IRVM Objectives

Integrated Roadside Vegetation Management (IRVM) objectives are the same across all roads in the First State:

1. to provide safe conditions both for motorists and for residents adjacent to the right of way,
2. to help preserve the road surface,
3. to remain in compliance with state and federal regulations,
4. to act as good land stewards in maintaining an environmentally healthy and aesthetically pleasing quality along the roadside,
5. to maintain good public relations,
6. to minimize the use of pesticides and develop alternative control strategies wherever possible (as specified by NPDES permits), and
7. to fulfill the above objectives through a program of maintenance operations that are efficient and cost effective.

Safe driving conditions are maintained by keeping vegetation far enough back from the roadside to maintain sight distance on the road ahead, especially around curves. Road signs, guardrails, and intersections must be kept clear of vegetation that would obstruct driver visibility.

Trees adjacent to the pavement may create several types of safety hazards. First, tree diameters larger than four inches are classified as obstructions because of their risk as targets for collision, and therefore must be kept out of the "clear zone" (see DelDOT Road Design Manual, 3.3.) Second, although the canopy effect created by deciduous trees whose branches reach out over the road may be attractive, they can create undesirable risk situations. Overhead branches fall down onto the road, particularly during storms. Shaded roads stay wet and slippery, especially when covered with fallen leaves. Leaves and branches can obstruct drainage flow. Evergreens can shade the road in winter and cause icy patches.

Preservation of the road surface can also be negatively affected by shaded or wet road surfaces. The road surface is subject to disintegration when moisture is allowed to remain or pond for extended periods especially through temperature extremes that allow freeze-thaw cycles. The road surface is also damaged when plants take root in pavement cracks.

Knowing when to encourage plant growth is as important as knowing when to prevent it. In some cases vegetative ground cover should be left in place to help prevent erosion. Proper drainage along the road shoulder is necessary to prevent undermining the pavement and guardrail posts.

Abiding by State and Federal laws is an important objective of roadside vegetation management. Environmental and human safety laws to be considered include Delaware Noxious Weed law, State

pesticide regulations, County and State Erosion and Sedimentation laws, NPDES permits, Occupational Safety and Health Regulations (OSHA), and Federal Department of Transportation requirements.

Maintaining good public relations is both a moral and a practical obligation of the DOT. Plants can provide an attractive natural screen to be viewed by residents and travelers both to and from the road. Undesirable views can be screened for the benefit of travelers and buffer zones can be created by attractive complementary vegetative screens for the benefit of adjacent residents.

Trees, shrubs and herbaceous perennials welcome travelers to Delaware with a display of autumn color.

Roadsides maintained with environmental quality in mind will contribute to the pleasure and safety of the traveling public. A roadside that offers a diverse variety of natural vegetation and scenery is not only pleasing to residents and travelers but can help drivers stay alert.

Roadside Features

Guardrails

Guardrails are metal structures installed along highways to help prevent motorists from exiting the road surface or crossing median lines into oncoming traffic. Guardrails that do not block sight distances minimize the chance of head-on collisions. Allowing grasses or broadleaf weeds to grow up along guardrails will affect visibility. The following are appropriate management practices for vegetation around guardrails:

Maintain low vegetation under guardrail – Low vegetation is maintained by hand trimming with hand mowers or weedeaters. Low fescue can be planted under guardrails as a groundcover requiring infrequent or no mowing.

Weed control barriers – These barriers are expensive and their lifespan is unkown.

IRVM Objectives

- IRVM is an integrated management tool that uses native vegetation while reducing the use of pesticides.
- Roadside vegetation in Delaware will be managed following IRVM objectives.

DelDOT and other departments of transportation throughout the country are testing the following products for potential use under guardrails. Designers should contact the Roadside Environmental Administrator for the most current products available. Products include:

- Permeable systems such as woven fiber mats and weed prevention fabric under a 2- to 3- inch layer of rubber mulch. These systems have the advantage of not creating additional impervious highway surfaces, which may impact stormwater permitting and mitigation requirements.
- Interlocking rubber or molded plastic tiles, sized to fit typical guardrail post spacing, made from recycled materials.
- Pavement under guardrail. (Vegetation that is allowed to grow in pavement compromises pavement integrity resulting in greater weed problems.)

Control existing vegetation with herbicides- Non-selective herbicides are used to maintain bare ground below guardrails. Selective herbicides are used to control tall broadleaf plants but allow short grasses to grow. Soil residuals are used only when necessary for long term control. Low volume, low pressure spray equipment is used to apply herbicides under guardrails in a 2 1/2- to 3- foot wide zone. Spraying beyond the zone can result in erosion. Guardrails are treated once a year.

Low fescue seeded under guard rail provides a low cover that stabilizes soil but requires only infrequent mowing.

DelDOT is testing various weed control barriers for use under guard rail

Herbicides are used to control tall vegetation obstructing the guard rail.

Edges of crossovers are mowed to allow visibility for turning vehicles.

The berm between I95 and 495 has been planted with trees, shrubs and warm-season grasses. Mowing is routinely required at the base of the berm only and warm-season grasses are cut back once each year.

Medians

Medians are areas of varying width between two directions of traffic on divided highways. Medians often consist of a shoulder, edge and swale. Medians may have a soil berm in the center. Medians can range in width from 20 feet wide to more than 100 feet wide. Medians may not contain trees greater than 4 inches in caliper unless they are behind guardrail or on an elevated berm. Medians are usually planted with turfgrass. Traditionally, medians have been mowed from pavement edge to pavement edge but this is counter to current DelDOT policy. Any deviation from the mowing policy must be approved by the District Engineer.

DelDOT Median mowing policy:

1. Mow entire medians when equal to or less than 40 feet wide.
2. Mow one mower width on either edge when median is greater than 40 feet wide. Mow entire median once yearly to control woody vegetation or leave unmowed and treat woody vegetation with selective herbicides.
3. Mow edges of crossovers to allow for a sight triangle appropriate to posted speed as described in the Road Design Manual. On controlled access highways the edge of the sight triangle should be no greater than 50 feet from the edge of paved crossover.
4. Mow medians to a height of no less than 6 inches.
5. Keep woody vegetation out of drainage swales unless swales are designed to accomodate them (yearly mowing or selective herbicides).

One mower pass provides a neat appearance, while allowing the interior grasses to grow.

6. Plant berms or allow natural succession to occur on berms in medians to eliminate the need to mow.

Roadsides

Roadsides typically include five zones that might occur on either side of the pavement (back slope or cut slope, swale or ditch zone, edge or border zone, edge or border zone, approach or shoulder zone, front or fill slope). These areas vary significantly in their geomorphic characteristics from high, dry and well-drained to low, moist wetlands. Slopes vary from steep (2:1) to relatively flat (2% or less) and soils vary from relatively undisturbed to highly compacted or reconsolidated. The edge or border zone should be mowed routinely to provide a safe stopping zone for vehicles.

1. Flat roadsides can be maintained with one mower width routinely mowed.
2. Roadside with swales or drainage ditches can be mowed up to the swale.

Along I95, the roadside is mowed one mower pass beyond the swale.

Mowing neatly to the edge of the planting bed ensures an attractive appearance.

A mowed strip around this bed of switchgrass on a prominent corner in Lewes keeps the area looking neat and well-maintained.

Beds

Beds are ornamental enhancements planted on roadside or in medians that require special maintenance. Low weeds in established beds can be tolerated when desired species are tall and the planting is viewed at relatively high speeds. Beds at intersections and adjacent to sidewalks

Flowering trees along 896 are obstructed by unmowed vegetation (left) but provide an attractive spring display when turf has been properly mowed (right).

must have a higher level of weed control. Preemergent herbicides can be used in beds. It is critical to maintain a neatly mowed edge around planted beds and areas released from mowing. If unmowed grass and weeds are allowed to grow in front of desired species, the beds look poorly maintained. Perennial forb, warm-season grass or shrub bed edges can be maintained by spraying a line of non-selective herbicide (glyphosate) at the edge of the bed. A mow strip must be maintained at the edge of areas of released turf.

Low fescue turf should be planted as a groundcover below woody plantings in beds, especially in shaded areas. When existing turf is released and allowed to serve as a groundcover to woody plantings it forms a relatively consistent groundcover growing to about one-foot tall, but it is highly competitive with the desirable woody species. For spring flowering trees, it is important to mow the ground layer in early spring (or previous fall) to appreciate spring bloom.
To maintain beds as ornamental enhancements:

1. Mow to edge of bed routinely. Edge of bed should be marked yearly before the first mow of the year.
2. Provide weed control with preemergent herbicide.
3. Use selective herbicides for grass or broadleaf control depending upon composition.
4. Handweed, depending on location and prominence.
5. Mow annually if comprised of herbaceous plants.
6. Mow every 5-7 years if comprised of cutback shrubs.

Bed edges are reflagged every spring to ensure proper mowing up to the edge of the bed with the first mow. Once the area has been mowed correctly, subsequent mowing follows the established pattern and flags can be removed.

Ducks and other water birds frequent the stormwater pond constructed at the corner of Bala Road and 273.

Stormwater best management practices

Stormwater ponds are a common best management practice (BMP) along Delaware roadsides and defined by NRCS Pond code 378 as “a water impoundment made by constructing a dam or embankment or by excavating a pit or dugout”(DelDOT Erosion & Sediment Control and Stormwater Management Design Guide section 7). A stormwater pond serves the primary purpose of absorbing stormwater runoff and improving water quality by filtering out sediments and pollutants before the water moves into local waterways. Stormwater ponds are also valuable for the plant and wildlife habitat they can support and the aesthetic value a well-designed body of water can add to a landscape. Ponds can be designed as ‘wet ponds’, which contain a fairly consistent water level or ‘dry ponds’, which may fill with water only after storm events.

“Green technology” stormwater quality BMPs include infiltration trenches, bioretention cells, and bioswales. Manufactured BMPs include filtration systems, hydrodynamic separators, and sand filters. All erosion, sediment control and stormwater management measures have been designed and installed in accordance with the latest versions of the Delaware Sediment and Stormwater Management Regulations, the DelDOT Standard Construction Details, and the DelDot Standard Specifications and Design Guidance for Drainage, Erosion Control and Stormwater Management manuals.

In the design phase, ponds and embankments should be shaped to blend with the natural topography of a site. A low flow channel stabilized with a permanent vegetative lining system, such as turf reinforcement mat, should be used to route water between detention ponds. Included in the design should be a planned sediment disposal site and easy access routes to any areas requiring annual maintenance inspection such as hydraulic structures or manmade embankments. Seedbed preparation, seeding, fertilizing, and mulching must comply with the SCS Standards and Specifications for Critical Area Planting, Practice Code 342.

Fencing stormwater ponds is advised against because of the false sense of safety created (a fence is no obstacle to a child who wants to get to a pond, but one will certainly block rescue efforts). Fences

Extensive plantings surround and protect a stormwater pond along renovated 141 and 202.

Mowed turf is restricted to a narrow strip adjacent to the guardrail. The slope is planted with grasses and other low maintenance vegetation and serves as a buffer enhancing the habitat quality of this stormwater pond.

also create additional maintenance challenges and scar the beauty of a well-designed pond. Safety is much better addressed by incorporating an extended shallow edge at the pond's perimeter.

This submerged "bench" at the pond's perimeter should be 10 feet wide and submerged 1-3 feet below normal water level in a wet pond. Planting this shallow freshwater marsh with appropriate native vegetation will provide real beauty and excellent wildlife habitat, in addition to limiting damage by nuisance species like Canada geese.

Do not mow up to pond's edge but leave a ten-foot wide buffer strip along the perimeter of the pond beyond the top of the pond banks. The pond banks and this landscaping buffer should be planted with low maintenance grasses, trees, and shrubs to improve aesthetics, limit maintenance needs, and improve pond ecology. Relatively flat terrain on grassed buffer strips is desirable to facilitate easy maintenance and turn around space for mowers. Avoid planting woody plants on manmade dam or embankment areas to preserve their structural integrity. Avoid mowing any slopes steeper than 3:1 (H:V). Plant species suggestions for submerged, marshy, or dry areas can be found in Section 5-7 of the DelDOT Erosion & Sediment Control and Stormwater Management Design Guide.

Pond systems require regular maintenance. Yearly inspection is the responsibility of the NPDES section of DelDOT. From those inspections, work orders are generated for various activities including control of invasive species, removal of trees, excess sediment removal, reseeding of eroded slopes and structural maintenance.

Stormwater mitigation sites

Stormwater mitigation sites are intended to reduce the negative effects that add significant quantities of

stormwater to a natural wetland has on water quality, species diversity, and overall ecosystem health. The state of Delaware does not encourage the use of existing natural wetlands for stormwater management purposes.

Road construction in a rapidly urbanizing state such as Delaware creates many acres of impervious road surface where wetlands once existed. To address this loss of natural wetland area and the stormwater management issues created, Delaware law requires that for every acre of wetland used in road construction, DelDOT must provide 2 acres of (new) wetlands. For smaller areas these new 'wetlands' are often created as roadside stormwater ponds, swales, or other drainage areas. However, the DelDOT / DNREC Memorandum of Agreement on Stormwater provides that "…where DelDOT has demonstrated it cannot provide stormwater quality management on a given project [locally], the "deficit" thus created will be mitigated at another DelDOT project, or existing road, highway, or bridge within the same watershed or another watershed determined by DNREC to be in greater need of water quality control" (1, Sec 8). The anticipated need for these stormwater mitigation sites has led DelDOT and DNREC to work together to create artificial wetland areas, thus 'banking' these sites for future mitigation needs. These constructed wetlands are spacious, formerly-dry areas engineered to drain poorly and have the primary purpose of stormwater absorption and filtration. However, created wetlands are not able to support the same level of species diversity or the complex ecology of natural wetlands.

Expensive to create, these areas require intensive maintenance for the first 3 years to ensure establishment of appropriate vegetation. Initial establishment is most effective using nursery stock such as dormant rhizomes, containerized plants, or bare rootstock. Establishing plants at appropriate water depth is especially important. A "wetland mulch" soil taken from a natural wetland can help establish native plant species. Wetlands may also be left to 'volunteer-seed' via air or animal borne seed. However, this inexpensive method leads to the most problems with invasive species like Phragmites.

Wetland sites should not be mowed to water's edge, but should include a minimum 10 foot wide landscaped buffer strip planted with native grasses, trees, and shrubs at the water's perimeter. Inspect wetlands on a yearly basis for:

- invasive vegetation (often a persistent problem in wetlands, especially those that are 'volunteer' established),
- damage to the embankment,
- signs of oil build-up (a potential problem in wetlands fed with roadside runoff),
- level of sediment accumulation in the facility and forebay, and

Boulders enhance habitat by providing perches for wildlife in this constructed wetland.

- blockage or other damage to inlet and outlet structures.

Replace vegetation to maintain at least 50% surface area coverage (in planted wetlands only). Based on findings in yearly inspections, repair undercut or eroded areas and clean and remove debris from inlet and outlet structures as needed. Every 5 to 7 years, sediment may need to be removed from the forebay. Every 20 to 50 years, sediment may need to be removed from the wetland (potential dredging operation) if the water holding capacity has become reduced significantly, plants are "choked" with sediment, or the wetland becomes eutrophic.

Roadside Features

- Keep guardrails free of tall vegetation using herbicides, low-growing vegetation or weed barriers, depending on the guardrail location.
- Mow one mower pass on either side of medians routinely and mow entire median once yearly to control woody vegetation (unless otherwise directed in specific locations).
- Mow flat roadsides with one mower width during routine mowing and mow roadside with swales or drainage ditches up to the swale.
- Mow up to the edge of enhancement beds during routine mowing.
- Design stormwater ponds in accordance with the latest versions of the Delaware Sediment and Stormwater Management Regulations, the DelDOT Standard construction Details, and the DelDot Standard Specifications and Design Guidance for Drainage, Erosion Control and Stormwater Management manuals.
- Do not fence stormwater ponds.
- Do not mow up to stormwater pond or wetland mitigation site edges; leave a ten foot wide buffer strip along the perimeter of the pond beyond the top of the pond banks.

Design Approaches

Design approaches as outlined in the Enhancing Delaware Highways Roadside Vegetation Concept and Planning Manual include the regional approach, regional-ornamental approach and fully ornamental approach. These approaches help determine the management technique employed to properly maintain each site.

Regional approach

Plant selection is restricted to Delaware native species. The design intent is to develop attractive, naturalistic landscapes based directly on the regional ecology: the dynamics, patterns, colors and cycles of Delaware's native plant communities.

- Plant competition from desirable species is the primary method of weed control, but spot control of aggressive species that threaten the long-term survival of the site is also practiced.
- Supplemental watering is provided during establishment only.
- Mulch may be used around planted specimens, but the long-term ground layer will develop from seeded, planted or existing vegetation.

Switchgrass was seeded into the slope along the Milford bypass exit ramp. Along with groundsel bush and eastern red cedar, the grass provides a continual vegetative cover that suppresses weeds.

'Blue ice' bluestar, asters and 'Northwind' switchgrass were mulched after planting but have grown together and now provide a continual vegetative cover.

Traffic islands in Newark are routinely mulched and weeded to maintain a highly managed aesthetic.

Regional-ornamental approach

Plant selection is restricted to Delaware native species plus other North American native species that reflect the general character of Delaware's native flora. The design intent is to develop ornamental landscapes inspired by the regional colors, patterns and cycles of the native Delaware landscape, but is not necessarily based upon plant community dynamics.

- Spot control of aggressive weeds on a regular basis may be employed to supplement plant competition as the primary method of weed control.
- Supplemental watering is provided during establishment and only in extreme drought conditions.
- Mulch may be used around planted specimens, but the long-term ground layer will develop from seeded, planted or existing vegetation.

Fully ornamental approach

Plant selection is unrestricted. Design intent is to create highly ornamental garden-like landscapes based primarily on visual impact and functionality, not necessarily related to the colors, patterns and cycles of the native Delaware landscape. If site conditions are suitable and aesthetic requirements are met, regional flora should be given preference.

- Routine weed control is employed to remove most non-planted species.
- Supplemental watering is provided whenever conditions would negatively impact the visual effectiveness of the planting.
- Mulch is the typical ground layer.

Design Approaches

- Select a design approach appropriate for each site following recommendations outlined in the Planning and Concept Manual. Design approaches provide guidance for appropriate management strategies.

Vegetation Reduction Techniques

Vegetation along the roadsides can be reduced in a variety of ways. Turf is routinely mowed on roadsides. Mowing frequency affects the type of vegetation that develops. When mowing is discontinued, woody vegetation will become established. Woody vegetation can be managed by editing or cutting back.

A neatly mowed turf edge provides contrast with taller grasses and contributes to an overall attractive appearance.

Groundsel bush, goldenrod, thoroughworts and various warm-season grasses quickly filled in an unmowed median in Seashore State Park.

Discontinued mowing or release

Stopping routine mowing releases the desirable regional vegetation to develop through natural growth or seeding. Undesirable plants are controlled by spot treatment. A released site may require occasional intervention such as periodic mowing, editing or cutting back.

The composition of species found in an area of released turf depends primarily on the density of the original turf and species mix present in original turf cover. Dense vigorous cool-season turf stands are comprised primarily of cool-season turf even three to four years after they have been released to an annual mow regime. Sparse stands of cool-season turf will allow relatively rapid incursion of opportunistic species once an annual mowing regime is followed. When the existing seed bank of native species is large, desirable species establish themselves quickly (i.e. Route 1 in Seashore State Park).

A mowed edge is critical to make released turf attractive.

Discontinued mowing or release

- Release turf areas from routine mowing whenever possible in the right-of-way. Spot spray or mow periodically to control invasive woody plants. Mow an edge routinely.

Trees are marked for selective removal to maintain groves and open space adjacent to Iron Hill at the 896 exit from I95.

A boom ax attachment is used to cut back overgrown groundsel bush and encourage dense regrowth.

Vigorous shrubs and trees such as sassafras and sumac can be mowed to the ground and will emerge as a solid hedge of similar height vegetation.

Editing

Evaluate existing vegetation and identify opportunities to introduce aesthetic order by highlighting individual specimens or plant groups through the process of removing other vegetation. After editing, maintain the open areas with periodic spot weed control.

Cutting back

Periodic cutting of woody vegetation maintains dense and healthy growth within desired height and spread parameters. Vigorous species, like sumac and sweet gum will move out from an existing wood edge when mowing is curtailed. Cutting back periodically (every 5-7 years) will create hedges of these vigorous species that are both attractive and within the requirements for safety and line of sight.

Tall, open shrubs such as groundsel bush, sumac and choke berry can be managed with a cutback procedure every 5 years to encourage regrowth into dense shrub masses.

Editing	• Edit roadsides to introduce order and a maintained appearance.
Cutting back	• Cutback vigorous trees and shrubs to form dense hedges along the roadside.

Mowing

The primary maintenance procedure required for turf is mowing. The frequency of mowing or the number of mowing cycles in a given season is regulated by the amount of turf growth. The amount of growth is dependent upon temperature, fertility, moisture status, season, and natural growth rate of the grass species.

Mowing operations should be performed when the soil and grass are dry. This helps prevent the spread of disease and injury to the turf. Grass clippings should be left to decay and release their nutrients back to the turf, thus minimizing the need for fertilizer. Grass clippings should be removed if they are heavy or thick enough to damage the turf.

Routine mowing of all roadside rights-of-way is an unnecessary management practice. Improper mowing can increase some weeds' ability to compete and degrade the plant community making the roadside more susceptible to weeds and erosion. Mow only the immediate road shoulder and where dictated by safety considerations (such as intersections, bridges, sharp curves, and farm and field entrances). A reduced mowing plan requires the ability to identify desirable and undesirable plant species, and to provide spot treatment at the proper growth cycle for undesirable species. Maps or detailed instructions may be required to show operators where to mow, depending on the specific roadside conditions.

Different types of turf management are appropriate depending on the location:

Routine mowing – mow the site frequently to maintain a specified height of vegetation.

Routine mowing operations are divided into two turf categories: residential-quality turf and utility turf. Residential-quality turf is located at facilities that are maintained by DelDOT-namely rest areas, welcome centers, DOT office buildings, and maintenance complexes. Utility turf is located along the roadsides and it is the majority of the turf DelDOT maintains.

Residential-quality turf should be maintained at a height of 3 inches and mowed weekly or bi-weekly. Mow community entrances as often as necessary to maintain an attractive appearance. When maintaining an area of high quality turf, grass should be mown so that no more than one-third of the leaf surface is removed with each mowing.

Residential quality turf is maintained around planted beds in Wilmington's riverfront.

Mowing of high quality turf should begin when the grass is one-third higher than the desired height. For instance, if one desires a 3-inch height, mowing should begin when the turfgrass reaches 4 1/2 inches. The number of mowing cycles varies and depends on the growth rate of the turfgrass. In most instances, weekly to biweekly mowing accomplishes the desired effect.

Maintain utility turf at a height of 6 inches. Mowing will be required approximately 8 times per year. Utility turf constitutes the majority of DelDOT's mowed areas. In rural areas, 3:1 and steeper slopes shall not be mowed and shall be marked accordingly. Slope indicator shall be utilized on each tractor. In urban areas, some 3:1 slopes will be mowed with specially designed equipment.

When grass is allowed to grow too tall in-between mowings and is then cut short, remaining clippings contribute to an unsightly appearance. In addition, the clippings block light from the turf and can cause dead patches.

Interstates – 8 mowings depending on growth rate. Follow median mowing guidelines (page 7). On roadsides, mow to ditchline and one mower pass on backslope. Mow entire median and specified roadside rights-of-way at the end of the growing season (late November) or in early spring if area is not likely to retain moisture. Mowing height – 6 inches

Primary roads – mow 6 times, on average, per growing season (April – October). Mowing height – 6 inches

Secondary roads – mow 4 times, on average, per growing season (April – October). Mowing height – 6 inches

Tertiary roads – mow 3 times per growing season (April – October). Mowing height – 6"

Stormwater ponds - Mow 10-foot wide access paths to all inlet and outlet structures regularly. For warm-season grasses, the previous season's stalks should be cut down to 8-12 inches in early spring (mid March), before new season's growth emerges. Do not mow up to pond's edge but leave a 10 foot buffer strip along the perimeter of the pond beyond the top of the pond banks. Mow buffer strip at the end of the growing season (late November) or in early spring, if area is accessible, to control woody invasive species. In rural settings, a single mowing per year should be sufficient. Mow between September 1 and 30 to allow for regrowth of winter cover while avoiding

potential negative effects on wildlife such as nesting birds. In urban settings, mow once in early growing season (April 1 – June 30) and a second time during dry period (Aug 1 – Oct 31). A dry pond bottom can be mowed once a year during dry period; weekly during peak growing season (April – November).

Wetland mitigation sites - Mow dry grassy areas/buffer strip once per year during dry season (Aug 1 – Oct 31).

Biofiltration swales – If turf cover is used, mow regularly (weekly from April to November). Mow no lower than 6 inches to maintain desired design height. The vegetation height should be 2 times the depth of flow during the quality storm. The vegetation height should be specified on the plan.

Filter strips – Mow, annually, between September 1 and 30 to allow for regrowth of winter cover while avoiding potential negative effects on wildlife such as nesting birds. For warm-season grasses, the previous season's stalks should be cut down to 8-12 inches in early spring (mid March), before new season's growth emerges. The approved plan will specify the mow height. Filter strip vegetation should be maintained at a height of 2 times the depth of flow during the quality storm.

Regardless of the class of roadside, all intersections must be mowed at necessary intervals to provide for adequate sight distance. Mowing shall be performed where needed to maintain sight distance, such as on inside curves, off ramps, on ramps, intersections, and private entrances.

The mowing cycle should begin before the grass reaches ten inches in height. The first mowing is most important since it will dictate the appearance of the turf throughout the balance of the year. Specific areas have specific instructions, e.g., mow one strip along fence, interiors of interchanges, or up to residential or business lawns.

Clean mowers regularly to reduce the spread of invasive plant parts, insects and disease from one mowed area to another.

Annual mowing can be conducted in late fall; however cutting growth at this time is hardest on equipment. Autumn mowing also reduces the visual appeal of the site and destroys winter cover, which is important to local wildlife.

Periodic mowing – mow the site annually or as necessary to discourage establishment of woody species and maintain an herbaceous composition. Annual mowing can be completed at the last mow of the season to clean up an area prior to the dormant period. Fall mowing is useful for sites that are

Grass is mowed in this median north of Odessa in late fall to allow spring bulbs to come up unimpeded.

Switchgrass begins to grow in mid-spring and covers the dying bulb foliage.

routinely wet and will be difficult to mow in early spring or if spring flowering perennials or bulbs exist at a site. Some sites contain warm-season grasses and other perennials that are attractive during the winter. If possible, allow this vegetation to remain standing throughout the winter and mow during the first mow of the following season. This technique utilizes the natural break-down of herbaceous vegetation over the winter making the areas much easier to mow in the spring.

Equipment - Either a rotary or flail (impact) mower can be used to mow turfgrass. Rotary mowers are useful for mowing tall grass at the end of the growing season. Rotary mowers should be rear discharge. Mower blades should be sharp to obtain the best results. Dull mower blades tear the grass blade instead of cutting it, thus reducing the quality of the turf. Grass tearing results in poor turf appearance and allows disease to enter the plant. Well-sharpened mower blades will also reduce mower vibration, lengthen mower life, and reduce fuel consumption.

The appealing apricot winter color of little bluestem is a benefit of allowing warm-season grasses to remain standing all winter.

Various mowers are used depending on the desired cut width and maneuverability required.

Repeated scraping and the resulting exposed soil provides an opportunity for weed species to germinate and take over.

Mowing

- Mow residential quality turf to a height of 3 inches routinely.
- Mow utility turf (medians and roadsides) to a height of 6 inches.
- Mowing frequency is determined by growth rate and traffic volume of roadway.
- Mow intersections and inside curves, off ramps, on ramps, and private entrances as needed to maintain sight distances.
- Complete yearly mowing at the end of the growing season (November) or in early spring (if area is not prone to spring water accumulation).
- Mow stormwater ponds in rural settings once a year (August – October) and in urban settings twice yearly (April – June and August – October)
- Mow dry grassy areas/buffer strips once per year (August – October).

Pruning

Reasons for pruning

Pruning is the selective removal of plant parts for the purpose of increasing the value of the remaining plant. Tree pruning is performed for three purposes: health, structure, and safety.

Health – Pruning for health involves removing diseased, injured, insect-infested, or dead wood. Removing crossing and rubbing branches can eliminate abrasions that, along with dead wood, can serve as an entry point for insects and disease organisms. The removal of injured and broken limbs encourages wound closure. Thinning the crown increases airflow and can reduce some pest problems.

Structure – Structural pruning enhances the natural form and character of the tree. It also reduces the likelihood of storm damage.

Safety - Remove branches that impact visibility (signs and roadway), could fall and cause injury or property damage, and grow into utility lines. For the most part, safety pruning can be avoided by choosing plants that won't grow beyond the space provided, and have characteristics suited to the site.

Pruning is often required along roadsides to keep utility lines clear.

Pruning tools

Prune with sharp tools that are appropriate for the branch size. The tool choice depends on the size of branches to be pruned. Keep tools clean and sanitized to prevent the spread of disease from infected to healthy trees.

Pruning shears – used for branches no thicker than a pencil. There are two basic types of hand pruners. Scissors-action utilizes a curved cutting blade that slides past a broader lower blade. Anvil-action pruners feature a straight blade that cuts the branch against a small anvil or block when you squeeze the handle. Because anvil-action pruners do not make close cuts and can crush the tissues, it is best to use scissor-action pruners.

Lopping shears – used for branches up to 3/4 inch thick. Loppers are like scissor-action hand pruners with larger blades and long handles for better leverage.

Pruning saw – used for branches thicker than 3/4 inch. Pruning saws have narrow blades (for maneuverability) and coarser teeth than carpenter saws. They are designed to cut on the draw stroke (pulling the blade toward you). A bow saw can also be used, but may be more awkward to maneuver in tight areas.

Pole pruners – used to cut branches beyond reach. Most pole pruners have both a cutting blade and a saw. Exercise caution when using around utility wires. Pole pruners will conduct electricity if they come into contact with energized wires.

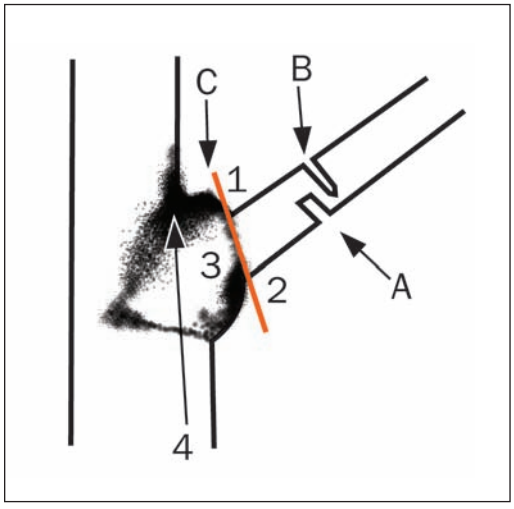
Chain saws – used for branches larger than 4 inches. Should only be used by trained personnel.

Pruning techniques

Natural target pruning – Plants do not "heal" like people do. When a tree is pruned, a wound is created, causing some decay. The tree then seals or compartmentalizes the wound. However, the wound is contained within the tree forever. If the cut is made through only branch tissue, the decay will be confined to that tissue. If the cut is made through the trunk tissue, it is much more difficult for the tree to compartmentalize the wound, and the entire tree is subject to decay. Therefore, the smaller the branch is when pruned, the sooner the wound created will heal.

To locate the proper place to cut a branch, find the branch collar, which is a swelling or bulge at the underside of the base of the branch (3). If the branch collar is difficult to find, the branch bark ridge (BBR; 4)) can be used to determine the proper placement for the pruning cut. The BBR is a ridge of bark that forms in a branch crotch and partially around the trunk. A proper pruning cut does not damage either the branch bark ridge or the branch collar.

A proper cut begins just outside the branch bark ridge (BBR;4) and angles down and away from the trunk of the tree (1-2). Make the cut as close as possible to the trunk, but be sure that it's outside the BBR, so that the trunk tissue is not injured.



Branches large enough to require saws should be supported with one hand while cutting. When a branch is too large to support, use three cuts to ensure the bark doesn't rip.

1. Make a small notch on the underside of the branch, outside of the branch collar to prevent the tree bark from stripping down the trunk. (A)

2. Make a cut beyond the first cut, all the way through the branch, to remove most of the weight of the limb. (B)

3. The remaining stub is cut just outside of the branch collar. (C)

Sap flow from pruning wounds is not generally harmful. Although unsightly, tree sap, gums and resins are the natural means by which trees combat the invasion by pathogens. Wound dressings may cause more harm than good. They will not stop decay or cure tree diseases. They may actually slow the tree's natural process of closing the wound surface.

Pruning sequence- prioritize pruning in the following order:

1. Remove diseased and dead wood.
2. Remove crossing branches that rub together and branches that grow back into the center of the tree.
3. Remove branches that form narrow-angled crotches before they become heavy enough to split the trunk below the crotch.
4. Remove suckers, water sprouts (soft, fast growing branches that usually grow vertically from large limbs or the trunk), and any branch that detracts from the natural shape of the tree.

Pruning timing – There is no single "best time of the year" to prune. The timing is determined by the type of plant, plant species, the reason for pruning, and desired effect. Remove dead or diseased wood anytime. Avoid pruning during the spring when trees are leafing out or when they are losing their leaves in the fall. Prune spring-flowering trees and shrubs immediately after the flowering period. Prune summer-flowering shrubs during their dormant period from mid-November to February. Prune evergreens from mid-November to mid-March. Evergreens cannot tolerate severe pruning. With newly planted trees, only remove branches damaged during the transplanting process. Wait until after a full season of growth in the new location before doing any additional pruning.

Complete removal – Remove all dead trees, brush, shrubs and woody vines within the legal right-of-way. Remove all trees, shrubs and woody vines in safety clear zones and drainage swales (unless designed to accomodate woody plants).

- safety clear zone - at least 30 feet from the outside edge (white line) of the travel lane.
- drainage swales - up to a maximum of 5-feet outside of the swale limits on each side

Fell and remove downed trees in a manner that will prevent injury and/or damage to remaining vegetation, structures, and people. If the potential for damage exists, carefully remove trees in sections. Make cuts level to the ground, or to a height not to exceed 2 inches for safety reasons. Clean up all vegetative debris (wood chips). Treat live stumps, 2-inch caliper or larger, and all woody vines on the day of cutting with an appropriate herbicide. Clean the stump cut surface of all sawdust and dirt to ensure proper treatment. Repeat herbicide treatment (as directed by engineer), if suckers or sprouts develop at any time prior to the final acceptance of the work.

Cutback – Also know as rejuvenating, cutback is a drastic form of pruning used to manage a woody shrub border by mowing or cutting with a tractor and extended arm mower or mechanical brush hog attachment on roadsides and along embankments of woody (brush) and herbaceous (grass) vegetation at a designated frequency, leaving stubble or stump height not shorter than 6 inches and not to exceed 12 inches. Cutback is done only as directed by an engineer.

Shrubs like red twig dogwood benefit from rejunvenation pruning every other year to promote young bright red stems.

Pruning

- Prune with sharp tools that are appropriate for the branch size (pruning shears for branches no thicker than a pencil; loppers for branches up to 3/4 inch; pruning saw for branches thicker than 3/4 inch).
- Prune branches following the natural target pruning procedure (i.e. do not damage the branch collar).
- Small cuts do less damage to the tree than large cuts. Prune when trees are young.
- Do not apply wound dressing or tree paint to the cut surface.
- Remove dead or diseased wood anytime.
- Correct crossing branches, branches that grow back into the center of the tree or branches that form narrow-angled crotches when a tree is young.
- Remove suckers and water sprouts that disrupt the natural shape of the tree.
- Avoid pruning during the spring when trees are leafing out or when they are losing their leaves in the fall. Prune spring-flowering trees and shrubs immediately after flowering. Prune summer-flowering shrubs from mid-November to February. Prune evergreens from mid-November to mid-March.
- Avoid topping or tipping a tree.
- Remove all dead trees, brush, shrubs and woody vines within the legal right-of-way.
- Remove all trees, shrubs and woody vines in safety clear zones and drainage swales (unless designed to accomodate woody plants).
- Make cuts level to the ground or no greater than 2 inches above ground level.
- Treat live stumps with an herbicide on the day of cutting and re-treat as necessary.
- Cutback to rejuvenate a woody shrub border.

Trash Accumulation

Trash accumulation can ruin the aesthetics of any planting, yet the vulnerability of sites to trash accumulation is highly variable. A few factors should be considered so that aesthetics can be maintained without requiring an unreasonable amount of maintenance.

Primary factors influencing the potential for trash accumulation are prevailing winds, topography and the specific plants employed. Some sites are in areas where trash is prevalent and in addition some sites are the likely terminus for trash movement in the local landscape. For example, a site might be between two roadways and trash from the top roadway may naturally sweep across the plane of the paved surface, under a guardrail and into the plantings. If the plants used in such a site are of a nature that makes it difficult to remove trash, such a site will be difficult to maintain at acceptable aesthetic levels. Some plant species are more prone to trapping trash than others. Plants with thorns, spines, or highly twiggy structure are especially likely to trap and hold trash within them, making trash removal difficult and time-consuming. Plants with smoother texture and/or plants that form an even face at the exposed edge of the planting are less likely to trap trash. If trash accumulates it will be concentrated along an easily accessed edge that facilitates easy removal.

Accumulated trash detracts significantly from an enhancement sites. The smooth texture of the blue aster would not have trapped this plastic bag, but the stem of a taller weed did.

Trash Accumulation

- Consider potential for trash accumulation when selecting enhancement sites.
- Use appropriate plants considering the relative vulnerability of a site to accumulate trash.
- Include trash removal as part of routine landscape maintenance.

Weeds

A weed is any plant growing in an area where it is not wanted. Plants may be considered weeds when they do one or more of the following:

- Compete with desirable plants for water, nutrients or sunlight.
- Act as contaminants in a product at harvest.
- Harbor and act as alternate hosts for pests.
- Release toxins in the soil that inhibit growth of desirable plants.
- Reduce the aesthetic value of landscape areas and rights-of-way
- Increase costs of trimming, mowing or cultivation.
- Hinder easy travel or movement.
- Clog drainage areas.
- Increase the level of fire hazard.
- Act as threats to human health (toxic plant parts).

Weed classification

Weeds can be classified in a number of different categories based on plant type, life cycle, aggressive nature or legal status.

Plant type is a classification based on morphological differences between plants.

Grasses have:

- one cotyledon (seed leaf) emerging from the seed.
- narrow leaves with parallel veins.

Annual weed grasses germinate soon after planting between these two rows of chokeberry.

- a growing point at or below the soil surface; so most grasses tolerate close mowing.

Common annual grass weeds include crabgrass, goosegrass, foxtail and barnyard grass. Common perennial grass weeds include bermudagrass, johnsongrass and quackgrass.

Sedges:

- have triangular stems and three rows of leaves.
- are found in wet places (but nutsedge, the principle pest species is found in fertile, well-drained soil).

Broadleaves have:

- two cotyledons (seed leaves) emerging from the seed.
- broad leaves with net-like veins.
- growing points are at the end of each stem and in leaf axils.

Common annual broadleaf weeds include common chickweed, henbit, black medic, knotweed, purslane, lambsquarters, morning glory, pigweed, ragweed, spurge and many others. Biennial broadleaf weeds include mullein, burdock, Queen Anne's lace, yellow rocket and wild parsnip. Perennial broadleaf weeds include Canada thistle, dandelion, curly dock, bindweed, horse nettle, poison ivy, red sorrel and many others.

Although it has long been used for slope stabilization, crown vetch is now considered a persistent broadleaf weed that can plague planting sites for many years.

Life cycle is a useful classification when determining control methods.

Annuals complete their life cycle in less than one calendar year. Control strategies include preventing seed from germinating or plants from emerging each year. But annuals grow fast and produce a lot of seed, so control can be difficult. Summer annuals germinate in spring or summer, grow, set seed and die before winter. They include weeds such as cocklebur, knotweed, pigweed, lambsquarters, ragweed, crabgrass, foxtail and barnyard grass. Winter annuals germinate in fall, overwinter, mature, set seed, and die in spring or early summer. They include chickweed, henbit, shepherd's purse and cornflower. They are difficult to control because they germinate over a long period and have less aboveground competition.

Biennials complete their life cycle within two years. During the first year, the plant forms basal leaves (rosette) and a tap root; the second year it flowers, matures and dies. Wild carrot, bull thistle, common mullien and common burdock are all biennials.

Perennials live more than two years and have a persistent root system. Most reproduce by seed and are able to spread vegetatively as well. Simple perennials spread by seed, crown buds and cut root segments. Examples include dandelion, dock plantain and pokeweed. Creeping perennials reproduce by creeping above ground stems (stolons) or below ground stems (rhizomes). Examples include red sorrel, field bindweed, wild strawberry, mouseear chickweed, ground ivy, bermudagrass, johnsongrass, quackgrass and Canada thistle.

Aggressive nature or legal status affects how a weed must be managed.

Classic weeds require consistent disturbance to become established and persist. Examples include Queen Anne's lace, pokeweed and evening primrose. These early successional species, both native and exotic, often dominate initially when an existing cool-season turf cover is removed. If desirable vegetation is established, it will out-compete these weeds in a few years and they will disappear from the mix. Classic weeds are consistent components of continually disturbed right-of-ways. Undisturbed right-of-ways that have developed into more stable native grass and forb meadows, shrub borders or forests do not provide

the conditions necessary for classic weeds to persist.

Invasive plants are able to replace desirable species. Invasive species can be problematic in both disturbed and established environments. The Delaware Invasive Species Council used a modified risk assessment tool to designate invasive plants as widespread and invasive, restricted and invasive, and restricted and potentially invasive.

Queen Anne's lace and chicory are classic weeds that come into an unmowed area in the first few years after disturbance. They are eventually replaced by other more permanent plants.

Delaware Invasive Species Designations:

Widespread and Invasive	Restricted and Invasive	Restricted and Potentially-invasive
Multiflora rose	Japanese barberry	Butterfly bush
Oriental bittersweet	Periwinkle	
Japanese stiltgrass	Garlic mustard	
Japanese knotweed	Winged euonymus (burning bush)	
Autumn olive	Porcelain berry	
Norway maple	Bradford pear	
Common reed	Marsh dewflower	
Hydrilla	Lesser celandine	
Mile-a-minute	Reed canarygrass	
Clematis	Honeysuckle – bush honeysuckle species	
Privet	Tree of heaven	
European sweetflag	Spotted knapweed	

Japanese stilt grass is the primary ground cover on this disturbed roadside edge in Newark.

A vigorous patch of Canada thistle must be controlled before it goes to seed.

Noxious weeds is a legal classification. Johnsongrass, bur cucumber, giant ragweed and Canada thistle are legally classified as noxious weeds in Delaware. It is unlawful to allow noxious weeds to set seed or exceed 24 inches in height.

Nuisance weeds is a legal classification. It is unlawful to grow nuisance weeds in a manner that impacts adjacent property. In Delaware, bamboo was designated as a nuisance weed. Due to an inability to enforce nuisance weed legislation, bamboo is no longer considered a nuisance weed. There are no legally classified nuisance weeds in Delaware.

Weed Control

Weeds are controlled on roadside rights-of-way:

- To maintain the integrity of the paved surface,
- To prevent or reduce erosion,
- To provide for the safety of the traveling public,
- To provide for efficient maintenance practices,
- To maintain drainage,
- To provide beauty, and,
- To provide wildlife habitat.

Control methods

An integrated vegetation management program (IRVM) uses a combination of mechanical, cultural, biological and chemical methods for control. In an IRVM

Weed classification

- Weeds are categorized as grasses, sedges or broadleaves, which affects the ability to selectively control weeds in desirable plantings.
- Weeds can be annuals, biennials or perennials, which affect the timing of control measures.
- Weeds are classified as classic, invasive, noxious or nuisance, dictating different levels of required or recommended control. Specific control recommendations can be found in Appendix C.

program the least toxic alternative is always selected first.

Cultural - Prevention is an effective method of weed control and is best accomplished by:

1. Making sure weed seeds and reproductive plant parts are not carried onto the area via contaminated seed, water, topsoil or mulch. For example, in road construction projects, the topsoil may be contaminated with a weed such as Canada thistle. This soil should not be stockpiled and reused as topsoil on the project.
2. Preventing weeds from going to seed. Noxious weed control is based on preventing seed production to reduce the spread of those species.
3. Preventing the spread of perennial weeds that reproduce vegetatively. Mulch and topsoil are notorious for carrying perennial weed parts. Use a reliable weed-free source and do not purchase mulch, topsoil or organic matter that has been stockpiled without appropriate covering or weed control.

Many weed species require sunlight to germinate. Weed control can often be achieved with a thin covering of an organic material to prevent sunlight from reaching the soil surface. A thick cover of desirable vegetation will also prevent sunlight from reaching the soil and prevent many weed problems. For example, dense turf maintained at a height of 3-6 inches will block sunlight and dramatically reduce crabgrass germination. If turf is mowed

It is unlawful to allow a field of Canada thistle to go to seed, but it happens all the time. Preventing seed production is one of the best ways to reduce the spread of noxious weeds such as Canada thistle.

Sawdust is used as a medium to spread seed and also acts as a mulch to reduce weed seed germination in the soil below the sawdust.

Warm-season grasses, such as this Northwind switchgrass, are self-mulching. The past season's vegetation provides a dense mat that excludes light and reduces weed seed germination.

Fragrant sumac has colonized the slopes along I95 through Wilmington, creating dense stands that prevent weeds from developing.

Aromatic aster is so vigorous that few weeds are able to germinate in this Dewey Beach median planting.

Close spacing at planting allows desirable plants to cover the ground quickly and reduces the need for hand weeding in roadside plantings.

too close to the ground, the weed suppressing effect is lost.

In addition to preventing germination, desirable vegetation can provide effective weed suppression by outcompeting weed plants for nutrients and other resources. For example, a vigorous stand of a colonizing shrub such as sumac will make conditions relatively inhospitable to invasive plants. Herbaceous plants can also be effective in this way. Thick healthy turfgrass will minimize weed problems and dense stands of colonizing native plants like goldenrod, switchgrass and aromatic aster create conditions inhospitable to weeds.

Biological – In biological weed control, a "natural enemy," which is otherwise harmless, is used to control the weed. Insects have been the most successful natural enemies to date. Other control agents include disease organisms, parasitic plants, rodents, fish and selective grazing by livestock. Purple loosestrife has been successfully controlled in a number of regions with an imported beetle. Mile-a-minute is potentially controllable with an introduced insect.

Cultural control

- Cultural control is accomplished by preventing weed seeds and reproductive plant parts from contaminating growing areas.
- Reduce weed seed germination by preventing light from reaching weed seeds (mulch or dense vegetation).
- Use desirable plant competition to prevent weed incursion.

Currently pervaded by purple loosestrife, this environment could benefit from the introduction of two European beetle species (*Galerucella calmariensis* and *G. pusilla*), which have proved to be an effective biological control for some North American regions.

- Introduced insects are available for the control of some invasive weeds.

Biological control

Mechanical – Mechanical control methods are the oldest methods of weed control. These include – manual weeding, hoeing, blading, grubbing, mowing, girdling, burning, flooding, mulching, cultivation and other tillage operations. Many of these methods are labor intensive and therefore expensive. Mechanical methods are still an important component of a total weed management program.

The woody weed species appearing in this roadway median meadow will be controlled by this annual mowing.

Mowing is routinely used to control woody invasive species along roadsides. Mowed strips can be used to prevent weeds outside the roadside right-of-way from spreading into managed right-of-way areas. Mowing can also be used to control classic weeds that invade new meadow plantings. Repeated mowing in the first two years of establishment will control taller classic weed species and allow shorter native grasses and perennials to become established.

Multiple mowing during the first two years of establishment allowed this meadow full of black-eyed Susan to flourish.

Manual weeding is not practical for miles of roadside, but if feasible for specific enhancement sites. There are times when hand pulling prior to flowering and seed development can greatly reduce

A mowed strip along the back edge of this plot prevents aggressive plants from growing over the fence and into the right-of-way.

a weed infestation. Manual weeding is also a technique that may be warranted during an establishment period until the desirable vegetation becomes dense enough to out-compete weeds.

Selective hand weeding in this small roadside enhancement is a practical way to remove tall broadleaf plants.

Girdling is a mechanical control technique useful for controlling established woody species. Remove phloem in a collar around the trunk. Xylem is still able to translocate to the leaves but the leaves no longer send energy back to the roots. Eventually the tree, shrub or vine will die and may require removal. With vines, do not physically remove vines once the stems/trunks have been cut. In most situations the dead vines will be removed by natural weathering processes. Allowing this to occur is the most efficient and environmentally friendly approach to vine removal. It avoids damage to trees that may occur with mechanical removal and eliminates the need to transport and dispose of dead organic material.

Chemical – Chemicals used to kill, change or inhibit plant growth are called herbicides. They are "phytotoxic," meaning injurious or toxic to plants. Pesticides are a broader group of chemicals that includes herbicides but may also target undesirable insects and disease organisms.

Herbicides can be efficient and effective tools for vegetation management and weed control; however, there are potential impacts to health and the environment. The need for herbicide and pesticide use should be minimized whenever possible by adoption of cultural, biological and mechanical control methods. Though herbicides are frequently

Mechanical control

- Mow yearly to control woody plants in an herbaceous meadow.
- Mow 2-3 times during the first two growing seasons to control classic weeds in an establishing meadow.
- Mow strips around the periphery of a meadow or shrub planting prevent weed incursion from outside the right-of-way.
- Handpull weeds in enhancements during the establishment period or periodically when warranted.
- Girdle invasive woody trees, shrubs and vines as one method of control.

necessary in the initial stages of site development, the ultimate establishment of desirable vegetation should minimize the continuing need for their use. Minimizing risks to human health and the environment must be of primary concern when selecting and applying herbicides on Delaware roadsides. In addition DelDOT policy prohibits the use of restricted-use chemicals when managing roadside vegetation.

Herbicides are an integral part of the overall vegetation management program of the Delaware Department of Transportation. The use of herbicides is often more effective, more economical and requires less labor and equipment than the alternate methods of hand cutting and mowing. Selective herbicide use can preserve greater species diversity in roadside rights-of-way.

A survey of Delaware drivers conducted in 2005, asked how drivers feel about pesticide use on the roadside. Most (80%) respondents agreed that pesticide use should be kept to a minimum, and most (75%) disagreed with the statement suggesting pesticides be used freely to keep costs down; only 20 percent believed that DelDOT should use no pesticides at all. Most respondents (77%) approved of using herbicides along the roadside to protect natural areas from being impacted by invasive plants.

It is the intent of this manual to provide information and guidance in promoting the safe and proper use of herbicides, thereby protecting the environment and the public health while performing indispensable highway maintenance and safety. Personnel responsible for the application of herbicides to roadside vegetation must become familiar with the fundamentals of herbicides, treatment guidelines, equipment, environmental safety and record keeping. All personnel must participate in periodic training programs and must be licensed as a certified pesticide applicator in the right-of-way category (06) and ornamental and turf category (03). Licensed operators must participate in re-certification programs that are made available to departmental personnel.

Chemical control

- Selective herbicide use can preserve greater species diversity in roadside rights-of-way.
- Delaware drivers do not support excessive use of pesticides but do believe herbicides are important for controlling invasive plants.
- Training personnel properly is the key to safe and proper herbicide use.

Herbicide labels include:	Material Safety Data Sheets include:
uses for which the chemical is legally permitted, application rates, timing, and procedures, lists of susceptible plants, specific environmental concerns, and safety precautions and proper cleanup.	emergency telephone numbers, product ingredients, physical data, fire and explosion hazard information, reactivity data, environmental and disposal information, health hazard data, first aid procedures, handling precautions, and any necessary additional information.

Herbicide safety

Product labels and MSDS - Herbicides must be used in accordance with their registered label. This manual serves as a supplement to, not a replacement for, herbicide labels and Material Safety Data Sheets (MSDS). The use of any herbicide requires a thorough understanding of the information printed on the label and MSDS. Regulations affecting herbicide usage and the registration status of specific herbicide materials can change without notice.

Each herbicide varies in the hazard or danger that it presents to the user. Labels are required to contain a signal word to inform the user of the product's potential danger. Knowing the meaning of these signal words will help you determine precautions you may wish to take in addition to those on the label. The signal words are as follows:

- **DANGER** - the herbicide is highly toxic. A teaspoonful taken by mouth could kill an average-sized adult. Any product that is highly toxic orally, dermally, or through inhalation OR causes severe eye and skin burning will be labeled DANGER. If the product is highly toxic orally, dermally, or through inhalation, it will also be labeled.
- **WARNING** - The herbicide is moderately toxic. A teaspoonful to tablespoonful taken by mouth could kill an average-sized adult.
- **CAUTION** – The herbicide is slightly toxic. An ounce to a pint taken by mouth could kill an average-sized adult.

Every label contains precautionary statements regarding hazards to humans, domestic animals, and the environment, agricultural use requirements, and recommended personal protective equipment, as well as physical or chemical hazards. These statements should be read before using the product to prevent accidents and misuse.

Herbicide labels vary in the type of protective clothing and equipment safety statements they contain. The signal words will alert you to look for these precautions. Herbicides can enter the body in three principal ways – through the mouth (orally), through the skin and eyes (dermally), and through the lungs by

inhalation. To prevent herbicides from entering the body, applicators may need to use protective clothing and equipment. As a user, your common sense and knowledge of the product should help you assess potential hazards and select the kind of protection you need.

Each herbicide label contains general cautions and precautions about the application of the product. Not all of these statements have been included in the label section of this manual. The following precautionary statements are often found and should be followed unless the label specifically states otherwise.

- Do not apply herbicides through irrigation equipment.
- Avoid spray drift onto off-target species and out of the treatment area.
- Avoid runoff to adjacent water or wetland areas.
- Do not apply more than the recommended rates and treatments over a given period of time.
- Always wear the prescribed personal protection equipment for mixing, loading, and application.
- Where appropriate, follow all Worker Protection Standards including restricted entry intervals and protective clothing.

The only way to obtain specific information on application of a particular herbicide is to READ THE PRODUCT LABEL AND MATERIAL SAFETY DATA SHEET. For this reason, up-to-date labels and MSDS for any chemical being used should be kept at hand for reference, to be used by applicators while on the job and by specialists while planning activities. MSDS reference websites include:

www.greenbook.net

www.cdms.net/manuf/manuf.asp

Herbicide safety

- Read the product label and MSDS before using any herbicide.
- Understand the meaning of signal words (danger, warning and caution) on product labels.
- Keep MSDS sheets in appropriate vehicles.
- Refer to MSDS reference website for updates.

Herbicide use

To achieve maximum benefit from any herbicide program, you must select appropriate chemicals and follow proper application procedures. The way an herbicide can be used and applied depends on the characteristics of the active ingredient (ai), the chemical that does the work: whether it is absorbed by foliage or by the root system, whether it works on contact or is translocated, whether it is selective or nonselective and whether it is persistent or nonpersistent. The application timing and techniques employed will greatly affect the results. Timing depends on the stage of weed growth, weed pressure, weed and crop species, environmental conditions, soil type, and chemical characteristics of the herbicide. Choose the application technique based on the chemical activity (such as preemergence versus postemergence), treatment area, proximity of nontolerant crops, chemical formulation, and available resources.

Herbicide mode of action

Contact herbicides control weeds by direct contact with plant parts and are usually applied directly to plant foliage. Contact herbicides are sometimes called "chemical mowers," because they kill only the plant parts contacted by the herbicide. They are most effective in controlling annual weeds, but will kill the tops of perennial weeds. Results are obtained from within a few hours to a few days and require favorable plant conditions for optimum performance. Contact herbicides are often added to root absorbed ones to speed up plant kill. A contact herbicide such as fosamine (Krenite®) can be applied in July through September to inhibit bud expansion the following spring.

Krenite® applied to this roadside edge killed the foliage it contacted.

Systemic herbicides are absorbed through plant foliage, shoots or roots and move throughout the plant. Foliar applied systemics are absorbed through green leaf or stem tissue. Glyphosate is an example of a foliar applied systemic that must be applied to green tissue in order to be effective. Root absorbed herbicides

Herbicide use

- Choose the herbicide, application technique, application timing to achieve maximum benefits with minimum exposure to non-targets.

A directed spray of glyphosate was used to control Japanese stilt grass and other weeds on the roadside edge.

require precipitation to become dissolved and moved into the root zone. Residual root absorbed herbicides have a low order of solubility, and depending upon the amount applied, will remain in the soil for various lengths of time making it nonproductive for plant growth. Nonresidual herbicides rapidly break down completely in the soil and have no effect on soil productivity. Systemic herbicides accumulate in growth centers where they speed up and disorganize cell division or interfere with food production. Death of the plant occurs after a period of time, perhaps even weeks or longer following the absorption of the herbicide into the plant. Systemics comprise the majority of highway related herbicides.

Herbicide selectivity

Non-selective herbicides will kill or control almost all plants. Non-selective herbicide application may be used to control vegetation periodically in the following roadside situations:

- Bridge ends and bridges sites
- Curb, gutter and sidewalk edging
- Delineators and signs
- Drainage ditches, culvert ends
- Fences
- Guardrails overgrown with broadleaf weeds or woody plants
- Rip rap
- Under asphalt

Selective herbicides are those that control undesirable vegetation without seriously injuring surrounding desirable plants. Selectivity is a relative rather than an absolute characteristic and is influenced by plant factors, chemical and application factors, and environmental factors.

Plant factors – Plant structure, leaf shape and leaf surface affect susceptibility to herbicides. Flat, wide leaves will retain a spray solution, while the spray will bounce off narrow, vertical leaves. Waxy leaf coatings and thick hair can prevent an herbicide solution from entering a leaf. Young plants have thinner cuticles and less hair, so selectivity is often based on the weed life stage. Sometimes perennials are especially susceptible to herbicides when in the bud-to-flower stage of growth. Variation in growing points between grasses (growing point at or below ground) and broadleaf plants (exposed growing points) can be a

- Contact herbicides control only the tissue touched by the herbicide.
- Systemic herbicides are translocated throughout the entire plant.

Herbicide mode of action

A selective broadleaved herbicide was used to control broadleaves in this warm-season grass planting.

By using a directed spray of glyphosate, hayscented ferns were saved, while Japanese stilt grass was controlled.

A preemergent herbicide was applied early in spring, allowing the Amsonia to bloom in a relatively weed-free bed.

way to achieve selectivity. Weeds are most susceptible to herbicides when they are seedlings or when rapid growth is taking place in another growth stage. Tough-to-control woody plants like poison ivy and multiflora rose are controlled best in late summer to early fall when they are well-established and flowering. Actively growing plants take up and translocate herbicide throughout the entire plant. Plant physiology, the chemical differences between plant species, can control selectivity.

Herbicide and application factors – Selectivity can be controlled by application rate (high rates are nonselective but lower rates are selective), formulation (granular vs. spray), placement and application timing. Directed sprays, wiper treatments or suspension in gel, can allow the applicator to apply an herbicide selectively to weed species without harming desirable species. The following times of application also result in selectivity:

Pre-emergent treatment – Treatment made prior to the emergence of weeds. An herbicide barrier is created that kills newly germinated weeds before they emerge.

Post-emergent treatment – Treatment is made after the weed and desirable plants emerge. These treatments must employ some method of selectivity.

Environmental factors – Soil placement and texture can affect herbicide activity. By placing the herbicide near the surface, you can control shallow-rooted weeds without harming deep-rooted plants. Sandy soils, clay soils and highly organic soils tie up herbicides differently and affect plant availability and therefore toxicity. Most herbicides are not effective when applied to dry soils. Some herbicides become

highly toxic when temperatures are high, causing excessive volatilization and plant injury.

Herbicide selectivity

- Non-selective herbicides kill or control almost all plants. They can be used selectively by applying through spot treatment or applying when the weeds are susceptible and the desirable plants are tolerant of the herbicide.
- Waxy leaf coatings and dense hairs can make some plants less susceptible to herbicides.
- Younger plants (seedlings) are usually more susceptible to herbicides.
- Plants that are in a rapid growth stage are usually more susceptible to herbicides.
- Woody plants like poison ivy and multiflora rose are most susceptible to herbicides in late summer to early fall.
- Selectivity can be achieved by using lower rates of herbicides.
- Selectivity can be achieved by applying the herbicide to the weed only through spot treatment with a directed spray or suspension in a gel, or wick application when the weed is taller than the desirable plants.
- Pre-emergent herbicides are applied prior to weed emergence and control annual weeds.
- Post-emergent herbicides are applied after emergence and must be used selectively.

Herbicide formulations

The active ingredient in an herbicide is the chemical that does the work. Active ingredients can rarely be used in their pure form. They are usually changed or mixed with inert ingredients to make them convenient to handle and safe, easy, and accurate to apply. An herbicide formulation contains the active ingredient along with a liquid or dry carrier and may also contain surfactants, emulsifiers, or other adjuvants to improve the safety or performance of the active ingredient or both.

Some formulations are ready for use. Others must be diluted with water or some other liquid carrier specified on the label. The label directions explain how to use a formulation. The most common liquid and dry formulations are discussed here.

Liquids or aqueous suspensions (L or AS). Some active ingredients can be produced only as a solid or, at best, a semisolid. These solids are finely ground and suspended in a minimal amount of liquid carrier (water) for a flowable

formulation (which is often about the consistency of latex paint). The fine particles in these formulations seldom clog spray nozzles, but require agitation to prevent settling in the spray tank.

Emulsifiable concentrates (EC or E). An emulsifiable concentrate is a liquid formulation that can mix with water to form an emulsion (typically turns milky-white in water). Each gallon of an EC usually contains 1 to 8 pounds of active ingredient. Diluted ECs usually need little agitation in the spray tank. The carrier is generally an organic solvent. An emulsifier is added to permit mixing of the organic solvent with water. The emulsifying agents and solvents in EC formulations can damage some crops. These crops may require a different formulation of the active ingredient, such as a wettable powder or granule.

Solutions (S). True solutions contain a mixture of two or more substances, the solute (active ingredient) and a solvent (usually water). Those true solutions that are soluble in water require no agitation in the spray tank. Highly concentrated solutions are possible as special formulations.

Liquified gases. Some fumigants are gases that become liquid when under pressure. For this reason, such formulations are stored under pressure, which may be either high or low, depending on the product. These formulations are applied by:

- injecting them directly under tarps.
- releasing them under tarps, or
- releasing them into structures such as pot and equipment storage areas.

Other active ingredients remain liquid in an ordinary container but turn into a gas or vapor when or after they are applied. These formulations do not require storage under pressure. Consequently, they must be put into the soil or confined in a space before they change to a gas; otherwise, they could be lost to the air.

Wettable powders (WP or W). These are dry, finely ground herbicide formulations. They look like dusts, but unlike dusts they are designed to mix readily with water and most are more concentrated. They contain 15 to 98 percent active ingredient, usually in amounts of 50 percent or more. Wettable powders form a suspension rather than a true solution when added to water. To maintain this suspension, good agitation is needed in the spray tank. Compared to ECs, good wettable powders are safer to use on plants. However, dust can be a problem when mixing wettable powder formulation.

Water dispersible granules (WDG or DG) and dry flowables (DF) are improved versions of wettable powders. The WDG, DG and DF formulations readily pour from containers with little or no dust. Active ingredients in these formulations are expressed as a percent by weight. For

example: a Gallery 75 DF contains 75 percent isoxaben, or 75 pounds of isoxaben in every 100 pounds of Gallery 75 DF.

Soluble Powders (SP). Soluble powders are also dry formulations. When they are added to water, they completely dissolve to form true solutions. The mixture in the spray tank may need to be agitated for these solutions to dissolve. Once they have dissolved, no more agitation is usually needed. The amount of active ingredient in a soluble powder may be between 50 percent and 94 percent.

Granules (G or GR). Granular formulations are small, individual particles that are applied dry. Most are made by applying a liquid formulation of an active ingredient to inert coarse particles (granules) of some porous carrier material. Carrier materials often used are clay, ground corn cobs, or recycled newspaper. The pesticide is either absorbed into the granule, coats the outside, or both. The amount of active ingredient typically ranges from 1 to 10 percent. Granular formulations are used most often as soil treatments and are applied either directly to the soil or over plants. Granular formulations should always be applied dry. Never mix them with water. However, granules require rainfall or irrigation to activate the herbicide and to remove excess chemicals from the foliage. Certain preemergence herbicides, such as oxyfluorfen and oxadiazon, can injure plant foliage, especially if the foliage is wet. Formulating these compounds as granules reduces the potential for foliar uptake and crop injury.

Granular formulations of preemergence herbicides can sift through dense foliage onto the soil surface, unlike liquid formulations that may adhere to foliage and prevent soil contact. Placement on the soil surface enables the herbicide to work properly and may enhance its selectivity with marginally sensitive plants. However, there are several difficulties associated with the use of granules.

- Runoff water from excess rain or irrigation may remove the granules.
- Granules may collect in the crowns of rosette-form plants or leaf bases, causing injury.
- Compared to other formulations, granules cost more per unit of active ingredient.
- The application rate is more difficult to control.
- Uniform herbicide distribution is more difficult to achieve than for sprayed formulations.

- Use an herbicide formulation most appropriate for the weed control situation.
- Read label directions for an explanation of how to use a formulation.

Herbicide formulations

Application equipment

Conventional sprayers, regardless of size have certain common components. Each has a tank, pressure source, pressure regulator and gauge, shutoff valve, and nozzles.

Backpack or hand-held sprayers are preferred when treating small areas. All the functional parts of a large sprayer can be found in these smaller sprayers, but there are some differences and limitations:

- The tank is smaller and lacks an agitator. Spray mixtures that contain wettable powder formulations require frequent shaking of the tank for agitation.
- The power-driven pump is replaced by continual positive displacement pumping, compressed air, or carbon dioxide (CO_2).
- Often there is no pressure regulator other than the discretion and reliability of the operator. Applying herbicides accurately requires some level of pressure regulation, whether it is done by monitoring pressure gauges or by adding a pressure regulator to the system.
- The boom is smaller yet similar in design and function. With minor modifications most continuous-pump, compressed-air, or carbon-dioxide sprayers are satisfactory for applying herbicides to small areas (up to several acres).

For directed spraying beneath the foliage of sensitive crops, flooding nozzles can be used to direct a low-pressure spray to the lower few inches of the plant stem. On uneven terrain, these nozzles should be mounted on floating skids. Spray shields are often used in combination with directed sprays to further minimize injury from spray drift.

Rope-wick applicators were developed to apply herbicides to weeds that grow taller than the desired plants. Rope-wick applicators consist of a loop of rope saturated with a concentrated herbicide solution by a wicking action. The saturated rope is wiped across the tall weeds without touching the desired plant, thus preventing injury.

Controlled droplet applications (CDA) technology provides another option for herbicide application. The most commonly encountered CDA systems are Herbie and Micromax. The CDA system is based on releasing the spray liquid onto a spinning disk or cylinder, where it is spun to the outer edge and broken into droplets. The delivery to the outer edge of the capillary tubes, disc notches, or cylinder perforations produces droplets of more uniform size than those produced by conventional spray systems. The CDA system operates with little power and little or no pressure. Researchers claim that by using a CDA system to apply postemergence herbicides one can reduce the amount of pesticide needed because the droplets are in the best size range for

peak activity. However, additional data are needed to verify this claim.

CDA systems have a few disadvantages. Foliar penetration can be limited, especially in the gravitational types. They are unsuited to windy conditions. They make it difficult for the operator to see and direct the spray pattern. Furthermore, gravity-flow systems are particularly difficult to calibrate because slight changes to the concentration of herbicide in the spray solution will change the viscosity and flow rate through the sprayer.

Granular spreaders. As with sprayer application, accurately metering and distributing granular formulations is essential to achieving good weed control and minimizing plant injury. Granular spreaders distribute the herbicides in one of three ways: by gravitational drop, mechanically fed drop, and centrifugal force. All three types are available as tractor-mounted models or as smaller hand-operated spreaders.

Gravitational drop spreaders allow the granules to drop through an adjustable orifice. The application rate is adjusted by changing the orifice size, the travel speed, or both. Differences in size and density of the granules affect the rate of flow at any given orifice size. For example, smaller, heavier particles flow more easily than larger or lighter particles. A beater bar must be present within the chemical bin to prevent clogging and to ensure uniform distribution to the orifice.

Mechanically fed drop spreaders have an orifice that can be replaced with a slotted roller or similar device that measures the volume of granules to be dropped. This method is more accurate but more expensive. The application rate can be adjusted by gearing the roller to the ground speed or by replacing the slotted roller with a roller of a different calibration.

Centrifugal (or rotary) spreaders drop the herbicide onto a revolving plate or oscillating arm from which it is expelled by centrifugal force. The application pattern is nonuniform; therefore, two fully overlapping passes in opposite directions are recommended. Hand-operated centrifugal spreaders should be geared so that the spinning plate revolves faster than the hand crank, reducing both operator fatigue and irregularities in swath width. Because these spreaders are versatile and highly maneuverable, they are the type most often used.

To ensure product effectiveness, do not apply herbicides when rain is likely within six hours of application. You must read the label before you mix or use any product. Add surfactant to most liquid applications to achieve best control. Allow approximately 10-14 days after application for systemic herbicides to be translocated before disturbing the site. Allow time for one application of herbicide followed by a follow-up application to control spots that were missed during the first treatment.

Equipment calibration – is required to apply the precise amount of herbicide.

Calibration of large ground sprayers:

1. Measure the output of all spray nozzles and replace any whose output varies more than 10 percent from the average output.
2. Fill the spray tank with clean water to a marked level.
3. Select throttle and gear settings for the desired speed of travel and operating pressure. Spray the water over a pre-measured distance – for example, 500 feet.
4. Measure the amount of water required to fill the tank to the original mark. This is the amount that was delivered over the spray area.

Or follow alternate step 4.

4. Measure the time it takes to travel the measured distance. Then collect the sprayer output for that time. You may collect the output of one nozzle and multiply that by the number of nozzles.

The volume (number of gallons) applied per acre for broadcast spray applications may be calculated as shown below.

Example: You want to treat 1 acre using a spray boom with six nozzles spaced 20 inches apart. When calibrated, the spray rig took 105 seconds to travel 500 feet. It sprayed a total of 365 ounces of water in this time. How many gallons, at this calibration, will it take to cover one acre?

Step 1:
Convert the number of ounces delivered to gallons using this formula:

$$\frac{365 \text{ oz}}{128 \text{ oz/gal}} = 2.85 \text{ gal}$$

Step 2:
Calculate the number of square feet treated during the calibration by calculating swath width and using the following formula:

Spray swath width x distance = sq ft treated

swath width = 6 nozzles x 20 inch spacing
= 120 inches or 10 feet

10 ft x 500 ft = 5,000 sq ft treated

Step 3:
The application rate is 2.85 gallons per 5,000 square feet. To convert this value to gallons per acre, use the following formula:

$$\frac{\textbf{Rate delivered}}{\textbf{area covered}} \textbf{ x square feet/acre = gallons per acre}$$

$$\frac{2.85 \text{ gal}}{5{,}000 \text{ sq ft}} \text{ x } 43{,}560 \text{ sq ft/acre} = 25 \text{ gal/acre}$$

If the amount applied is different from the desired rate, correct it by changing the speed or nozzle size. A change in the operating pressure has less effect on the rate of application (increasing pressure four-fold will double output) yet significantly affects spray drift. Higher pressure makes the droplet size smaller, so drift is increased and more herbicide may be sprayed off-target. Once you know the volume applied in gallons per acre, you must calculate the amount of herbicide needed to achieve the desired application rate. The following example shows how to calculate the correct rate.

Calibration of hand-held and backpack sprayers:

To calibrate a small sprayer, it is recommended that you use 650 feet as the calibration spray area with an 80-inch boom (four nozzles set 20 inches apart). This area is 1/10 of an acre and will simplify calculations. To calibrate the sprayer, follow these steps:

1. Fill the spray tank to a known level with water, leaving at least one-fourth of the tank empty for air compression.
2. While maintaining a steady pressure (within 5 psi), spray 650 feet (measured before-hand).
3. Refill the tank to the original level, accurately measuring the amount of water required. The number of gallons used times 10 equals the number of gallons per acre the sprayer applies at your speed of travel.

Correct application depends on the applicator walking at the same speed during calibration as during field application.

Maintaining a constant speed of travel while spraying is important. The best speed of travel is one that is natural and comfortable for the applicator. Altering a person's natural pace will typically lead to inconsistent applications. However, a cadence which is comfortable for many is a normal military cadence, which with 30-inch steps equals 3 miles per hour. Some find it helpful to use a battery operated metronome to maintain a constant pace. To practice, measure 100 feet and walk this distance carrying the sprayer. Walking this distance at a speed of 3 miles per hour should take approximately 23 seconds.

To adjust the application rate, alter the concentration of herbicide in the tank or change nozzles. Once you have established a constant cadence, do not attempt to change the rate by adjusting ground speed. Doing so will produce an uneven application. As with large sprayers, periodically check the nozzle outputs, and replace any that very more than 10 percent from the average.

Calibration of granular applicators:

The procedures for calibrating a granular applicator are similar to those used to calibrate spray rigs.

1. Collect the output over a known distance and swath width. Many spreaders

are equipped with catch pans for this purpose. For others, collect the granules in a plastic bag covering the spreader orifice.

2. Adjust the spreader orifice or ground speed until the desired application rate is achieved. Maintain a constant ground speed when using hand-held equipment.

3. Since the delivery rate varies for each formulation, the calibration procedure must be performed with each chemical, preferably by the person who will make the field application.

Hand-held granular spreaders are inconsistent and each unit must be calibrated for each granule to be used.

Cleaning and care of equipment. When spraying has been completed, excess spray solution must be disposed of properly according to the manufacturer's and governmental guidelines. When cleaning spray equipment, make certain that the chemical solution does not drain into areas of desirable vegetation or into waterways. Rinse the tank and nozzles thoroughly with water or a cleaning solution appropriate for the chemical used. Partially fill the tank and run clean water through the system for several minutes.

Many companies suggest lubricating the moving parts periodically. Consult the owner's manual for specifics. If no spraying is scheduled for some time, remove both the pump and nozzle. Never clean nozzles with wire, knives, or other hard-surfaced objects. They can damage the nozzle, which may change the spray pattern and delivery rate. Soft wood (toothpicks), toothbrushes, or liquid solvents are recommended. Do not save worn out tips for later use. Throw them away. Keep spares of each type of tip and several diaphragm check valves in the spray unit. Prior to equipment storage over the winter season, flush tanks, boom, and hoses with several changes of water. Clean all tips and screens, dry them and store them in a lightweight oil. Antifreeze can be circulated through the system to prevent the pump from freezing or locking down if it is not used for a long period.

- Select the appropriate equipment for the formulation and application method.
- Calibrate equipment to insure the application of the precise quantity of herbicide required.
- Dispose of excess solution according to manufacturer's recommendations.
- Rinse applicator thoroughly and run clean water through system.
- Clean tips and screens and store in lightweight oil.
- Circulate antifreeze through systems when storing application equipment over the winter.

Calculating application rates

Herbicide recommendations are made in one of two ways:

1. Amount of active chemical per unit area, such as 2 pounds of active ingredient (ai) per acre.
2. Amount of product per unit area, such as 3 quarts per acre.

The examples that follow illustrate how to calculate the amount of herbicide required to meet the recommended rate for a given area.

Example 1: The herbicide label shows that the product contains 4 pounds of active ingredient per gallon. The recommended application rate is 6 pounds of active ingredient per treated acre. How many gallons of product do you need to treat 1 acre?

Complete the following steps to convert from pounds of product to pounds active ingredient (ai) or vice versa. Substitute the values from the label into the following formula:

$$\frac{\text{amount of ai}}{\text{amount of formulated}} = \frac{\text{desired ai/acre}}{\text{amount of product}}$$

After setting up the formula, (step 1) cross multiply (step 2) and then divide both sides of the equation by 4 lb ai (step 3):

Step 1:

$$\frac{4 \text{ lb ai}}{1 \text{ gal product}} = \frac{6 \text{ lb ai/acre}}{? \text{ gal of product/acre}}$$

Step 2:

4 lb ai x ? gal of product/acre = 6lb ai/acre x 1 gal of product

Step 3:

$$? \text{ gal of product/acre} = \frac{6 \text{ lb ai/acre} \times 1 \text{ gal of product}}{4 \text{ lb ai}}$$

$$= 1.5 \text{ gal of product/acre}$$

Therefore, 1.5 gallons of product contains 6 pounds of active ingredient. This amount must be accurately distributed over 1 acre.

Example 2: Suppose that you want to apply 4 pounds active ingredient of a 90 percent wettable powder (90W) formulation per acre. How much of the product would be required per acre?

Use the following formula to solve the problem:

$$\frac{\text{ai/acre}}{\text{\% of ai in product}} = \text{product needed/acre}$$

$$\frac{\text{4 lb ai/acre}}{\text{0.90 (or 90\%)}} = \text{4.4 lb of product per acre}$$

Thus applying 4.4 pounds of a 90 percent wettable powder formulation per acre will produce the desired rate.

Additional application methods

Stem cutting – cut at or near ground level and treat with herbicide (such as glyphosate (Roundup® Pro) or the amine formulation of triclopyr (Garlon®) or use repeated cutting to deplete plant resources.

Basal bark treatment – Use herbicides that penetrate the bark of trees, especially seedlings. Spray Garlon 4® (triclopyr mixed with petroleum based oil) to a height of 12-15 inches around trunk.

Bare ground (complete) vegetation control – Bare ground situations may be appropriate where there is a specific reason for such a treatment. Treating the edge of pavement or vegetation encroachment within paved shoulders are good examples where bare-ground herbicide rates may be appropriate. Continuous bare ground treatment, especially on sloped areas, increases the potential for erosion and sediment loss. For those areas that receive bare-ground herbicide applications, additional spot-treatments may be necessary. Application of an excessive quantity of herbicide is not economical and may result in damage to nearby desirable vegetation. Complete control may be achieved by using Roundup® Pro at a 4 quart per acre (9.3 liters per hectare) rate.

Calculating application rates

- Use the preceding examples to learn how to calculate the amount of product required to cover a given area.

- Stem cutting and basal bark treatment can be used to apply a small quantity of herbicide directly on the targeted plant, dramatically reducing the quantity of herbicide applied as compared to a foliar spray application or broadcast granular application.
- Bare ground control is only appropriate in limited situations and care must be taken to reduce potential for erosion.

Spray drift control

Drift is a side effect of pesticide use associated with ground and aerial application. Drift is the uncontrolled airborne movement of spray droplets, vapors, or dusts particles, away from the intended point of application. Drift is important because of potential injury to non-target plants and animals, and the potential for producing illegal residues on non-target food crops.

Virtually every pesticide application produces some amount of drift. How much drift depends on such factors as the formulation of the material applied, how the material is applied, the volume used, prevailing weather conditions at the time of application, and the size of the application job.

Pesticide applications, which are directed upwards or made by aircraft, are the most likely to be subject to drift. Pesticide application by aircraft can result in residue problems on sites that are distant from the actual application site. Pesticides released close to the ground are not as likely to be suspended in the air as those released from a greater height or distance from the target.

Air currents very easily carry lightweight particles, especially dusts and low volatility vegetable oils. Heavier formulations such as granules and pellets settle out of the air very quickly. High pressures and small nozzle openings produce very fine spray droplets with accompanying high drift potential. Lower pressures and larger nozzle openings produce coarser sprays with larger droplet sizes having less drift potential.

Vaporization (volatilization) increases as:

- Air and surface temperatures increase
- Relative humidity increases
- Particle or droplet size decreases
- Air movement increases

Drift control is the responsibility of the applicator. DelDOT applicators and contractors are required to use drift control agents. Drift cannot be completely eliminated, but it can be greatly reduced.

Spray drift control

- Use as coarse a spray as possible and still obtain good coverage and control. For sprays, use a formulation that gives large diameter spray droplets (150 microns or larger). Droplet size is one of the most important factors affecting drift; however, addressing droplet size alone is not sufficient to reduce the probability of drift and potential damages.
- Don't apply pesticides under windy conditions; don't apply at wind-speeds over 10 mph.
- Use drift control/drift reduction agents. These materials are basically thickeners and are designed to minimize the formation of droplets smaller than 150 microns. They help produce a more consistent spray pattern and aid in deposition. Some of these are: LoDrift, Nalcotrol, 41-A and Nalcotrol II.
- Choose the formulation carefully. Water based sprays will volatilize more quickly than oil based sprays, however, oil-based sprays can drift farther because they are lighter, especially above 95˚ F.
- Apply pesticides early in the morning, when feasible; the air is often more still than later in the day.
- Don't spray during thermal inversions, when air closest to the ground is warmer than the air above it. When possible, avoid spraying at temperatures above 90-95˚ F.
- Use a solid cone or fan spray nozzle. These produce larger droplet sizes than hollow cone nozzles.
- Be sure you are getting the spray deposition pattern you think you are; maintain and calibrate your equipment regularly.
- Check for system leaks; small leaks under pressure can produce very fine droplets.
- Determine wind direction and take this into account in determining application timing, equipment and whether or not to make an application. The wrong wind direction can cancel out everything else you have done to reduce drift.
- For application of liquid and dry formulations, commercially available or homemade shrouds or skirts attached over or behind the application equipment can help prevent spray droplets and pesticide particles from becoming airborne.

Bittersweet, grape and honeysuckle were controlled repeatedly and this sunny opening along Wyoming road was planted with locally indigenous shrubs to discourage recolonization by invasive vines.

Specific recommendations

Invasive woody plants – such as Norway maple, will require stump treatment after physical removal. Both physical removal and chemical control are required for invasive vine removal on forest edges. After physical removal, follow up with chemical control of resprouts and planting of desirable colonizing species to reestablish an attractive, healthy forest edge. When patches of weeds are removed in an existing planting, the space occupied by the weed must be replanted for aesthetics and to prevent recolonization by the same or another weed.

Meadows – Weed control is a critical component of meadow establishment. Inspect a newly seeded meadow 4 to 6 weeks after planting to identify weed species present. For grass meadows, mow 2 to 3 times during the first year. Apply Plateau® the second year if the meadow is predominantly indiangrass (*Sorghastrum nutans*). Apply 2,4-D, dicamba and MCPP the second year if the meadow is predominantly switchgrass (*Panicum virgatum*). Another strategy is to apply glyphosate early in the season after weeds have emerged but before warm-season grasses have emerged.

In a planting comprised completely of forbs, use a grass herbicide (ethoxydim (Barricade®) or fluazifop (Acclaim®). Several preemergent herbicides—metolachlor (Pennant Magnum®), EPTC (Eptam®), trifluralin (Treflan®), benefin (Balan®) and pronamide (Kerb®)—are tolerated by seeded forbs (including yarrow, coreopsis, evening primrose, black-eyed susan and goldenrod). Good to excellent preemergence control of many annual grasses and broadleaved weeds can be expected with those herbicides once desirable plants are established.

Broad leaved weeds can be controlled using a grass herbicide in a meadow sown to warm-season grasses only. Once broadleaved weeds are controlled and grasses have filled in, desirable broadleaved forbs can be added.

Stormwater ponds. Debris and erosion are the major stormwater facility problems. Selectively treat undesirable vegetation in buffer zones or on slopes/banks and at bottom of dry ponds. Undesirable vegetation includes invasive species in any area or woody plants growing on manmade dams or embankments. Take care when removing plants not to create erosion problems. Maintain vegetation so that hydraulic structures are easily accessed for inspection and maintenance.

In **wetland mitigation sites**, control invasive plant species annually by spot treating with a wetland-appropriate herbicide.

Sensitive areas

Sensitive areas along the roadside include rights of way adjacent to any body of water. DelDOT personnel and contractors will be responsible for knowing the location of all sensitive areas. In these locations, vegetation must be managed without the use of herbicides or with only aquatic-labeled herbicides.

Specific recommendations

- Use a combination of physical removal and stump or resprout treatment for invasive woody plants.
- Control weeds aggressively during the first three years of meadow establishment. Use selective broadleaf herbicides on grass meadows and selective grass herbicides on forb meadows.
- Control invasive woody plants around stormwater ponds and wetland mitigation sites using an herbicide appropriate for use around water.
- Follow good housekeeping practices in maintenance yards to prevent pollution and reduce the sources of contamination to stormwater facilities.

Sensitive areas

- Know the location of all sensitive areas.
- Manage vegetation in sensitive areas without herbicides or with aquatic labeled herbicides.

Product policies

Equipment operators employed by DelDOT will use only herbicides approved for use in sensitive areas on any roadside right-of-way unless authorized in writing by the Roadside Environmental Administrator. DelDOT requires all glyphosate products to have an aquatic label. Restricted use pesticides are prohibited on DelDOT roadsides. A chart of pesticides for use on Delaware roadsides is included in Appendix G Any new pesticides must be approved by the Roadside Environmental Administrator prior to use on Delaware roadsides.

Product policies

- DelDOT equipment operators may use herbicides approved for sensitive areas only (unless they acquire written approval).
- No restricted use herbicides will be used on Delaware roadsides.
- All glyphosate products must have an aquatic label.
- All new products must be approved by the Roadside Environmental Administrator.

Fertilization

Turf

Take a soil sample prior to establishing turf and correct soil fertility and pH based on soil test results. Plant nutrients are essential for turf growth. Thus, they must be present in adequate amounts in the soil for optimum turf growth. The primary nutrients – nitrogen, phosphorus, and potassium – are used by turf in large quantities, and they are the most likely to be deficient. Nitrogen gives the turf a dark green color and promotes rapid vegetative growth. Phosphorus promotes root formation, and potassium aids in translocation of food and increase disease resistance and health. Fertilize residential quality turf by applying one pound of nitrogen per 1000 square feet in September/October in the form of a complete fertilizer. Do not fertilize utility turf, unless soil tests indicate a specific nutrient deficiency.

Trees and shrubs

Do not apply fertilizer during the first year after planting. Fertilizer may burn tender roots and promote top growth before the root system becomes well established. Fertilize as needed in subsequent years depending upon the prominence of the planting. Generally two to four pounds of a complete fertilizer per 1000 square feet per year are recommended for optimum growth, depending on the plant species. The fertilizer is applied by broadcasting. One application may be all that is needed on mature plants, while more than one application may be required on young plants. Fertilizer should be applied before spring growth if possible. Watering after fertilization is recommended. Trees confined to small planting areas usually have a greater need for fertilizer.

Lime

Lime is required when the soil is acidic, i.e., pH below 5.5. The pH of the soil is usually determined through soil analysis. When the soil pH is low, phosphorus and several of the micronutrients become unavailable for plant use. Lime raises the pH of the soil and, thus, the availability of those nutrients to the plant increases. Liming is important in the maintenance of a healthy turf and it should be done whenever soil test reports indicate a need for lime.

The amounts of clay and organic material greatly affect liming rates. The lime requirement increases with increasing amounts of clay and/or organic matter. The following table shows the amount of lime needed to raise the pH from 5.5 to 6.5 in soils with various textures.

Lime does not move readily through the soil. Therefore, it should be mixed well with the top 4-5 inches of soil during seedbed preparation. On established turf, a centrifugal spreader or a drop spreader is used to evenly broadcast lime and,

thus, increase its effectiveness.

Ornamental plants vary in their pH requirements. Most plants grow best if the pH is maintained between 6.0 and 7.0. Some exceptions are azaleas, camellias, pieris, and rhododendrons, which grow well in the pH range of 5.0 – 6.0.

Relationships between soil-buffer and lime requirements for target pH values of 5.5, 6.0, and 6.5 for mineral soils.

		Lime requirement*	
Soil buffer pH	pH 5.5	pH 6.0	pH 6.5
		Mg/ha	
6.5	0	0	0
6.4	0	0.2	0.3
6.3	0	0.2	0.3
6.2	0.2	2.6	2.2
6.1	1.1	3.8	3.2
6	2	4.9	4.3
5.9	2.9	6.1	5.4
5.8	3.8	7.3	6.6
5.7	4.6	8.5	7.9
5.6	5.5	9.6	9.2
5.5	6.4	10.8	10.6
5.4	7.3	12	12
5.3	8.2	13.2	13.6
5.2	9.1	14.4	15.1
5.1	10	15.5	16.7
5	10.9	15.5	16.7
4.9	11.7	17.9	20.2
4.8	12.6	19	22
4.7	13.5	20.2	23.9
4.6	14.4	21.4	25.8
4.5	15.3	22.6	27.8
4.4	16.2	23.7	29.8
4.3	17	24.9	32
4.2	18	26.1	34.1
4.1	18.8	27.3	36.4
4	19.7	28.4	38.7
3.9	20.6	29.6	41

*Lime requirement values to soil pH 5.5 and 6.0 were developed by Tran and van Lierop (1982), and to soil pH 6.5 by Ssali and Nuwamanya (1981).

Table developed by J.T. Sims and published in Methods of Soil Analysis. Part 3. Chemical Methods-SSSA Book Series no. 5.

Fertilization

- Adjust soil nutrients and pH prior to planting turf or trees/shrubs/perennials based on soil sample test results and recommendations.
- Fertilize residential quality turf in the fall.
- Do not fertilize utility turf.
- Do not fertilize trees or shrubs at planting.
- Broadcast fertilizer to promote tree and shrub growth as warranted by location of planting.
- Apply lime as needed to raise soil pH in turf areas to 6.5.
- Adjust pH prior to planting trees, shrubs or perennials.

Problems

Insect and disease

There are a wide variety of insect and disease problems that could negatively impact roadside vegetation. For a complete set of fact sheets on disease and insect problems common on Delaware turf, trees, shrubs and perennials visit the Delaware Cooperative Extension Home and Landscape Horticulture website (http://ag.udel.edu/extension/horticulture/index.htm). Fact sheets provide pest identification and control recommendations.

Cultural problems

Insects and disease-causing pathogens are not usually the primary reasons for trees failing even though they may be the first things that come to mind when you recognize unhealthy trees. Typically, insects and diseases are the secondary agents that attack already weakened, wounded, improperly treated, neglected or generally unhealthy trees. Healthy, vigorous trees have defense mechanisms to combat insect and disease problems. In order to maintain healthy trees in an urban environment, it is necessary to identify and avoid some basic cultural mistakes.

Compaction - When soil is excessively compacted, there is no room for the oxygen necessary for the health of tree roots. Eliminate traffic over the root system of trees.

Excess mulch - A two- to three-inch layer of mulch is sufficient. When mulch is piled upon mulch each year, roots grow into the mulch layer. Those roots are susceptible to drought stress and winter injury. Mulch can also become crusted, causing water to run off. Add mulch to maintain a two- to three-inch layer only as the old mulch decomposes. Rake the mulch periodically to break up the crust that forms, then incorporate it into the soil.

Trunk, bark, branch and root damage- Any damage to the physical integrity of the tree provides an entry point for insects and disease organisms. Keep lawn mowers and string trimmers away from the base of trees. Do not fasten bicycle lock chains around tree trunks. Never put nails into the tree trunk.

Supports, wire, twine and tree wrap - Supports, wire and twine left on newly planted trees are common causes of girdling damage. The girdling will gradually cut off the flow of water and nutrients and by the time damage becomes noticeable the tree can be near death. Tree wrap left on too long provides a haven for insects and can cause girdling. Remove all twine and tree wrap at planting and remove supports after one growing season.

Failure to keep mowers away from the base of this tree has resulted in damage that is likely to necessitate replacement.

The root flare is clearly visible on this newly planted oak indicating that the tree is planted at the proper depth.

Salt damage - Salt used on roads and sidewalks for de-icing will cause tree root damage. De-ice sidewalks with sand, ash or calcium chloride instead of sodium chloride or rock salt.

Soil grade changes - Adding or removing even a small amount of soil at the surface of the tree's root zone will damage the tree. Excess soil on top of the roots reduces the oxygen available. Since most of a tree's roots are in the top 6 inches, removal of soil also means removal of roots. Avoid grade changes greater than 2 inches. Be aware that the root system may spread far beyond the furthest branches (drip line) of the tree, typically two to three times or more.

Diagnosing problems

There are several signs that can help pinpoint tree problems while they are still treatable:

Root flare – Look to see if the tree enters the ground with a natural flare or swelling.No flare may mean soil has been filled around the tree and roots are suffocating. No flare may also mean there is a girdling root restricting food, nutrients, and water.

Crown dieback – Search for dead twigs or branches dying back from the tips to the trunk in the tree crown. Dead twigs and branches may mean old age, insect or disease infestation, or root injury. Crown dieback may indicate too much or too little moisture, or too much competition.

Abnormal leaf size – Larger or smaller leaves than normal can indicate problems. A tree that has leaves smaller than the normal size may have a root injury. Leaves that are larger than normal, especially on root suckers, can also indicate root damage.

Trunk scars - Partially “healed” wounds on trunks may be signs of hidden decay. Look for ragged scars on the trunk that are not callused over. To speed callusing, remove damaged, ragged tissue carefully with a sharp knife. Coating wounds with preparations has not proven to promote healing, and coatings can trap water and provide habitat for insects and diseases that cause damage and decay.

Yellow foliage - The general yellowing of a leaf, often called chlorosis, can be caused by a variety of factors including insects, disease, too much moisture, cold weather, air and soil pollution, excess minerals in the soil, nutrient deficiencies, or a pH imbalance.

Problems

- Visit the Delaware Cooperative Extension Home and Landscape Horticulture website. (http://ag.udel.edu/extension/horticulture/index.htm) for fact sheets on diseases and insects.
- Maintain healthy trees and shrubs by avoiding common cultural problems such as compaction, excess mulch, mower damage to trunks, girdling from wire, salt damage, and soil grade changes.
- Lack of root flare, crown dieback, abnormal leaf size, trunk scars and yellow foliage can all be signs of plant problems.

Record Keeping

DelDOT Forms

A Pesticide Application Daily Report Form must be completed after each pesticide application. Forms are available on the DelDOT intranet. Forms should be stored in the district office and must be kept for two years after the application date. Send a copy of each completed form to the Roadside Environmental Supervisor. The application information will be keyed in to a database. The herbicide database will be used to track trends in herbicide use. A sample form is found in Appendix B.

Record Keeping

- After every pesticide application, complete a Pesticide Application Daily Report Form.
- Send a copy to the Roadside Environmental Supervisor.
- Keep a copy in the district office for two years.

Inventories

Guardrails

A guardrail inventory was conducted for DelDOT by a private contractor in 2008–2009. The inventory includes all guardrail sections on DelDOT maintained roadways throughout the state of Delaware and attribute data for each section. A field-verified inventory of all guardrail sections will include GPS locations data for the beginning and end of each section. Attribute data includes material of construction, material beneath guardrail, guardrail end treatment, guardrail to barrier connection, surrounding landscape and environmental features and landscape photos. The guardrail inventory will be included in the DelDOT GIS database system and the NPDES Inventory Database.

Existing stormwater system

Locations of all wet ponds, extended detention dry ponds, sand filters, filter strips, biofiltration swales, bioretention facilities, infiltration trenches and storm drains are included in DelDOT's NPDES GIS database system and available to every DelDOT employee.

Noxious and invasive weeds

Locations of noxious weeds are identified by Roadside Environmental Supervisors, and control recommendations are made to prevent the flowering of noxious weeds on DelDOT property. Pesticide application forms and the herbicide use database are used to identify sites known to contain noxious or invasive weeds. Yearly inspection by Roadside Environmental Supervisors is used to identify noxious and invasive weed sites.

The Delaware Invasive Species Council maintains a database of invasive weed locations throughout the state.

Inventories

- The guardrail inventory includes all sections of guardrail with GPS coordinates for the beginning and end of each section as well as guardrail attribute data for each section.
- All stormwater BMPs can be found on the DelDOT NPDES GIS database system.
- Records from previous years and yearly inspections are used to identify noxious and invasive weeds on DelDOT rights-of-way.

Training Program

Routine training for DelDOT maintenance personnel is conducted on a yearly basis. Training includes information on pesticides, application techniques, calibration and equipment maintenance. Training videos on Facility and Vehicle Maintenance, Stormwater Contamination and Spill Prevention and Vegetative Control and Pollution Prevention on Public Roads and Highways are available for district personnel. Annual viewing is required by the NPDES section. Training for mowing supervisors is conducted each spring prior to the mowing season. All DelDOT employees who apply pesticides must become Certified Pesticide Applicators in the state of Delaware. To maintain certification, all applicators must attend 8 credits of recertification programs over a three-year period. All DelDOT applicators must attend recertification and take an internal exam each year.

Bringing DelDOT maintenance employees to roadside plots is critical for explaining detailed instructions such as mowing regimes and herbicide treatments.

Training Program

- Annual viewing of NPDES videos is required.
- Training for mowing supervisors is conducted each spring prior to mowing season.
- All DelDOT employees who apply pesticide are certified pesticide applicators.
- All DelDOT applicators attend yearly recertification and complete an internal exam.

Glossary

Adventitious roots – Roots arising from an unusual or irregular location.

Aesthetic order – A set of design principles relating to order and beauty; especially as they relate to plants.

Annual – A plant that completes its life cycle in one growing season.

Balled & burlapped plant (B&B) – Field grown plants harvested with a root mass and soil (root ball) contained by burlap. This is a common production method for woody shrubs and trees. Not typically used for herbaceous plants.

Bare-root plants – Field grown woody plants harvested with a root mass that is lacking soil. Bare root plants are typically used only when plants are in a dormant state.

Berm – Soil or earthen embankment erected to provide protection from the elements or to act as a landscape screen.

Best Management Practices (BMP) – Cover a wide spectrum of management practices. Some address introduction of Integrated Roadside Vegetation Management. BMPs also refer to implemented procedures for stormwater management.

Biennial - A plant that completes its life cycle in two growing seasons. Biennials typically undergo vegetative growth during the first growing season and reproductive growth during the second.

Biodiversity – The variety of organisms present in a given ecological community. The variety of life forms that exist in an ecosystem, including different genetic, species and natural communities.

Biofiltration swales – An open and gently sloping vegetated channel (minimum 6 inches grass height) designed for treating stormwater runoff.

Broadcast seeding – The simple dry distribution of seed often mixed with a carrier such as sawdust to improve dispersal.

Broadleaf herbicides – Formulation of chemicals designed to combat weeds with a broad leaf. These herbicides are to be applied directly to the leaf, a practice that requires the leaf to be visible and actively growing. Also called post-emergent control.

Brush removal – The process of cutting and removing woody plants by hand or mechanical means.

Caliper – The diameter of a tree trunk. It can be an approximate indication of age.

Clear zone – The total unobstructed and relatively flat area bordering the roadside that is available for safe use by disabled or out of control vehicles.

Compaction – The reduction or absence of air space in soil particles that results in restricted rooting depth thus causing the decrease or nutrient and water uptake by a plant.

Container-grown plants – Plants grown in an artificial medium within a container. This is a common practice for growing woody and herbaceous plants.

Cool-season grass – species of grasses that grow best in temperature ranges between 60°-70 ° F. They typically undergo summer dormancy. These species include most of the mowed turfgrasses.

Cover crops - A crop planted with the intention to protect the soil from erosion and to improve the soil through the addition of organic matter.

Crimping - Process by which straw mulch is secured to the seed bed by pulling a weighted disk across the seedbed and tucking the straw into the grooves that are created.

Culti-packing – Process by which soil is firmly packed to prepare a hard bed for planting thus ensuring efficient seed to soil contact.

Cut back - Periodic cutting of woody vegetation to maintain a dense and healthy growth pattern within certain parameters.

Dibble – A small hand tool used to make holes in the ground for seeds, bulbs or roots.

Discontinued mowing – Cessation of routine mowing that results in the release of desirable regional vegetation.

Disturbed sites – Sites that have had the topsoil removed or altered. Re-vegetation is essential for stabilization of the soil and to prevent weed infestations.

Ditch lines – The imaginary line to the bottom of a V ditch or to the back of a flat bottom ditch.

Dormancy – The period of a plant's life cycle when growth, development and physical activity is temporarily suspended.

Drainage ditch – A small or shallow depression in the land created to drain water from low-lying areas along roadsides.

Drill seeding – The placement of seed in a shallow trench created by a disc.

Ecology – The study of interactions between organisms and the environment.

Ecosystem – A naturally occurring system encompassing all plants, animals and micro-organisms that function in conjunction with the non-living elements of the surrounding environment.

Editing – The evaluation of existing vegetation and identification of opportunity to introduce aesthetic order by highlighting individual specimens or plant groups through the process of removal of unwanted vegetation.

Embankment – A raised mound of earth used for the purpose of supporting a roadway or to hold water back.

Ephemeral – Short-lived plant.

Erosion – The gradual breakdown or transportation of rock or soil through wind or water.

Eutrophic – A state in which a body of water becomes enriched in dissolved nutrients that stimulate the growth of aquatic plant life and usually results in the depletion of dissolved oxygen.

Fertility – The quantity and quality of nutrients present in a soil system.

Filter strips – A vegetated area that is situated between a shallow body of water and a disturbed land or roadway with the intention of filtering runoff and sediment as well as reducing the flow and velocity of storm water.

Forbs – Broadleaved flowering herbaceous plants.

Friable soils – A soil that crumbles easily when handled. This type of soil is ideal for the root growth of most plants.

Gateway – entrance or exit, such as to a community, city or state.

Germination – The process from which dormancy is broken and plant growth emerges.

Girdling – The process of completely removing a strip of bark around the tree's circumference resulting in the death of the tree.

Habitat – The natural conditions or environment of an organism, plant or animal; the place where it is usually found.

Herbaceous - Any non-woody plant. A plant that dies back to the ground after each growing season.

Herbicide – A chemical compound designed with the intent to kill plants, specifically weeds, or to inhibit their growth.

Humus – Organic matter that has broken down completely in a soil while also functioning to amend the soil.

Hydrology – The study of movement, distribution and quality of water.

Hydroseeding – The distribution of seed with fiber mulch through a stream of high-pressure water.

Innocuous species – A species of plant or animal that is not harmful or oppressive to others.

Integrated Roadside Vegetation Management (IRVM) – Management process for maintaining roadsides that employs biological, cultural, mechanical and chemical pest control methods in order to efficiently manage vegetated roadsides for safety, aesthetic and environmental reasons.

I**nvasive plant** - An aggressive plant that reproduces rapidly and spreads over large areas of land while stifling the growth of naturally occurring plants.

Median – A strip of land down the center of a road separating opposing lanes on a divided highway.

Mulching – Applying a protective layer of material over the soil to control weeds, prevent erosion, maintain even soil temperature and conserve water.

Native plant (indigenous plant) – A plant that originates in and is typical of a region. A plant that records indicate to be naturally occurring prior to colonization. For the purpose of this manual, "native plants" are native to Delaware.

Naturalization – The process of allowing existing soil banks to germinate and/or encroaching adjacent seed sources to take over.

Non-selective herbicide – A herbicide that kills all plants with which it comes in contact.

No-spray zone – A zone that has, by request, been authorized to be free of insecticide or chemical spray.

Noxious weed – A plant that is regulated by a state; it is illegal for property owners to allow these plants to go to seed or grow taller than 24 inches on their land.

Ornamental plant – A plant that is grown for its aesthetic qualities.

Perennial – A plant that lives for two or more growing seasons.

Perennial forb – Broadleaved herbaceous flowering plant (as opposed to the narrow-leaved grasses, sedges and rushes).

Periodic mowing – Mowing annually or as necessary to discourage establishment of woody species and maintain an herbaceous composition.

pH - A measure of acidity or alkalinity of a soil.

Piedmont – Area of the Eastern US characterized by the low rolling hills situated between the Appalachian Mountains and the coastal plain.

Plant communities – Associated plant species that form the natural vegetation of a place.

Plugs - Herbaceous plants grown in very small containers.

Propagules – Any cutting or plant part used for propagation.

Regeneration – A process that allows existing soil banks to germinate, and/or encroaching adjacent seed sources to take over. Proximity to natural plant communities and a diligence to remove invasive plants are necessary for success.

Regional - Limited to or typical of a specific area of a country. As it pertains to management strategies, a regional approach considers the local character and ecology of the place and allows for input of local citizens. To be truly regional, an application must be fitted to the local biological processes and systems, and must conform to the local knowledge of cultural and historical traditions that result from extended residence in a place.

Regionally indigenous vegetation – Vegetation that occurs naturally in a particular region or environment.

Residential quality turf – Turf maintained for aesthetic purposes.

Restoration - The process of improving the ecosystem health of disturbed land. Soils that are not disturbed will restore and re-vegetate without outside influence, but disturbed soils are subject to weed invasion, compromising the original ecosystem.

Re-vegetation – The process of returning plant cover to exposed or bare soils. Re-vegetation can occur through planting, allowing existing seed to germinate or by allowing seed from surrounding vegetation to encroach.

Rhizome – An underground stem that develops roots and shoots.

Right-of-way - A narrow strip of land along the route of a transportation corridor.

Routine mowing – Frequent mowing of the site to maintain a specified height of vegetation.

Rush – A marsh plant with slender stems.

Sedge – A family of plants that resemble grasses or rushes but are (distinguishable by their triangular stems.

Seeding - A random or informal distribution of herbaceous plants (grasses and forbs) that is economical and practical for large areas where the precise location of individual plants is not of primary importance.

Selective herbicide – An herbicide that kills or stunts an unwanted plant or weed while causing little or no harm to desirable species.

Self-seeding – Plants that come back year after year from seeds that have fallen from a plant in the area.

Self-sustaining plant – A plant that is able to sustain itself independently.

Sense of place – Can be an abstract or subjective concept. It is a place that gives us our identity in a social, topographical, historical, physical and vegetative construct.

Soil horizon – A layer of the soil that possesses physical characteristics that differ from the layers above and beneath.

Stewardship – An ethical practice that involves cooperative planning and management practices that prevent the loss, or facilitate the recovery, of ecological diversity and habitat.

Stormwater pond - A pond that retains a permanent pool of water and temporarily retains stormwater allowing it to filter out slowly over a period of days.

Succession – A series of changes that create a mature plant or animal community over time.

Sustainability – The ability of an ecosystem to continue to function indefinitely into the future, meeting its own needs, while not compromising the needs of future generations.

Swale – A low depression in the land that is designed to capture and slow water runoff facilitating its infiltration into the soil.

Tillage – Preparation of a soil by turning or plowing.

Tilth – The structure and quality of a cultivated soil.

Topdressing – Process of adding a thin layer of quality soil to the surface of a lawn to increase resistance to drought, improve root development, or increase infiltration.

Transportation corridor – a long, narrow strip of land dedicated to movement of humans and their commodities usually delineated by rights-of-way boundaries.

Turf reinforcement mat – A layer of protection against erosion meant to stabilize soil while reinforcing vegetation.

Understory trees – Layer between the shrub layer and the canopy layer. Trees in this layer generally range from 20-40 feet in height.

Utility turf – Turf planted for its functionality (i.e. soil stabilization or dust control) and managed at a level to maintain these functions.

Vegetation management – The practice of maintaining healthy ecosystems through the control and maintenance of regionally appropriate vegetation.

Volunteer seed – A cultivated seed that grows without having been intentionally sown or planted.

Warm-season grass – Grasses that grow best at warmer temperatures (ideal range is 80˚–90˚F). They typically begin growth late in spring. Switchgrass, Indiangrass, broomsedge and little bluestem are examples of locally indigenous warm-season grasses.

Wetland – An area of land whose soil is either permanently or seasonally saturated with water. Wetlands are extremely diverse ecosystems.

Woody Plant - A plant that has a permanent above ground structure whereas herbaceous plants die back to the ground seasonally.

Wound dressing - A synthetic application often applied after pruning meant to heal cuts, control decay or protect against fungus and insects. Wound dressings are not necessary as trees have the natural ability to seal their wounds.

Literature Cited

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Appendix A

Do's and Don't s While Applying Herbicides

1. Read label prior to opening the container. Follow instructions and pay attention to precautions and warnings.
2. Store products in original containers.
3. With powdered herbicides, like Oust® and Escort® , hold the container inside the mouth of the tank and pour slowly. This will eliminate much of the dust blowing up from the tank.
4. Do not use soil active products near desirable susceptible vegetation. In these areas use foliar applied products such as Roundup® Pro.
5. Dispose of herbicide containers according to label recommendations or recycle. Disposal usually consists of triple rinsing the container and punching holes in it rendering it useless.
7. All of the herbicides can be left in the tank overnight but should not be left for an extended period of time. The solution should be used up if an application is not scheduled for several weeks.
8. Oust® and Escort® are unstable in acidic water and should not be left in the spray tank for long periods of time.

Application Knowledge

1. Drive at the correct speed.
2. Discontinue spraying if wind velocity rises. Winds above 5 mph (8 km/h) may cause drift. All spraying must cease when patterns cannot be kept on target. The applicator may need to begin application early in the morning, in order to cover as much area as possible, before the wind velocity rises.
3. Discontinue herbicide application if rainfall is threatening. Most of our herbicides are rainfast within 1-2 hours. Postpone treatment until favorable conditions are present. Wet soil and/or foliage may yield poor results.
4. Do not apply herbicides when ground is frozen.
5. Avoid contaminating water in lakes or streams with herbicides that are not labeled for use in water.
6. Use only clean water in the tank. Sand or clay particles will damage the pump, solenoids, and nozzles, and will deactivate Roundup® Pro.
7. Clean equipment when changing chemicals. Flush with water several times and spray rinseate on the right-of-way as a typical application.

DelDOT, Division of Maintenance and Operations
Daily Report Form
Pesticide Application

DISTRICT: **EXPRESSWAYS** **NORTH** **CANAL** **CENTRAL** **SOUTH**

DATE & TIME OF APPLICATION : _____ **ROAD NO.:** _____

LOCATION(S):(Use reverse if necessary)

_____

_____

PEST(S) TO BE CONTROLLED: _____

_____

APPLICATOR NAME (PLEASE PRINT): _____

APPLICATOR CERTIFICATION NO.: _____

CHEMICAL INFORMATION

PRODUCT NAME(S) _____
ACTIVE INGEDIENT(S) _____
EPA REG. NUMBER(S) _____
RATE OF PESTICIDE (OZ/GAL) or (% SOLUTION) _____
TOTAL AMOUNT OF PESTICIDE ADDED _____
TOTAL VOLUME OF MIX (WATER + PESTICIDE) _____
FINAL APPLICATION RATE (GAL/ACRE) _____
TOTAL VOLUME APPLIED _____

WEATHER INFORMATION

TEMPERATURE: _____ WIND DIRECTION/SPEED: _____

RELATIVE HUMIDITY: HIGH MEDIUM LOW

SPECIAL NOTES OR INSTRUCTIONS: _____

_____

DEPARTURE FROM DEL D. O. T. YARD: _____

RETURN TO DEL D. O. T. YARD: _____

TOTAL APPLICATION TIME: _____ **HOURS**

_____

APPLICATOR SIGNATURE

Appendix C

Selected Weed Species Control Recommendations:

Autumn olive – Treat with Confront® (1/2%) and Roundup Pro® (1%) tank mixed together. Spray to wet after July 4.

Burcucumber – Treat with Roundup Pro® . Multiple applications will be required to get late flushes.

Canada thistle – Treat with Confront® (1/2%) when Canada thistle is vigorously growing prior to planting the area. Multiple applications will be needed. Roundup Pro® is weak on Canada thistle. Treat with a preemergent herbicide such as Casoron as a winter application. Or spot treat with a postemergent herbicide such as Garlon® , Roundup Pro® , or Stinger® .

Crown vetch – Treat with Roundup Pro® when crown vetch is vigorously growing prior to planting the area. Treat in woody plantings with a preemergent herbicide containing Goal® (such as Rout® or OH2®). Treat in herbaceous plantings with a preemergent herbicide containing Gallery® . Spot spray in existing woody plantings that are listed as tolerant on the herbicide label with an herbicide containing clopyralid (such as Lontrel® or Transline®).

Giant ragweed – Pre-emergent herbicides can be used to control giant ragweed. Post-emergence herbicides that provide good control include Roundup Pro® , dicamba, and 2,4-D. Broadcast applications of Roundup Pro® at 2.0 pt/A will control plants up to six inches in height. Tank mixing 2,4-D at 1 pint/A with Roundup Pro® will also provide giant ragweed control. Pursuit® (imazethapyr) is also recommended for post emergence control of giant ragweed. Tillage is effective for control of seedlings because of their early emergence in relation to many other summer annual weeds. Tillage becomes less effective as plants become larger. Under moist soil conditions, plants may be “transplanted” and begin growing in another area. Repeated mowing will effectively reduce seed production but will not eliminate giant ragweed.

Japanese honeysuckle – Treat with Roundup Pro® (1%) when honeysuckle is actively growing, preferably after July 4. Treat with Confront® (1/2%) anytime. When honeysuckle is mixed with desirable species, it is possible to treat in mid-November to early winter when honeysuckle has green leaves but other plants are dormant. Mow twice a year (July and September) in established plantings to limit vegetative spread.

Japanese knotweed – Treat with Roundup Pro® (2%) during September and early October.

Johnsongrass – Treat with Roundup Pro® when Johnsongrass is actively growing. Repeated and close mowing kills Johnsongrass seedlings, prevents seed production, and reduces rhizome growth and regrowth of shoots. Sites may be

tilled where it is practical (e.g. abandoned cropland) and the exposed roots left to winter kill. Repeated tillage (e.g. 6 times at 2- week intervals during the growing season) prevents rhizome development and reduces Johnsongrass populations. Limited early season tillage, however, encourages rhizome growth by spreading pieces of the rhizomes.

Mile-a-minute – Control with a preemergent in March or April. After emergence, treat with Confront ® (1/2%) spray to wet.

Multiflora rose – Treat foliage in April or May with Escort® (1 oz/acre) before most desirable species have produced leaves, or anytime rose has green leaves. Use Roundup Pro® after July 4 until leafdrop. Remove the bulk of the shrub/vine by mechanical means and treat cut stems with a systemic herbicide.

Nutsedge – Treat with a preemergent herbicide such as Casoron as a winter application. Or spot treat with a postemergent herbicide such as Image® or Sedgehammer® .

Oriental bittersweet – Cut trunks and treat with a systemic herbicide. Or tank mix Confront® (1/2%) and Roundup Pro® (1%). Spray to wet after July 4.

Phragmites – Treat with Rodeo® (aquatic glyphosate) in combination with an aquatic wetting agent in late summer to early fall.

Porcelain berry – Cut stems and treat trunks with a systemic herbicide. Or tank mix Confront® (1/2%) and Roundup Pro® (1%). Spray to wet after July 4.

Appendix D

SOP's from DelDOT

(To be added in the future)

Appendix E

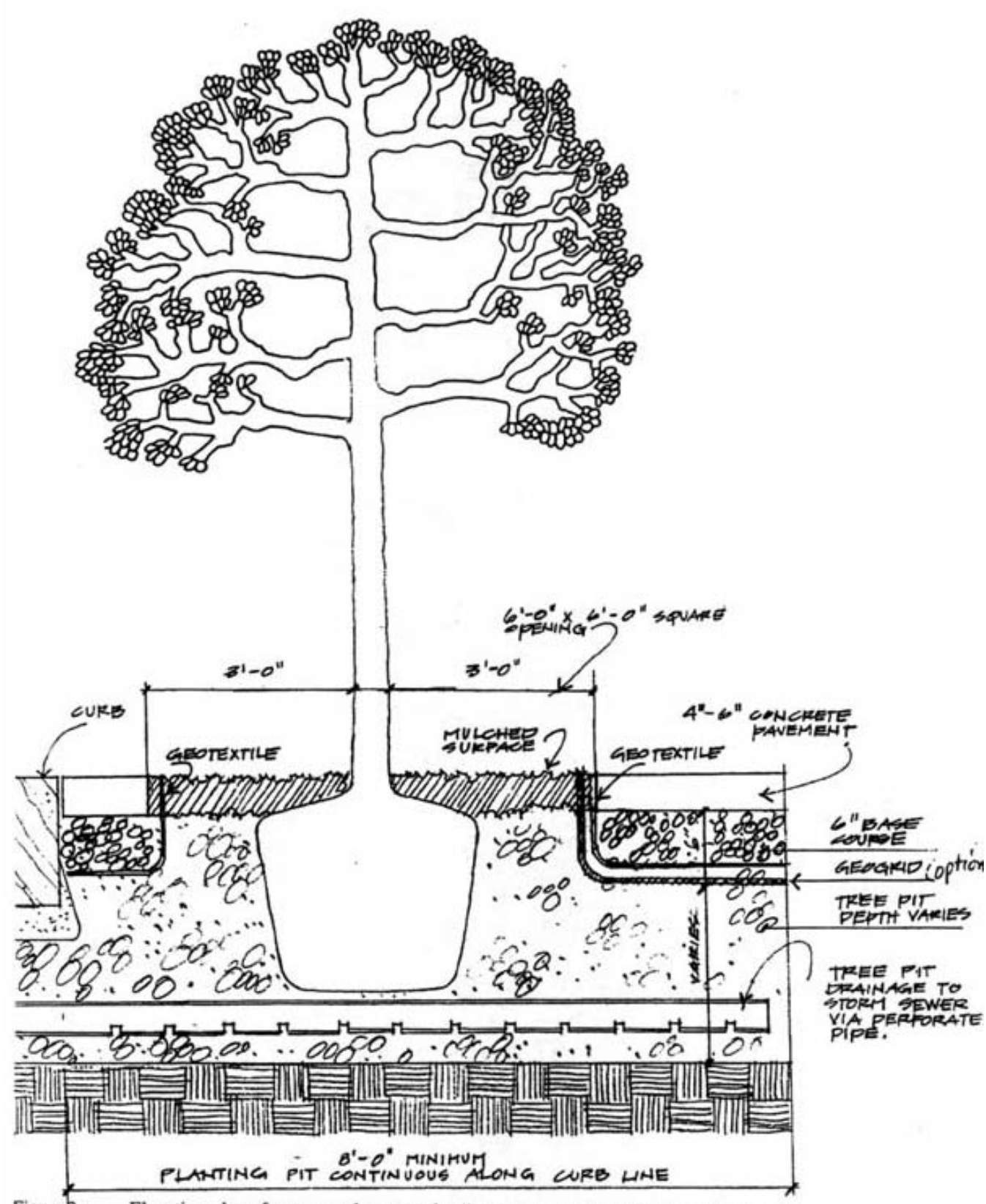


Figure 2: Elevation plan of a proposed structural soil pavement profile using the sub-base as the rooting zone.

Modular Pavement

Description

Modular pavement comes in pre-formed modular pavers of brick and concrete. When the brick or concrete is laid on a permeable base, water will be allowed to infiltrate. Grass can be planted between the pavers, allowing structural support in infrequently used parking areas.

Other Terms Used to Describe

Lattice concrete blocks
Monoslab concrete blocks
Modular brick or concrete pavers
Pre-cast concrete
Perforated pavers laid over pre-cast concrete

Pollutants Controlled and Impacts

Some of the possible benefits of this practice include: removal of fine particulates and soluble pollutants through soil infiltration; attenuation of peak flows; reduction in the volume of runoff leaving the site and entering storm sewers; reduction in soil erosion; and groundwater recharge. The degree of pollutant removal is related to the amount of runoff which exfiltrates the subsoils. It may also help reduce land consumption by reducing the need for traditional stormwater management structures.

There is a potential risk to groundwater due to oils, greases, and other substances that may leak onto the pavement and leach into the ground. Pre-treatment of stormwater is recommended where oil and grease or other potential groundwater contaminants are expected.

Application

Land Use
Urban, urbanizing, rural

Soil/Topography/Climate
This practice should only be used on sites with soils which are well or moderately well drained. Since subgrade soils will differ in their capacity to infiltrate and percolate water, the design of modular pavement will vary slightly based on soil type. See the "Specifications" section of this BMP.

Weather conditions will also affect frost penetration depth. This practice is not recommended for barren areas with expected wind erosion.

When to Apply
Apply when the soil, topography and climatic conditions listed above can be met.

Where to Apply

Apply in low-volume parking lots and roads, and in high activity recreational areas like basketball and tennis courts or playground lots. The area is generally limited to 0.25 to 10.0 acres and generally serves only a small section of the watershed. This BMP can also accept rooftop and adjacent parking lot runoff.

Relationship With Other BMPs

Subsurface Drains may collect water infiltrating the subbase of the modular pavement and route it to an Extended Detention Basin or Infiltration Basin. This may be necessary for soils having marginal infiltration capabilities. The use of subsurface drains may diminish the pollutant removal efficiency of this BMP by not allowing the water to fully exfiltrate the soil. Subsurface drains may also be installed but allowed to remain capped, acting as a backup system if the modular pavement becomes clogged.

Specifications

Planning Considerations:

Soil tests should be conducted to determine permeability, load bearing capacity, resistance to frost heaving, swell and shrink. Soils with a permeability rating of A or B (higher permeability) are more suitable than soils with a permeability rating of C (lower permeability). Evaluate the soils and drainage area to estimate the amount of water that may enter the modular pavement, and how fast this water will percolate through the soil. Underlying soils should have a minimum infiltration rate of 0.27 in/hr, or 0.52 in/hr for full exfiltration systems.

Diversions should be placed around the perimeter of the modular pavement to keep runoff and sediment completely away from the site both before and during construction. Plan to design Diversions in conjunction with the modular pavement.

Design Considerations for Various Types of Modular Paving:

As discussed below, modular pavement comes in a variety of materials, from lattice concrete blocks to modular brick or concrete pavers. This information was derived from "Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development," the Urban Land Institute (Tourbier and Westmacott).

Lattice concrete blocks are used for infrequent parking use, for lining grass swales, and for grass ramps. In parking areas, blocks should be laid on a bed of gravel or crushed aggregate (to give a sufficient capacity), and a 2-inch layer of fines and gravel. Interstices of blocks should be filled by screening with coarse sand. Spaces between blocks should be filled with coarse sand. Where the only purpose is for erosion control, blocks may be laid directly on soil and screened with topsoil. On driveways under lawns, blocks may be covered with 1-2 inches of topsoil

Monoslab concrete blocks result in a surface which is 25% concrete and 75% permeable soil. Blocks are of high-strength freeze/thaw resistant concrete, with both a rough and a smooth side. Lay the smooth side down for driveways, parking lawns, construction roads, erosion control, slopes banks, and waterways. Lay the rough side down for footpaths, sidewalks, bike trails, patios, malls

and tree grilles.

Modular brick or concrete pavers are perforated bricks, or bricks with lugs to control spacing. The brick or concrete pavers are made to a variety of specifications depending on the intended use, usually with a compressive strength of between 7,500-10,000 psi for use in areas where more wear is expected than for lattice blocks. Uses include paving around trees and dividing strips between impermeable paved surfaces. It is generally not conduce for walking. Interstices and perforations are usually kept free of vegetation.

Lay on a bed of gravel topped with 2 inches of coarse sand. The depth of the gravel will depend on the required stormwater storage capacity.

Pre-Cast Concrete Perforated Pavers Laid over Pre-cast Concrete Lattice Blocks can be made to a variety of specifications. A "web" opening may be in the order of 5" x 5" and 4.5" deep. The entire slab may be only 2.5 inches thick, with 0.75 inch diameter holes. These are laid on a base course of gravel of the necessary depth to provide storage capacity and 2 inches of coarse sand. This type of system is used in formal areas, especially where "warping" of large impermeable surfaces would be unsightly; also as a strip cover for French drains between areas of impermeable surface. Concrete blocks may be lifted and the web and sand filter cleaned out if the percolation rate falls.

Construction Considerations:

Where necessary, install a temporary Diversion to prevent runoff from entering the site during construction.

Install all modular pavement following manufacturer's specifications. The requirement for skilled labor for laying modular pavement may be reduced if mechanical vibrators are used for levelling uneven surfaces.

After Construction:

1. Stabilize the surrounding area and any established outlet following specifications in the Seeding and Mulching or Sodding BMPs. This will prevent sediment from entering the modular pavement.

2. Where applicable, remove temporary Diversions after vegetation is established.

3. Although snow and ice tends to melt more quickly on modular pavement, it may still be necessary to apply de-icing compounds to melt snow and ice. Do not use sand or ash because they may cause clogging of the pavement.

Maintenance

All modular pavement should be inspected several times in the first few months after construction, and at least annually thereafter. Inspections should be conducted after large storms to check for surface ponding that might indicate local or widespread clogging. If severe clogging occurs, the entire structure may have to be removed and old (clogged) filtering material replaced with new material.

Additional maintenance requirements will differ depending on the type of modular pavement selected. Follow the manufacturer's recommendations.

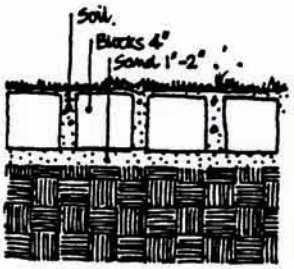
Exhibits

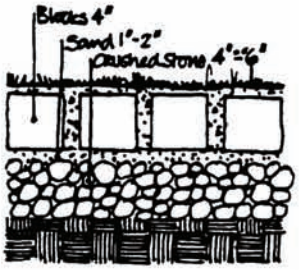
Exhibit 1: Examples of Modular Pavement. Source: "Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development," the Urban Land Institute.

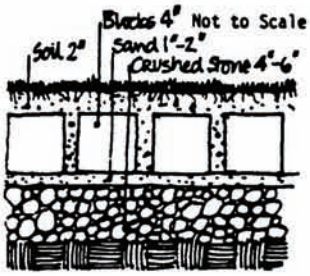
Exhibit 1

Examples of Modular Pavement

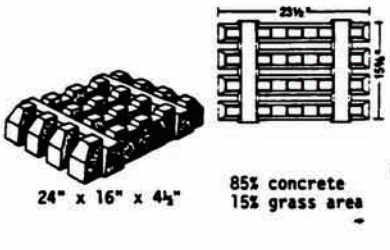
Concrete Blocks



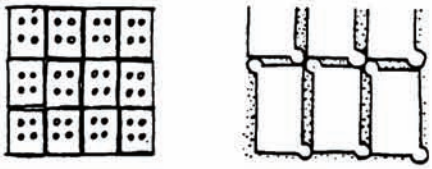




Monoslab Concrete



Modular Brick or Concrete Pavers



Pre-cast Concrete Lattice Block

Perforated Paver Laid Over Pre-Cast Concrete

"Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development," the Urban Land Institute.

Herbicides Approved for Use on DelDOT Rights of Way

When making herbicide applications:

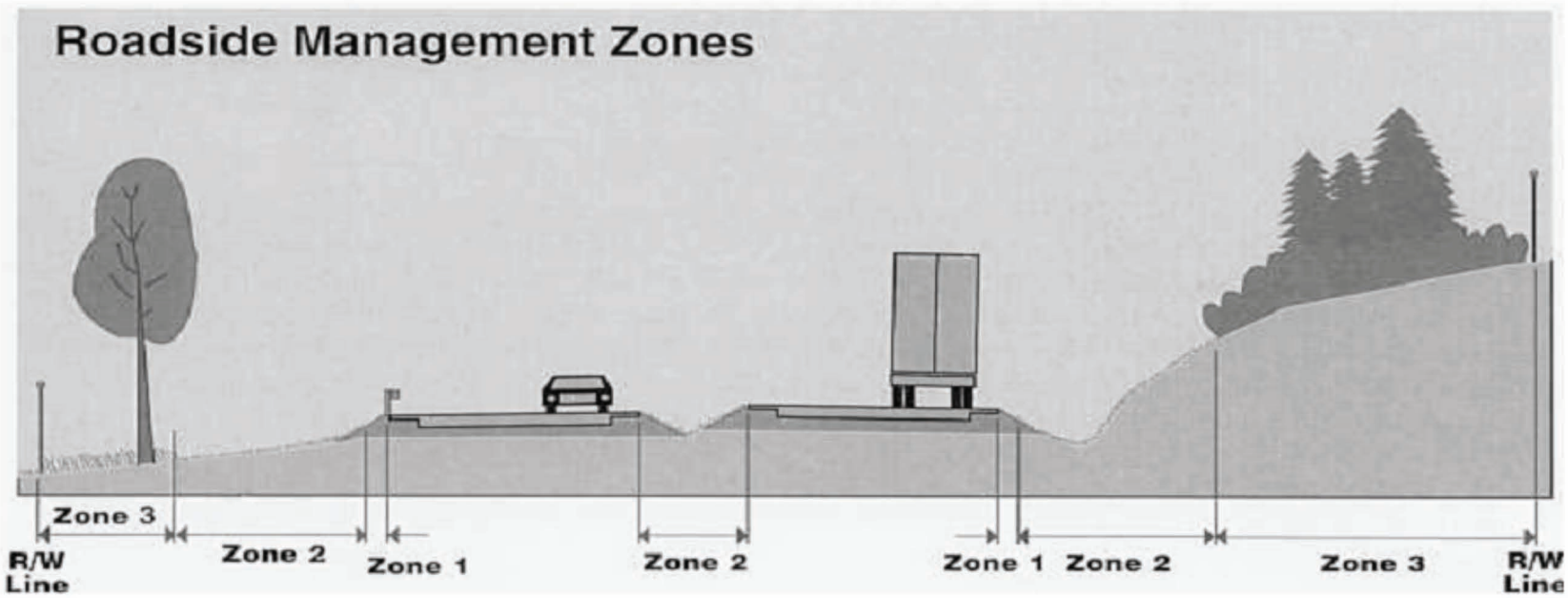
1. Always read and follow product label
2. Always use personal protective equipment when mixing, loading, and applying

Chemical Name	Product Name(s)	Where Used	How/Why Used	Notes/Recommendation	Restrictions	Cautions
2,4-D	Weedar 64 Amine 4 Veteran 720 Curtail WeedDestroy 4 Platoon Crossbow Escalade Weedmaster SolutionSavage Weedone LV4	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	Ester and acid formulations of 2,4-D may provide a good alternative to amine formulations	Amine formulations of 2,4-D are restricted for use within 60' of all water	Amine formulations cause irreversible eye damage and are highly toxic to rainbow trout. All 2,4-D products pose risks when applied near grapes and other sensitive crops
Chlorsulfuron	Telar XP Landmark XP	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	Product highly effective on Canadian thistle and Horse tail	None	None
Clopyralid	Transline Curtail	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	Transline is a copyralid formulation without 2,4-D	Curtail is restricted for use within 60' of all water because of 2,4D amine content	Curtial contains 2,4-D amine which causes irreversible eye damage and its highly toxic to rainbow trout
Dicamba	Vanquish Veteran 720 Veteran 10G	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	Vanquish is the dicamba formulation without 2,4-D	Verteran 720 is restricted for use within 60' of all water because of 2,4-D amine content	Veteran 720 contains 2-4-D amine which causes irreversible eye damage and is highly toxic to rainbow trout

Chemical Name	Product Name(s)	Where Used	How/Why Used	Notes/Recommendation	Restrictions	Cautions
Dichlobenil	Norosac 4G Casoron	Ornamental planting beds	Pre-emergent weed control in ground cover beds. Post emergernt control of grasses	Highly Effective for pre-emergent control of unwanted weeds in ornamentals	Restricted for use within 60' of all water	Dichlobenil is highly toxic to aquatic insects
Diflufenzopyr	Overdrive	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	None	None	None
Diuron	Karmex Diuron 4 L Diuron 80 DF	Under guardrails, on traffic control islands and around signposts	Nonselective pre-emergent grass and weed control	Cost effective weed control for	Restricted for use within 60' of all water	Highly toxic to fish
Fosamine	Krenite S	Tree and brush control in Zones 2 and 3*	Selective broadleaf treatment	Effective broadleaf tree control without visual impacts	None	None
Glyphosate	Various	Spot spray around shrub and tree planting, aquatic weed control (Rodeo Aquamaster)	Nonselective weed control	Only formulations of glyphosate labeled for use in aquatics situations are approved for use on DelDOT roadsides	None	Avoid drift.
Imazapyr	Arsenal Habitat	Bare ground locations (guardrails, islands, signposts); brush control	Pre/post emergent, non-selective control of all vegetation	Habitat is an aquatic version of Arsenal-good alternative to glyphosate in certain cases	None	High surface runoff potential high potential to leach into ground water.
Isoxaben	Gallery 75 DF	Turf & Ornamental	Pre-emergent weed control in ground cover bed	Works well by itself or with Ronstar	Restricted for use within 60' of all water	High surface runoff potential
Metsulfuron-methyl	Escort XP Metsuluforn Methyl 60 DF	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf and confier treatment	None	None	None
Oryzalin	Oryzalin AS Surflan AS Surflan DF	Ornamental planting beds	Pre-emergent weed control in ground cover beds	Products requires additional rinsing to thoroughly remove residues from empty container	Restricted for use within 60' of all water	Highly toxic to fish

Chemical Name	Product Name(s)	Where Used	How/Why Used	Notes/Recommendation	Restrictions	Cautions
Oxadiazon	Ronstar G Ronstar 50 WSP	Turf & Ornamental	Pre-emergent weed control in ground cover beds	Works well by itself or with gallery	Restricted for use within 60' of all water, gardens, plants bearing ediable fruit	Highly toxic to fish
Pendimethalin	Pendulum 2G Pendulum Aqua Cap	Turf & Ornamental	Nonselective pre-emergent grass and weed control	None	Restricted for use within 60' of all water	Highly toxic to fish, high potential for loss on eroded soil
Triclopyr Amine	Garlon 3A Pathfinder II Redeem R&P	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	None	None	Irreversible eye damage
Triclopyr Ester	Garlon 4 Tahoe 4E Crossbow	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	Works well for invert applications	Restricted for use within 60' of all water	Highly toxic to fish

*See Roadside Management Zones, below.



Zone 1-Vegetation Free Zone: (0 to 2 feet from pavement or as necessary.

- Provide for surface drainage
- Reduce fire potential
- Provide for visibility and maintenance of roadside hardware
- Prevent pavement breakup by invasive plants
- Provide sight distance for passing, stopping and at intersections
- Prevent the buildup of wind blown debris and winter sand at the pavement edge

Zone 2-Operational: (From Zone 1 or pavement edge to meet operation and maintenance needs)

- Maintain design width for vehicle recovery
- Provide sight distance for passing, stopping at interchanges and at intersections
- Maintain hydraulic capacity of ditches
- Eliminate vegetative obstructions (trees with trunk diameter of 4" or more
- Control weeds
- Prevent erosion
- Provide wildlife habitat where compatible with roadway traffic
- Accommodate underground utilities
- Enhance visual quality

Zone 3-Transition/Buffer: (From Zone 2 to Right of Way line)

- Promote self-sustaining plant communities
- Blend and/or screen adjacent surroundings as necessary
- Eliminate hazard trees causing excessive shade (ice and frost potential) on the highway pavement
- Control weeds
- Prevent erosion
- Maintain and enhance visual quality
- Preserve wetlands and wildlife habitat
- Accommodate utilities
- Preserve and conserve native plants and wildflowers

AASHTO Policy on Geometric Design of Highways and Streets, 5th Edition. 2004. American Association of State Highway Transportation Officials. ISBN Number: 1-56051-263-6. (URL to purchase book: https://bookstore.transportation.org/item_details.aspx?ID=110)

Barton, S.S., Darke, R. Schwetz, G. 2006. Enhancing Delaware Highways: Planning and Concept Manual. Delaware Department of Transportation. University of Delaware.

Berger, R.L. 2005. NCHRP Synthesis 341, Integrated Roadside Vegetation Management, A Synthesis of Highway Practice, Transportation Research Board, National Cooperative Highway Research Program, Washington, DC.

Delaware Sediment and Stormwater Management Regulations (http://www.swc.dnrec.delaware.gov/Drainage/Documents/Sediment%20and%20Stormwater%20Program/5101%20Sediment%20and%20Stormwater%20Regs_Rev8-06.pdf)

DelDOT Erosion and Sediment Control and Stormwater Management Design Guide (http://www.deldot.gov/information/pubs_forms/manuals/es2m/index.shtml)

DelDOT Road Design Manual (http://www.deldot.gov/information/pubs_forms/manuals/road_design/index.shtml

DelDOT Standard Construction Detail (E-9) (http://www.deldot.gov/information/pubs_forms/const_details/2005/pdf/e09.pdf)

DelDOT Standard Specifications (http://www.deldot.gov/information/pubs_forms/manuals/standard_specifications/index.shtml)

DNREC Eorison Control & Sediment Control Handbook (http://www.dnrec.state.de.us/DNREC2000/Divisions/Soil/Stormwater/New/Delaware%20ESC%20Handbook_06-05.pdf)

Integrated Roadside Vegetation Management Program Task Force. 1997. How to Develop and Implement an Integrated Roadside Vegetation Management Program. National Roadside Vegetation Management Association, March 1997.

SCS Standards and Specifications for Critical Area Planting, Practice Code 342 (ftp://ftp-fc.sc.egov.usda.gov/NHQ/practice-standards/standards/342.pdf