennessee, Agricultural Extension Service http://www.utextension.utk.edu/publications/spfiles/sp573.pdf

Treatment of Trees Damaged During Construction

Source: taken from ***Protecting Trees from Construction Damage: A Homeowners Guide,*** Gary Johnson 1999, University of Minnesota …

Are city streets, curbs, sidewalks, and buried utilities about to be widened, modernized, or replaced? Before you start, consider the impact of construction on plants.

Trees and shrubs contribute to property values by enhancing appearance, reducing noise, cutting energy costs, screening unsightly views, and attracting songbirds and other wildlife. Unfortunately, plants meant to be part of … permanent landscape often are needlessly damaged or killed during construction. Careful planning and coordination with a tree-care specialist and … builder can reduce damage and save … the trouble and expense of treating or removing injured plants.

This publication explains some things … to minimize the impact of construction on trees. It describes landscape protection plans, special construction techniques, symptoms of damage, and treatment strategies. Although the information presented focuses on trees, it also can be applied to protecting shrubs.

Hiring a Tree Care Specialist

Each construction site has its own unique set of soil, tree species, and building process conditions. For this reason we recommend that you get advice from a professional urban forester or arborist *with experience in protecting trees from construction damage*. This person will be familiar with the growth characteristics and common problems faced by tree species in your area. He or she can help you evaluate plant health and the likely impacts of construction activities. (See section on hiring an arborist).

Check with your local Extension office, or contact the local chapter of the International Society of Arboriculture (217-355-9411) for a directory of tree-care companies with certified arborists.

The Root of the Matter

Trees can be damaged or killed by a wide variety of construction activities. Some practices lead to obvious injuries such as broken branches or torn bark. Open wounds of this type deplete a plant's energy resources and provide entry points for insects, or for diseases such as oak wilt.

The worst damage, however, often remains hidden underground. Roots are one of the most vital parts of a tree. They are responsible for nutrient and water uptake, store energy, and anchor the plant.

Figure 1. *One common method used to define a tree's protected root zone (PRZ) is to consider it to be the part of the roots that lie directly below its branches within an area known as the* ***dripline****.*

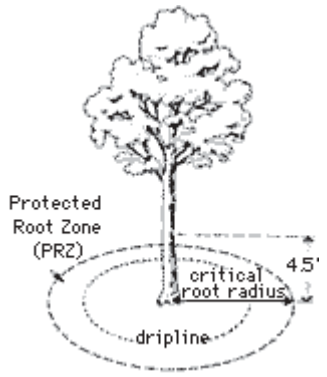


Figure 2. *Approximate a tree's* ***Protected Root Zone*** *by calculating the critical root radius (crr). First, measure the tree diameter in inches at breast height (DBH). Then multiply that number by 1.5 or 1.0. Express the result in feet.*

Example:
dbh=8 inches
8 X 1.5 =12
crr=12 feet

Measure diameter (width)=dbh

Dbh X 1.5=critical root radius for older, unhealthy, or sensitive species

or *dbh X 1.0=critical root radius for younger, healthy, or tolerant species*

Because they are so important, it is critical that you protect roots that lie in the path of construction.

Trees are never the same shape below ground as they are above, so it is difficult to predict the length or location of their roots. Typically, however, approximately 90-95 percent of a tree's root system is in the top three feet of soil, and more than half is in the top one foot. The part of this root system in which construction damage should be avoided is called the Protected Root Zone (PRZ).

One common method used to identify the PRZ is to define it as the "dripline"—the area directly below the branches of the tree (Figure 1). However, many roots extend beyond the longest branches a distance equal to two or more times the height of the tree. For this reason you should protect as much of the area beyond the dripline as possible.

Unfortunately, on most sites space is limited and this rule must be bent. Just how close an activity can come without seriously threatening the survival of a tree depends on the species, the extent of damage, and the plants health. Some healthy trees can survive after losing 50 percent of their roots. However, other species are extremely sensitive to root cutting, even outside the dripline.

Table 1 shows the relative sensitivity of various tree species to root disturbance. If possible, disturb no more than 25 percent of the roots within the dripline for any tree, protect intermediate species to the dripline, and allow extra space beyond the dripline for sensitive species. For all trees, avoid needless or excessive damage. A qualified tree-care specialist can help you determine how much root interference a particular tree can tolerate.

When dealing with trees that have been growing in the forest or that naturally have a narrow growth habit, an approach called the **"critical root radius"** (crr) is more accurate than the dripline method for determining the PRZ. This is particularly true for columnar trees and for those where competition has reduced the canopy spread.

To calculate critical root radius, begin by measuring the **diameter at breast height (dbh).** This is done by measuring the tree's trunk diameter (thickness) at a point 4.5 feet above the ground. The measurement should be done in inches. For each inch of dbh, allow for 1.5 feet of critical root radius for sensitive trees, or 1.0 feet for tolerant trees. For example, if a tree's dbh is 10 inches, then its critical root radius is 15 feet (10 x 1.5 = 15). The PRZ is an area around the tree

Table 1. Tree Characteristics

Species	Root Severance[6]	Soil Compaction & Flooding[6]	Soil pH Preference[8]	Mature Tree Height (feet)[8]	Mature Crown Spread (feet)[8]	Hazard Tree Rating*[7]	Damage-Causing Roots	Landscape Value**[1]
Northern white cedar	Tolerant	Tolerant	6.0-8.0	40-50	10-20	Low	.	High
Balsam fir	Tolerant	Tolerant	4.0-6.0	40-60	20-35	Medium	.	Medium
White fir	Tolerant	Sensitive	4.0-6.5	50-75	10-20	Medium	.	High
Tamarack	Tolerant	Tolerant	4.0-7.5	50-75	15-25	Medium	.	High
White pine	Tolerant	Sensitive	4.5-6.5	80-100	50-80	Medium	.	High
Jack pine	Tolerant	Sensitive	4.5-6.5	30-80	20-30	High	.	Low
Red pine	Tolerant	Sensitive	4.5-6.0	50-80	20-40	(Medium)	.	Medium
Scotch pine	(Tolerant)	(Sensitive)	4.0-6.5	60-100	30-50	Medium	.	Medium
Eastern redcedar	Tolerant	Sensitive	4.7-7.8	40-50	10-20	Low	.	Low
Black spruce	Tolerant	Tolerant	3.5-7.0	30-70	15-30	(Medium)	.	Low
Colorado spruce	Intermediate	Tolerant	4.6-6.5	50-100	20-30	Medium	.	High
White spruce	Tolerant	Intermediate	4.5-7.5	40-80	20-30	Medium	.	Medium
Black ash	Tolerant	Tolerant	4.1-6.5	40-70	30-60	(Medium)	.	Medium
Green ash	Tolerant	Tolerant	6.0-7.5	30-60	30-50	Medium	.	Low
White ash	Tolerant	Intermediate	5.0-7.5	70-80	50+	(Medium)	.	Medium
Bigtooth aspen	Tolerant	Sensitive	4.8-6.3	50-75	20-35	Medium	Yes	Low
Quaking aspen	Tolerant	Sensitive	4.8-6.5	40-60	20-35	Medium	Yes	Low
Blue beech	Sensitive	Sensitive	6.5-7.5	20-30	15-20	Low	.	High
Paper birch	Intermediate	Sensitive	5.0-8.0	50-70	30-50	Medium	.	Medium
River birch	Tolerant	Tolerant	4.0-6.5	40-70	30-50	Low	.	High
Yellow birch	Intermediate	Sensitive	4.5-8.0	50-70	25-50	Medium	.	Medium
Boxelder	Tolerant	Tolerant	6.5-7.5	40-60	35-50	High	Yes	Low
Ohio buckeye	Intermediate	Intermediate	6.1-6.5	30-50	30-40	Medium	Yes	Medium
Butternut	Sensitive	Intermediate	6.6-8.0	40-60	50-60	(Medium)	.	Medium
Catalpa	Intermediate	Tolerant	6.1-8.0	50-80	30-50	Medium	.	Medium
Black cherry	Intermediate	Sensitive	6.0-7.5	50-70	40-50	Low	.	Low
Kentucky coffeetree	Intermediate	Intermediate	6.5-7.5	50-80	40-50	Low	.	High
Eastern cottonwood	Tolerant	Tolerant	5.5-8.0	80-100	80-100	High	Yes	Low
Red-osier dogwood	Tolerant	Intermediate	6.1-8.5	8-10	10-12	(Low)	.	Medium
American elm	Tolerant	Intermediate	5.5-8.0	70-100	70-150	Medium	Yes	Low
Slippery elm	(Tolerant)	(Intermediate)	6.6-8.0	60-70	40-60	Medium	Yes	Low
Hackberry	Tolerant	Intermediate	6.6-8.0	30-130	50+	Low	.	High
Hawthorn	Intermediate	Intermediate	6.0-7.5	20-40	20-30	Low	.	High
Bitternut hickory	Intermediate	Intermediate	6.0-6.5	40-75	30+	(Medium)	.	Medium
Honeylocust	Tolerant	Intermediate	6.0-8.0	50-75	50-75	Medium	Yes	Medium
Ironwood	Sensitive	Sensitive	6.1-8.0	25-50	20-30	(Low)	.	High
Basswood	(Intermediate)	Sensitive	5.5-7.3	70-100	50-75	(High)	.	Medium
Black locust	Tolerant	Sensitive	4.6-8.2	30-60	20-50	(Medium)	.	Low
Red maple	Tolerant	Tolerant	4.5-7.5	50-70	40-60	Medium	Yes	High
Silver maple	Tolerant	Tolerant	5.5-6.5	60-90	75-100	High	Yes	Low
Sugar maple	(Intermediate)	Sensitive	5.5-7.3	60-80	60-80	Medium	Yes	High
Mountain ash	Tolerant	Intermediate	4.0-7.0	15-25	15-25	Medium	.	High
Black oak	Sensitive	Sensitive	6.0-6.5	50-80	50-70	(Medium)	.	High
Bur oak	(Tolerant)	Intermediate	4.0-8.0	70-80	40-80	Low	.	High
Northern pin oak	Sensitive	Sensitive	5.5-7.5	50-75	30-50	(Medium)	.	Medium
Red oak	Tolerant	Sensitive	4.5-7.0	60-80	40-50	(Medium)	.	High
Bicolor oak	(Intermediate)	Tolerant	6.0-6.5	60-70	40-50	Low	.	High
White oak	Sensitive	Sensitive	6.5-7.5	60-100	50-90	Low	.	High
Wild plum	Tolerant	Sensitive	6.5-6.6	20-25	15-25	Low	.	Medium
Serviceberry	Intermediate	>Sensitive	6.1-8.5	6-35	6-15	>(Low)	.	>High
Black walnut	>Sensitive	Intermediate	6.6-8.0	70-100	60-100+	Medium	.	Medium
Black willow	Tolerant	Tolerant	6.5-8.0	30-60	20-40	High	Yes	>Low

1: Hightshoe, 1988; 2: Minnesota Association of Soil and Water Conservation Districts Forestry Committee, 1986; 3: Matheny and Clark, 1991; 4: Minnesota Society of Arboriculture, 1996.Values in parentheses reflect the authors' or technical advisors' opinions.***Hazard Tree Rating** refers to the relative potential for a tree to become hazardous. For a tree to be considered hazardous, a potential "target" (e.g., a house, a sidewalk, or other trees) must be present. A high hazard tree rating does not imply that the tree will always fail.****Landscape Value** refers to the relative value of each species in Minnesota based on hardiness, form, color, growth habits, flowering and fruiting characteristics, structural strength, longevity, insect and disease resistance, maintenance requirements, and general desirability.

with a diameter of 30 feet (2 x radius), and is the area in which a critical amount of the tree's roots may be found. Whenever possible, isolate this area from construction disturbance (see Figure 2).

Plan Ahead

You'll save time and money if you develop a landscape protection plan before construction begins. Careful planning will help you avoid the expense and heartache of later repairing or removing trees located too close to construction activities.

These steps will help you create a successful landscape protection plan:

1. **Mark construction zone boundaries.** Obtain a complete set of site development plans, including the proposed location of buildings, drive-ways, sidewalks, and utility lines. Ask the builder or architect to mark areas where heavy equipment will be used, where soil will be permanently added or removed and to what depth, and where fill and building materials will be temporarily stockpiled. Use a measuring tape, stakes, and string to temporarily mark the boundaries of construction activities on the site.
2. **Inventory trees on the site.** Record the location, size, and health of each tree. Wilted leaves, broken or dead limbs, trunk rot, and thin tops are all symptoms of stress. Trees that are over-mature, display poor form, lean heavily over future buildings, or have severe insect or disease problems (Figure 3) should be marked for removal prior to construction. Also mark trees that need pruning to make room for future structures and construction equipment.
3. **Select the trees to be saved.** Examine the site carefully and note how each tree fits into the future landscape. Keep in mind that the builder may be able to shift the location of a building, utility line, or driveway. Although local ordinances differ, driveways and utility lines don't always have to be straight, and homes don't always have to be in the center of the lot (Figure 4). If considerable damage to the tree's root system within the PRZ is inevitable, you should seriously consider changing the original design, adding protection measures, or removing the tree before construction begins.
4. **Protect the trees you plan to save.** Develop a map with the builder or architect showing the location of trees to be protected and the safest route for access to the building zone. Then install bright orange polypropylene fencing and post "Off Limits" signs at the PRZ of the trees you plan to save (Figure 5). Your primary objective is to protect delicate root systems, so provide your trees with as much space as possible. Make sure all construction workers know that nothing inside this area is to be raked, cut, stored, or otherwise disturbed. A landscape protection contract signed by the builder and all contractors will help ensure compliance. Take several photographs of the site before construction begins to document the protection methods used and the condition of individual trees.
5. **Prepare the trees for construction disturbance.** You'll boost your trees' chance for survival if you make sure they're as healthy as possible before construction begins. Regularly water the trees if rainfall is not adequate. Fertilize them if soil tests or deficiency symptoms indicate they are nutrient stressed. (For soil test information, contact your county

extension agent or call … the University of Vermont Soil Testing Lab (see Section 6 of this manual for information). Prune branches that are dead, diseased, hazardous, or detrimental to the plant's natural form.

6. **Protect and preserve the soil for future tree planting.** Apply a layer of wood chips at least six inches thick over areas that will be used for traffic or materials storage during construction. If these areas become part of the new landscape, the wood chips will prevent the soil from becoming too compacted.
7. **The construction process.** Visit the site periodically and inspect the trees. Irrigate the PRZ of the trees regularly— never let trees become water-stressed. Your presence alerts workers of your concern for the careful treatment of the trees. Should damage occur, begin repairs as soon as possible. Immediately inform the builder of any violations in the landscape protection contract and photograph the damage. Insist that protective fences remain in place until all construction workers have left the site.
8. **Make a final inspection of the site.** After construction has been completed, evaluate the condition of the remaining trees. Look for indications of damage or stress. It may take several years for severe problems to appear. Careful monitoring and preventive treatment (e.g., watering) may help minimize damage.
9. **Commit to long-term maintenance.** Trees will not recover from construction damage in one or two years. Mulch as much of the PRZ as you can tolerate and plant understory shrubs and perennials within the mulched areas. Irrigate the PRZ regularly for several years—never let the trees become water-stressed. Have an arborist inspect the trees every year or two for several years to determine if pruning, fertilization, and/or pest/disease control tactics are necessary.

Figure 5. *Put up fences and signs around trees you want to save to alert construction workers to damage potential.*

Tree Selection Tips

- Save the best and chip the rest. Use those wood chips to provide a blanket of protection over the root systems of trees that can be saved. It is expensive for the builder to work around trees, and it also is expensive to remove damaged trees after construction has been completed.
- Understand the characteristics of your trees or get the advice of someone who does. If you know about your trees you can help insure their survival and improve the future site appearance of the site.
- Select tree species that fit the spatial constraints of the site (Table 1), remember that trees grow throughout their lives.
- Be sure to consider overhead powerlines.
- Young, small trees tend to survive disturbance better than old, large trees. Large trees almost never survive within five feet of a new building and should not be kept.
- Healthy young trees that fall in the construction zone may be saved by transplanting.
- Don't put all your eggs in one basket! Save a mixture of tree species to safe-

guard your landscape against contagious diseases or insects.

Improve tree survival by saving groups of trees rather than individuals.

Minimize the Impact of Construction Activities

In addition to protecting the PRZ, there are other ways in which you can reduce the impact of construction activities on your trees. Some of these are relatively simple; others can be extremely expensive. Carefully consider the importance of each tree to the future appearance of the site and consult a tree-care specialist before deciding whether protective measures are worth the cost.

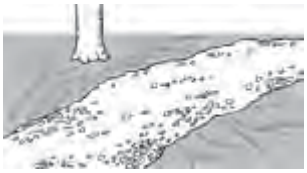


Figure 6. *A root system bridge will help protect trees in the path of construction vehicles.*

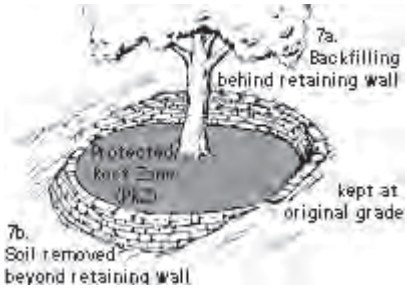


Figure 7. *If you change the grade within the root zone, use retaining walls to keep as much of the original grade as possible.* ***a)*** *backfilling;* ***b)*** *cutting.*

Site Clearing

When you remove a large number of trees, you expose the remaining plants to new conditions. Sudden increases in amounts of sunlight and wind will shock many of your trees. It is not uncommon to find scorched leaves, broken branches, and uprooted trees after a site is cleared. Although some of these problems are temporary, they may compromise tree health when coupled with additional construction damage.

You can avoid sun and wind stress by saving groups of trees rather than individuals. When possible, remove the unwanted plants in winter after the leaves have fallen. Dormant plants are less susceptible to damage, and frozen ground helps protect roots. Bulldozers should not be used to remove trees near plants to be preserved. Heavily wooded sites should be gradually thinned over two to three years to reduce removal shock on remaining plants. This is especially important in dense pine, spruce, or fir forests.

Soil Damage

Soil compaction is the single largest killer of urban trees. Tree roots need loose soil to grow, obtain oxygen, and absorb water and nutrients. Stockpiled building materials, heavy machinery, and excessive foot traffic all damage soil structure. Lacking good soil aeration, roots suffocate and tree health declines.

Prevent soil compaction by carefully selecting storage areas and traffic routes (the future driveway is a good choice for both) and installing protective fences and signs. If you can't reroute traffic, install root system bridges with steel plates suspended over railroad ties or spread several inches (six inches or more) of wood chips on the soil within the PRZ (Figure 6). Trees that are pruned or removed during the construction process should be chipped on site and the chips used for soil preservation tactics such as this. Heavy mixing trucks can be kept off tree roots by transporting concrete from the truck through conveyor pipes.

Improper handling or disposal of materials used during construction also can harm roots. For example, wood products treated with pentachlorophenol and creosote can be deadly to tree roots; CCA-treated timber (greenish color) is a better alternative. Ask the builder about the materials to be used on the site and read product labels. Chemical spill damage can be prevented by filling gas tanks, cleaning paintbrushes and tools, and repairing mechanical equipment well outside tree PRZ's. Insist that all building debris and chemical wastes be hauled away for proper disposal, and not burned or buried on the site.

Finally, avoid changes in soil pH (acidity). Increases in pH are particularly dangerous to many species (Table 1). Alkaline clays or limestones should not be used for fill or paving, and concrete should be mixed on a thick plastic tarp or outside the site. Mixing trucks should never be rinsed out on the site.

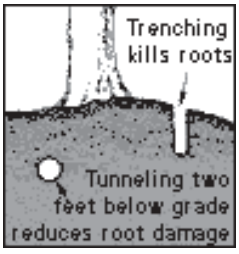


Figure 8. *Protect roots from damage when laying utility lines by tunneling rather than trenching.*

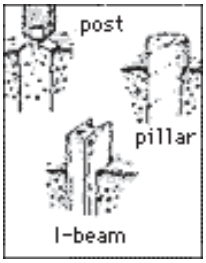


Figure 9. *You can minimize damage to trees near foundations by using posts, pillars, or I-beams rather than foundation walls.*

Grade Changes

Moving large amounts of soil within the PRZ usually kills a tree. Except where absolutely necessary, avoid disruptions to the natural contour of the site or shift them well outside the PRZ.

Soil additions compact the soil around a tree and often raise the water table. You may be able to protect compaction-tolerant trees (Table 1) from additions of six inches or less of soil by using a porous fill within the PRZ. Porous fill can be made by mixing one part loam, one part coarse sand, and one part shredded bark.

Deeper fills require more expensive measures. A retaining wall beyond the PRZ may protect some trees (Figure 7a). These walls preserve much of the original root system and redirect excess water away from sensitive plants. Your tree-care specialist may suggest other, more elaborate measures for protecting trees that must be covered with soil close to the trunk. However, as a general rule, it is best to remove trees that would be buried by 24 inches or more of fill around the base.

Cutting the soil away from a tree removes vital feeder roots, eliminates nutrient-rich topsoil, and often lowers the water table. Damage caused by shallow cuts (less than two inches) at least three feet away from the base of the tree may be minimal, but still can be a shock to a tree's vitality (health). If possible, avoid making the cut during hot, dry weather; water the tree (undisturbed portions) before, during, and after soil removal; and allow only hand digging inside the PRZ. A shallow layer of mulch (pine needles, wood chips, or coarsely chopped twigs and bark) and clean root cuts will help wound closure and regrowth. Deeper cuts within the root zone will require construction

of a retaining wall no closer than the limit of the PRZ (Figure 7b).

Excavation

As much as 40 percent of a tree's root system could be cut during the installation of a nearby utility line. This reduces water and nutrient uptake, and may compromise the stability of the tree. If it is not possible to relocate the utility line outside the tree's PRZ, you can reduce root damage by as much as 25 percent by tunneling under the tree's root system (Figure 8). When digging a trench near a tree, begin tunneling when you encounter roots larger than one inch in diameter.

Trenching for building foundations also poses a danger to nearby trees. Although not often used in Minnesota, posts, pillars, or I-beams sometimes can be substituted for foundation walls and footers on homes (Figure 9). Drilling single holes as opposed to cutting deep trenches saves many critical roots.

For all digging operations, insist that exposed roots be cut cleanly to promote quick wound closure and regeneration. Vibratory plows, chain trenchers, and hand tools do a better job at this than bulldozers and backhoes. Minimize damage by avoiding excavation during hot, dry weather; keeping the plants well watered before and after digging; and covering exposed roots with soil, mulch, or damp burlap as soon as possible.

Pavement

Sidewalks and driveways located too close to a tree endanger its health and may threaten pavement stability. Factors such as frost heaving, poor drainage, and pavement flaws give roots an opportunity to expand, gain a foothold, and cause damage. Homeowners are faced with costly repair bills and potential liability for the hazardous situation that develops.

These problems can be avoided if you consider the spatial needs of a tree and its root system when designing the layout of new sidewalks and driveways. Just how much space is required depends on a tree's sensitivity to root cutting and its future size (Table 1). It's best to locate sidewalks and driveways outside the anticipated PRZ. At a minimum, walkways should be at least three feet from the trunk of a tree; driveways may cover up to half the distance from the tree's PRZ to its trunk, as long as no excavation occurs. No tree should be boxed into an area less than eight feet by eight feet by three feet deep, with larger trees receiving at least 300 cubic feet of root/soil volume.

You can minimize disruption by using alternatives to conventional paving materials. In some communities, brick or flagstone walkways on sand foundations can be substituted for concrete (Figure 10). These materials protect soil pH and allow water and oxygen penetration. Preserve natural contouring by spanning uneven areas with wooden walkways elevated on posts. Elevated decks are excellent alternatives to concrete porches. Where additional pavement strength is needed (e.g., driveways), concrete requires less excavation than asphalt. "Structural soils" may be used under pavement to allow for both adequate pavement base strength and tree root penetration. Structural soils are composed of 80% stone chips, 20% clay-loam soil, and a polymer binding agent. Ask your builder about raised pavement techniques near valuable trees

There are several techniques for repairing pavement that has been damaged by protruding roots. For trees that are highly sensitive

to root disturbance, consider creating a concrete or asphalt mini-ramp to smooth the uneven surface between two sidewalk sections (Figure 11). Local ordinances governing liability should be consulted prior to using this technique. Relocate walkways with broken concrete slabs a few feet farther from the tree. For trees that can tolerate root disturbance, a vertical underground barrier may redirect root expansion away from pavement (Figure 12).

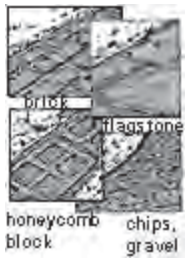


Figure 10. *Paving materials such as brick or flagstone over sand will produce less disruption than poured concrete to the roots of a nearby tree.*

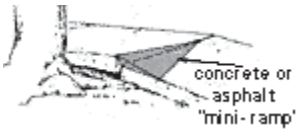


Figure 11. *A "mini-ramp" can be used to smooth the uneven surface caused by root damage to pavement.*

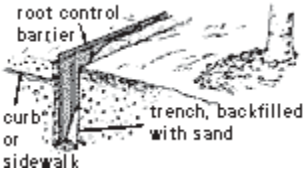


Figure 12. *A vertical underground barrier will help keep tree roots from damaging concrete as they grow.*

All tree species are capable of causing root damage to sidewalks, foundations, or pipes. Species notorious for damage-causing roots are noted in Table 1.

Symptoms of Construction Damage

Conspicuous symptoms of construction damage may take years to appear. Tree decline from soil compaction, for instance, may take three to seven years to appear as obvious symptoms of distress. Because of this delay, landowners often attribute tree losses to other causes. Carefully monitor affected plants and keep written records to help you recognize the less visible signs of tree stress. Remember, the most serious damage remains hidden in the root system.

Figure 13. *Suckering is one symptom of construction damage.*

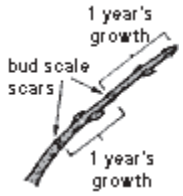


Figure 14. *Annual growth is the distance between bud scale scars on twigs. The twigs of healthy trees usually grow two to six inches longer each year.*

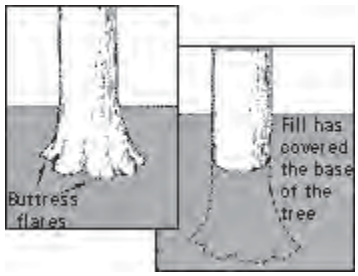


Figure 15. *To determine whether the grade has been changed around trees on a newly built site, check for the presence of* ***buttress flares*** *at the base of the trunk.*

Wilted or scorched leaves and drooping branches usually are the first signs of construction damage. In deciduous plants

these symptoms may be followed by early fall coloring and premature leaf drop. Damaged conifers will drop excessive amounts of inner needles. In subsequent years you may notice yellowed or dwarfed leaves, sparse leaf cover, or dead branches.

Other indicators might include flowering out of season, excessive water sprout formation on the trunk (Figure 13), abnormal winter dieback, or abnormally large amounts of seed. Flower and seed production and water sprout formation are defense mechanisms for ensuring species survival and commonly indicate that the plant is experiencing extreme stress.

In addition to observing a tree's appearance, monitor its annual growth. A slightly damaged plant will grow more slowly and be less resistant to insects, diseases, and weather-related stress. Examine the annual shoot and branch growth (Figure 14). Healthy trees generally will grow at least two to six inches at the ends of the branches each year. Photographs and records of the tree prior to construction also can help identify growth problems.

If you purchased your home following construction, you can identify deep fills around large trees by looking for buttress flares at the base of the trunk (Figure 15). Most common shade trees in Minnesota have buttress flares, and their absence usually indicates that the tree's base has been covered. It may be helpful to examine the condition of trees on other sites where your builder has worked.

Treatment of Damaged Plants

In many cases you would be wise to have a tree-care specialist look for early symptoms of tree stress. Dollars invested in consultations with professionals before damage becomes obvious may be repaid in considerable savings later on.

When a tree is injured by construction activities, energy and resources normally used for growth must be redirected toward the process of wound closure and regrowth. During this critical period plants are particularly vulnerable to additional stress, especially insects, diseases, and severe weather. You can minimize these problems by quickly treating the damage.

Water

Construction activities often alter the amounts of water received by trees. Thoroughly water plants before and immediately after they receive any kind of direct damage (e.g., severed roots). Continue periodic watering (at least four to five times per summer) throughout the next several growing seasons. Be careful not to over water your trees. Soaking the soil to a depth of 8-10 inches throughout the PRZ is a good rule-of-thumb.

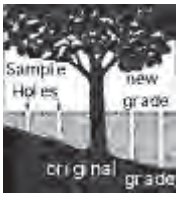


Figure 16. *Before you remove fill that has been added around trees, take vertical samples to determine how deep you need to go.*

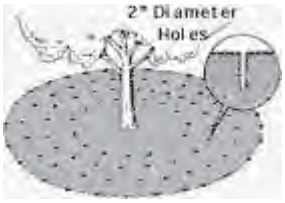


Figure 17. *A series of two-inch holes 12 to 18 inches deep will help alleviate root damage caused by compaction.*

Two to four inches of mulch (wood chips or bark) spread over as much of the root system as practical will help the tree retain

water and stimulate root regeneration. Living ground covers over the root system will have a similar effect, and may be more aesthetic. Apply these techniques to any deciduous tree exhibiting wilted leaves or any coniferous tree dropping excessive amounts of needles from the inner branches.

If you or your tree-care specialist has determined that excessive soil additions have been made around valuable trees, efforts should be made to restore the original grade, at least within the PRZ.

Excavation of Back Filled Trees

Approach this grade restoration carefully. Determine how much fill has been added by sampling depths at several different points within the PRZ (Figure 16). If the depth is great (more than 12 inches), you may remove most of the backfill with mechanical equipment. Once you are within 10 to 12 inches of the original grade, complete the fill excavation carefully with shovels and rakes. Make certain no soil is piled up against the tree trunk, and aerify the soil within the PRZ to complete the operation. If the tree is already exhibiting advanced symptoms of decline, however, restoration to original grade will probably be fruitless. In this case, remove the tree and plant a new one.

Aeration and vertical mulching

Soil compaction around a tree's roots may cause leaf wilt, early fall coloring, top dieback, and slow growth. Reduce the effects of compaction by carefully drilling a series of two-inch-diameter holes in the soil to a depth of 12 to 18 inches. Begin three feet from the tree trunk and continue drilling at one to three-foot intervals in concentric rings around the tree out to the PRZ (Figure 17). Each hole may be refilled with sand, peat moss, or mulch. For severely compacted soils, this procedure—called vertical mulching—should be repeated every two to three years until the tree has fully recovered. A tree-care specialist may recommend other alternatives, including soil injections of air or pressurized water, to improve soil aeration.

Fertilizer

Injured trees may need additional nutrients to replace damaged root systems. Fertilizers containing phosphorus and nitrogen can help stressed plants recover since these nutrients promote root and plant growth. Avoid excessive nitrogen; increased stem and foliage growth can cause stress, especially during hot, dry weather or if the tree has been stressed due to construction activities. Because of this problem, many experts recommend waiting two years after damage has occurred before fertilizing the trees. Specific guidelines for selecting and applying fertilizer are described in *Tree Fertilization* (Minnesota Extension Service publication FO-2421).

Pruning and Wound Repair

Careful pruning and wound repair are important treatments for damaged trees. Prune broken or dead branches cleanly at the branch collar (Figure 18). To test whether a branch is dead, bend several twigs. Twigs on live branches tend to be pliable, while twigs on dead branches tend to break. Buds also can be used to evaluate branch condition. Live buds appear full and normal in color while dead ones appear shriveled or dry.

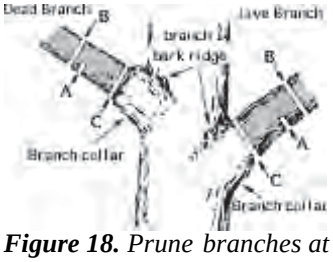


Figure 18. *Prune branches at the branch collar.*

Pruning is commonly recommended for large trees that have suffered root damage. However, opinions differ over the merits of this practice. Assuming that the tree has adequate water and is not in severe decline, some experts believe that retaining maximum leaf cover is important for root regeneration and only dead limbs should be removed. Others argue that pruning selected live limbs is necessary to compensate for lost roots. Generally, it is best to follow the recommendation of your tree-care specialist experienced in construction damage to trees.

When properly done in moderation by a skilled professional, pruning may reduce wind resistance and limb failure and improve tree health and appearance. DO NOT let anyone cut off all of the top branches to the same height ("topping").

The treatment of trunk wounds depends on the extent of damage. If 50 percent or more of the bark has been removed around the entire trunk, the tree will not likely survive and should be removed. If only a patch of bark has been removed leaving a few splinters, use a sharp knife to cleanly cut off the loose bark to a place on the stem where it is firmly attached. DO NOT make the wound any larger than necessary.

You do not need to use pruning paint or dressing to cover exposed wounds or pruned limbs. Except for special cases involving disease control, these products do little more than improve appearance.

Oak Wilt

Oak wilt is a lethal fungal disease normally spread through root grafts between adjoining oak trees. The disease also may be spread overland by sap beetles of the Family Nitidulidae. In Minnesota, construction activities that injure roots, break branches, or otherwise open a wound on an oak between April 1 and July 1 provide the beetles easy access to transmit the fungus. (Some studies have found the occurrence of oak wilt to be four times more likely within 160 feet of a construction site.) Immediately (within minutes) cover all open wounds with any water-based paint or shellac during this period. If you suspect oak wilt, contact your city forester or private tree-care specialist. If you have oaks on your site, obtain a copy of *Oak Wilt in Minnesota* (Minnesota Extension Service publication MI-3174) for additional information on identifying the disease and protecting your trees.

Other Insect and Disease Problems

Insects are attracted by distinctive chemicals that are released by plants recovering from injuries. Examples of insect pests that can sense a tree under stress include the pine bark beetle, bronze birch borer, two-lined chestnut borer, sap beetle (transports oak wilt fungus), and some scale insects. These insects can kill a plant by their feeding or boring or by transmitting disease.

Likewise, some diseases multiply in plants experiencing stress. Verticillium wilt, ash yellows, and *Armillaria mellea* are examples of diseases that attack weakened trees.

Continually monitor the health of your trees, especially those near construction activities, for insect and disease problems. Proper treatment, including corrective pruning, watering, and pesticide or fungicide applications, can restore tree health. Contact your county extension educator or local forester for additional information on specific tree pests.

Tree Removal

Even the best protection plans cannot guarantee plant survival. Death may occur shortly after construction or years later. Look for trees with very few leaves and many dead branches. If the tree does not leaf out the following year it is dead. Large trees that lean or exhibit rot, deep trunk cracks, or extensive top dieback are potentially hazardous (Figure 19). They should be evaluated by a tree-care specialist or be removed. Dead trees are excellent for wildlife, but dangerous to people and buildings. Large trees should be carefully removed by professionals so as not to damage the remaining plants.

Tree loss can have a dramatic impact on site appearance. Prompt replacement will minimize your grief. Remember, the tree you plant is your own.

Street Trees and Construction Damage

Established street trees are subjected to damage from construction activities perhaps even more frequently than forest trees. The infrastructure of any community—streets, sidewalks, curbs, and buried utilities—is continually updated, repaired, or expanded and trees growing in boulevards (tree lawns) or close to these public services are vulnerable to construction activities.

The most common type of damage street trees suffer is root loss. This is particularly harmful because these trees already are growing in root-limited spaces, and are often less healthy than other landscape trees due to the environmental stresses of boulevards (small volumes of soil, often a poor quality of soil, accumulations of deicing salts, and characteristically drier conditions than other landscape sites).

Trees growing in boulevards or near streets typically have an unbalanced and very restricted root distribution. Therefore, any root removal or damage during construction is often a more significant loss compared to trees growing in more open areas. Root loss not only affects the health of these trees but a more serious effect may be on their condition or stability. A boulevard tree that experiences significant root loss will have a different center of gravity as a result. This shift in balance often results in less stable trees—especially the large, mature ones - and leaves them more vulnerable to toppling (wind throwing) during severe weather.

Minimizing construction damage to street trees

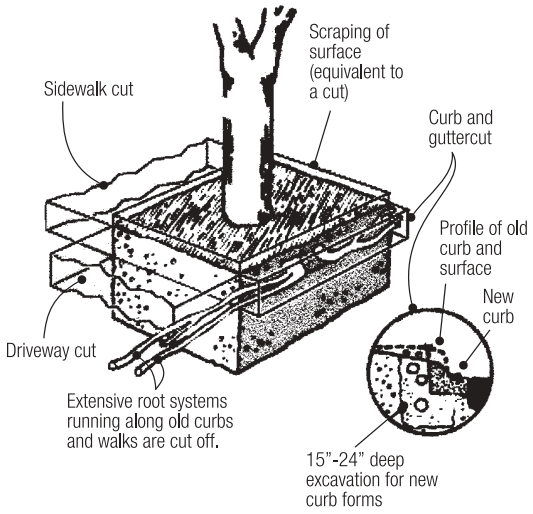


Figure 20. *Root cuts on more than one side seriously affect the health and stability of even healthy trees.*

Minimize root loss.

Most healthy trees can tolerate one-sided root cutting and recover from the loss with long-term after-care. Trees that have roots cut on two sides usually suffer much more damage and are less stable (see Figure 20). It is questionable whether to save trees that suffer root loss on three or more sides.

The number of cuts near street trees may be reduced by a variety of methods and

compromises. If possible, avoid widening streets or sidewalks when they are replaced. If curbs are slated to be replaced, hand-form the curbs adjacent to tree roots, rather than excavating with machinery for mechanical forms. Excavation with machinery destroys major branch roots, even if the new curb remains in the same position as the old curb.

Consolidate utilities into common trenches whenever possible, and tunnel under tree root systems (see Figure 8). Often it is possible to run several utilities in a common trench, minimizing the number of trenches and root cuts.

Do not regrade the surface of the boulevard. Although it is not trenching, it still cuts and removes roots, usually the fine roots that absorb most of the water and nutrients for the tree. If the new grade creates a mowing/maintenance problem, consider the installation of retaining walls at the curb line, or remove the turf grass from the boulevard and replace it with mulch and landscape plantings.

Avoid Damage to the Soil.

Do not allow equipment, vehicles, or materials to be stored on the boulevard. Establish a separate staging and parking area on a paved area away from the tree lawn. If this is not possible, cushion the boulevard with at least six inches of wood chips applied as mulch.

Do not allow any foreign materials to be buried or deposited into the boulevard soil. Don't bury debris (such as concrete) or wash out equipment or tools in the boulevard soil area.

Maintain the Health of the Trees During Construction.

As long as the soil drains water adequately, water, water, water the trees root systems. Adequate water before, during, and after construction is the most critical requirement for boulevard trees if they are to tolerate construction damage. Place soaker hoses over their root systems and soak them a minimum of one time per week during construction and immediately after, allowing two to three hours per soaking.

Continue Therapy and Care for Several Years After Construction.

Never let the trees become water stressed. Plan on having an arborist remove dead wood in the canopy within two to three years after the construction. Seriously consider removing the turf from the trees' root systems and replacing it with mulch and low-growing shrubs and herbaceous perennials. "Blooming boulevards" are becoming more common in communities across the nation and are often allowed in city ordinances (Figure 21). If your community's ordinances don't allow "blooming boulevards," try to have them changed.

Reconsider Replanting Narrow Boulevards.

Not all boulevards should have trees growing in them. Trees are most at risk for future construction/reconstruction damage when they are planted in boulevards less than 8-10 feet wide. In places where boulevards are very narrow, consider creating "green easements" that allow public trees to be planted in private lawns adjacent to the public property. They will enjoy a larger rooting area and a longer life.

Conclusion

It's not always easy to save trees during construction, but your efforts are worth the trouble. Healthy, well-placed trees can increase property values by 9 to 27 percent. Protecting tree health on a construction site

is a matter of recognizing the potential impacts. Advance planning and simple steps to minimize damage often can prevent future problems. Many trees have a tremendous capacity to survive disturbance, but in an urban setting we continually test them. Take the time to protect and monitor the health of your investment. Your home and our communities will be healthier, more attractive places to live.

References

Cervelli, Janice A. 1984 "Container Tree Plantings in the City" *Journal of Arboriculture* 10(3):83-86.

Fazio, J. R., ed. 1988. *Resolving Tree-Sidewalk Conflicts (No. 3)*. Tree City USA, National Arbor Day Foundation, 100 Arbor Avenue, Nebraska City, NE 68410. 8 p.

Fazio, J. R., ed. 1989. *How to Save Trees During Construction (No. 7)*. Tree City USA, National Arbor Day Foundation, 100 Arbor Avenue, Nebraska City, NE 68410. 8 p.

Forest Health Monitoring, 1998 Field Methods Guide. USDAFS, 1998. Number 649. National Forest Health Monitoring Program. Research Triangle Park, NC 27709.

French, D. W., and J. Juzwik. 1999. *Oak Wilt in Minnesota* (MI-3174). University of Minnesota, Minnesota Extension Service, St. Paul, MN 55108. 6 p.

Harris, R. W. 1992. *Arboriculture: Integrated Management of Landscape Trees, Shrubs, and Vines.* Prentice-Hall, Inc., Englewood Cliffs, NJ 07632. 674 p.

Hauer, Richard J., Robert W. Miller, and Daniel M. Ouimet. 1994 "Street Tree Decline and Construction Damage" *Journal of Arboriculture* 20(2): 94-97.

Hightshoe, G. L. 1988. *Native Trees, Shrubs, and Vines for Urban and Rural America.* Van Nostrand Reinhold, New York, NY 10003. 819 p.

Maryland Department of Natural Resources. October 30, 1990. *Natural Design in Development . . . Development Potential Through Forest Conservation.* Maryland Department of Natural Resources, Annapolis, MD.

Matheny, N. P., and J. R. Clark. 1991. *Evaluation of Hazard Trees in Urban Areas.* International Society of Arboriculture, Urbana, IL 61801. 72 p.

Matheny, Nelda, and James R. Clark. 1998. Trees and Development—A Technical Guide to Preservation of Trees During Land Development. International Society of Arboriculture, Champaign, IL 61826-3129. 184 p.

Miller, F. D., and D. Neely. 1993. "The Effect of Trenching on Growth and Plant Health of Selected Species of Shade Trees" *Journal of Arboriculture* 19(4):226-229.

Minnesota Association of Soil and Water Conservation Districts Forestry Committee. 1986. *Minnesota Tree Handbook.* Adventure Publication, Staples, MN 56479. 408 p.

Minnesota Society of Arboriculture. 1996. . "Minnesota Supplement to the Guide for Plant Appraisal." Minnesota Society of Arboriculture, c/o Tree Trust, 6300 Walker Street, St. Louis Park, MN 55416. 25 p.

Moll, Gary A., ed. 1990. "Community Forests Get a Check Up." *Urban Forest Forum* 9(6):10-12.

Perry, T. O. 1982. . "The Ecology of Tree Roots and the Practical Significance Thereof." *Journal of Arboriculture* 8(8):197-211.

Swanson, B. T., and C. Rosen. 1990. *Tree Fertilization (FO-2421).* University of Minnesota, Minnesota Extension Service, St. Paul, MN 55108. 4 p.

Watson, Gary W., and Dan Neely, ed. 1995. *Trees and Building Sites.* International Society of Arboriculture, Champaign, IL 61826-3129. 191 p.

Contributors

Author: Gary R. Johnson, **Associate Professor, Urban and Community Forestry, University of Minnesota Extension Service, Department of Forest Resources.**

Technical Advisors

Melvin J. Baughman, Extension Specialist, Extension Specialist—Forest Resources and Professor, University of Minnesota, Department of Forest Resources. **David W. French**, Professor

Emeritus, University of Minnesota, Department of Plant Pathology. **Rich Hauer,** Plant Health Specialist, Minnesota Department of Agriculture. **Paul G. Walvatne,** Senior Forestry Staff Specialist, Minnesota Department of Transportation, Environmental Service. **Patrick Weicherding,** Extension Horticulturist, Anoka County Extension Service.

The authors also wish to acknowledge Scotty Scholten, Michael Zins, Charlie Blinn, and Carl Vogt of the University of Minnesota for reviewing the manuscript and providing valuable insights.

Production

Product Manager: **Gail M. Tischler**

Editor: **Mary Hoff**

Design & Illustration: **Jim Kiehne**

This publication was produced with the support of the USDA Forest Service, Northeastern Area, State and Private Forestry; the Minnesota Department of Natural Resources, Division of Forestry, Urban and Community Forestry Program; the Minnesota Shade Tree Advisory Committee; and the Minnesota Extension Service.

10-a

Soil Bioengineering/Biotechnical Erosion Control—Design Guidance

Source: New York State Department of Transportation Engineering Instruction EI 02-019, 2002

I. INTRODUCTION

Soil bioengineering/biotechnical erosion control methods are revegetation and stabilization technologies applied on disturbed sites, including slopes and streambanks. Soil bioengineering is the reliance on plant material for slope protection, rebuilding and stabilization, erosion control, etc. Biotechnical engineering combines the use of plant materials and structural elements to achieve the same goal.

Environmental benefits include habitat enhancement, water quality preservation and improvement, that are realized through the rapid reestablishment of a natural vegetative cover. Soil bioengineering/biotechnical erosion control methods are typically cost-effective and non-intrusive methods, that utilize living plant material as an integral component of the erosion control system. The plant material anchors and stabilizes soil in areas where traditional structural stabilization methods are impractical or unwarranted or where rapid revegetation of woody plantings is desired. Soil bioengineering/biotechnical erosion control limits site disturbance and does not have severe access requirements. Therefore, soil bioengineering/biotechnical erosion control methods are ideal for sites that are steep, inaccessible, or sensitive to the proper use of machinery. Soil bioengineering/biotechnical erosion control techniques use native, sometimes indigenous materials and are visually compatible in the landscape. These characteristics can make the soil bioengineering/biotechnical engineering erosion control approach especially attractive for scenic corridors and select environmentally sensitive areas.

Soil bioengineering/biotechnical engineering erosion control should only be undertaken following a thorough site assessment. This site assessment should include a multidisciplinary consideration of slope geometry, aspect, climate, water regime, soil properties, and surrounding vegetation. Consult the Regional Geotechnical Engineer and the Regional Hydraulics Engineer about characteristics of specific sites which may warrant hard armor or a combination of hard armor and soil bioengineering erosion control.

II. APPLICATION

A. Opportunities and Limits

1. Situations for effective soil bioengineering/ biotechnical engineering erosion control

Properly designed soil bioengineering/ biotechnical engineering erosion control measures are ideal in many situations where soil erosion and stabilization are concerns. These situations can include cut/fill slope stabilization, earth embankment protection, shallow mass movement, small gully repair, and streambank stabilization. Biotechnical erosion control systems offer immediate resistance to erosion due to the placement or configuration of elements in the system. This resistance to erosion, sliding, or shear displacement increases over time as root systems develop and bind the soil.

Benefits of soil bioengineering/biotechnical engineering erosion systems are their natural appearance and low cost. In areas that have aesthetic and environmental concerns, soil bioengineering/biotechnical engineering erosion control methods offer designers a means that may help to address these concerns. Stream bank stabilization offers one of the greatest opportunities for utilizing soil bioengineering/biotechnical engineering erosion control techniques. The benefits of these techniques for streams include more natural, productive riparian habitats, shade, addition of organic matter, cover for aquatic species, and improved aesthetic value and water quality.

Live staking, live fascines, brush layering, branch packing, and brush mattressing are techniques that utilize live plant material (cut stems or branches) as the primary means of soil stabilization. The cut surface of the plant material is brought into contact with soil and as root systems develop, the plants increase reinforcement over time.

Live crib walls, vegetated rock gabions, tree revetments, and joint plantings are techniques that utilize structural elements in conjunction with live stem or branch cuttings. They may be suitable for more challenging sites where the methods that utilize solely live material are not sufficient. The structural elements create open structures into which the live cuttings are placed, and provide immediate protection from erosion and sliding. This importance declines over time however, as the vegetative component becomes established. Coir/straw logs and vegetated mats are additional tools that can be used by the designer.

2. Constraints

Soil bioengineering/biotechnical engineering erosion control combines biological elements with engineering principles. Like other methods they have their limitations. For example, the engineering requirements of a project, such as compacted soil may make the successful application of these techniques untenable.

The vegetative cuttings used in these systems are living materials and must be handled properly to avoid excessive stress, such as drying or excessive heat. The plants must be installed to the proper depth in soil that remains moist. The adjacent soil should be tamped to eliminate or minimize excessive air pockets around the buried stems. The success of a system is also dependent upon the available soil. Rocky soils or gravelly slopes that lack sufficient fines and/or moisture will not provide an adequate growing environment for most species, and soil-restrictive layers, such as hardpans, may prevent root growth.

Installation of soil bioengineering/biotechnical engineering erosion control is best accomplished in the early spring or late fall while the plant materials are dormant. However, installation during the fall can leave the site vulnerable through the winter and early spring snowmelt cycles, before the dormant plants can establish themselves. When the designer anticipates work to be completed in the fall the soil bioengineering/biotechnical engineering erosion control features should be used in conjunction with other temporary erosion control measures.

Installation should not be attempted when the ground is frozen and summer installation is not recommended. Installation after some initial spring growth has started can be successful if extreme care is exercised. It is critical to use suitable plant species that are adapted to the specific climate and soil conditions of the installation site. The

Regional Landscape Architect should be consulted choosing appropriate sites, plant species, and for proper placement of the plant species being used. Since timing of plant material installation is critical the Regional Landscape Architect should be consulted for the project scheduling.

Many sites will require significant earthwork for successful installation. A steep undercut or slumping bank, for example, may require regrading the slope to 1:3 or flatter to enable establishment of the plant material. Extensive grading and earthwork should be avoided as much as possible, especially in critical areas.

Backfill for soil bioengineering/ biotechnical engineering systems requires a medium which must be conducive to plant growth yet more cost-effective than topsoil as specified in Section 713-01. A recommended mixture is specified in the Method and Materials section below.

Soil bioengineering/biotechnical engineering erosion control systems should receive regular inspection after installation, and provision should be made for prompt maintenance and repair as necessary. Repairs to an installation can be easily performed when problems are caught early and are not too extensive. Neglect of any small repairs can cause problems to expand and result in failure of the entire installation.

Some of the specific limitations to the use of vegetation for streambank erosion control include:

1. Lack of design criteria and knowledge about properties of vegetative materials.
2. Possible failure to grow and susceptibility to drought conditions.
3. Depredation by wildlife or livestock.

Soil bioengineering/biotechnical engineering erosion control systems are usually more cost-effective than many of the alternatives. However, where labor is scarce or very expensive, soil bioengineering/biotechnical engineering erosion control systems can be more expensive than comparable structural methods. Also, some of the cost-effectiveness of these methods derives from the harvesting of locally available plant material. If the plant material must be purchased, some of the cost benefit may be lost.

In summary, bioengineering/biotechnical engineering systems can be useful and cost-effective in controlling bank erosion or providing bank stability while increasing the aesthetic and habitat diversity of the site. Where failure of the countermeasure could lead to failure of a bridge or highway structure, the only acceptable solution may be traditional “hard” engineering approaches. Biotechnical engineering needs to be applied in a prudent manner, in conjunction with channel platform and bed-stability analysis, and rigorous engineering design. (Federal Highway Administration/FHWA HEC-23)

B. Characteristics

Biotechnical engineering erosion control systems utilize specific attributes of the vegetative and structural components to prevent erosion. The components of the system have differing characteristics that apply to different situations. These characteristics need to be considered prior to selecting a system for use. One attribute of vegetation is the root system’s ability to bind the soil. In most cases when using soil bioengineering, topsoil will not be used due to economic constraints. On site excavation may be suitable if it meets the criterion of Soil Bioengineering backfill material as specified in the Methods and Materials section of this guidance.

1. Vegetative

a. Herbaceous vegetation

Well established herbaceous vegetation, especially grasses and forbs will provide long term protection from surface erosion by binding the soil with their roots. Herbaceous vegetation should always be considered as a component of soil bioengineering systems to aid in protection from surface erosion. This vegetative mat helps to prevent surface erosion by:

- Binding and restraining soil particles in place.
- Reducing sediment transport.
- Dissipating raindrops.
- Reducing velocity of runoff.
- Improving infiltration capacity.
- Minimizing freeze-thaw cycles of soils susceptible to frost.

One shortcoming of the exclusive use of herbaceous vegetation is that it offers less protection from shallow mass movement. However, the Department has successfully used grasses on slopes as steep as 1:2 for many years.

Herbaceous species useful as a component of soil bioengineering/biotechnical engineering erosion control systems can be found in Appendix II. Seeding is the most common, and least expensive, method of successfully establishing herbaceous vegetation. However, seedlings or established plants can also be used. Herbaceous plantings can become established in a short period of time, thus providing soil erosion protection until the soil bioengineering erosion control system develops.

b. Woody vegetation

Woody vegetation is normally more densely and deeply rooted and offers extensive protection from shallow mass movement. It does this by:

- Mechanically reinforcing the soil with extensive root systems.
- Reducing the amount of soil water through interception and transpiration.
- Buttressing and soil-arching action from imbedded stems.

This woody vegetation is installed in specified arrangements that are designed to impede erosion and offer immediate soil protection and reinforcement.

2. Structural

The role of structural elements in biotechnical engineering erosion control systems is to stabilize and support or enable the growth of the vegetative component of the system. The characteristics of a site may be such that vegetation cannot become established prior to the potential effects of erosion. Structural elements play a critical role in stabilizing soil while vegetation becomes established. Without stabilization, plantings may fail at their most vulnerable time. In many instances, a structure is designed only to be a temporary feature of the system until vegetation becomes established.

Structures are constructed from either natural or manufactured elements. Natural material such as earth, rock, stone, and timber are often less expensive, more environmentally compatible and integrates well with vegetation. Natural materials may also be available on a site at little or no cost.

Structures are generally capable of resisting higher lateral earth pressures and shear stresses than vegetation alone. In situations where such stresses are expected, biotechnical engineering erosion control

measures that incorporate structures should be used.

a. Retaining structures

A retaining structure will often be necessary to protect and stabilize steep slopes. Low retaining structures at the toe of the slope make it possible to grade the slope back to a more stable angle that can be successfully revegetated, without loss of soil at the crest. (Example: Vegetated Crib Wall)

b. Grade stabilization structures

Grade stabilization structures are used to control and prevent gully erosion. This type of structure reduces the grade above it and dissipates the excess energy of flowing water within the structure itself. Debris and sediment are deposited and trapped upstream of the structure. This allows the establishment of vegetation behind the structure, which further stabilizes the ground. These structures may range from a series of simple timber check dams to complex concrete overflow structures and earth embankments with spillways. (Example: Live Fascines)

Gully control provides a good example of integration of structures and vegetation. Structural measures may be required in the short term to stabilize critical locations. The long-term goal is to establish and maintain a vegetative cover that prevents erosion. The goal is seldom realized unless the severe gully conditions can be altered immediately. Vegetation alone, for example, will rarely stabilize gully headcuts due to concentrated water flow, overflows, and pervasive forces that promote the gully enlargement in an unstable channel system. Initially, the vegetation and structure work together in an integrated fashion. The ultimate function of these structures however, is to help establish vegetation which will provide long-term protection.

C. Design Considerations

The decision to use soil bioengineering/biotechnical engineering erosion control methods should be based upon a thorough investigation of the site. This investigation should take into account the soil types, slope gradient, moisture availability, climate, and the project objectives.

When soil bioengineering/biotechnical engineering controls are placed in or immediately adjacent to a stream channel, a temporary water diversion may be necessary. The designer should consider use of cofferdams, turbidity curtains, or other similar techniques to protect the stream from sediment. These items will be paid for separately and should be specified in the plans or contract documents.

If the conditions mentioned are too severe, soil bioengineering/biotechnical engineering erosion control methods alone may not be the best choice for the site. When soil bioengineering/biotechnical engineering erosion control methods are to be used, it is important to choose the proper methods. The methods chosen will be based upon what was learned from the site investigation. It is recommended to consult the Regional Geotechnical Engineer for the determination of the soil profile, analysis of slope stability, and retaining wall designs. The Regional Hydraulics Engineer should be consulted when work is contemplated adjacent to any bridge or highway structure, or where the work would be subject to stream or flood flows.

Sometimes it will be necessary to adapt a method or combine methods to fit the conditions inherent to the site. For example, on slopes that could be prone to a washout prior to root establishment, live cuttings could be supplemented with another technique,

such as live fascines. Soil bioengineering/ biotechnical engineering erosion control methods can also be used with other engineering methods on more difficult sites. Such combinations of methods can take advantage of their strengths to create a functioning slope-stabilization system.

The use of standard planting items, seeding, sodding, and mulching can also be incorporated into the soil bioengineering/ biotechnical engineering erosion control design, as necessary, to integrate the structure with its surroundings, and improve the vegetative diversity. Collected or salvaged plant materials may also be considered with similar objectives.

D. Other Considerations

1. Monitoring and maintenance

Soil bioengineering/biotechnical engineering erosion control methods should only be used in areas where there is reasonable probability that the systems will propagate and otherwise be successful, and require minimal maintenance. The systems should be designed for areas that have sufficient moisture throughout the growing season to continuously support vegetative growth. Consult the Regional Geotechnical Engineer and the Regional Landscape Architect about specific areas of installation.

Monitoring of bioengineered structures during the life of the Contract should be done on a regular basis to assure that the natural processes are working to establish self-sustaining and stable functions of the systems. Early problem indicators such as gullying or erosion, loss of structure or plant materials, unforeseen groundwater appearance, mechanical injury, and need for repair or replacement of components, etc., should be brought to the attention of the Regional Landscape Architect. Intensive maintenance may be required during monitoring period of the bioengineered structure to repair or restore problem areas, replace damaged components, or augment the original design.

Monitoring prior to the acceptance of the soil bioengineering/biotechnical engineering erosion control methods should be conducted on a bi-weekly basis and after storm events of 12 mm or more in a 12-hour period. Maintenance on the structures/plantings should be undertaken, when failures occur, to reestablish the structures and vegetated material.

General post construction maintenance of the bioengineered structure following proper establishment should be minimal, in accordance with the restorative concept of using a living material as a solution. Maintenance, other than that which will be performed for any other area of the highway right-of-way, such as pruning, vegetation removal, maintenance of sight distance, etc., should not be necessary on the bioengineered structure.

2. Hydraulic Analysis

In any situation where the use of soil bioengineering/biotechnical methods will result in an increase in vegetation over existing conditions within an area subject to a 1% annual probability of flooding, consult the Regional Hydraulics Engineer to ascertain the effect on hydraulic roughness. A hydraulic analysis may be required to assure that increased resistance to flow will not raise floodwater levels upstream in violation of Federal Emergency Management Agency (FEMA) Flood Insurance requirements.

III.METHODS AND MATERIALS

A. Live cuttings/live stakes-in soil (see details)

Live cuttings/live stakes create a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by contributing to the reduction of excess soil moisture. Live cuttings/live stakes are an appropriate technique for repair of small earth slips and slumps that are frequently wet. Live cuttings are applied for vegetative growth only. The size of cuttings limit their usefulness as support members. Live stakes are used for vegetative growth as well as support of other soil bioengineering techniques.

This technique is for relatively uncomplicated site conditions when construction time is limited and an inexpensive vegetative method for stabilization is desired. It is not intended to be used where the integrity of a road or structure is dependent upon the cuttings or stakes. It is not designed for or intended to resist large, lateral earth stresses.

Live cuttings range from 12 to 25 mm in diameter and 0.3 to 1.2 m long. Live stakes range from 26 to 50 mm or 51 to 100 mm in diameter and 1.5 to 1.8 m long. The live cuttings and live stakes must have side branches cleanly removed and the bark must be intact. The basal ends should be cut at an angle for easy insertion into the soil and the top cut square. Materials harvested on site shall be installed the same day they are prepared. Nursery material must be soaked for 24 hours prior to installation. Live cuttings or live stakes could be used for any application as specified in the contract documents.

Drive the live cuttings/live stakes into the ground pointing up from the slope. Live stakes should be installed 600 to 900 mm apart using triangular spacing. The density will range from two to four live cuttings/live stakes per square meter. The buds on the live cuttings/live stakes should be oriented up. Two-thirds of the length of the live cuttings/live stakes shall be installed in the ground and soil firmly packed around them after installation. Care should be taken not to damage live cuttings/live stakes during installation. Live cuttings/livestakes that are damaged should be left in place and supplemented with an intact live cutting/live stake. A dibble or similar tool may be used to make a pilot hole for installing the plant material. Drive the live stakes into the ground with a dead blow hammer (hammer head filled with shot or sand). (Refer to details.)

B. Live cuttings/live stakes-joint planting (see details)

Joint planting involves driving live cuttings/live stakes into soil between the joints and open spaces, in rocks that are being placed on a slope face (“Stone Filling - Section 620”), or stone that has previously been placed on a slope. The roots will improve soil drainage and create a living root mat. There is no value in utilizing this technique where geo-textile has been placed under the stone filling, as there is little expectancy of plant survival. Joint planting should not be used in stone fill or riprap slope protection placed adjacent to bridge or highway structures.

One-half of the live cutting/livestake should be driven into the soil below the stone filling. Approximately 50 to 100 mm should be exposed above the stone filling. A pilot hole is required to insure that the cutting/stake will not be damaged from being driven into place through the stone filling. For

sizing, refer to live cuttings/live stakes in soil. (Refer to details.)

C. Live Fascines (see details)

Live fascines are long bundles of live branch cuttings bound together into sausage-like structures. Fascines are constructed only from freshly cut dormant branches of materials and from sources approved by the Engineer. Live fascines must be prepared and installed within 48 hours of the time the plant material is harvested.

The use of live fascines is an effective stabilization technique for slopes. This procedure is suited to steep, rocky slopes, where digging is difficult. The fascines enhance vegetation establishment by creating a microclimate.

When cut from appropriate species and properly installed with both live stakes and wooden posts to secure them, the live stakes will root and immediately begin to stabilize slopes. The fascines should be placed in shallow contour trenches on dry slopes. On wet slopes, to reduce erosion and shallow face sliding, the fascines should be placed on an angle to the contour to direct surface runoff toward a suitable drainage area.

Use the chart below for spacing requirements of fascine rows along a variety of slopes.

Slope	Slope Distance Between Trenches (mm)	Maximum Slope Length (m)
1:1.0 to 1:1.5	900 to 1200	4.5
1:1.5 to 1:2.0	1200 to 1500	6.0
1:2.0 to 1:2.5	1500 to 1800	9.0
1:2.5 to 1:3.0	1800 to 2400	12.0
1:3.5 to 1:4.0	2400 to 2700	15.0
1:4.5 to 1:5.0	2700 to 3000	18.0

Cuttings must come from species, such as young willows or shrub dogwoods that root easily and have long, straight branches. They should be tied together to form live fascine bundles which can vary in length (minimum length of 1.2 meters). The length of the fascines depends on site conditions and limitations in handling. Fascines are to be constructed in bundles ranging from 150 to 200 mm in diameter, with all of the growing tips oriented in the same direction. The cuttings in the bundles are staggered so that tops are evenly distributed throughout the length of the uniformly sized live fascine. Wooden support posts shall be 750mm long in cut slopes and 900 mm long in fill slopes. They must be untreated 38 by 89 mm lumber. Each length should be cut again diagonally across the 89 mm face to make two posts from each length. Only new, sound, unused lumber should be used. Any post that shatters upon installation should be left in place and supplemented with an intact post. String used for bundling should be untreated twine. If specified, live stakes may be used in place of posts.

Live stakes can also be installed on the down-slope side of the bundles. The live stakes are driven below and against the bundles, between previously installed posts. The live stakes should protrude 50 to 75 mm above the top of the live fascine. Moist soil is placed along the sides of the live fascine. The top of the fascine should be slightly visible when the installation is completed.

Live fascine bundles should be prepared immediately before installation. Dig trenches, starting at the base of the slope, on the contour, just large enough to contain the live fascine. The trench will vary in width from 300 to 450 mm, depending on the individual bundle's final size.

Live fascines are placed into the trench. Posts are driven directly through the live

fascine every 600 to 900 mm along its length. Extra posts should be used at connections or bundle overlaps. The tops of the posts are left flush with the installed bundle. Repeat the preceding steps at contour intervals to top of the slope. Place two rows at the top of the slope. (Intervals are specified on the details.)

Seed or other erosion control material should be placed between rows and paid for under separate items. (Refer to details.)

D. Branchpacking (see details)

Branchpacking consists of alternate layers of live branch cuttings and tamped backfill to repair small, localized slumps and holes in slopes. It is effective in earth reinforcement and mass stability of small, earthen fill sites.

Branchpacking produces a filter barrier, reduces erosion and scouring conditions, and can be used to repair holes in earthen embankments. The live branch cuttings serve as tensile inclusions for reinforcement, once installed. As plant tops begin to grow, the branchpacking system becomes increasingly effective in retarding runoff and reducing surface erosion. Trapped sediment refills the localized slumps or holes, while roots spread throughout the backfill and surrounding earth to form a unified mass. Branchpacking is not effective in slump areas greater than 1.2 m deep or 1.5 m wide.

Live branch cuttings may range from 12 to 50 mm in diameter. They should be long enough to touch the undisturbed soil at the back of the trench and extend slightly from the backfill area.

Wooden posts should be used to secure the material in place. These posts should be 1.5 to 2.4 m long and made from 75 to 100 mm diameter poles or 38 by 89 mm lumber, depending upon the depth of the particular slump or hole. Where specified, live stakes may be used in place of posts.

Installation should begin at the lowest point. Wooden posts are driven vertically 0.9 to 1.2 m into the ground, approximately 300 to 450 mm apart. A layer of living branches, 100 to 150 mm thick, is placed in the bottom of the hole between the vertical posts and perpendicular to the slope face. They should be placed in a crisscross configuration with the growing tips generally oriented toward the slope face. Space branch cutting layers 900 mm apart on slopes up to 1:3. For steeper grades, spacing should be 450 to 750 mm apart. Some of the basal ends of the branches should touch the back of the hole or slope. Subsequent layers of branches are installed with the basal ends lower than the growing tips of the branches. Each layer of branches must be followed by a layer of tamped soil to ensure soil contact with the branch cuttings. Moist soil is necessary to insure that the live branches do not dry out. The final installation should match the existing slope. Branches should protrude slightly from the filled face. Seed or other erosion control material should be placed between rows and paid for under separate items. (Refer to details.)

E. Brushlayering (see details)

Brushlayering is somewhat similar to live fascine systems. Both involve the cutting and placement of live branch cuttings on slopes in rows. The two techniques differ principally in the orientation of the branches and the depth to which they are placed in the slope. In brushlayering, the cuttings are oriented perpendicular to the slope contour.

Brushlayering is not recommended for fill slopes greater than 1.0 m in depth.

Brushlayering consists of placing live branch cuttings in small benches excavated

into the slope. The benches can range from 600 to 900 mm wide. This system is recommended on slopes up to 1:2 in steepness and not to exceed 4.5 m in vertical height. The portions of the brush which protrude from the slope face assist in retarding runoff and reducing surface erosion.

Brushlayering preforms several immediate functions in erosion control, earth reinforcement, and mass stability. It reinforces the soil with unrooted branch stems, traps debris on the slope, dries excessively wet sites, and redirects adverse slope seepage by acting as horizontal drains. Use the chart below for spacing requirements of brushlayer rows along a variety of slopes.

Slope Distance Between Trenches (mm)

Slope	Wet Slopes	Dry Slopes	Max. Slope Length (m)
1:2.0 to 1:2.5	900	900	4.5
1:2.5 to 1:3.0	900	1200	4.5
1:3.5 to 1:4.0	1200	1500	6.0

Brushlayering cuttings should be 12 to 50 mm in diameter and long enough to reach the back of the bench. Side branches should remain intact for installation.

Starting at the toe of the slope, benches are excavated on the contour, or angle slightly down the slope if needed to aid drainage. The bench should be constructed 600 to 900 mm wide. The surface of the bench should be angled so that the outside edge is higher than the back of the bench. Live cuttings should be placed on the bench in a crisscross or overlapping configuration. Live branch cuttings shall be placed in layers between 75 to 100 mm thick. Branch growing tips should be aligned out of the slope face. Place backfill on top of the branches and tamp to minimize air spaces. The brush tips should extend slightly beyond the fill in order to filter the sediment. Each lower bench is filled with soil excavated from the bench above. The brushlayer rows should vary from 0.9 to 1.5 m apart, depending upon the slope angle and stability (see above table). Seed or other erosion control material should be placed between rows and paid for under separate items. (Refer to details.)

F. Brushmattressing (see details)

Brushmattressing is a combination of posts, wire, and branch cuttings installed to cover and stabilize streambanks. It may be used in conjunction with live stakes and live fascines. A brushmattress consists of live branches that are placed on stream banks, secured in place with posts and wire, and covered with soil. The application typically starts above stream-forming flow conditions and moves up the slope. It forms an immediate, protective cover over the streambanks. This technique is useful on steep, fast-flowing streams and captures sediment during flood conditions. Brushmattresses are used to rapidly restore riparian vegetation and streamside habitats.

Live materials consist of branches 1.8 to 2.7 m long and approximately 25 mm in diameter or less. They must be flexible to enable installations that conform to variations in the slope face. Brushmattresses should be constructed of 90 branches minimum, evenly distributed per linear meter for the full width of the mattress. Live stakes may be used in the installation but should be alternated with wooden posts. Live stakes, if used, should be 0.8 to 1.2 m long, driven a minimum of 0.5 m into the ground. Live fascines may also be included in the installation. If included, they should be installed at the base of the brushmattress at the mean water level (Refer to details.)

The unstable area of the streambank should be uniformly graded to a maximum steepness of 1:3. If included, the live stakes and live fascine bundles should be prepared immediately before installation. Excavate a trench for the fascine, if specified, at the base of the slope near the stream forming flow stage and on the contour. It must be large enough to accommodate a live fascine and the basal ends of the branches.

Posts made of 38 by 89 mm lumber sawn diagonally from 0.9 to 1.2 m long are installed to a minimum depth of 500 mm over the face of the graded area using a 600 mm square spacing pattern. If live stakes are specified, every other one is alternated with posts. Branches are placed in a layer 3 to 5 branches thick on the prepared slope with basal end facing down slope. If fascines are included in the installation the branches will be placed in the previously excavated fascine trench with the fascine placed on top of the branch ends. The branches should be comprised of live, quick-rooting species. Number 16 gauge nongalvanized wire is stretched diagonally from one post to another by tightly wrapping wire around each post no closer than 150 mm from its top. The wire is only to be attached to the posts and not the live stakes, if they are specified. The posts are driven into the ground until branches are tightly secured to the slope.

Once the mattress is in place, soil should be applied on top of the live cuttings to a depth of approximately 100 mm and tamped.

Live fascines, if specified, are placed in the prepared trench over the basal ends of the branches. Posts are driven into the soil in front and behind the live fascine every 600 mm along its length. The fascines are secured to the posts with 16 gauge nongalvanized wire. Any voids between brushmattress and live fascine cuttings are filled with thin layers of soil to promote rooting. The top surface of the brushmattress and live fascine installation are left slightly exposed. Wire should be secured to posts only. (Refer to details.)

G. Vegetated cribwall (see details)

A vegetated cribwall consists of a hollow, box-like interlocking arrangement of untreated logs or timber members. The structure is filled with suitable backfill material and layers of live branch cuttings which root inside the crib structure and extend into the slope. Once the live cuttings root and become established, the subsequent vegetation gradually takes over the structural functions of the wood members which will deteriorate over time.

The technique is appropriate at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness at locations such as boat launches or stream/river accesses. It is not intended to be used where the integrity of a road or structure is dependent upon the cribwall. It is not designed for or intended to resist large, lateral earth stresses. It should be constructed to a maximum of 1.8 m overall height, including the excavation required for a stable foundation. A vegetative crib wall is useful where space is limited and a vertical structure in needed. The crib wall also provides immediate protection from erosion, while establishing vegetation for long-term stability. The cribwall should be battered or constructed in a stair-step fashion. (Refer to details.)

Live branch cuttings should be 12 to 50 mm in diameter and long enough to reach from the front of the structure to the undisturbed soil. Logs or timbers should range

from 100 to 150 mm in diameter or dimension. The length of the branch cuttings will vary with the size of the crib structure. Large spikes or rebar are required to secure the logs or timbers together. Starting at the lowest point of the slope, material is excavated 600 to 900 mm below the ground elevation until a stable foundation is reached. The back of the stable foundation (closest to the slope) is excavated slightly deeper than the front. The first course of logs or timbers is placed at the front and back of the excavated foundation, approximately 1.2 to 1.5 m apart and parallel to the slope contour. The next course of logs or timbers is placed at right angles (perpendicular to the slope) on top of the previous course to overhang the front and back of the previous course by 75 to 150 mm. Each course of the cribwall is placed in the same manner and fastened to the preceding course to the desired grade. Stone filling is placed in the bottom of the structure up to the ground level and up to the base-flow in a stream channel (See "Stone Filling - Section 620"). When the cribwall structure reaches the existing ground elevation, live branch cuttings are placed on the stone filling perpendicular to the slope. The cuttings are then covered with Soil Bioengineering Backfill Material as detailed in this section and tamped. The live branch cuttings should be placed at each course followed by the Soil Bioengineering Backfill Material to the top of the cribwall structure with growing tips slightly protruding from the cribwall face. Each layer of branches is followed with a layer of Soil Bioengineering Backfill Material tamped to ensure good contact between the live branch cuttings and soil. Some of the basal ends of the live branch cuttings in each layer should reach the undisturbed soil at the back of the cribwall. It is recommended to consult the Regional Geotechnical Engineer for aid in analyzing the configuration of the cribwall. (Refer to details.)

H. Vegetated rock gabions (see details)

Vegetated Rock Gabions begin as rectangular containers fabricated from a triple twisted, hexagonal mesh of P.V.C. coated heavily galvanized steel wire (See "Gabions - Sections 620-2.07 and 712-15"). P.V.C.-coated galvanized gabions are recommended as permanent features in stream channel applications. Empty gabions are placed in position and wired to adjoining gabions. They should then be filled with a mixture of stones conforming to the provisions of Section 712-15 and Soil Bioengineering Backfill Material as detailed in this section. The ratio of stone to backfill material will depend upon the application. When the structure is in the presence of water, the suggested mix should be 70% stone and 30% backfill material, with the stone being placed first, followed by the backfill material. The backfill material should be worked in to fill the voids in the stone. When the unit is out of the water a 50/50 mix is recommended.

This technique is appropriate at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness. It is not intended to be used where the integrity of a road or structure is dependent upon the rock gabions. It should not be used in stream channels carrying significant bedload, where abrasion of the wire mesh will destroy the gabion baskets. It is not designed for or intended to resist large, lateral earth stresses. Vegetated gabion walls should be constructed to a recommended maximum overall height of 1.5 m, including the excavation required for a stable

foundation. This technique is very useful where space is limited and a more vertical structure is required.

Live branches should range from 12 to 25 mm in diameter. The length of the cuttings will vary according to the size of the gabions and the depth of the cut in the embankment. The live branches should, at a minimum, be long enough to protrude slightly from the front face of the gabion and extend at least 300 mm into the backfill. Some of the live branches should be long enough to reach beyond the back of the rock basket structure into the undisturbed soil. Inert materials include wire gabion baskets and rocks to fill the baskets.

Starting at the lowest point of the slope, material is excavated 600 to 900 mm below the ground elevation until a stable foundation is reached. The back of the stable foundation is excavated slightly deeper than the front. This will provide additional stability to the structure and ensure that the living branches root well. The fabricated wire baskets are placed in the bottom of the excavation and filled with rock.

Backfill is placed behind the wire baskets and at the horizontal joints. A 25 mm layer of soil is placed at each horizontal joint, and live branch cuttings are placed on each layer of soil. The live branch cuttings are placed with the growing tips oriented away from the slope and extended slightly beyond the exposed faces of the gabions. The cuttngs must extend at least 300 mm into the backfill. Some of the live cuttings must also extend beyond the backs of the wire baskets and be in contact with the undisturbed soil. Soil is placed over the cuttings and tamped. This sequence is repeated until the structure reaches the required height. It is recommended to consult the Regional Geotechnical Engineer for aid in analyzing the configuration of the gabions. (Refer to details.)

I. Fiber roll (see details)

A fiber roll is a coir-woven roll encased with a synthetic webbing used to dissipate energy along streams, channels, bodies of water or on slope contours.

Fiber rolls, in conjunction with plant material, are used along ponds, streams, creeks, and where water levels are relatively constant. Artificially controlled streams for hydro power are not good candidates for this technique. The rolls provide a good medium for the introduction of herbaceous vegetation. The vegetation needs to be a suitable wetland species. Well rooted dormant plants are preferred, but containerized plugs of growing plants are feasible. Planting in the fiber roll is appropriate where the roll will remain continuously wet. The plant species to be used are identified on the Supplemental Landscape Development Sheets in the project proposal or specified elsewhere in the contract documents.

Fiber rolls must be installed at an elevation which will allow the rolls to be continuously wet. This technique is not suitable where water levels fluctuate as the rolls will dry out. Size and specialized material requirements should be specified in the contract documents.

A shallow trench is excavated at the toe of the slope slightly below streambed depth. The rolls are placed in the trench and anchored with 50 by 50 by 900 mm long posts. Posts are placed on both sides of the fiber roll. Twine holds the fiber rolls together. The posts should be spaced laterally on 0.6 to 1.2 m centers. Trim the top of the posts even with the top edge of rolls as necessary. The posts are tied together

across the rolls with 16 gauge nongalvanized wire. Soil is placed behind the rolls and planted with suitable herbaceous or woody vegetation. Vegetation is placed in contact with the fiber rolls to promote rapid root extension into the rolls. Herbaceous vegetation may also be planted into the fiber rolls, as specified. If additional stabilization is necessary a brushmattress placed over the top of the roll will quickly reinforce the installation.

Fiber rolls may also be used on contours along slope faces as a erosion control measure. When used in this fashion it should not be used with herbaceous plant as conditions will not be favorable for plant growth.

J. Vegetated mat (see details)

A vegetative mat consists of a coir-woven blanket reinforced with organic or synthetic netting used along streams, channels, or bodies of water to control erosion and provide a suitable planting medium for selected plants. Vegetated mats are biodegradable and may contain selected preinstalled vegetation. As an alternative, non-vegetated mats can be planted or live-staked after installation (refer to details). These mats can contain grasses, sedges, or shrubs as specified. The plants dissipate the water's energy due to wave action or currents through leaf and stem elasticity. The mats provide a good medium for plant material, and they resist erosion.

The vegetated mats should be installed as per the manufacturer's recommendation. Once established, vegetation is self-maintaining. Slope geometry, water regime, and other site factors should be considered in determining the products to be specified in the contract documents.

K. Tree revetment (see details)

A tree revetment consists of a whole tree, except rootwad, cabled to an earth anchor which is buried in the stream bank. This method uses inexpensive, readily available materials to form temporary streambank protection. The tree revetments will capture sediment and enhance conditions for colonization of native species. They have self-repairing ability following damage after flood events if used in combination with other soil bioengineering/biotechnical engineering erosion control techniques. Tree revetments are not appropriate near bridges or other structures where there is a potential for downstream damage if a revetment dislodges. Tree revetments have a limited life and depend on year round stream conditions and durability of tree species used. They may be damaged in streams where heavy ice flows occur. This use should be limited to non-flashy streams, where the needs for future maintenance are not important.

A tree is placed along the stream bank with the basal end oriented upstream. The trunks are attached by galvanized cable and clamps to earth anchors set in the bank. Anchors should consist of commercially manufactured earth anchors inserted into the streambank. Multiple tree revetments along the stream are overlapped by approximately 25% of their length and secured together to insure continuous protection to the bank. The revetments should also extend vertically up the streambank covering two-thirds of the streambank.

Use trees that have a trunk diameter of 300 mm or larger and a trunk length of 6.0 m or greater. The best types of trees to be used as revetments are those that have a brushy top and are naturally durable wood, such as spruce, Douglas fir, or cedar. Vegetative

plantings or soil bioengineering/biotechnical engineering erosion control systems should be used within and above the structures to restore stability and establish a vegetative community. When planting in the revetment below stream-forming flow stage, plant species that will withstand inundation should be staked in openings. (Refer to details.)

There are several commercial anchoring systems available which can be installed with less disturbance to the site than is caused by installing deadmen. Substitutions for the commercial anchors may be made at the designer's discretion. Pilings may be used in lieu of earth anchors in the bank if they can be driven well below the point of a maximum bed scour. Recycled materials such as concrete anchors or structurally sound wood may also be used as substitutes, but must be a minimum of 140 mm in diameter and 1.0 m in length. These substitutes should be installed no less than 1.8 m into the streambank.

The required cable size and anchorage design are dependent upon many variables and should be custom designed to fit a specific site. A minimum cable size of 6.4 mm is recommended.

L. Log, rootwad, and boulder revetment (see details)

These revetments are systems composed of logs, rootwads, and boulders selectively placed in and on streambanks. These revetments can provide excellent overhead cover, resting areas, and shelters for insects and other fish food organisms, and can be used to increase stream velocity that results in sediment flushing and deeper scour pools.

These systems are used for stream stabilization and to create instream structures for improved fish rearing and spawning habitats. They are effective on meandering streams with out-of-bank flow conditions and they will tolerate a high boundary shear stress if logs and rootwads are well anchored. These revetments should be used in combination with soil bioengineering/biotechnical engineering erosion control systems or vegetative plantings to stabilize the upper bank and ensure a regenerative source of streambank vegetation. Log, rootwad, and boulder revetments have limited life depending on climate and tree species used. Some species, such as cottonwood or willow, often sprout and accelerate natural colonization. Revetments may need eventual replacement if natural colonization does not take place or if other soil bioengineering/biotechnical engineering erosion control methods are not used in combination.

The rootwad trunks should be conifers for maximum resistance to rot. If hardwoods must be used locust, oak or hard maple are preferred.

The combination log, rootwad, and boulder revetment is made up of a log of at least 400 mm in diameter that has a crooked and irregular shape. The rootwads should have 2.4 to 3.6 m of trunk length with numerous root protrusions attached. Loose soil should be removed, thereby exposing as many roots as possible. Rootwads are trenched into the streambank so that the tree's primary brace roots are flush with the streambank and at a slight angle facing upstream.

A footer log is installed at the toe of the eroding bank by excavating trenches at the slope or stream base to a depth of one-half the footer log diameter. The length of the footer log should be 3 to 4 times the diameter of the rootwad log, at least 1200 mm long. The footer log is placed at a slight angle upstream into the direction of the

stream flow. Boulders are used to anchor the footer log against flotation.

The boulders should meet the requirements of Item 620.05M, stone filling (HEAVY), and should be placed to anchor the footer log. The boulders should have irregular surfaces. The boulders should be at least 1.0 to 1.5 times the diameter of the rootwad trunk.

If boulders are not available, logs can be pinned into agravel and rubble substrate with 19 mm rebar 1.4 m or longer. Rebars are anchored to provide maximum pull out resistance. Cable and anchors may also be used in combination with boulders and rebar.

Backfill and combinations of vegetative plantings or soil bioengineering/biotechnical engineering erosion control systems are placed behind and above the rootwad. These can include live stakes and dormant stake plantings in the openings of the revetment below stream-forming flow stage, live stakes, bare root, or other upland methods at the top of the bank. The use of log, rootwad and boulder revetments should be limited to non-flashy streams, were the needs for future maintenance is unimportant. They should not be used upstream of bridges or other structured subject to damage or debris blockage should the revetment fail. (Refer to details.)

M. Select Clean Fill

All soil used as backfill material should be a well-graded soil suitable for vegetative growth. When utilizing several of the above mentioned techniques substantial quantities of soil may be required. It is preferable that backfill be obtained which is more economic than topsoil. A specification has been furnished by Materials Bureau which provides guidelines with which proposed backfill can be evaluated.

APPENDIX I

Woody plants with fair to good or better rooting ability from unrooted cuttings.

Scientific name	Common name
*Baccharis halimifolia**	Eastern baccharis
*Cephalanthus occidentalis**	Buttonbush
*Cornus amomum**	Silky dogwood
Cornus drummondii	Roughleaf dogwood
*Cornus foemina**	Stiff dogwood
Cornus racemosa	Gray dogwood
Cornus rugosa	Roundleaf dogwood
Cornus sericea ssp. sericea	Red-osier dogwood
*Physocarpus opulifolius**	Common ninebark
Populus balsamifera	Balsam poplar
*Populus deltoides**	Eastern cottonwood
Rosa palustris	Swamp rose
Rosa virginiana	Virginia rose
Rubus allegheniensis	Allegheny blackberry
*Rubus idaeus ssp. strigosus**	Red raspberry
*Salix amygdaloides**	Peachleaf willow
*Salix discolor**	Pussy willow
Salix exigua	Coyote willow
Salix humilis	Prairie willow
Salix interior	Sandbar willow
Salix lucida	Shining willow
Salix lutea	Yellow willow
*Salix nigra**	Black willow
Salix purpurea	Purpleosier willow
*Sambucus canadensis**	American elder
*Sambucus racemosa ssp. pubens**	Red elderberry
*Spiraea alba**	Meadowsweet spirea
*Symphoricarpos albus**	Snowberry
*Viburnum dentatum**	Arrowwood
Viburnum lantanoides	Hobblebush viburnum
*Viburnum lentago**	Nannyberry

APPENDIX II

Grasses useful in conjunction with soil bioengineering/biotechnical engineering erosion control.

Scientific name	Common name
Agrostis alba	Redtop
Ammophila breviligulata	American beachgrass
*Andropogon gerardii**	Big bluestem
Arundo donax	Giant reed
Elymus virginicus	Wildrye
Eragrostis trichodes	Sand lovegrass
Festuca rubra	Red fescue
Hemarthria altissima	Limpograss
Lolium perenne	Perennial ryegrass
Panicum amarulum	Coastal panicgrass
Panicum clandestinum	Deertongue
*Panucum virgatum**	Switchgrass
Phalaris arundinacea	Reed canarygrass
Poa pratensis	Kentucky bluegrass
*Schizachyrium scoparium**	Little bluestem
*Sorghastrum nutans**	Indian grass
*Spartina pectinata**	Prairie cordgrass
Zizaniopsis miliacea	Giant cutgrass

Salvage or collected materials

Cattails
Alnus roots
Swamp grasses/forbs-blueflag, sagittaria, filbert
Hammaelis
(*) Denotes native to New York.

Glossary of Terms

POSTS –Used for supports. (Posts shall be wood but do not have to be alive. They shall not be treated lumber.)

STAKES –Used for vegetative growth and support (live plant material).

CUTTINGS –Used for vegetative growth.

FLASHY STREAM - Stream characterized by rapidly rising and falling stages.

SEED MIX - Standard seed mix per Section 610 or otherwise specified by the Regional Landscape Architect**.**

FORB - An herb other than grass.

DIBBLE - Small tool used for planting, or to plant by means of using a small tool (i.e., a dibble.)

CAMBIUM LAYER - A thin formative layer beneath the bark of most vascular plants that is responsible for secondary growth.

BASAL END – The base of a branch, stem, or stick, not the growing tips.

10-b

Soil Bioengineering/Biotechnical Engineering—Special Specifications

Source: New York State Department of Transportation Engineering Instructions EI 02-020

Technical Information:

Soil bioengineering/biotechnical erosion control methods are revegetation and stabilization technologies applied on disturbed sites, including slopes and streambanks.

Soil bioengineering is the reliance on plant material for slope protection, rebuilding and stabilization, erosion control, etc.

Soil biotechnical engineering combines the use of plant materials and structural elements to achieve the same goal. The attached transmitted materials; vegetated cribwall, vegetated gabions, and vegetated mats are examples of soil biotechnical engineering.

Policy. Where there is a need for a more natural approach to bank stabilization, soil bioengineering/biotechnical engineering should be considered. However, a thorough assessment of the site should be undertaken to determine the appropriateness of these approaches. This site assessment should include a multidisciplinary consideration of slope geometry, aspect, climate, water regime, soil properties, and surrounding vegetation.

Consult the Regional Geotechnical Engineer, the Regional Hydraulics Engineer and the Regional Landscape Architect about characteristics of specific sites which may warrant hard armor or a combination of hard armor and soil bioengineering erosion control. Additionally the Regional Landscape Architect should be consulted for specific site conditions appropriate for these techniques and plant material recommendations.

The designer should note that with several of the specifications other items are involved which are not being paid for under the Soil Bioengineering item itself. These extra items should be taken into consideration when developing the estimate of quantities. See the table below which shows this relationship.

Items Being Specified	Associated Items Which May Be Needed
24616.11 M - Vegetated Gabion 24616.12 M - Vegetated Crib Wall 24616.13 M - Tree Revetment 24616.14 M - Rootwad Revetment 24616.15 M - Live Fascines 24616.17 M - Brushmattressing 24616.19 M - Branchpacking	24616.20 Select Clean Fill
24616.11 M - Vegetated Gabion 24616.12 M - Vegetated Crib Wall Excavation and	203.02 M Unclassified Disposal
24616.12 M - Vegetated Crib Wall	620.03 Stone Filling
24616.07-.09 M - Live Cuttings/ live Stakes 24616.10 M - Brushlayering 24616.11 M - Vegetated Gabion 24616.12 M - Vegetated Crib Wall 24616.15 M - Live Fascines 24616.16 M - Fiber Rolls 24616.17 M - Brushmattressing 24616.18 M - Vegetated Mat 24616.19 M - Branchpacking	Misc. erosion control material or methods
24616.15 M - Live Fascines 24616.16 M - Fiber Rolls 24616.17 M - Brushmattressing 24616.18 M - Vegetated Mat	24616.07-.09 M - Live Cuttings/ live Stakes
24616.17 M - Brushmattressing	24616.15 M - Live Fascines

Transmitted Materials:

New Specifications:

ITEM 24616.07-.09 M: Live Cuttings/Live Stakes
ITEM 24616.10 M: Brushlayering
ITEM 24616.11 M: Vegetated Gabion
ITEM 24616.12 M: Vegetated Crib Wall
ITEM 24616.13 M: Tree Revetment
ITEM 24616.14 M: Rootwad Revetment
ITEM 24616.15 M: Live Fascines
ITEM 24616.16 M: Fiber Rolls
ITEM 24616.17 M: Brushmattressing
ITEM 24616.18 M: Vegetated Mat
ITEM 24616.19 M: Branchpacking
ITEM 24616.20 M: Select Clean Fill

References:

U.S. Dept. of Transportation, Publication No. FHWA NHI 01-003, (March 2001)
Hydraulic Engineering Circular No. 23
"Bridge Scour and Stream Instability Countermeasures Experience, Selection, and Design Guidance, 2nd Edition"
U.S. Dept. of Transportation
Federal Highway Administration
400 7th Street, S.W. Washington, D.C. 20590
http://www.fhwa.dot.gov/

U.S. Dept. of Agriculture, Natural Resource Conservation Service, Engineering Field Handbook, Chapters 16 and18, "Soil Bioengineering for Upland Slope Protection and Erosion Reduction." December 1995
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd., Springfield VA 22161
(800) 553-6847 http://www.nrcs.usda.gov/

United States Army Corp of Engineers Technical Report EL-97-8, April 1997
"Bioengineering for Stream Bank Erosion Control"
by Allen, Hollis H. and Leech, James R.
Public Affairs Office, U.S. Army Engineer
Waterways Experiment Station
3909 Halls Ferry Rd., Vicksburg, MS 39180-6199
(601) 634-2502 http://www.wes.army.mil/

"Biotechnical and Soil Bioengineering Slope Stabilization, a Practical Guide for Erosion Control"
by Gray, Donald H. and Sotir, Robbin B.
Wiley-Interscience Publication, October 1995

Contact:

Gary Glath, Landscape Architecture Bureau at (518) 457-4460 or by E-mail at gglath@gw.dot.state.ny.us.

Item 24616.07-.09 M: Live Cutting Planting and Live stake Planting

Description

Live cuttings and live stakes consist of branch cuttings from freshly cut dormant plants. Under this item the Contractor shall furnish and install live cuttings and/or live stakes in soil, in joint plantings (plantings located in joints in riprap and stone fill), and in other erosion control applications in accordance with the contract documents.

Materials

Live cuttings shall be 12 to 25 mm in diameter and 0.3 to 1.2 m long.

Live stakes shall be 26 to 50 mm or 51 to100 mm in diameter and 1.5 to 1.8 m long.

No leaf buds shall have initiated growth beyond 6 mm and the cambium layer shall be moist, green, and healthy. All material shall be maintained in a continuously cool, covered, and moist state. All plant material shall be in good condition when installed. Materials harvested on site shall to be installed the same day they are prepared. Nursery grown material shall be soaked for 24 hours prior to installation.

The live cuttings/live stakes shall have side branches cleanly removed and with the bark intact. The basal ends shall be cut at an angle for easy insertion into the soil and the top cut square.

See contract documents for plant species, size, spacing, and planting season specifications.

Plant material substitutions shall be approved by the Engineer prior to delivery to the project site.

Water shall meet the requirements of § 712-01.

Construction Details

Live cutting/live stakes shall be planted with the pointed end in the ground.

Live cuttings shall be inserted by hand into a pilot hole. Use a dead-blow hammer to

drive live stakes into the ground. Care shall be taken not to damage live cutting/live stakes during installation. Use of a dibble, a bar, or similar tool for preforming holes and to work an access point through any rock layer is required to prevent damage to plant material during installation. Damaged plant material shall be left in place and supplemented with an intact live stake.

Live cuttings/live stakes shall be inserted at least two-thirds their length in soil. In joint plantings, live cuttings/live stakes shall be inserted to one-half their length into soil below stone fill with a minimum 50 mm to 100 mm and two buds exposed above the stone fill. When possible, upon insertion the soil around the live cutting/stake shall be tamped to insure contact with the soil.

Care of Planted Materials During Construction. The Contractor shall care for the planted materials until final acceptance of the contract. Care of planted material shall consist of keeping plant material in a healthy growing condition by watering.

When the Engineer determines that any area within the installation has failed, for any reason, to produce approximately 75% vegetative growth after a suitable period of time the Contractor shall repeat or rectify all the work required by the specification until the growth of vegetation has been established at no additional cost to the State.

Method of Measurement

The quantity of live cuttings/live stakes will be measured as the number of live cuttings/live stakes of each kind or size as set forth in the contract documents satisfactorily installed and accepted.

Basis of Payment

The unit price bid per live cuttings/live stakes shall include the cost of furnishing all labor, materials, and equipment necessary to complete the work including excavation, backfill and watering.

Item 24616.10 M: Brushlayering

Description

The brushlayering system consists of live branch cuttings installed in rows to stabilize cut and fill slope areas. Under this pay item the Contractor shall furnish and install live branch cuttings in accordance with the contract documents.

Materials

The branch cuttings shall be from freshly cut dormant plants. No leaf buds shall have initiated growth beyond 6 mm and the cambium layer shall be moist, green, and healthy. All plant material shall be maintained in a continuously cool, covered, and moist state. All plant material shall be in good condition when installed. Live plant material shall be installed within 48 hours of harvesting.

Live branch cuttings shall range from 12 to 50 mm in diameter and be long enough to reach the back of the bench. Side branches shall remain intact for installation. See contract documents for plant species, size, and planting season specifications. Plant material substitutions shall be approved by the Engineer prior to delivery or on-site harvesting.

Water shall meet the requirements of § 712-01.

Construction Details

Care shall be taken not to damage the live branch cuttings during installation. Those that are damaged shall be replaced before backfilling the layer.

Starting at the toe of the slope, excavate benches along the contour of the slope, or as specified in the contract documents. The benches shall range from 600 to 900 mm wide and the surface of the bench shall be angled so that the front edge is higher than the back of the bench. Space the benches as specified in the contract documents.

Live branch cuttings shall be placed on the bench in a crisscross or overlapping configuration in layers 75 to 100 mm thick. Branch

cutting shall be aligned with the growing tips slightly protruding out of the slope face and the basal ends to the back of the bench.

Unless otherwise specified, each lower bench shall be filled with the soil excavated from the bench above. The top bench shall be filled with soil from initial excavation. Backfill shall be placed on top of the live branch cuttings and hand tamped in 150 mm lifts. Seed or other erosion control material shall be used between the rows as stated in the contract documents.

Care of Plant Materials. The Contractor shall care for the planted materials until final acceptance of the contract. Care of planted material shall consist of keeping plant material in a healthy growing condition by watering.

When the Engineer determines that any area within the installation has failed, for any reason, to produce approximately 75% vegetative growth after a suitable period of time, the Contractor shall repeat or rectify all the work required by the specification until the growth of vegetation has been established at no additional cost to the State.

Method of Measurement

The quantity of brushlayers will be measured as the number of linear meters of vegetated layers, measured along each bench, satisfactorily installed and accepted.

Basis of Payment

The unit price bid for brushlayering shall include the cost of furnishing all labor, material, and equipment necessary to satisfactorily complete the work including excavation, backfill and watering.

Seed or other erosion control material shall be paid for under separate items.

Item 24616.11 M: Vegetated Rock Gabions

Description

Vegetated rock gabions shall consist of branch cuttings and gabions. The branch cuttings shall be installed in between horizontal layers of gabions. Under this item the Contractor shall furnish and install vegetated rock gabions in accordance with the contract documents.

Materials

Branch cuttings shall be from freshly cut dormant plants harvested from the site or nursery grown. No leaf buds shall have initiated growth beyond 6 mm and the cambium layer shall be moist, green, and healthy. All plant material shall be maintained in a continuously cool, covered, and moist state. All plant material shall be in good condition when installed. Live plant material shall be installed within 48 hours of harvest.

Live branch cuttings shall range from 12 to 25 mm in diameter. Length of the cuttings shall vary according to the size of the gabions and the depth of the cut in the embankment. See contract documents for plant species, size, and planting season specifications. Plant material substitutions shall be approved by the Engineer prior to delivery to the project.

Vegetative plantings, additional soil bioengineering techniques or other erosion control methods, if specified, shall be in accordance with the item specified.

Backfill material used shall meet the requirements of Item “Select Clean Fill”.

Water shall meet the requirements of § 712-01.

Gabions shall be as specified in § 712-15 except that the gabions and backfill shall be further specified as follows:

1. Gabions shall meet the requirements of § 712-15.B, P.V.C. Coated Galvanized Gabions.
2. Gabion filling shall consist of approximately 70% stone filling conforming to the provisions of § 712-15, Gabions and 30% Select Clean Fill Material as specified, unless stated elsewhere in the contract documents.
3. All exposed vertical surfaces of the gabions shall be lined with a rolled erosion control product meeting the requirements of § 713-07, Class II, Type B or Type C.

Construction Details

Gabions shall be installed in accordance with § 620-3.07 Gabions and as specified in the contract documents except that the gabions shall be further specified as follows:

The 70% stone filling shall be placed into the gabion. The remaining 30% of Select Clean Fill Material shall be placed on the stone layer and worked into the layers such that all voids are filled and tamped prior to closing the gabion.

A layer of backfill material shall be spread over the top of the first row of completed gabions to a thickness of 25 mm. This layer shall be raked to remove rocks larger than 15 mm. Live branch cuttings shall be placed on top of the backfill layer in a layers one or two branches thick. An additional 25 mm layer of backfill shall be spread on the live branch cuttings prior to the placement of the successive row of gabions. The cuttings shall be placed perpendicular to the slope and with the growing tips slightly protruding from the front of the gabion wall. A minimum of 300 mm of each cutting shall be in contact with backfill material. Some of the basal ends of the live branch cuttings in each layer shall reach the undisturbed soil at the back of the gabion wall.

When the Engineer determines that any area within the installation has failed, for any reason, to produce approximately 75% vegetative growth after a suitable period of time, the Contractor shall rectify all work required by the specification until the vegetative growth is established at no additional cost to the State.

Method of Measurement

The quantity to be measured shall be the number of cubic meters of vegetated gabions satisfactorily installed and accepted in accordance with the contract documents.

Basis of Payment

The unit price per cubic meter shall include the cost of furnishing all labor, materials, and equipment necessary to complete the work, including excavation and watering.

Backfill material used shall be paid for under Item “Select Clean Fill”.

Vegetative plantings, additional soil bioengineering techniques or other erosion control methods, if specified, shall be paid for under separate items.

Excavation, as required, shall be paid for under Item “Unclassified Excavation and Disposal”.

Item 24616.12 M: Vegetated Cribwall

Description

A vegetated cribwall consists of a hollow, box-like interlocking arrangement of untreated logs or timber members on a stone base as indicated on the plans. The structure is filled with soil and layers of live branch cuttings. Under this item the Contractor shall furnish and install the vegetated crib walls, and install the backfill material, in accordance with the contract documents.

Materials

Branch cuttings shall be from freshly cut dormant plants harvested from the site or nursery grown. No leaf buds shall have initiated growth beyond 6 mm and the cambium layer shall be moist, green, and healthy. All plant material shall be maintained in a continuously cool, covered, and moist state. All plant material shall be in good condition when installed. Live plant material shall be installed within 48 hours of harvest.

Live branch cuttings may range from 12 to 50 mm in diameter and long enough to reach from the front of the structure to the undisturbed soil. See contract documents for plant species, size, and planting season specifications. Plant material substitutions shall be approved by the Engineer prior to delivery to the project site.

Only untreated logs or timber shall be used in the crib wall. Logs or timber shall range from 100 to 150 mm in diameter.

Large spikes or #5 rebars are required to secure the logs or timbers together. The minimum length of the securing spikes or rebar shall be 250 mm. See contract documents for specifications.

Water shall meet the requirements of § 712-01.

Construction Details

The Contractor shall excavate a trench 600 to 900 mm deep below the existing grade at the base of the slope, or as indicated in the contract documents. The excavation shall extend into the embankment a minimum of 1.5 to 1.8 m or as indicated in the contract documents to form the foundation for the cribwall. The back of the excavation shall be slightly lower than the front.

The first course of logs or timbers shall be placed parallel to the slope at the front and back of the excavated foundation, approximately 1.2 to 1.5 m apart as indicated in the contract documents. The next course of logs or timbers shall be placed on top of and perpendicular to the previous course and fastened with spikes or rebars. The logs or timbers shall overhang the front and back of the previous course by 75 to 150 mm. The vegetated cribwall shall be battered or constructed in a stair-step fashion, as specified in the contract documents. Each course of the vegetated cribwall shall be placed in the same alternating fashion until approximately flush with the existing grade at the base of the slope.

The cribwall structure, and the excavated area behind, shall then be filled with Item stone Filling (light), from the bottom of the excavation up to the existing grade and firmly tamped. Live branch cuttings shall be placed on top of the stone filling in a layer one to two branches thick. The branches shall be orientated perpendicular to the slope with the tips slightly protruding from the front of the wall and the basal ends reaching the undisturbed soil.

Successive courses of logs or timbers and live branch cuttings shall be placed in the similar fashion as the previous courses, except the following: After the layer of light stone filling reaches the existing grade the cribwall, the area behind the structure, shall be backfilled with Select Clean Fill Material as specified elsewhere in the contract documents.

A layer of live branches, one to two branches thick, shall be placed after each transverse log course followed by a layer of hand tamped Select Clean Fill Material. Each face log course (front and rear) shall be backfilled and tamped. This shall be repeated until the wall reaches the height specified in the contract documents.

Care of Plant Materials. The Contractor shall care for the planted materials until final acceptance of the contract. Care of planted material shall consist of keeping plant material in a healthy growing condition by watering.

When the Engineer determines that any area within the installation has failed, for any reason, to produce approximately 75% vegetative growth after a suitable period of time, the Contractor shall repeat or rectify all the work required by the specification until the growth of vegetation has been established at no additional cost to the State.

Method of Measurement

The quantity of vegetated crib walls shall be measured as the number of square meters of the front wall face area satisfactorily installed and accepted in accordance with the contract documents.

Basis of Payment

The unit price bid per square meter shall include the cost of furnishing all labor, materials, and equipment necessary to complete the work including watering.

Backfill material used shall be paid for under Item “Select Clean Fill”.

Vegetative plantings, additional soil bioengineering techniques or other erosion control methods, if specified, shall be paid for under separate items.

Excavation, as required, shall be paid for under Item "Unclassified Excavation and Disposal".

Stone filling shall be paid for under Item "Stone Filling (light)".

Item 24616.13 M: Tree Revetment

Description

A tree revetment consists of a whole tree, except rootwad, cabled to an earth anchor forming a semipermanent streambank protection. Under this item the Contractor shall furnish and install tree revetments in accordance with the contract documents.

Materials

Trees shall be structurally sound, recently felled conifers with a minimum trunk diameter of 300 mm and a trunk length of 6.0 m or greater. They shall be of a species approved by the Engineer prior to installation.

Anchors shall consist of a commercially manufactured earth anchoring system specified elsewhere in the contract documents. Use of other materials or methods shall be approved by the Engineer prior to installation.

Galvanized cable shall be used to attach trees to the anchor and shall be a thickness stated in the contract documents. The cables shall be clamped together using two galvanized clamps at each connection. Additional cables shall also be used to attach tree revetments together when multiple tree revetments are specified.

Constructiona Details

Installation shall begin downstream at the farthest point of the work area. An anchor, with galvanized cable attached, shall be installed according to the manufacturers specifications.

The tree shall be laid with the butt end orientated upstream. Branches shall be trimmed on the bank side prior to placement.

Each tree shall be secured to the stream bank by galvanized cable to two anchors. The first attached to the butt end of the tree and the second to the mid-section of the tree. The cable, where attached to the tree, shall be inserted through a drilled hole, wrapped at least one and one-half times around the main trunk, and then clamped using two galvanized clamps at each connection. The cable shall be secured such that the tree is held snug to the embankment.

Where multiple tree revetments are specified they shall overlap each other by 25%. At the point of tree overlap, the trees and shall be secured together with galvanized cable and clamps.

Minor excavation and backfill may be necessary to fit the tree revetments to some stream banks.

Method of Measurement

The quantity of tree revetments will be measured as shall be the number of tree revetments satisfactorily installed and accepted.

Basis of Payment

The unit price bid per tree revetment shall include the cost of furnishing all labor, materials, and equipment necessary to complete the work including excavation and backfill.

Backfill material used shall be paid for under Item "Select Clean Fill".

Item 24616.14 M: Rootwad Revetment

Description

Rootwad revetment shall consist of a footer log, rootwad (tree stump), and boulders placed in and on streambanks to stabilize streambanks and create instream structures for improved fish rearing and spawning habitats. Under this item the Contractor shall furnish and install rootwad revetments in accordance with the contract documents.

Materials

Footer logs and rootwads shall be structurally sound conifers or other species approved by the Engineer prior to installation on the site.

The root wad shall have 2.4 to 3.6 m of trunk length, a minimum of 400 mm in diameter and a root bundle with numerous root protrusions attached. Loose soil shall be removed to expose as many roots as possible.

Footer logs shall be the same diameter as the rootwad and a length of 1.2 to 1.6 m.

Anchoring system shall be heavy stone boulders a minimum of 1 to 1.5 times the size of the revetment log diameter, approximately 400 to 600 mm in the greatest dimension weighing from 75 to 300 kg and with an irregular surface. Alternate anchoring systems shall be approved by the Engineer prior to installation.

Construction Details

Excavate for the footer log at the slope or stream base to a depth of one half the footer log diameter. Install the footer log at a slight angle upstream into the direction of the stream flow.

Each end of the footer log shall be anchored with at least three boulders. Trench and place rootwads into the stream bank so that the roots are flush with the stream bed and at a slight angle facing upstream and the trunk perpendicular to the footer log. The rootwad shall be placed in between the anchors. Backfill shall be placed around the rootwad, boulders, and to match the existing slope. The backfill shall be tamped sufficiently to secure the rootwad to the stream bank.

Method of Measurement

The quantity of rootwads will be measured as the number of rootwad revetments satisfactorily installed and accepted.

Basis of Payment

The unit price per rootwad revetment shall include the cost of furnishing all labor, materials, and equipment necessary to complete the work including excavation.

Backfill material used shall be paid for under Item “Select Clean Fill”.

Item 24616.15 M: Live Fascines

Description

Live fascines shall consist of long bundles of live branch cuttings bound together into sausage-like structures. Under this item the Contractor shall furnish, install, and backfill live fascines in accordance with the contract documents.

Materials

Live fascines shall be prepared from freshly cut dormant plants. No leaf buds shall have initiated growth beyond 6 mm and the cambium layer of each cutting shall be moist, green, and healthy. All plant material shall be maintained in a continuously cool, covered, and moist state. All plant material shall be in good condition when installed.

Live fascines shall be obtained from sources approved by the Engineer. Live fascines shall be prepared and installed within 48 hours of the time the plant material is harvested. See contract documents for plant species, size, and planting season specifications. Plant material substitutions shall be approved by the Engineer prior to delivery or on site harvesting.

Wooden posts shall be prepared from new, sound, and untreated 38 by 89 mm lumber sawn diagonally. See contract documents for length. Where specified live stakes shall be substituted for posts.

Water shall meet the requirements of § 712-01.

Construction Details

Live fascines shall be prepared in bundles 150 to 200 mm in diameter and a minimum length of 1.2 m. The bundle lengths will vary to suit the installation conditions. The tips of the branches within the live fascine shall be staggered. All growing tips shall be oriented in the same direction. Untreated natural fiber twine shall be used to tie the bundles together. The twine shall be wrapped at least twice around the bundle and tied securely at intervals not less than every 400 mm along

the length of the bundle and where bundles overlap.

Care shall be taken not to damage the live fascines during assembly or installation. Those damaged shall be replaced before installation is completed.

Trenches shall be dug along the slope as indicated in contract documents. The trenches shall be dug just large enough to contain the live fascines. Live fascines shall be placed in the prepared trenches. The fascines shall overlap by 10% of the bundle length and tied where two live fascines come together in a trench. Wooden posts shall be driven every 610 to 900 mm along length of the bundles, as shown on the plans. Any post that shatters upon installation shall be left in place and supplemented with an intact post. Extra posts shall be used at connections or bundle overlaps. The tops of the posts shall be left flush with the installed bundle.

Trenches shall be backfilled with the excavated soil, unless specified elsewhere in the contract documents. The backfill shall be tamped to minimize air voids and to insure contact with the fascine. The tops of the live fascines shall be slightly visible when the installation is complete.

Seed or other erosion control material shall be used between the fascine rows, as specified in the contract documents and paid for under separate items.

Care of Plant Materials. The Contractor shall care for the planted materials until final acceptance of the contract. Care of planted material shall consist of keeping plant material in a healthy growing condition by watering.

When the Engineer determines that any area within the installation has failed, for any reason, to produce approximately 75% vegetative growth after a suitable period of time, the Contractor shall repeat or rectify all the work required by the specification until the growth of vegetation has been established at no additional cost to the State.

Method of Measurement

The quantity of live fascines will be measured as the number of linear meters of live fascines satisfactorily installed and accepted.

Basis of Payment

The unit price bid per linear meter of live fascines shall include the cost of furnishing all labor, material, and equipment necessary to satisfactorily complete the work including excavation and watering.

Backfill material used shall be paid for under Item “Select Clean Fill”.

Seed or other erosion control materials and techniques, if specified, shall be paid for under separate items.

Item 24616.16 M: Fiber Rolls

Description

A fiber roll is a coir, straw or excelsior woven roll encased in webbing. The tube material may be burlap unless otherwise specified in the Contract Documents. Fiber rolls are used to dissipate energy along banks of streams, channels, bodies of water or on slope contours. It must demonstrate the ability to conform to terrain details and reduce water velocity.

Materials

The fiber roll shall be of the size and type specified elsewhere in the Contract Documents. The following minimum performance requirements shall be met as verified by the manufacturer’s written certification:

- Sediment retention capacity of 40 kg/m under a minimum of three simulated 10 year predicted storm events on a 3:1 slope with clayey sand soil.
- Soil loss effectiveness shall not be less than 50% (minimum sediment yield reduction value) under the simulated rainfall event specified above.
- The maximum destabilizing moisture content of the fiber rolls shall not exceed 10% under the simulated rainfall event described above.

Wooden posts shall be prepared from new, sound, and untreated 50 by 50 mm lumber a minimum of 900 mm long.

Wire used to secure fiber rolls shall be 16 gauge nongalvanized wire.

Construction Details

The fiber roll manufacturer and the product proposed for use shall be approved by the Engineer prior to delivery to the project site based on the manufacturer's certification indicating compliance with the material requirements.

Under this item the Contractor shall furnish and install fiber rolls in accordance with the contract documents.

Installation includes, all excavation and backfill necessary to embed and fit the material to the proposed site.

Install vegetative plantings and use other erosion control methods and techniques were specified in the Contract documents.

Method of Measurement

The quantity of fiber rolls will be measured as the number of linear meters of fiber rolls satisfactorily installed and accepted.

Basis of Payment

The unit price bid per linear meter shall include the cost of furnishing all labor, materials, and equipment necessary to complete the work.

Vegetative plantings, additional soil bioengineering techniques or other erosion control methods, if specified, shall be paid for under separate items.

Item 24616.17 M: Brushmattress

Description

Brushmattressing consists of a combination of branch cuttings, posts, wire and backfill installed to cover and stabilize stream banks. Under this item the Contractor shall furnish and install select vegetative material and place select clean fill material in accordance with the contract documents.

Materials

Live branch cuttings shall be from freshly cut dormant plants harvested from the site or nursery grown. No leaf buds shall have initiated growth beyond 6 mm and the cambium layer shall be moist, green, and healthy. All plant material shall be maintained in a continuously cool, covered, and moist state. All plant material shall be in good condition when installed. Live plant material shall be installed within 48 hours of harvest.

Live branch cuttings shall range from 25 mm and smaller diameters and from 1.8 to 2.7 m long. Live stakes, if specified in the contract documents, shall be 26 to 100 mm in diameter and 0.9 to 1.2 m long. See contract documents for plant species, size, and planting season specifications. Plant material substitutions shall be approved by the Engineer prior to delivery to the project site or on-site harvesting.

Wooden posts shall be used to secure the material in place. Wooden posts shall be prepared from new, sound, untreated 38 by 89 mm lumber sawn diagonally and 0.9 to 1.2 m long.

Wire used for securing brush and fascines shall be 16 gauge nongalvanized wire.

Water shall meet the requirements of § 712-01.

Backfill shall meet the requirements of Item "Select Clean Fill".

Construction Details

Installation shall begin at base of the slope as specified in the contract documents. If specified, a trench for live fascine and branch ends shall be excavated. Branch cuttings shall be placed in a layer two or three branches thick on the prepared slope with basal ends facing down slope. Posts shall be installed to a minimum depth of 500 mm over the face of the graded area using 600 mm spacing. Live stakes, if specified, shall be used in place of every other post.

Wire shall be stretched diagonally from one post to another, **excluding live stakes,**

if specified. The wire shall be wrapped tightly around each post no closer than 150 mm from its top. The posts shall be driven into the ground until branches are tightly secured to the slope. The entire area of installation shall be covered with approximately 100 mm of backfill and tamped to work soil into the branch layer. The top surface of the brush mattress shall be left slightly exposed.

If specified, the live fascines shall be constructed as stated elsewhere in the contract documents.

The fascines shall be placed in a prepared trench, over the basal ends of the branches at the base of the brushmattress. The fascine shall be staked with posts as specified and fastened to the posts with wire. The trench shall be backfilled and any voids between brushmattresses and fascine shall be filled with soil. The backfill shall be tamped to insure contact with fascine and branches.

Care of Plant Materials. The Contractor shall care for the planted materials until final acceptance of the contract. Care of planted material shall consist of keeping plant material in a healthy growing condition by watering.

When the Engineer determines that any area within the installation has failed, for any reason, to produce approximately 75% vegetative growth after a suitable period of time, the Contractor shall repeat or rectify all the work required by the specification until the growth of vegetation has been established at no additional cost to the State.

Method of Measurement

The quantity of brushmattress will be measured as the number of square meters of surface area satisfactorily installed and accepted.

Basis of Payment

The unit price bid per square meter shall include the cost of furnishing all labor, materials, and equipment necessary to complete the work including excavation and watering.

Live stakes and live fascines, if specified in the contract documents, shall be paid under separate items.

Seed or other erosion control material shall be paid for under separate items.

Backfill material used shall be paid for under Item “Select Clean Fill”.

Item 24616.18 M: Vegetated Mat

Description

A vegetative mat consists of a reinforced coir-woven blanket used along banks of streams, channels, or bodies of water to control erosion and provide a suitable planting medium for selected plants. Under this item the Contractor shall furnish and install vegetative mats in accordance with the contract documents.

Materials

The vegetative mat shall meet the minimum requirements of § 713-07 Class 1, Type C erosion control material or as specified otherwise in the contract documents. In addition, the matrix shall be no less than 70% coconut fiber and 30% straw, excelsior, rice straw or other approved material and be manufacturer-certified 100% weed free. The matrix shall be encased in a net material which shall be an open mesh, photodegradable or biodegradable material with a grid size of between 5 and 10 mm. The netting material shall be attached on both sides of the matrix and stitched together. The netting shall have a minimum effective life span of no less than one year.

Construction Details

Vegetative mats shall be installed according to manufacturers recommendations, except when otherwise specified in the contract documents.

The Contractor shall supply vegetative mats as specified in the contract documents. The vegetated mat manufacturer and the product proposed for use shall be approved by the Engineer prior to delivery to the site. Herbaceous plugs and other erosion control

methods and techniques may be specified in the Contact Documents.

Method of Measurement

The quantity of vegetated mat will be measured as the number of square meters of surface area satisfactorily installed and accepted in accordance with the plans.

Basis of Payment

The unit price per square meter shall include the cost of furnishing all labor, materials, and equipment necessary to complete the work.

Herbaceous plugs, live cuttings, live stakes, fiber rolls, live fascines or other erosion control items shall be paid for under the item specified, if used in conjunction with vegetative mats.

Item 24616.19 M: Branchpacking

Description

Branchpacking consists of alternate layers of live branch cuttings and tamped backfill to repair small localized slumps and holes in slopes. Under this item the Contractor shall furnish and install select vegetative material and place select clean fill material, in accordance with the contract documents.

Materials

Branchpackings shall consist of branch cuttings from freshly cut dormant plants. On branches no leaf buds shall have initiated growth beyond 6 mm and the cambium layer shall be moist, green, and healthy. All plant material shall be maintained in a continuously cool, covered, and moist state. All material shall be in good condition when installed. Live plant material shall be installed within 48 hours of harvesting.

Live branch cuttings may range from 12 to 50 mm in diameter. They shall be long enough to touch the undisturbed soil at the back of the trench and extend slightly from the rebuilt slope face. See contract documents for plant species, size, and planting season specifications. Plant material substitutions shall be approved by the Engineer prior to delivery to the project site.

Wooden posts shall be used to secure the material in place. These posts shall be 1.5 to 2.4 m long and made from 75 to 100 mm diameter poles or 38 by 89 mm lumber, depending upon the depth of the particular slump or hole. Where specified, live stakes shall be used in place of posts.

Water shall meet the requirements of § 712-01.

Backfill shall meet the requirements of Item “Select Clean Fill”.

Construction Details

Installation shall begin at the lowest point of the work area. Wooden posts shall be spaced in a grid pattern, throughout slump or hole, 300 to 450 mm apart and driven vertically into the ground to a depth of 0.9 to 1.2 m.

A layer of live branch cuttings 100 to 150 mm thick is to be placed between the posts and perpendicular to the slope face. They shall be placed in a crisscross configuration with the basal ends lower than the growing tips. Some of the basal ends of the branches shall touch the back of the hole or slope and the growing tips shall be generally oriented toward and protruding from the slope face.

Each layer of branches shall be covered by a layer of moistened backfill 450 to 900 mm thick. The soil layer shall be hand tamped in 175 mm lifts to minimize air voids and insure contact with the branches.

The final grade installation shall match the existing slope.

Care of Plant Materials. The Contractor shall care for the planted materials until final acceptance of the contract. Care of planted material shall consist of keeping plant material in a healthy growing condition by watering.

When the Engineer determines that any area within the installation has failed, for any reason, to produce approximately 75% vegetative growth after a suitable period of time, the Contractor shall repeat or rectify all

the work required by the specification until the growth of vegetation has been established at no additional cost to the State.

Method of Measurement

The quantity of branchpacking will be measured as the total number of square meters of surface area satisfactorily installed and accepted, as measured along the slope face.

Basis of Payment

The unit price bid per square meter shall include the cost of furnishing all labor, materials, and equipment necessary to complete the work including watering.

Excavation shall be paid for separately.

Seed or other erosion control material shall be paid for under separate items.

Backfill material used shall be paid for under Item "Select Clean Fill".

Item 24616.20 M: Select Clean Fill

Description

Select clean fill material is a naturally occurring soil having characteristics making it suitable for promoting plant growth. Under this item the Contractor shall furnish this backfill material for installation between the payment lines shown on the plans or as otherwise specified.

Material

Place the material in a storage pile in a manner that ensures uniformity throughout the pile.

Backfill shall be a reasonably well graded naturally occurring soil meeting the following requirements:

Gradation:

Sieve Designation	Percent Passing by Weight
75 mm	100
2 mm	50
0.075 mm	20

Organic Content: Not less than 1% or greater than 5%.

pH: Between 5.5 and 7.6.

Material acceptance will be based on visual inspection by the Engineer, or his/her representative, unless the State elects to test the material for the criteria listed previously.

Construction Details

The material shall be hand tamped into place as required in the applicable specifications.

Method of Measurement

The quantity of Select Clean Fill will be measured as the number of cubic meters of fill satisfactorily installed and accepted within the payment lines shown in the Contract Documents.

Basis of Payment

The unit price bid per cubic meter shall include the cost of furnishing all labor, materials, and equipment necessary to satisfactorily complete the work.

EB 02-037Soil Bioengineering/ Biotechnical Engineering - Details

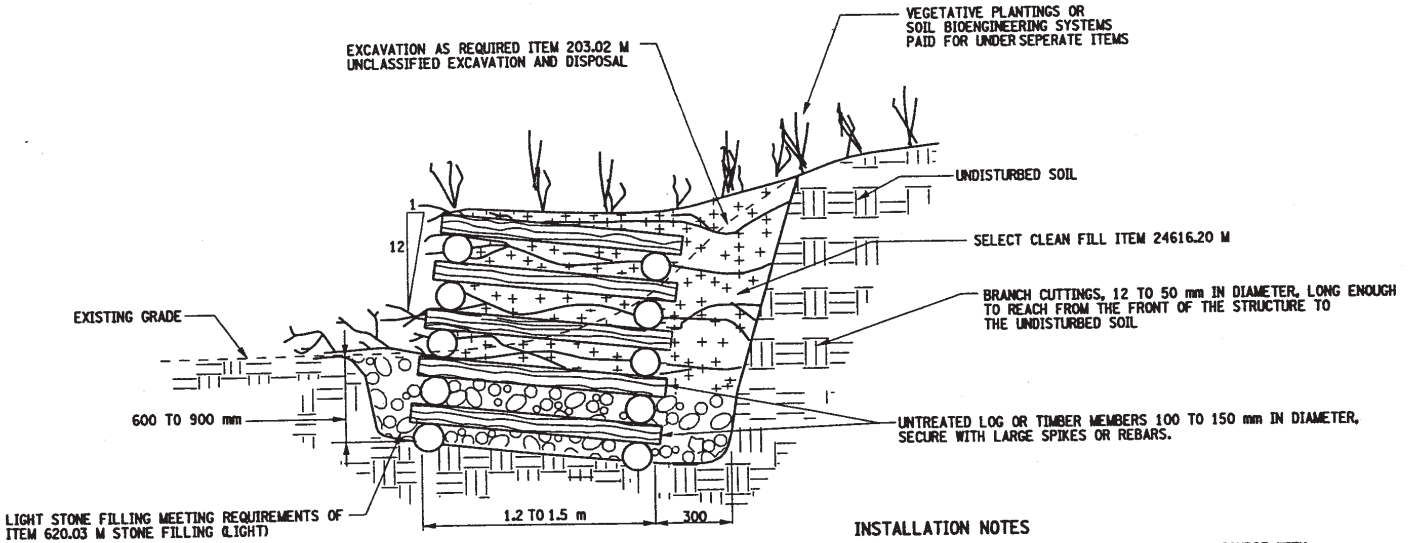
Technical Information:

The details attached to this EB should be incorporated in contract documents when using the corresponding special specifications issued in EI 02-020, Soil Bioengineering/ Biotechnical Engineering - Special Specifications.

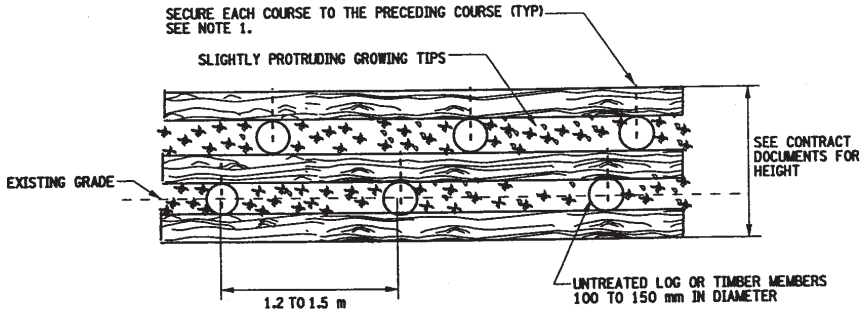
Additional guidance and resources are available to designers in EI 02-019, Soil Bioengineering/Biotechnical Engineering - Design Guidance.

Contact

Direct questions regarding this EB to Gary Glath in the Landscape Architecture Bureau at (518) 457-4460 or by e-mail at gglath@gw.dot.state.ny.us.



CROSS SECTION



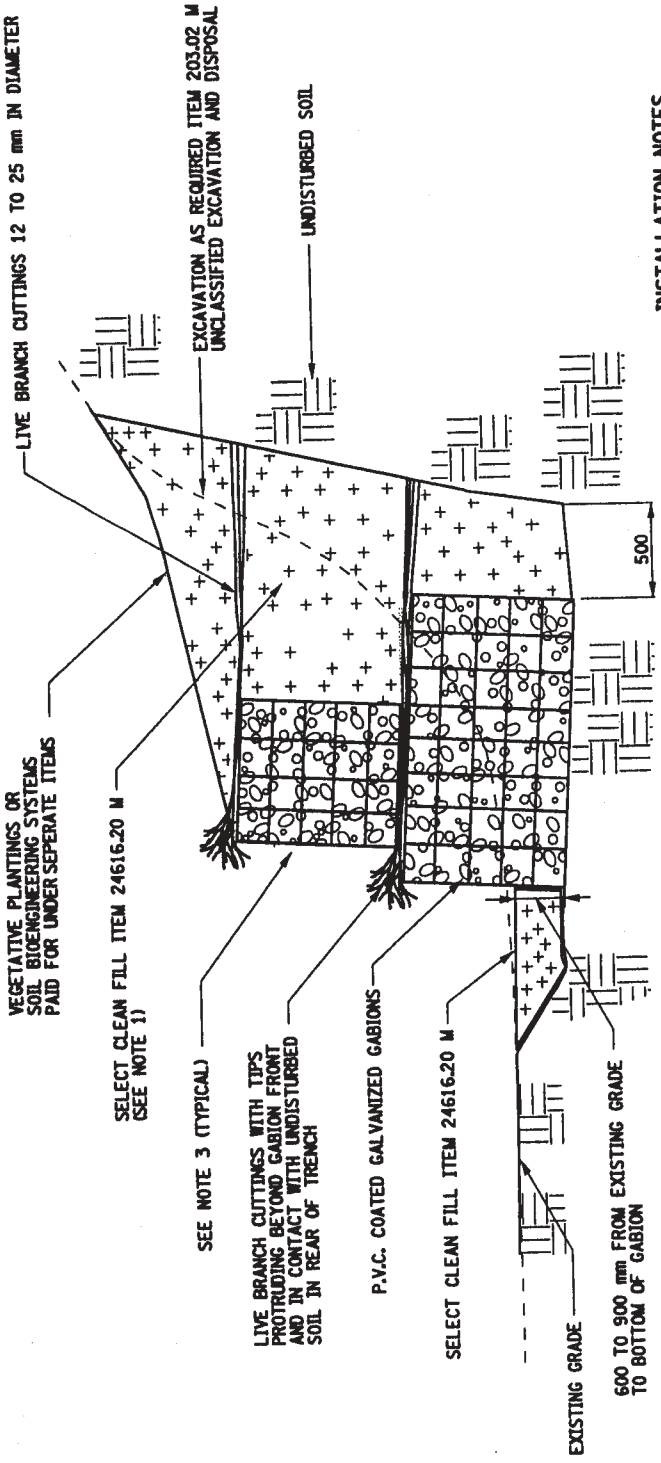
FRONT ELEVATION

INSTALLATION NOTES

1. EACH COURSE SHALL BE SECURED TO THE PRECEDING COURSE WITH SPIKES OR REBARS. SEE CONTRACT DOCUMENTS FOR SIZE AND LENGTH.
2. BACKFILL IN AND AROUND TIMBER CRIB WITH ITEM 620.03 M STONE FILLING (LIGHT) FROM BOTTOM OF EXCAVATION TO THE LOWER GROUND LEVEL, OR WHEN IN STREAM CHANNEL UP TO BASEFLOW.
3. EACH TRANSVERSE LOG COURSE CONTAINS LIVE CUTTINGS FOLLOWED BY A LAYER OF TAMPED BACKFILL.
4. EACH FACE LOG COURSE (FRONT AND REAR), AND THE ARE BEHIND THE STRUCTURE, SHALL BE BACKFILLED AND HAND TAMPED.

VEGETATED CRIB WALL DETAIL

NOT TO SCALE



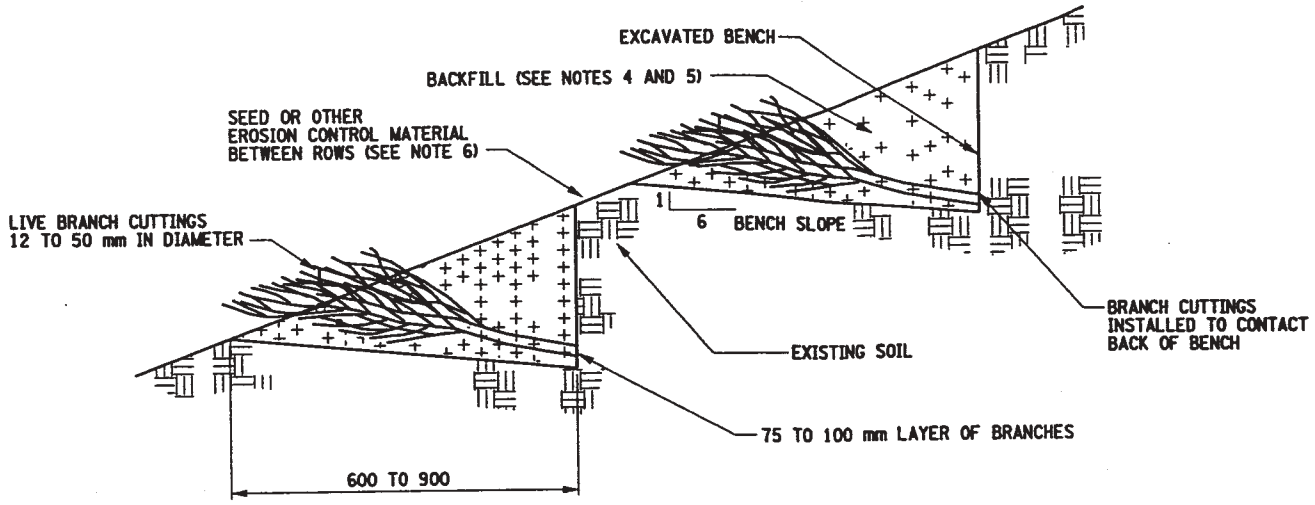
CROSS SECTION

INSTALLATION NOTES

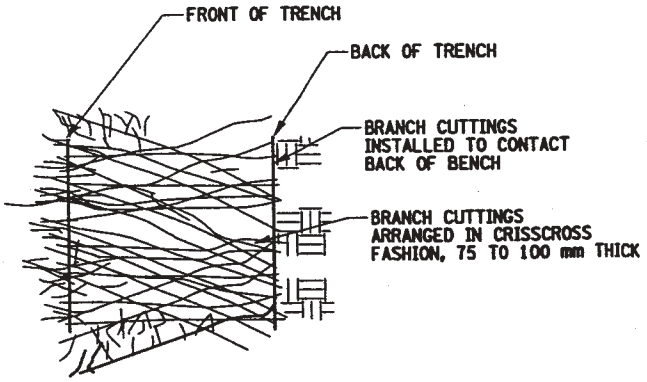
1. BACKFILL BEHIND GABIONS HAND TAMPING IN 150 MM LIFTS
2. A 25 mm LAYER OF BACKFILL SHALL BE PLACED ON TOP OF THE ROW OF GABIONS AND RAKED. THE CUTTINGS SHALL BE PLACED ON THE BACKFILL MATERIAL AND ANOTHER 25 MM OF BACKFILL SHALL BE PLACED ON THE CUTTINGS BETWEEN THE GABIONS.
3. CLASS 2, TYPE B OR C, INTERMEDIATE EROSION CONTROL PRODUCT SHALL BE INSTALLED ON THE FRONT INSIDE FACE AND ANY OTHER EXPOSED VERTICAL SURFACE OF THE GABION.

VEGETATED ROCK GABIONS

NOT TO SCALE



CROSS SECTION OF BRUSHLAYER ON CUT SLOPE



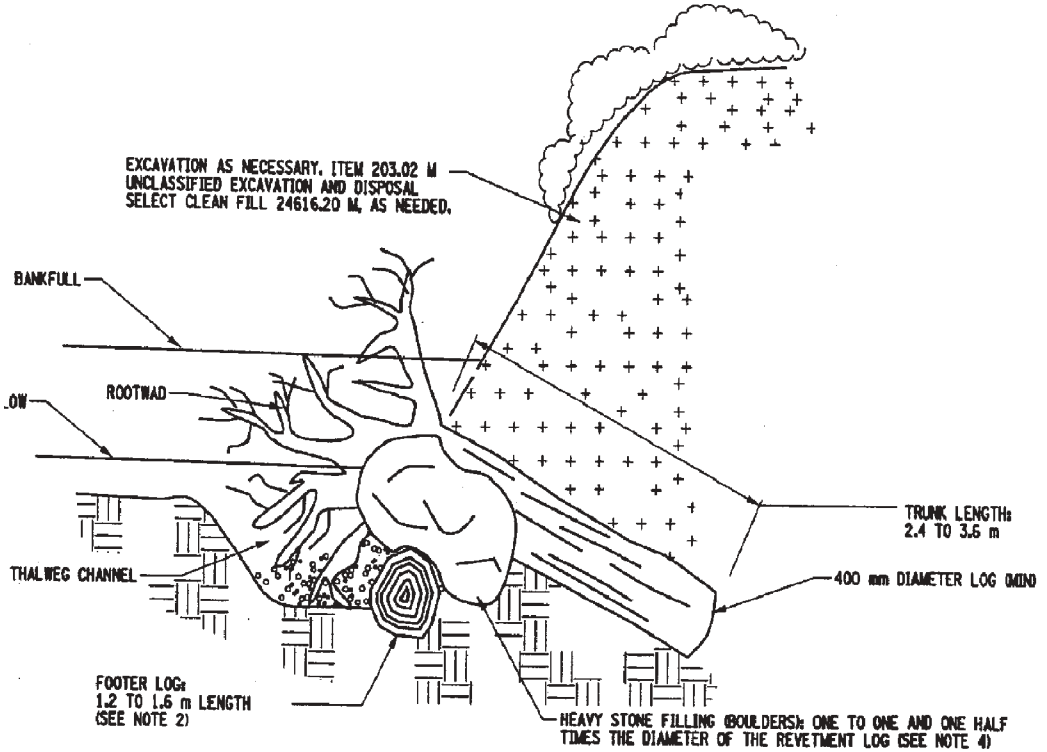
PLAN VIEW

INSTALLATION NOTES

1. BENCH SHALL BE ANGLED SO OUTSIDE EDGE IS HIGHER THAN BACK OF BENCH.
2. LIVE BRANCH CUTTINGS SHALL BE PLACED ON THE BENCH IN A CRISSCROSS OR OVERLAP CONFIGURATION, 75 TO 100 mm THICK.
3. GROWING TIPS SHALL BE ALIGNED OUT OF THE SLOPE FACE AND SHALL EXTEND SLIGHTLY BEYOND THE FILL AREA.
4. FILL EACH LOWER BENCH WITH SOIL EXCAVATED FROM THE BENCH ABOVE. TOP BENCH TO BE BACKFILLED WITH INITIAL EXCAVATION.
5. PLACE BACKFILL ON TOP OF BRANCHES AND HAND TAMP IN 150 mm LIFTS TO ELIMINATE AIR POCKETS.
6. SEED OR OTHER EROSION CONTROL MATERIAL SHALL BE USED BETWEEN THE ROWS AS STATED IN THE CONTRACT DOCUMENTS AND PAID UNDER SEPARATE ITEMS.
7. BRUSHLAYER BENCHES SHALL BE FROM 0.9 TO 1.5 m APART, ACCORDING TO CONTRACT DOCUMENTS MEASURED BETWEEN FRONT EDGE OF BENCHES.

BRUSHLAYER DETAILS

NOT TO SCALE



CROSS SECTION

INSTALLATION NOTES

ROOT WADS SHALL HAVE A 2.4 TO 3.6 m TRUNK ATTACHED AND HAVE NUMEROUS ROOT PROTRUSIONS.

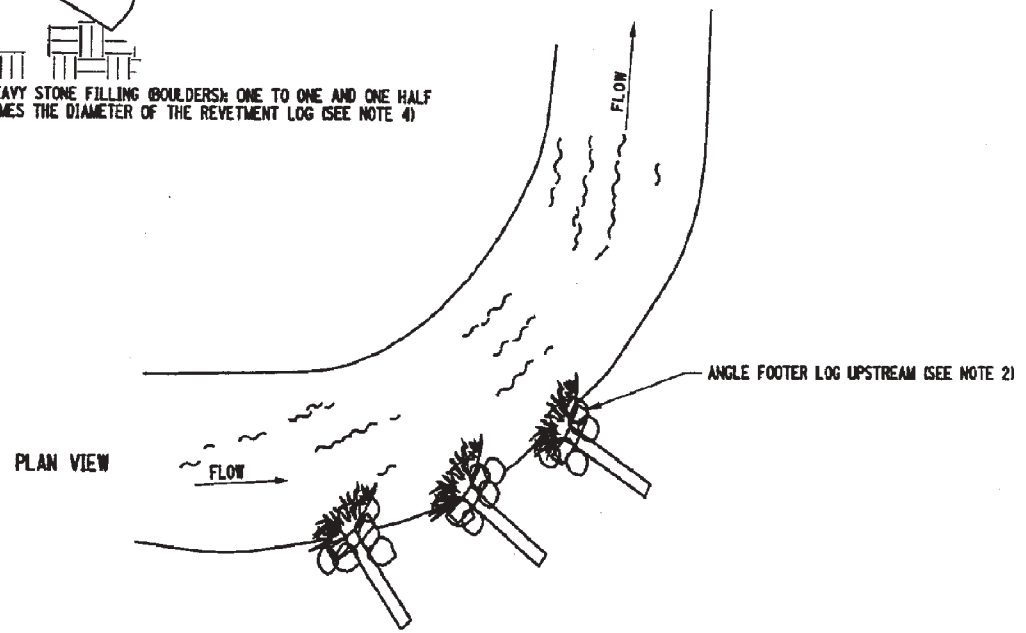
INSTALL A FOOTER LOG 1.2 TO 1.6 m IN LENGTH AT THE SLOPE OR CHANNEL BASE, EXCAVATING BELOW THE STREAMBED TO ½ THE FOOTER LOG DIAMETER. THE FOOTER LOG SHALL BE THE SAME DIAMETER AS THE ROOTWAD TRUNK. THE FOOTER LOG IS PLACED AT A SLIGHT ANGLE FACING UPSTREAM INTO THE DIRECTION OF THE STREAM FLOW.

ANCHOR THE FOOTER WITH BOULDERS. ALTERNATIVE ANCHOR SYSTEMS MAY BE SUBMITTED FOR APPROVAL.

ANCHORING SYSTEM SHALL BE HEAVY STONE BOULDERS. BOULDER SIZE WILL BE A MINIMUM OF 1 TO 1½ TIMES THE REVETMENT LOG DIAMETER, APPROXIMATELY 400 TO 600 mm IN THE GREATEST DIMESION WEIGHING FROM 75 TO 300 kg AND WITH AN IRREGULAR SURFACE. ALTERNATE ANCHORING SYSTEMS SHALL BE APPROVED BY THE ENGINEER.

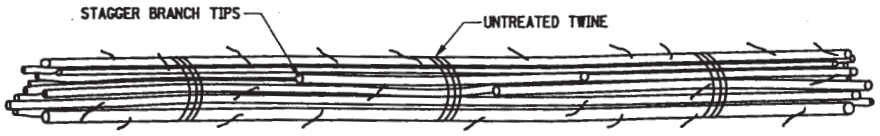
TRENCH THE ROOTWAD TRUNK INTO THE BANK SO THAT THE TRUNK IS ANGLED SLIGHTLY UPSTREAM. BACKFILL AS NECESSARY.

THE ROOTWAD TRUNKS SHOULD BE CONIFERS OR OTHER SPECIES APPROVED THE ENGINEER PRIOR TO INSTALLATION.



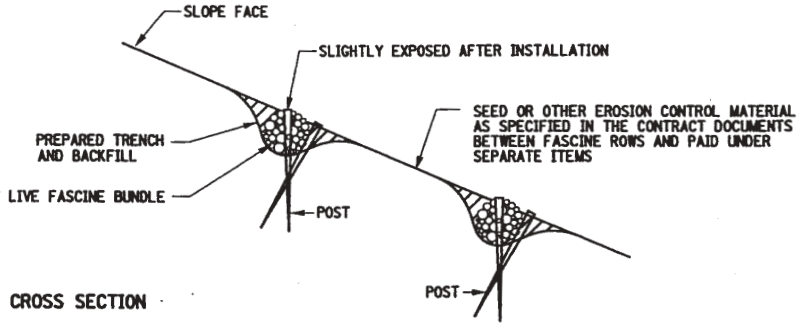
ROOTWAD REVETMENT DETAIL

NOT TO SCALE



150 mm - 200 mm DIAMETER AND
MINIMUM LENGTH OF 1.2 m REQUIRED

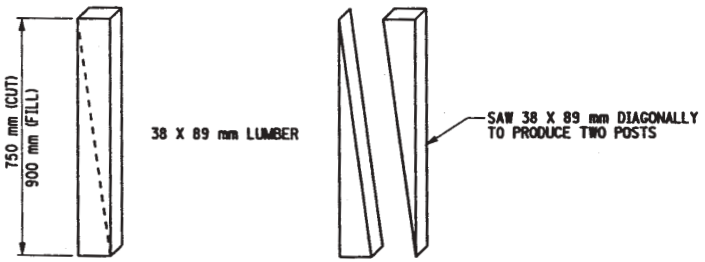
FASCINE BUNDLE DETAIL



CROSS SECTION

INSTALLATION NOTES

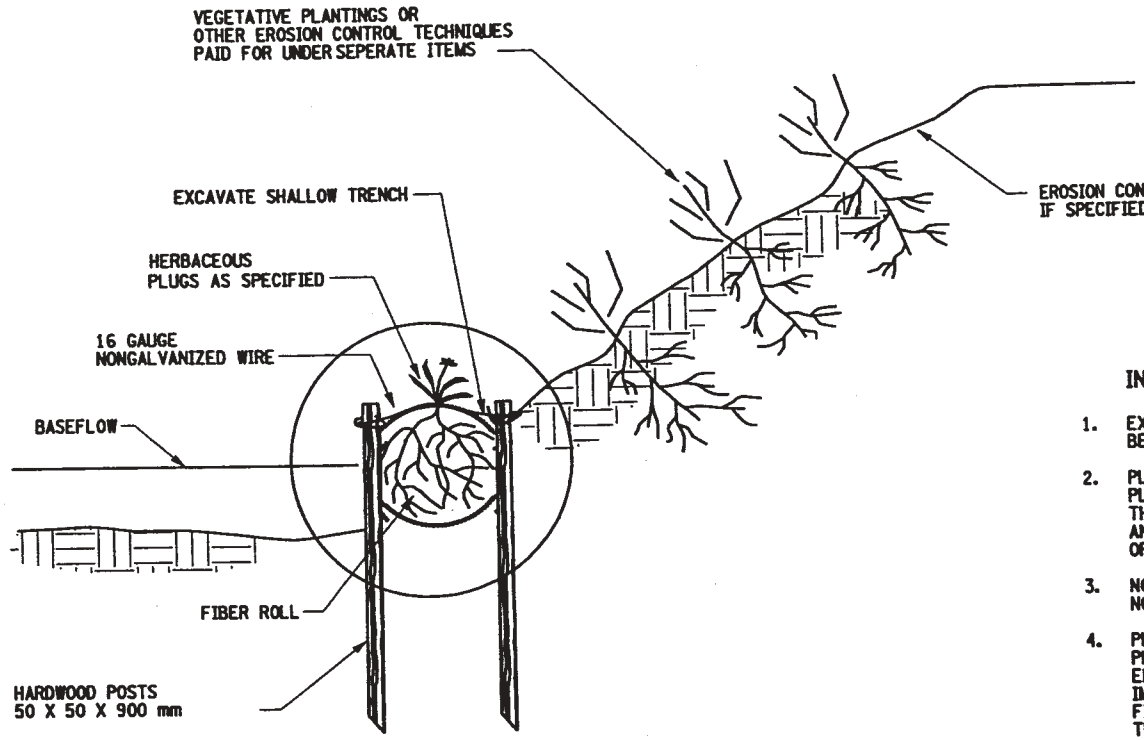
1. LIVE FASCINES SHALL BE PREPARED FROM FRESHLY CUT DORMANT PLANTS.
2. LIVE FASCINE SHALL BE PREPARED AND INSTALLED WITHIN 48 HOURS OF THE TIME THE MATERIAL IS HARVESTED.
3. LIVE FASCINE SHALL BE OBTAINED FROM SOURCES APPROVED BY THE ENGINEER.
4. LIVE FASCINES SHALL BE 150 TO 200 mm IN DIAMETER. LENGTHS MAY VARY TO SUIT CONDITIONS. A MINIMUM LENGTH OF 1.2 m IS REQUIRED.
5. THE TIPS OF THE BRANCHES WITHIN THE LIVE FASCINE SHALL BE STAGGERED WITH ALL GROWING TIPS ORIENTED IN THE SAME DIRECTION. ONLY UNTREATED NATURAL FIBER TWINE SHALL BE USED TO SECURE THE BUNDLE.
6. FASCINES SHALL BE PLACED AS INDICATED IN THE CONTRACT DOCUMENTS.
7. BEGINNING AT THE BASE OF THE SLOPE, A TRENCH SHALL BE DUG LARGE ENOUGH TO CONTAIN THE LIVE FASCINE. THE LIVE FASCINE SHALL BE PLACED IN THE TRENCH. WHERE ENDS MEET IN THE TRENCH, THE FASCINES SHALL OVERLAP BY 10% OF THE FASCINE LENGTH.
8. WOOD POSTS SHALL BE DRIVEN FLUSH TO TOP OF FASCINE EVERY 610 TO 910 mm ALONG THE LENGTH OF THE BUNDLES AS SHOWN ON THE CROSS SECTION. WHERE SPECIFIED LIVE STAKES MAY BE USED IN PLACE OF POSTS.
9. THE TRENCH SHALL BE BACKFILLED WITH MOIST SOIL AND HAND TAMPED. THE TOP OF THE FASCINE SHALL BE SLIGHTLY VISIBLE WHEN THE INSTALLATION IS COMPLETE AS SHOWN ON THE CROSS SECTION.
10. SEED OR OTHER EROSION CONTROL MATERIAL SHALL BE USED BETWEEN THE FASCINE ROWS, AS SPECIFIED IN THE CONTRACT DOCUMENTS AND PAID FOR UNDER SEPARATE ITEMS.
11. LIVE FASCINE TRENCHES SHALL BE FROM 0.9 TO 3.0 m APART, ACCORDING TO THE CONTRACT DOCUMENTS.



POST DETAIL

LIVE FASCINE DETAIL

NOT TO SCALE



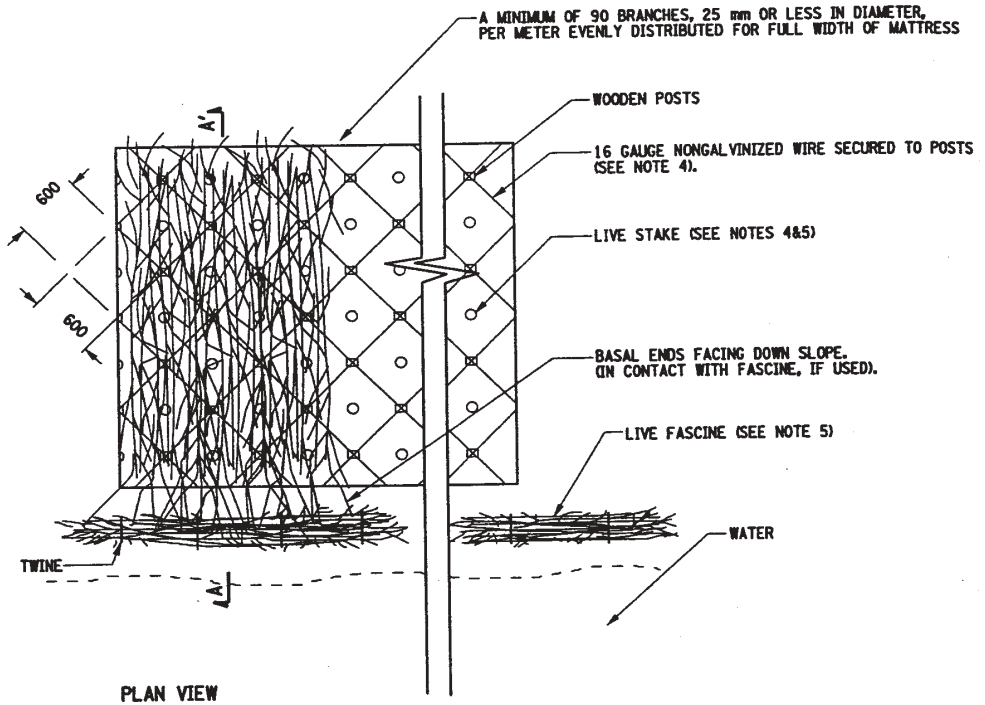
CROSS SECTION

INSTALLATION NOTES

1. EXCAVATE A SHALLOW TRENCH AT THE TOE OF SLOPE TO SLIGHTLY BELOW BASEFLOW.
2. PLACE THE ROLL IN THE TRENCH AND ANCHOR WITH 50 x 50 mm POSTS PLACED ON BOTH SIDES OF THE ROLL. POSTS ARE INSERTED BETWEEN THE FIBER ROLL AND THE TWINE, WHICH HOLDS THE ROLL TOGETHER, AND SPACED LATERALLY ON 600 TO 1200 mm CENTERS. TRIM THE TOP OF THE POSTS EVEN WITH THE TOP EDGE OF THE ROLL, IF NECESSARY.
3. NOTCH THE POSTS AND TIE TOGETHER, ACROSS THE ROLL, WITH 16 GAUGE NONGALVANIZED WIRE.
4. PLACE SOIL EXCAVATED FROM THE TRENCH BEHIND THE ROLL AND HAND TAMP. PLANT WITH SUITABLE HERBACEOUS OR WOODY VEGETATION AS SPECIFIED ELSEWHERE IN THE CONTRACT DOCUMENTS. VEGETATION SHALL BE PLACED IMMEDIATELY ADJACENT TO THE ROLL TO PROMOTE ROOT GROWTH INTO THE FIBER. HERBACEOUS VEGETATION, IF SPECIFIED, SHALL BE PLANTED INTO THE FIBER ROLL.

FIBER ROLL DETAIL

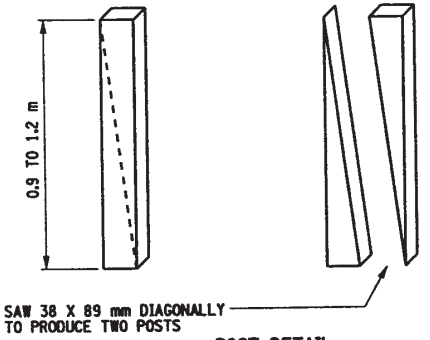
NOT TO SCALE



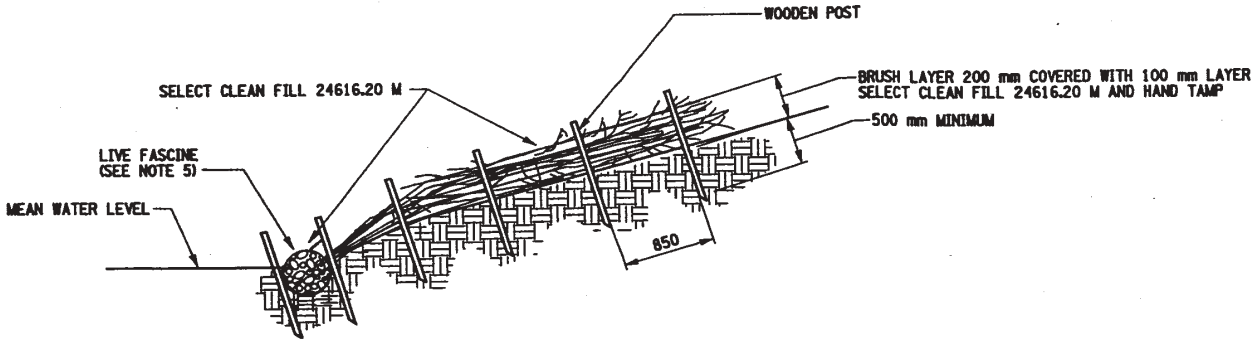
PLAN VIEW

INSTALLATION NOTES:

1. LAYERS SHALL BE COMPRISED OF LIVE QUICK-ROOTING SPECIES, SEE CONTRACT DOCUMENTS.
2. COVER MATTRESS WITH SOIL AND EVENLY DISTRIBUTE TO APPROXIMATELY 100 mm IN DEPTH AND HAND TAMP.
3. PLACE POSTS EVENLY OVER THE GRADED FACE USING 600 mm SQUARE SPACING. IF LIVE STAKES ARE SPECIFIED, ALTERNATE EVERY OTHER ONE WITH THE POSTS.
4. STRETCH 16 GAUGE NONGALVANIZED WIRE DIAGONALLY FROM ONE POST TO ANOTHER BY TIGHTLY WRAPPING WIRE AROUND POSTS, NO CLOSER THAN 150 mm FROM THE TOP OF POST. WIRE SHALL NOT BE ATTACHED TO LIVE STAKES, IF THEY ARE SPECIFIED.
5. LIVE FASCINES AND LIVE STAKES ARE INSTALLED WHEN AND WHERE DIRECTED ON THE PLAN SHEET AND PAID FOR UNDER SEPARATE ITEM.



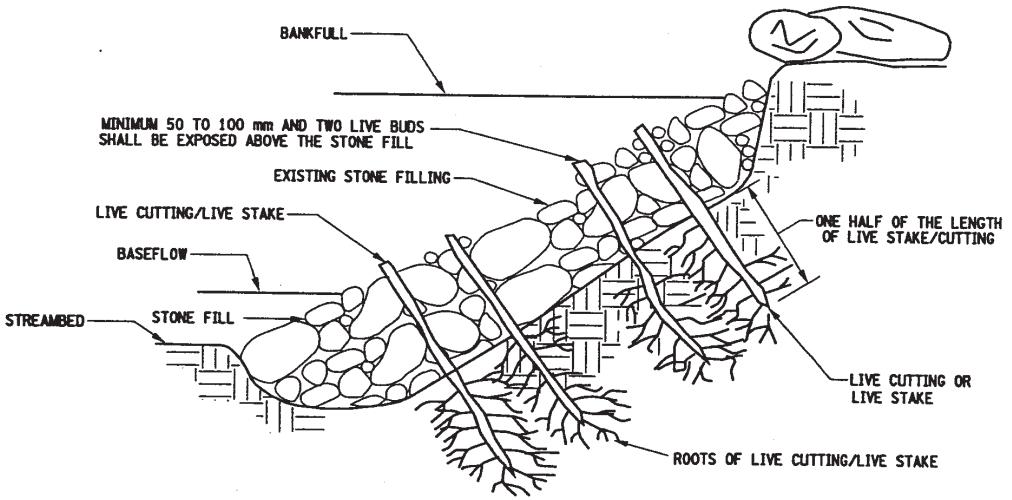
POST DETAIL



SECTION A-A'

BRUSHMATTRESS DETAILS

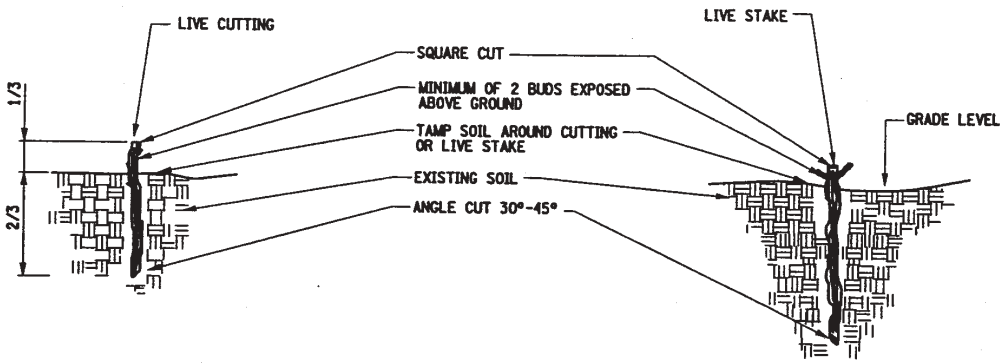
NOT TO SCALE



LIVE CUTTING/LIVE STAKE JOINT PLANTING CROSS SECTION

INSTALLATION NOTES:

1. CARE SHALL BE TAKEN NOT TO DAMAGE THE LIVE CUTTINGS/LIVE STAKES DURING INSTALLATION. THOSE DAMAGED SHALL BE LEFT IN PLACE AND SUPPLEMENTED WITH AN INTACT LIVE CUTTING/LIVE STAKE.
2. THE LENGTHS OF LIVE CUTTINGS/LIVE STAKES DEPENDS UPON THE APPLICATION. THE LENGTH SHALL EXTEND THROUGH THE SURFACE OF THE STONEFILL. AT LEAST HALF THE LENGTH SHALL BE INSERTED IN TO THE SOIL, BELOW THE STONE FILL.
3. A PILOT HOLE IS REQUIRED TO ENSURE THAT THE LIVE CUTTING/LIVE STAKE IS NOT DAMAGED WHEN DRIVEN THROUGH THE STONE FILLING. ACCESS SHALL BE MADE THROUGH THE USE OF A DIBBLE BAR, OR SIMILAR TOOL TO WORK AN OPENING THROUGH THE ROCK LAYER.
4. MINIMUM 50 TO 100 mm AND TWO LIVE BUDS OF THE LIVE CUTTING/LIVE STAKE SHALL BE EXPOSED ABOVE THE STONE FILLING.



LIVE CUTTING CROSS SECTION

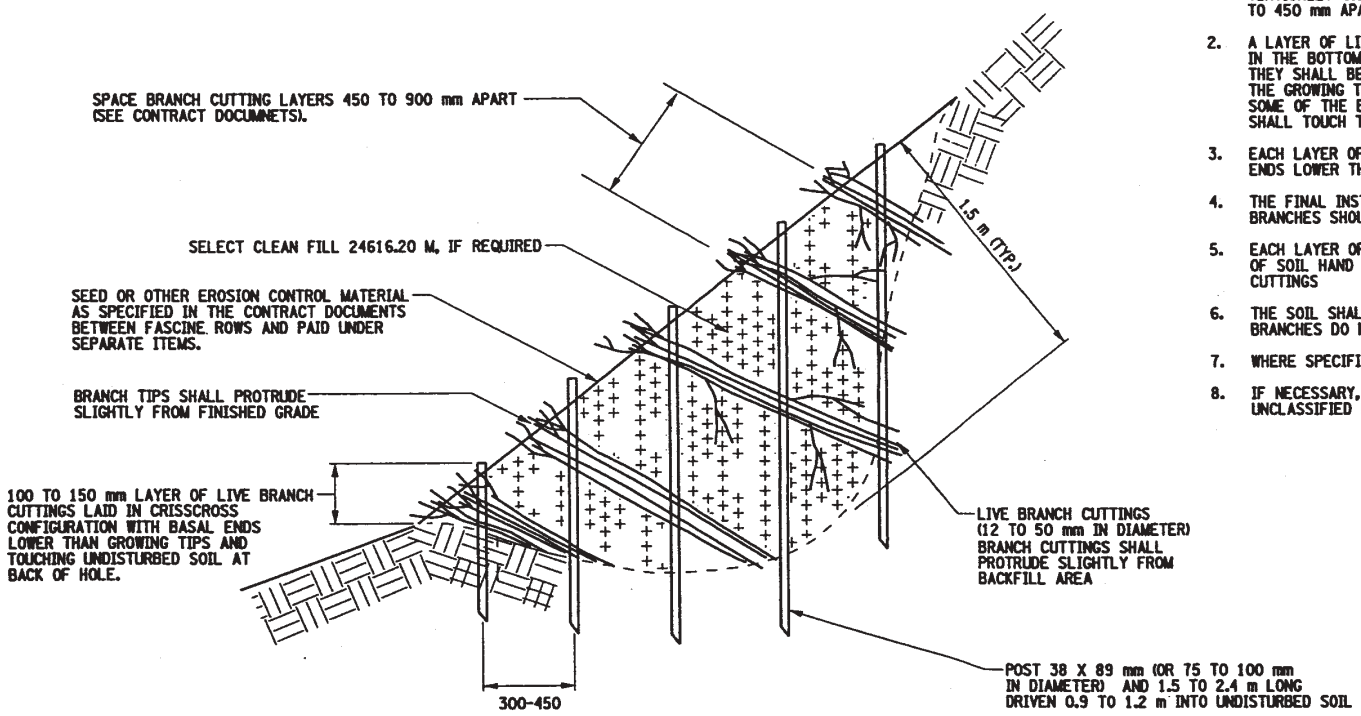
LIVE STAKE CROSS SECTION

INSTALLATION NOTES:

1. LIVE CUTTINGS SHALL RANGE FROM 12 TO 25 mm IN DIAMETER AND BE FROM 0.3 TO 1.2 m IN LENGTH.
2. LIVE STAKES SHALL RANGE FROM 26 TO 100 mm IN DIAMETER AND BE FROM 1.5 TO 1.8 m IN LENGTH.
3. SEE CONTRACT DOCUMENTS FOR SPECIES, SIZE, SPACING, LOCATION, AND FINAL DETERMINATION ON USE OF CUTTINGS OR STAKES.
4. LIVE CUTTINGS/LIVE STAKES SHALL BE CUT TO A POINT ON THE BASAL END FOR INSERTION IN THE GROUND.
5. USE A DEAD BLOW HAMMER TO DRIVE STAKES INTO THE GROUND. (HAMMER HEAD FILLED WITH SHOT OR SAND.) A DIBBLE, IRON BAR, OR SIMILAR TOOL SHALL BE USED TO MAKE A PILOT HOLE TO PREVENT DAMAGING THE MATERIAL DURING INSTALLATION.
6. LIVE CUTTINGS SHALL BE INSERTED BY HAND INTO PILOT HOLES.
7. WHEN POSSIBLE, TAMP SOIL AROUND LIVE CUTTING/LIVE STAKES.
8. ANY LIVE CUTTING/LIVE STAKE THAT IS DAMAGED SHALL BE LEFT IN PLACE AND SUPPLEMENTED WITH AN INTACT LIVE CUTTING/LIVE STAKE.

LIVE CUTTINGS/LIVE STAKES PLANTING DETAIL

NOT TO SCALE



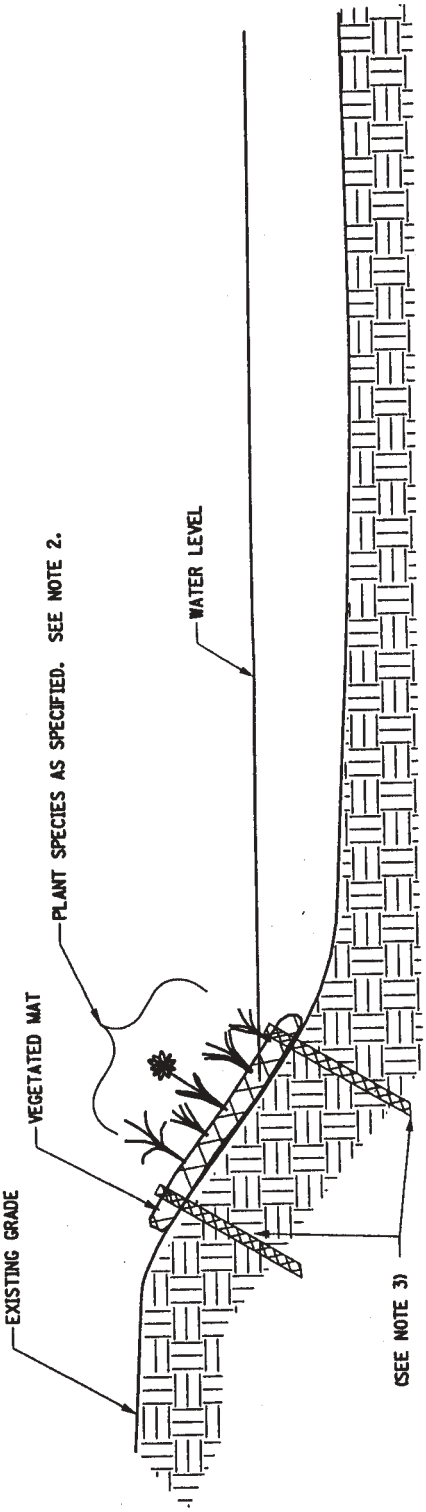
CROSS SECTION

INSTALLATION NOTES

1. STARTING AT THE LOWEST POINT DRIVE THE WOODEN POSTS VERTICALLY 0.9 TO 1.2 m INTO THE GROUND. SET THEM 300 TO 450 mm APART.
2. A LAYER OF LIVING BRANCHES 100 TO 150 mm THICK IS PLACED IN THE BOTTOM OF THE HOLE, BETWEEN THE VERTICAL POSTS. THEY SHALL BE PLACED IN A CRISSCROSS CONFIGURATION WITH THE GROWING TIPS GENERALLY ORIENTED TOWARD THE SLOPE FACE. SOME OF THE BASAL ENDS OF THE BRANCHES FROM EACH LAYER SHALL TOUCH THE BACK OF THE HOLE OR SLOPE.
3. EACH LAYER OF BRANCHES SHALL BE INSTALLED WITH THE BASAL ENDS LOWER THAN THE GROWING TIPS OF THE BRANCHES.
4. THE FINAL INSTALLATION SHALL MATCH THE EXISTING SLOPE. BRANCHES SHOULD PROTRUDE ONLY SLIGHTLY FROM THE FILLED FACE.
5. EACH LAYER OF BRANCHES SHALL BE FOLLOWED BY A 350 mm LAYER OF SOIL HAND TAMPED TO ENSURE CONTACT WITH THE BRANCH CUTTINGS
6. THE SOIL SHALL BE MOIST OR MOISTENED TO ENSURE THAT LIVE BRANCHES DO NOT DRY OUT.
7. WHERE SPECIFIED, LIVE STAKES SHALL BE USED IN PLACE OF POSTS.
8. IF NECESSARY, EXCAVATION SHALL BE PAID FOR UNDER ITEM 203.02 M UNCLASSIFIED EXCAVATON AND DISPOSAL.

BRANCHPACKING DETAIL

NOT TO SCALE

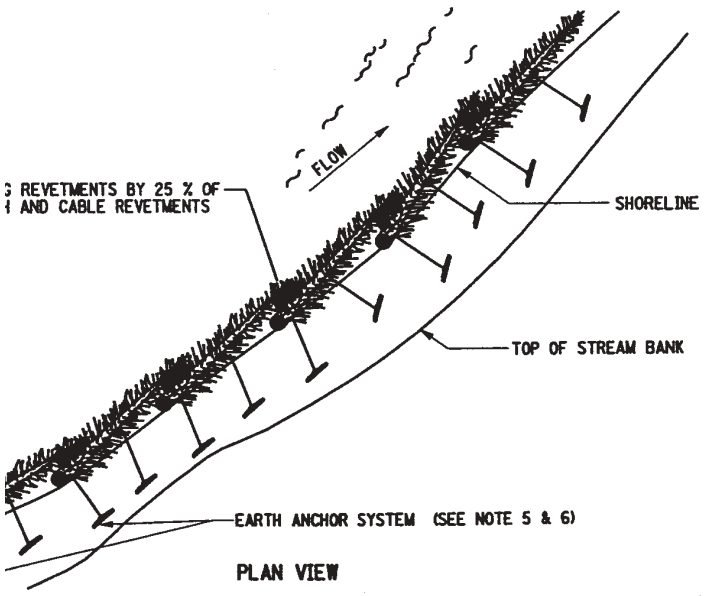


INSTALLATION NOTES:

1. VEGETATED MAT SHALL BE INSTALLED AS PER MANUFACTURER'S RECOMMENDATION.
2. WHEN SPECIFIED ELSEWHERE IN THE CONTRACT DOCUMENTS, PLANTS OR LIVE CUTTINGS SHALL BE PLACED IN VEGETATED MATS AFTER THE MATS ARE SATISFACTORILY INSTALLED.
3. STAKE VEGETATED MAT PER MANUFACTURER'S RECOMMENDATIONS

VEGETATED MAT DETAIL

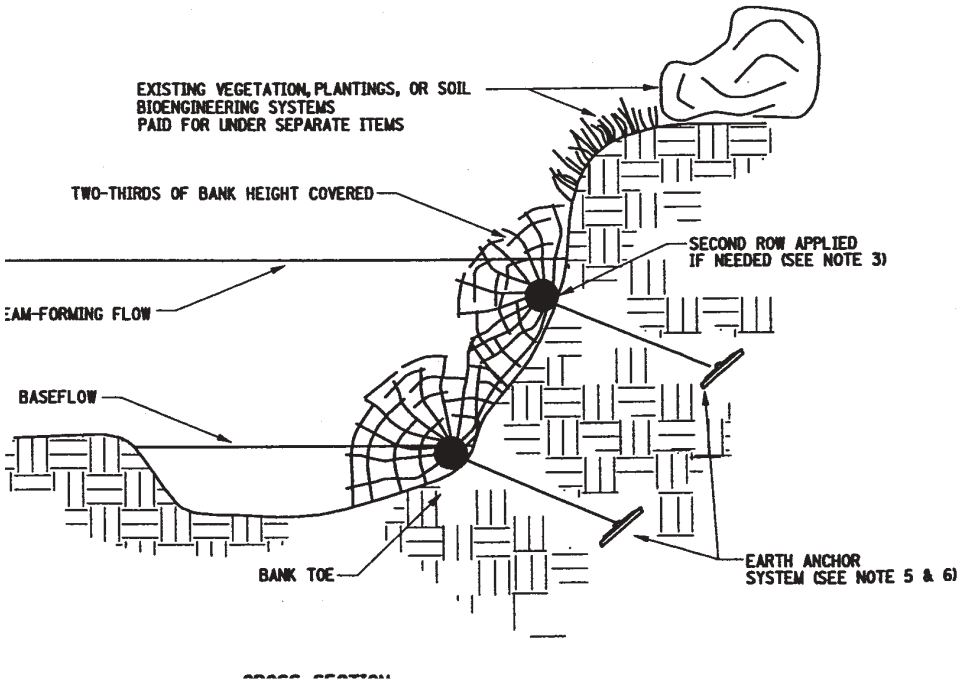
NOT TO SCALE

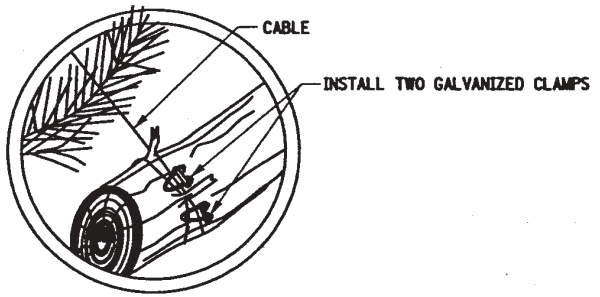


PLAN VIEW

INSTALLATION NOTES

1. TREES SHALL BE STRUCTURALLY SOUND, RECENTLY FELLED CONIFERS OF 300 mm DIAMETER OR GREATER AND AT LEAST 6.0 m IN LENGTH.
2. BRANCHES SHALL BE TRIMMED OFF THE SIDE OF THE TREE ADJACENT TO THE BANK.
3. TREES SHALL BE PLACED WITH THE BUTT END OF THE TREE UPSTREAM. TREES SHALL BE OVERLAPPED BY 25% OF THEIR LENGTH. TWO-THIRDS OF THE BANK HEIGHT SHALL BE COVERED.
4. EACH TREE SHALL HAVE TWO GALVANIZED CABLES. THE FIRST ATTACHED AT THE BUTT END, THE SECOND AT MID TRUNK WITH BOTH ATTACHED TO AN ANCHOR USING TWO GALVANIZED CLAMPS AT EACH CONNECTION.
5. THE ANCHORS SHALL BE COMMERCIALLY MANUFACTURED EARTH ANCHORING SYSTEMS OR AS SPECIFIED IN THE CONTRACT DOCUMENTS.
6. ANY MANUFACTURED ANCHORING SYSTEM USED SHALL BE INSTALLED AS PER MANUFACTURER'S RECOMMENDATIONS.
7. GALVANIZED CABLES SHALL BE INSERTED THROUGH A DRILLED HOLE AND WRAPPED AT LEAST ONE AND ONE-HALF TIMES AROUND THE MAIN STEM OF THE TREE OR ANCHOR, THEN CLAMPED.
8. SEE CONTRACT DOCUMENTS FOR CABLE SIZE AND ANCHORAGE DESIGN.





CABLE ATTACHED TO ANCHOR AND/OR TREE

TREE REVETMENT DETAIL
NOT TO SCALE

Appendix A.

Executive Order on Invasive Species

Source: U.S Department of Transportation, Federal Highway Authority http://www.fhwa.dot.gov/environment/020399em.htmartment

Executive Order 13112

February 3, 1999

Invasive Species

By the authority vested in me as President by the Constitution and the laws of the United States of America, including the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 et seq.), Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990, as amended (16 U.S.C. 4701 et seq.), Lacey Act, as amended (18 U.S.C. 42), Federal Plant Pest Act (7 U.S.C. 150aa et seq.), Federal Noxious Weed Act of 1974, as amended (7 U.S.C. 2801 et seq.), Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.), and other pertinent statutes, to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause, it is ordered as follows:

Section 1. *Definitions*

(a) "Alien species" means, with respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem.

(b) "Control" means, as appropriate, eradicating, suppressing, reducing, or managing invasive species populations, preventing spread of invasive species from areas where they are present, and taking steps such as restoration of native species and habitats to reduce the effects of invasive species and to prevent further invasions.

(c) "Ecosystem" means the complex of a community of organisms and its environment.

(d) "Federal agency" means an executive department or agency, but does not include independent establishments as defined by 5 U.S.C. 104.

(e) "Introduction" means the intentional or unintentional escape, release, dissemination, or placement of a species into an ecosystem as a result of human activity.

(f) "Invasive species" means an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health.

(g) "Native species" means, with respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem.

(h) "Species" means a group of organisms all of which have a high degree of physical and genetic similarity, generally interbreed only among themselves, and show persistent differences from members of allied groups of organisms.

(i) "Stakeholders" means, but is not limited to, State, tribal, and local government agencies, academic institutions, the scientific community, non-governmental entities including environmental, agricultural, and conservation organizations, trade groups, commercial interests, and private landowners.

(j) "United States" means the 50 States, the District of Columbia, Puerto Rico, Guam, and all possessions, territories, and the territorial sea of the United States.

Section 2. *Federal Agency Duties*

(a) Each Federal agency whose actions may affect the status of invasive species shall, to the extent practicable and permitted by law, (1) identify such actions;(2) subject to the availability of appropriations, and within Administration budgetary limits, use relevant programs and authorities to: (i) prevent the introduction of invasive species; (ii) detect and respond rapidly to and control populations of such species in a cost-effective and environmentally sound manner; (iii) monitor invasive species populations accurately and reliably; (iv) provide for restoration of native species and habitat conditions in ecosystems that have been invaded; (v) conduct research on invasive species and develop technologies to prevent introduction and provide for environmentally sound control of invasive species; and (vi) promote public education on invasive species and the means to address them; and (3) not authorize, fund, or carry out actions that it believes are likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere unless, pursuant to guidelines that it has pre-scribed, the agency has determined and made public its determination that the benefits of such actions clearly outweigh the potential harm caused by invasive species; and that all feasible and prudent measures to minimize risk of harm will be taken in conjunction with the actions.

(b) Federal agencies shall pursue the duties set forth in this section in consultation with the Invasive Species Council, consistent with the Invasive Species Management Plan and in cooperation with stakeholders, as appropriate, and, as approved by the Department of State, when Federal agencies are working with international organizations and foreign nations.

Section 3. *Invasive Species Council*

(a) An Invasive Species Council (Council) is hereby established whose members shall include the Secretary of State, the Secretary of the Treasury, the Secretary of Defense, the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Commerce, the Secretary of Transportation, and the Administrator of the Environmental Protection Agency. The Council shall be Co-Chaired by the Secretary of the Interior, the Secretary of Agriculture, and the Secretary of Commerce. The Council may invite additional Federal agency representatives to be members, including representatives from sub-cabinet bureaus or offices with significant responsibilities concerning invasive species, and may prescribe special procedures for their participation. The Secretary of the Interior shall, with concurrence of the Co-Chairs, appoint an Executive Director of the Council and shall provide the staff and administrative support for the Council.

(b) The Secretary of the Interior shall establish an advisory committee under the Federal Advisory Committee Act, 5 U.S.C. App., to provide information and advice for consideration by the Council, and shall, after consultation with other members of the Council, appoint members of the advisory committee representing stakeholders. Among other things, the advisory committee shall recommend plans and actions at local, tribal, State, regional, and ecosystem-based levels to achieve the goals and objectives of the Management Plan in section 5 of this order. The advisory committee shall act in cooperation with stakeholders and existing organizations addressing invasive species. The Department of the Interior shall provide the administrative and financial support for the advisory committee.

Section 4. *Duties of the Invasive Species Council*

The Invasive Species Council shall provide national leadership regarding invasive species, and shall:

(a) oversee the implementation of this order and see that the Federal agency activities concerning invasive species are coordinated, complementary, cost-efficient, and effective, relying to the extent feasible and appropriate on existing organizations addressing invasive species, such as the Aquatic Nuisance Species Task Force, the Federal Interagency Committee for the Management of Noxious and Exotic Weeds, and the Committee on Environment and Natural Resources,

(b) encourage planning and action at local, tribal, State, regional, and ecosystem-based levels to achieve the goals and objectives of the Management Plan in section 5 of this order, in cooperation with stakeholders and existing organizations addressing invasive species,

(c) develop recommendations for international cooperation in addressing invasive species,

(d) develop, in consultation with the Council on Environmental Quality, guidance to Federal agencies pursuant to the National Environmental Policy Act on prevention and control of invasive species, including the procurement, use, and maintenance of native species as they affect invasive species,

(e) facilitate development of a coordinated network among Federal agencies to document, evaluate, and monitor impacts from invasive species on the economy, the environment, and human health,

(f) facilitate establishment of a coordinated, up-to-date information-sharing system that utilizes, to the greatest extent practicable, the Internet; this system shall facilitate access to and exchange of information concerning invasive species, including, but not limited to, information on distribution and abundance of invasive species; life histories of such species and invasive characteristics; economic, environmental, and human health impacts; management techniques, and laws and programs for management, research, and public education, and

(g) prepare and issue a National Invasive Species Management Plan as set forth in section 5 of this order.

Section 5. *Invasive Species Management Plan*

(a) Within 18 months after issuance of this order, the Council shall prepare and issue the first edition of a National Invasive Species Management Plan (Management Plan), which shall detail and recommend performance-oriented goals and objectives and specific measures of success for Federal agency efforts concerning invasive species. The Management Plan shall recommend specific objectives and measures for carrying out each of the Federal agency duties established in section 2(a) of this order and shall set forth steps to be taken by the Council to carry out the duties assigned to it under section 4 of this order. The Management Plan shall be developed through a public process and in consultation with Federal agencies and stakeholders.

(b) The first edition of the Management Plan shall include a review of existing and prospective approaches and authorities for preventing the introduction and spread of invasive species, including those for identifying path-ways by which invasive species are introduced and for minimizing the risk of introductions via those pathways, and shall

identify research needs and recommend measures to minimize the risk that introductions will occur. Such recommended measures shall provide for a science-based process to evaluate risks associated with introduction and spread of invasive species and a coordinated and systematic risk-based process to identify, monitor, and interdict pathways that may be involved in the introduction of invasive species. If recommended measures are not authorized by current law, the Council shall develop and recommend to the President through its Co-Chairs legislative proposals for necessary changes in authority.

(c) The Council shall update the Management Plan biennially and shall concurrently evaluate and report on success in achieving the goals and objectives set forth in the Management Plan. The Management Plan shall identify the personnel, other resources, and additional levels of coordination needed to achieve the Management Plan's identified goals and objectives, and the Council shall provide each edition of the Management Plan and each report on it to the Office of Management and Budget. Within 18 months after measures have been recommended by the Council in any edition of the Management Plan, each Federal agency whose action is required to implement such measures shall either take the action recommended or shall provide the Council with an explanation of why the action is not feasible. The Council shall assess the effectiveness of this order no less than once each 5 years after the order is issued and shall report to the Office of Management and Budget on whether the order should be revised.

Section 6. *Judicial Review and Administration*

(a) This order is intended only to improve the internal management of the executive branch and is not intended to create any right, benefit, or trust responsibility, substantive or procedural, enforceable at law or equity by a party against the United States, its agencies, its officers, or any other person.

(b) Executive Order 11987 of May 24, 1977, is hereby revoked.

(c) The requirements of this order do not affect the obligations of Federal agencies under 16 U.S.C. 4713 with respect to ballast water programs. (d) The requirements of section 2(a)(3) of this order shall not apply to any action of the Department of State or Department of Defense if the Secretary of State or the Secretary of Defense finds that exemption from such requirements is necessary for foreign policy or national security reasons.

/S/
William J. Clinton

THE WHITE HOUSE,

February 3, 1999

[FR Doc. 99-3184]

Appendix b.

Presidential Executive Memorandum on Federal Landscaping Practices

Memorandum on Environmentally Beneficial Landscaping

Source: U.S Department of Transportation, Federal Highway Authority
http://www.fhwa.dot.gov/environment/042694em.htm

April 26, 1994

Memorandum for the Heads of Executive Departments and Agencies

Subject: Environmentally and Economically Beneficial Practices on

Federal Landscaped Grounds

The Report of the National Performance Review contains recommendations for a series of environmental actions, including one to increase environmentally and economically beneficial landscaping practices at Federal facilities and federally funded projects. Environmentally beneficial landscaping entails utilizing techniques that complement and enhance the local environment and seek to minimize the adverse effects that the landscaping will have on it. In particular, this means using regionally native plants and employing landscaping practices and technologies that conserve water and prevent pollution.

These landscaping practices should benefit the environment, as well as generate long-term costs savings for the Federal Government. For example, the use of native plants not only protects our natural heritage and provides wildlife habitat, but also can reduce fertilizer, pesticide and irrigation demands and their associated costs because native plants are suited to the local environment and climate.

Because the Federal Government owns and landscapes large areas of land, our stewardship presents a unique opportunity to provide leadership in this area and to develop practical and cost-effective methods to preserve and protect that which has been entrusted to us. Therefore, for Federal grounds, Federal projects, and federally funded projects, I direct that agencies shall, where cost-effective and to the extent practicable:

(a) use regionally native plants for landscaping;

(b) design, use, or promote construction practices that minimize adverse effects on the natural habitat;

(c) seek to prevent pollution by, among other things, reducing fertilizer and pesticide use, using integrated pest management techniques, recycling green waste, and minimizing runoff. Landscaping practices that reduce the use of toxic chemicals provide one approach for agencies to reach reduction goals established in Executive Order No. 12856 "Federal Compliance with Right-To-Know Laws and Pollution Prevention Requirements;"

(d) implement water-efficient practices, such as the use of mulches, efficient irrigation systems, audits to determine exact landscaping water-use needs, and recycled or reclaimed water and the selecting and siting of

plants in a manner that conserves water and controls soil erosion. Landscaping practices, such as planting regionally native shade trees around buildings to reduce air conditioning demands, can also provide innovative measures to meet the energy consumption reduction goal established in Executive Order No. 12902, "Energy Efficiency and Water Conservation at Federal Facilities;" and

(e) create outdoor demonstrations incorporating native plants, as well as pollution prevention and water conservation techniques, to promote awareness of the environmental and economic benefits of implementing this directive. Agencies are encouraged to develop other methods for sharing information on landscaping advances with interested nonfederal parties.

In order to assist agencies in implementing this directive the Federal Environmental Executive shall:

(a) establish an interagency working group to develop recommendations for guidance, including compliance with the requirements of the National Environmental Policy Act, 42 U.S.C.4321, 4331-4335, and 4341-4347, and training needs to implement this directive. The recommendations are to be developed by November 1994; and

(b) issue the guidance by April 1995.To the extent practicable, agencies shall incorporate this guidance into their landscaping programs and practices by February 1996. In addition, the Federal Environmental Executive shall establish annual awards to recognize outstanding landscaping efforts of agencies and individual employees. Agencies are encouraged to recognize exceptional performance in the implementation of this directive through their awards programs. Agencies shall advise the Federal Environmental Executive by April 1996 on their progress in implementing this directive. To enhance landscaping options and awareness, the Department of Agriculture shall conduct research on the suitability, propagation, and use of native plants for landscaping. The Department shall make available to agencies and the public the results of this research.

Appendix c.

Landscape Websites

The following list is provided as a resource to readers of this manual. It is not meant to be a comprehensive list but merely a useful guide to landscape websites.

Soils, Compost and Mycorrhizal Fungi

Composting - Master Gardening web site
http://www.uvm.edu/mastergardener/help/tipsindex.html

CU Structural soil - Amereq licensee
http://www.amereq.com/pages/2/

Mycorrhizal Applications, Inc.
http://www.mycorrhizae.com/

Suppliers of beneficial organisms in North America
http://www.cdpr.ca.gov/docs/ipminov/ben_supp/contents.htm

University of Vermont Soil Testing Lab Home Page
http://pss.uvm.edu/ag_testing

U.S. Composting Council
http://www.compostingcouncil.org/index.cfm

Trees and Urban Forestry

American Forests
http://www.amfor.org

Cornell Cooperative Extension
http://www.cce.cornell.edu/

Davey Tree Expert Company
http://www.davey.com/home/

International Society of Arboriculture
http://www.ag.uiuc.edu/~isa/

Landscape Nursery and Urban Forestry / U. Mass Green Info
http://www.umassgreeninfo.org/

National Arborist Association
http://www.NATLARB.com

National Arbor Day Foundation
http://www.arborday.org/

North East Center for Urban and Community Forestry / USDA
http://www.umass.edu/urbantree/tem.shtml

Rutgers University, Cooperative Extension
http://www.canadiancontent.net/dir/Top/Science/Agriculture/Education/Cooperative Extension/

Tree care and links to ISA
http://www.treesaregood.com/treecare/treecareinfo.asp

Tree care and Mulching
http://www.treesaregood.com/treecare/mulching.asp

Tree Emergency Manual for Public Officials USDA Forest Service, N.E. Center for Urban and Community Forestry, Monroe County NY Cooperative Extension
http://www.umass.edu/urbantree/TEM.pdf

Tree Hazards
http://www.utextension.utk.edu/publications/spfiles/sp573.pdf

Tree Hazards - Northeast Center for Urban & Community Forestry
http://www.umass.edu/urbantree/hazard/index.shtml

Tree Link
http://www.treelink.org/

University of Illinois Extension Solution Series
http://www.solutions.uiuc.edu/

University of Massachusetts, Amherst, Extension Service
http://www.umassextension.org/

Urban Tree Risk Management: A Community Guide to Program Design and Implementation. USDA, Forestry Service
http://www.na.fs.fed.us/spfo/pubs/uf/utrmm/

Vermont Urban and Community Forestry Program
http://www.vtcommunityforestry.org/index.htm

Wisconsin Natural Resources Magazine
http://wnrmag.com/stories/2000/jun00/parsnip.htm

Urban Horticulture Institute, Cornell University,
http://www.hort.cornell.edu/department/faculty/bassuk/uhi/index.html

Horticulture

American Association of Botanical Gardens and Arboreta
http://www.aabga.org/

American Horticultural Society
http://www.ahs.org

American Nursery and Landscape Association
http://www.anla.org/

American Society for Horticultural Science
http://www.ashs.org/

The Cyber-Plantsman
http://www.gardenweb.com/cyberplt/

Horticopia
http://www.horticopia.com

Horticulture
http://www.wcrl.ars.usda.gov/cec/teaching/horticul.htm

National Gardening Association
http://assoc.garden.org/

Native Plant Societies
http://michbotclub.org/links/native_plant_society.htm

Ohio State University "Plant Facts" Search Engine
http://plantfacts.osu.edu/

Organic Gardening
http://www.organicgardening.com

USDA Plant Hardiness Map
http://plant-materials.nrcs.usda.gov/

Vermont Master Gardeners
http://www.uvm.edu/mastergardener/help/tipsindex.html

Other sites

Context Sensitive Design - NCHRP, Performance Measures for Context-Sensitive Solutions - A Guidebook for State DOT's
http://www.trb.org/news/blurb_detail.asp?id=4400

Context Sensitive Design - FHWA, USDOT
http://www.fhwa.dot.gov/csd/index.htm

"Critter Crossings and Reducing Roadkill" – Federal Highway Authority
http://www.fhwa.dot.gov/environment/wildlifecrossings/index.htm

Environmentally and Economically Beneficial Landscaping Guidance – FHWA
http://www.fhwa.dot.gov/environment/rdsduse/rdus3_6.htm

LATIS Landscape Architecture Technical Information Series
http://www.asla.org/latis/pdf/Structural_soils_updated081202.pdf

National Invasive Species Management Plan
http://www.invasivespecies.gov/council/nmp.shtml

Natural Resource Conservation Service - Plant Materials Program

http://plant-materials.nrcs.usda.gov/

Native Wildflower Planting Requirement – FHWA /1998 Revised Guidance
http://www.fhwa.dot.gov/environment/rdsduse/rdus3_1.htm

New England Wildflower Society, Conservation Notes –
http://www.newfs.org/conserve/docs/wfn98.pdf

Roadside Vegetation Management, Federal Highway Authority/ FHWA
http://www.fhwa.dot.gov/environment/vegmgt/index.htm

VT Department of Agriculture Plant Health Resources
http://www.vermontagriculture.com/CAPS/index.html

U.S. Patent and Trademark Office
http://www.uspto.gov/

Appendix D

General Guidance for Landscaping Activities in the Highway Rights-of-Way

(Non-Limited Access)

Source: Utilities Section, Vermont Agency of Transportation, November 23, 1998

The following "guidance" should be used when responding to permit application requests to perform landscaping activities in the State's highway rights-of-way. As with drives, the Districts should process residential landscaping requests, and the Utilities & Permits Unit will process commercial requests.

Overview

It is common, and also historical practice, for landowners whose properties abut State-owned highways to conduct landscaping/yard work activities within the strip of land lying between the edge of the highway shoulder and the abutting land owner's front property line (hence forth, referred to as the "highway rights-of-way"). This is especially true in urban settings where abutting property owners typically maintain their lawns to the back of sidewalks/curbs or to the edge of pavement. This practice benefits both the property owner and the State in the following ways: Enhances roadside aesthetics, improves sight distance, provides traffic calming, and reduces highway maintenance costs. Businesses, in particular, rely on roadside landscaping to attract highway users. Examples include: Hotels, shopping malls, auto dealers, restaurants, and even landfills. This narrow strip of State property where landscaping has traditionally been allowed is also the space reserved for other diverse and competing uses. It is used as a utility corridor for water, sewer, gas, power, telephone, cable television, etc. Also, it is used for sidewalks, bike paths, parking, driveways, signage, noise barriers, street lighting, as well as highway maintenance and highway expansion. Needless to say, the importance of the highway rights-of-way cannot be understated, thus making land use oversight of the many competing uses an important, continuous function of the Vermont Agency of Transportation. Landscaping represents one of the more passive uses of the highway rights-of-way. Never-the-less, these application requests require close scrutiny to ensure that the public interests and driving safety are preserved. The following guidance should be considered when reviewing landscape permit application requests.

Uses Not Requiring a Permit

General yard maintenance and property enhancement by abutting property owners such as lawn mowing, brush cutting, and seasonal planting of low growing annuals. Plant height should be limited to a 24" mature height above pavement elevation, and be located at least 10 feet from the highway's white painted edge line. Activities associated with Adopt-A-Highway and other state/community sponsored non-construction highway beautification projects will not generally require permitting. These non-permitted activities cannot compromise the

safety of the highway users or interfere with highway infrastructure or utility plant maintenance.

Residential/Commercial/ Municipal Landscaping Requiring Permits

Any landscaping activities located in the highway rights-of-way, which involve the placement of boulders, planters fences, berms, landscaping timbers, hedges, shrubs, trees, perennials, etc., or use of construction equipment or work vehicles within the rights-of-way will require a permit. In most cases, this type of landscaping development must be located outside the limits of the established highway safety clear zone. Exceptions may be allowed behind guardrail and in urban settings where reduced speed limits, curbing, sidewalks, and established tree lines exist. Landscaping activities which obstruct corner sight distances, present safety hazards, or have the potential to interfere with the operation and maintenance of the adjacent highway and existing public utility facilities will not be allowed. In particular, only tree species which grow to a maximum of 12 to 15 feet high will be allowed under aerial utility lines. Trees should not be planted over buried utilities or highway storm drain pipes, in ditches, or any other location where they will interfere with routine highway/utility maintenance activities. Landscaping permits must be conditioned to inform Permit Holders that landscaping on State property is by suffrage only, and the State may, when necessary, exercise its right to have it removed for the public good. In all cases, the operation and maintenance of the highway and utilities serving the public will have precedence over landscaping proposals

Compliance

Whenever non-complying, non-permitted landscaping activities are observed taking place within the State highway rights-of-way, the owner should be immediately notified to stop operations. Only after a permit has been issued should the Permit Holder be allowed to proceed in accordance with the permitted landscaping plan and permit Special Conditions. Failure on the part of the property owner to acquire a permit will result in the property owner being ordered to remove the landscaping and rehabilitate any damages.

Site circumstances and common sense should always be factors when reviewing permit applications for landscaping. The width of the State highway rights-of-way, nature and extent of the landscaping project, speed limit, rural/urban location, etc., should be considered. In all cases, permits should be conditioned with the provision that the landscaping will be allowed until such time that the State requires the rights-of-way for highway purposes, including routine maintenance operations. Should landscaping need to be removed, it must be done so at the owner's expense within thirty (30) days of being notified by the State. Failure to comply may result in the State back charging the Owner for removal and any rehabilitation costs.

Bibliography

Roadside Design Manual:
AASHTO, American Association of State Highway and Transportation Officials, 444 North Capitol Street N.W., Suite 249, Washington, D.C. 20001. (202) 624-5800 (tel.) (202) 624-5806 (fax)
www.transportation.org

Compost Use on State Highway Applications:
The US Composting Council, 1924 N. Second Street, Harrisburg, PA 17102; Tel: 717-238-9759 Fax: 717-238-9985
www.compostingcouncil.org

International Society of Arboriculture:
ISA, P. O. Box 3129, Champaign, IL 61826-3129, USA
www.isa-arbor.com

- Avoiding Tree Damage During Construction
- Treatment of Trees Damaged by Construction
- Benefits of Trees
- Buying High-Quality Trees
- Why Hire an Arborist
- Trees and Turf
- Plant Health Care
- Insect & Disease Problems
- Mature Tree Care
- Pruning Mature Trees
- Why Topping Hurts Trees
- New Tree Planting
- Proper Mulching Techniques
- Pruning Young Trees
- Tree Values
- Avoiding Tree & Utility Conflicts

Vermont Invasive Fact Sheet Series:
Vermont Department of Agriculture: 116 State Street, Drawer 20, Montpelier, VT 05620-2901 Tel: 802-828-2416 Fax:802-828-3831 www.vermontagriculture.com/invasive.htm

Best Management Practice (BMP 32):
http://faculty.msmary.edu/envirothon/current/guide/ag_urban_bmp.htm

Critical Area Planting:
Natural Resource Conservation Service, 89 Main Street, Montpelier, VT 05602-2948 Tel: 802-828-6080 Fax: 802-828-6018
www.nrcs.usda.gov/

Vegetating with Native Grasses in Northeastern North America:
USDA, U.S. Department of Agriculture, 1400 Independence Ave., S.W. Washington, DC 20250 www.usda.gov/wps/portal/usdahome
Ducks Unlimited, Inc.: One Waterfowl Way, Memphis, Tennessee 38120 USA
www.ducks.org
USDA NRCS Technical Standards, Maryland Department of Agriculture, 50 Harry S. Truman Parkway, Annapolis, MD 21401 Tel: 410-841-5863

Ernst Seed Company:
Ernst Conservation Seeds, 9006 Mercer Pike, Meadville, PA 06335 www.ernstseed.com/

The New England Green Invasion:
William Brumback, Conservation Notes of the New England Wild Flower Society-5; Vol.2, No.3—1998

The Problem with Invasive Plant Species: Noxious Plants Rule:
Vermont Agency of Agriculture Quarantine #3:
Vermont Agency of Agriculture, 116 State Street, Drawer 20, Montpelier, VT 05620-2901 Tel: 802-828-2416 Fax:802-828-3831
www.vermontagriculture.com/invasive.htm

Invasive Species - ***Executive Order 13112, February 3, 1999 and Code of Federal Regulations:***
Federal Highway Administration, 400 7th Street, SW, Washington, DC 20590
www.fhwa.dot.gov/environment/020399em.htm

Establishment of Wet Area Vegetation along Highway Corridors (out of print):
1994 Ontario Ministry of Transportation, Research and Development , Queen's Park Ministers Office 71 Wellesley SW Toronto, Ontario M7A 1Z8 , www.mto.gov.on.ca/english/engineering/
Geometrics International Inc, 3370 South Service Road, Burlington Ontario L7N 3M6
The Landplan Collaborative Ltd 319 Woolwich Street, Guelph, Ontario NiH 3W4

How to take a Soil Sample:
Agricultural & Environmental Testing Lab, University of Vermont, Burlington, VT 05405
http://pss.uvm.edu/ag_testing/

University of Vermont Soil Test Report and Lab Analysis:
Agricultural & Environmental Testing Lab, University of Vermont, Burlington, VT 05405
http://pss.uvm.edu/ag_testing/

University of Vermont Soil Test Report:
University of Vermont: Agricultural & Environmental Testing Lab, University of Vermont, Burlington, VT 05405 http://pss.uvm.edu/ag_testing/

Estimating Soil Moisture by Feel and Appearance:
Norman L. Klocke, Extension Agricultural Engineer, Paul E. Fishback, Extension Irrigation Specialist Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska Lincoln NE
http://ianrpubs.unl.edu/irrigation/g690.htm
reprinted in Fall 2003 The Natural Farmer, The Quarterly Journal of the Northeast Organic Farmers Association /_NOFA 411 Sheldon Road Barre MA 01005

Mycorrhizal Management:
Michael Amaranthus, PhD, Mycorrhizal Applications Inc., P.O. Box 1181, Grants Pass, OR 97528 Tel: 541-476-3985, Fax: 541-476-1581
www.mycorrhizae.com

CU - Structural Soil, LATIS article:
Landscape Architecture Technical Information Series, American Society of Landscape Architects, 636 Eye Street, NW, Washington, DC 20001-3736
www.asla.org

CU - Structural Soil:
Dr. Nina L. Bassuk, Room 20 Plant Science, Cornell University, Ithaca, NY 14853 Tel: 607-255-4586 Fax: 607-255-9998
www.hort.cornell.edu/department/faculty/bassuk/uhi/research/subject.html

The Vermont Stormwater Management Manual, Volumes I & II, 2002, Introduction to Process:
Agency of Natural Resources, Secretary's Office, Center Building, 103 South Main Street, Waterbury, VT 05671-0301 Tel:802-241-3600 Fax: 802-244-1102

Protecting Trees from Construction Damage:
A Homeowners Guide FO 6135 S. 1993 University of Minnesota, Minnesota Extension Service, St Paul MN 55108, Gary Johnson PhD.

Soil Bio-Engineering
Soil Bio-Engineering Specifications, Design Guidelines and Details:
New York State Department of Transportation,– 2002, Engineering Instruction, Daniel D'Angelo, P.E., Director: 518-457-6467, Design Quality Assurance Bureau, P.O.D. 2350 Wolf Road, Albany, NY 12232
www.dot.state.ny.us/cmb/consult/eib/eiindex.html

Tree Risk Management:
Bartlett Tree Research laboratories, 13768 Hamilton Road Charlotte, N.C., 28278 Bruce Fraedrich, Ph.D., Neil Hendrickson Ph.D., E. Thomas Smiley Ph.D.,developed for Connecticut Department of Transportation, October- November 2004, Seminar Series

References:
Urban Tree Risk Management:
A Community Guide to Program Design and Development, USDA Forest Service Northeastern Area 1992 Folwell Avenue St. Paul MN 55108, NA –TP 03-03 coordinating author Jill Pokorny

A Photographic Guide to the Evaluation of Hazard Trees in Urban areas 2nd edition:
Methany N.P. and Clark J.R., International Society of Arboriculture, P.O. Box 3129 Champaign, Illinois, 61826

Trees and Development A Technical Guide to Preservation of Trees During Land development:
Methany N.P. and Clark J.R., 1998, International Society of Arboriculture, P.O. Box 3129 Champaign, Illinois, 61826

Architectural Graphic Standards:
Tenth Edition, John Ray Hoke Jr, FAIA, Editor in Chief, John A. Wiley & Sons, Inc.

A New Tree Biology:
Facts Photos and Philosophies on Tree Care and their Problems and Proper care, Alex L. Shigo, Shigo and Trees, Associates, Post Office Box 769, Durham, New Hampshire, 03824, USA. Tenth printing 2002.

Tree Hazards Your Trees Can Kill!
13 questions You Need to Ask and to discuss the results with a tree professional-arborist. Alex L. Shigo, Shigo and Trees, Associates, 4 Denbow Road, Durham, New Hampshire, 03824, USA

Utility Conflicts: Utilities Manual, 1998:
State of Vermont Agency of Transportation, Drawer 33, I National Life, Drive Montpelier, Montpelier, VT 05633

***Avoiding Tree & Utility Conflicts,* ISA Document:**
ISA, P. O. Box 3129, Champaign, IL 61826-3129, USA
www.isa-arbor.com

Tree Protection and Critical Root Zone:
University of Minnesota Extension Service, Office of the Director, 240 Coffey Hall, 1420 Eckles Ave., St. Paul, MN 55108-6068 Tel: 612-624-1222
www.extension.umn.edu/info-u/environment/BD443.html

Trenching and Tunneling near Trees:
National Arbor Day Foundation, 100 Arbor Avenue, Nebraska City, NE 68410 Tel: 1-888-448-7337 www.arborday.org