

Best Management Practices for Pine Barrens Roadside Plant Communities

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Pinelands Preservation Alliance

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Executive Summary

This report provides information and recommendations to improve the ecological health and appearance of native roadside plant communities in the Pine Barrens.

The Ecological Value of Pine Barrens Roadsides

Roadsides provide sunny, open habitat required by a large number of native plants. This type of habitat, which had naturally been created by intense wildfires, has become less common because of fire suppression and related prescribed burning intended to protect human life and property. In short, roadsides provide over 11,000 acres of critical refuge habitat for a host of rare and attractive species including native orchids, grasses, and wildflowers.

Threats to Ecological Values

The problems associated with fostering healthy native roadside plant communities fall into two basic categories: 1) mowing regimes and 2) construction materials and post-disturbance soil erosion control practices. Repeated growing-season mowing has severely degraded native plant communities. Construction materials and post-construction soil erosion control practices fundamentally alter soils by increasing soil pH and/or increasing soil nutrients, which shift the competitive balance to non-native species that destroy native plant communities. Construction materials that raise soil pH include trap rock gravel and pulverized concrete. The addition of nutrient rich topsoils, fertilizer and lime to prepare sites for sowing of non-native cool season grasses following construction or maintenance activities has significantly and perhaps permanently destroyed thousands of acres of roadside habitat.

Recommendations to Foster Healthy Native Roadside Plant Communities

Specific recommendations are included in Section III, and summarized Best Management Practices are provided on the next page. The simplest way to improve ecological health of roadside plant communities is to reduce mowing, which also provides tangible cost savings for roadside managers. Where necessary for road maintenance or provision of safe vehicle pull-off areas, regularly mown turf should be restricted to the Operational Zone (ca. 8 feet from the traveled lane edge). Annual dormant season mowing should be employed beyond the Operational Zone to foster native plants. Existing positive mowing regimes include the New Jersey Department of Transportation's GEMZ (Grassland Eco Mow Zone) program and Burlington County's delayed mowing program along Route 563. These programs should be perfected and expanded throughout the Pine Barrens.

Post-disturbance treatment of roadsides should shift focus from soil stabilization to ecological restoration that stabilizes soil. Current soil erosion control standards provide limited room for interpretation, but NJDOT (New Jersey Department of Transportation) and SSCC (State Soil Conservation Committee) can improve implementation to reduce impacts on native plants by carefully considering actual soil erosion risks on sandy, porous soils. However, formal changes to existing Standards, in consultation with the Pinelands Commission and other stakeholders, are recommended for both NJDOT and SSCC Standards. These changes should consider the uniqueness of the Pine Barrens and eliminate requirements or recommendations that raise soil pH, increase soil nutrients, or include use of non-native seed mixes. In addition to changing soil erosion control Standards, cooperative efforts to develop native roadside seed mixes, strategic control invasive plants, and restoration of impacted roadsides will be critical to maximize the ecological health and appearance of Pine Barrens roadsides.

Summary Best Management Practices for Pine Barrens Roadside Plant Communities

Road Construction, Maintenance, and Drainage Materials

- Avoid or minimize disturbance to existing native roadside vegetation
- Do not apply paving, underlayment or roadside fill materials that may raise soil pH or increase soil nutrients

Mowing and Maintenance Regimes

1. Areas within 8 Feet of Traveled Lane Edge (Operational Zone)

- Regular, repeated mowing during growing season (mow as necessary to maintain vegetation height between 6-10 inches)
- Do not apply fertilizer or soil amendments
- Do not mow bare or sparsely vegetated areas to reduce mower-generated soil erosion
- SPECIAL EXCEPTION TO REGULAR MOWING: Rare plant populations within 8 feet of traveled lane edge warrant special mowing regimes. Ideally, mowing should occur annually in March at no lower than 6 inches. These isolated areas require permanent markings to avoid inadvertent mowing during the growing season.
- SPECIAL EXCEPTION TO REGULAR MOWING: Many roadsides are less than 8 total feet in width from the traveled lane edge to forest habitat. These areas cannot provide safe emergency vehicular access. Narrow roadsides should receive an annual dormant season mowing as detailed below unless regular mowing is required for drainage ditches, utility access, etc.

2. Areas greater than 8 Feet from Traveled Lane Edge (Clear and Transitional Zones)

- Annual dormant season mowing to edge of Undisturbed Zone (i.e., forest edge)
- Mowing from November 30th to March 30th at 6" height to eliminate woody plants and maintain herbaceous plant cover by allowing full plant life cycle (i.e., growth, flowering, seed production/dispersal, seedling establishment)

Post-Disturbance Restoration Regimes

1. If USLE (Universal Soil Loss Equation) calculation suggests low soil erosion potential, then...

- Create necessary grade to minimize potential soil erosion
- Allow natural colonization by native species
- Do not apply non-Pine Barrens fill material, fertilizer or soil amendments
- Treat invasive species as necessary
- Follow above mowing and maintenance guidelines

2. If USLE calculation suggests moderate or high soil erosion potential, then...

- Create necessary grade to minimize potential soil erosion
- Do not apply non-Pine Barrens fill material, repeated fertilizer applications or soil amendments
- Treat invasive species as necessary
- Follow above mowing and maintenance guidelines

The following options are hierarchical and dependent upon project specific considerations. Option A should be the first option, followed by Option B and then Option C.

- **Option A:** Utilize biodegradable erosion control products/techniques that hold soil during natural colonization and allow establishment of native species that require sunlight for germination.
- **Option B:** As available, apply appropriate native ecotype Pine Barrens seed mix.
- **Option C:** If necessary, apply minimally required rate of non-native cool season grasses to temporarily hold soil prior to establishment of naturally colonizing native species. As available, apply appropriate native ecotype Pine Barrens species to the seed mix. If necessary, an initial addition of minimally required fertilizer may be considered.

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Section I. Introduction

The goal of this document is to present best management practices (BMPs) to foster healthy, attractive, native Pine Barrens plant communities along roadsides. This report includes relevant background information including a summary of roadside management principles and regulations, selected examples of current roadside management practices, and recommended best management practices including recommendations for invasive plant management.

Pine Barrens Roadsides as Habitat

The open, disturbed habitat (a.k.a. early successional habitat) of roadsides is required by a large number of native plants and animals. This type of habitat, which would naturally be created by intense wildfires, has become less common because of fire suppression and related prescribed burning that is intended to protect human life and property (typically, prescribed burns are not intense enough to produce early successional habitat because trees and shrubs are not killed and bare sand is not exposed). In short, the open habitat of roadsides has become a critical refuge for a host of native Pine Barrens species.

The New Jersey Pine Barrens consist almost entirely of fire-maintained ecological communities that can be categorized as early successional. Wetland communities range from densely shaded Atlantic white cedar swamps (late successional) to open, acidic bogs containing a variety of orchids and carnivorous plants. Upland communities include the pygmy pine ‘forests’, pitch pine forests & shrublands and mixed pine-oak forests. Although uncommon at present, open upland habitats were much more common in the past (Stone 1910, Harshberger 1916). Early successional habitats occur in areas following intense burning or other significant disturbances, but cleared areas can quickly be converted to pine or oak forests following fire or land clearing. Roadsides now represent a significant amount of the potential habitat for a variety of plants and the animals (such as Lepidoptera) that depend upon sunny, open habitats. Pinelands plants that can flourish on roadsides include a variety of orchids, Pine Barrens Gentian, Blazing Star, Bonesets, Asters, Goldenrods and Golden-asters along with a host of other species not commonly found outside of the Pine Barrens including Pine Barrens Sandwort, Pine Barrens Heather and Bearberry. Please see Appendix J for a complete listing of scientific names for plant species mentioned in this report. New Jersey also hosts over 100 species of butterflies (Gochfeld and Burger 1997) that rely on these wildflowers as sources of food and breeding sites. Common butterfly species that would benefit from diverse native roadside plant communities include monarchs, sulphurs, skippers and swallowtails.

The potential scope of habitat creation along Pine Barrens roadsides is significant. Table 1 provides road miles of various types by county within the Pinelands area boundary defined by the New Jersey Pinelands Commission. Although the width of non-forest roadside habitat is quite variable depending on road type and adjacent land uses, there exists an estimated 11,072 acres of potential early successional habitat for native Pine Barrens ecological communities (assuming 3,059 miles of roadways and average non-forest roadside width of 15 feet).



Sweet goldenrod just beginning to bloom

Table 1. Road Miles by Type and County within the New Jersey Pine Barrens

Road Type	Manager	County							Total Miles
		Atlantic	Burlington	Camden	Cape May	Cumberland	Gloucester	Ocean	
US Highways	NJDOT	84	15	10	9	0	0	0	118
State Highways	NJDOT	35	33	19	0	16	0	23	126
Atlantic City Expressway	SJTA	45	0	14	0	0	0	0	58
Garden State Parkway	NJTA	28	12	0	0	0	0	36	77
County Routes	Various Counties	230	178	77	43	31	31	154	744
Local Roads	Various Municipalities	730	660	172	54	22	100	200	1937
Interchanges	Various	26	2	7	0	0	1	6	42
TOTALS		1178	900	298	106	69	132	419	3059

Roadside Management Principles

Traditionally, roadside vegetation management has utilized a combination of mowing and herbicide application. Harper-Lore (2001) reported that the early emphasis of roadside management was to mimic “front yards” with well-manicured turf grasses. As early as the 1970’s, planting of wildflowers increased in popularity (spurred by Lady Bird Johnson’s support of the Highway Beautification Act of 1965) and environmental concerns coupled with higher energy costs started the search for less resource intensive alternatives to manicured turf grasses. The financially-intensive practices of frequent mowing and intensive herbicide applications continue to be challenged by reduced budgets and increased interest in more environmentally-friendly approaches. Newer practices, which are ultimately less costly and more environmentally benign, are generally referred to as Integrated Roadside Vegetation Management or IRVM (NCHRP 2005). The goal of IRVM is to maintain the functional integrity of roadsides while reducing costs and minimizing carbon emissions and herbicide use while enhancing habitat for flora and fauna.

The need to capture IRVM principles into Best Management Practices (BMPs) is still occurring but requires further development (NCHRP 2005). Principles of IRVM include needs of local communities and highway users, knowledge of plant ecology and natural processes, design, construction and maintenance considerations, monitoring and evaluation procedures, government statutes and regulations and technology that considers cultural, biological, mechanical and chemical pest control methods to economically manage roadsides for safety and environmental and visual quality. Specific implementation considerations include selection of appropriate seed mixes following roadside disturbance, minimization of mowing and herbicide use, controlled burning and biological control of invasive species.

Roadside managers delineate zones by distances from the traveled roadway to facilitate management decisions. Although different entities may apply different numbers of zones or name zones differently, nomenclature defined by the North Carolina Department of Transportation is utilized in this report (NCDOT 1998) because it allows an integration of principles that can clearly define direct human needs with an allowance for facilitating the preservation of native roadside plant communities.

The zone adjacent to the road is referred to as the ‘Operational Zone’, followed by the ‘Clear Zone’, ‘Transitional Zone’ and ‘Undisturbed Zone’. The Operational Zone is maintained as low growing vegetation to allow safe pull-off areas for vehicles, facilitate road maintenance, maintain hydraulic capacity of ditches and accommodate underground utilities. This area may be considered the ‘road shoulder’ whether paved or unpaved. The operational zone is typically between 5 to 15 feet from the traveled roadway (NDOR 2009). The maintenance of site lines at road intersections or highway access ramps may be considered an extension of the operational zone. The Operational Zone is generally maintained through repeated mowing during the growing season to maintain vegetation at heights below

ten inches. In New Jersey, vegetation in this zone generally consists of non-native, cool season grasses that can withstand repeated mowing, but there are also a variety of native, low-growing Pine Barrens plants (e.g. Wintergreen, Bearberry, Pine Barrens Heather, and Three-Awn Grasses) that meet safe operational zone requirements. Zones beyond the operational zone are more easily managed for self-sustaining plant communities that prevent soil erosion, enhance roadside visual quality, and preserve native plants.

The Clear Zone is intended to provide a safe area for errant vehicles (functionally, the operational zone edge is the nearest roadside edge of the clear zone). Therefore, clear zones are kept free of trees and shrubs that would provide a safety hazard. The width of a clear zone is determined by traffic volume, vehicle speed and roadside slope (Task Force for Roadside Safety 2002). Examples of clear zone distances may range from 10 to 40 feet beyond the traveled road edge (NJDOT 2009). Guardrails or other barriers are employed when required clear zone distances cannot be maintained due to obstructions (e.g., steep slopes, ditches, etc.). If managed appropriately, the clear zone represents significant potential habitat for early successional Pine Barrens ecological communities.

The Transitional Zone lies beyond the clear zone and its width may vary. This area is intended to buffer the clear zone from growth of trees and may be maintained as shrub thickets through periodic mowing. This zone may not be considered necessary in many cases, especially if an appropriately-sized clear zone is maintained. However, New Jersey state agencies have utilized ‘alcoves’ (areas kept free of woody plants) to create visual interest along major roadways (e.g., Garden State Parkway, Atlantic City Expressway). Alcoves occupy the transitional zone and are wider than clear zone requirements. The Undisturbed Zone lies beyond the clear and transitional zones and consists of forest communities that are not maintained through typical roadside management. This zone may represent the remaining distance from the clear zone or transitional zone to the boundary of the roadside right-of-way.

In practice, one or more of these zones may not occur or zones may be significantly compressed on particular roadways. This is most common on less travelled roadways (e.g., County or local roads), but may also apply to larger roadways. The variability of roadside zone width requires flexibility in suggested management regimes that might foster native Pine Barrens ecological communities. For example, particular roadways may not provide zones beyond the operational zone if mature trees grow less than 8 feet from the traveled roadway.

Review of Current Regulations and Management Practices

Regulations and management practices were reviewed and/or phone interviews were conducted with staff from each of the following organizations: New Jersey Pinelands Commission, New Jersey Department of Transportation, New Jersey Turnpike Authority, South Jersey Transportation Authority, State Soil Conservation Committee (and individual Soil Conservation Districts), County and municipal roadside managers, and multiple NJDEP land managers (Division of Parks & Forestry and Division of Fish & Wildlife) (See Appendix A - List of Interviewed Professionals).

New Jersey Pinelands Commission

The New Jersey Pinelands Commission (Commission) has regulatory authority over roadsides because the Comprehensive Management Plan (CMP) equates vegetation change with development, and the CMP requires an approval application for any development. Further, the CMP includes specific restrictions on establishment of permanent lawns, placement of fill materials, planting non-native species and destruction of rare species.

In an effort to streamline the regulatory process, the Commission has entered multiple Memoranda of Agreement (MOA's) with various governmental agencies (i.e., state agencies, counties, municipalities). The agreements allow government entities to perform projects, within limits defined by the MOA, without completing a formal Commission permit application. Generally, these agreements allow bridge replacement, road re-surfacing, roadway intersection improvements, and replacement of drainage structures / stormwater infiltration inlets where disturbance is less than 5,000 square feet.

A recent incident regarding placement of fill material over a population of Pine Barrens gentian (see Section II) highlighted the need for permanent signage to protect roadside populations of rare species along with the need to improve language of the MOA's between the Commission and state, local, and municipal governments (see Section III for detailed recommendations). Revisions to existing MOA's are currently being considered by the Commission.

State Soil Conservation Committee

The Soil Erosion and Sediment Control Act of 1975 and the 1979 amendments require the State Soil Conservation Committee to develop and maintain technical standards and guidance to assure that soil, water and related natural resources are managed during development in a manner which prevents or minimizes soil loss and related environmental damage (SSCC 1999). The United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) contributes to the Standards through the production of their Field Office Technical Guide, which provides a significant basis for the state Standards. In 1999, the State Soil Conservation Committee promulgated the sixth edition of the "Standards for Soil Erosion and Sediment Control in New Jersey" (SSCC 1999). This document includes vegetative standards and engineering standards along with appendices providing detailed technical guidance. Any disturbance greater than 5,000 square feet must include measures to protect the environment from soil erosion and sedimentation. These standards are enforced through county / multi-county Soil Conservation Districts (SCD's). There are six SCD's that regulate activities within the Pine Barrens (Burlington, Cape-Atlantic, Camden, Cumberland-Salem, Gloucester, and Ocean). The SCD's regulate 2,681 miles of county and municipal roadways in the Pine Barrens.

The primary objective of the Standards is to retain soil on the site and minimize offsite sedimentation. The primary soil retention method is the establishment of permanent vegetative cover ("Standard for Permanent Vegetative Cover for Soil Stabilization"). Other standards include temporary or permanent stabilization with mulch or sod based upon season of disturbance and site characteristics. The regulatory definition of the vegetative standard is: "Established permanent vegetation means 80% vegetative cover of the seeded species and mowed once." The Standards do not provide an establishment time frame or direct observation / measurement of soil erosion potential. In the Pine Barrens, naturally porous soils may not require 80% vegetative cover to meet the purpose of the Standards (i.e., retain soil on site and minimize off site sedimentation). See recommendations in Section III of this report.

The permanent vegetative cover standard requires site preparation prior to establishing vegetation. This includes use of fertilizer and lime as needed to maintain a dense stand of desirable species. Particular application rates are provided in the standards but may be modified based upon suggestions from soil testing. The maintenance level regimes defined in the Standard suggest fertilizer and lime application only in the first year of establishment.

Related Standards include "Standards for Land Grading" and "Standards for Topsoiling". The purpose of the land grading standard includes improving surface drainage and erosion control. Topsoil and engineering requirements are provided in this standard. The purpose of the topsoiling standard is to

improve the soil medium for plant establishment and maintenance. Stripping (4-6 inches deep) and stockpiling of soils prior to construction activities and post-construction replacement of original topsoil is allowed. Topsoil must have a minimum organic matter content of 2.75%. Topsoil substitutes having particular qualities may also be utilized. The recommended topsoil depth is 5 inches for soils with a pH greater than 4.0.

The permanent vegetative cover standards provide 23 pre-defined seed mixes for New Jersey (13 mixes are recommended for roadsides). Table 4-2 of the Standards provides seed mix recommendations based upon soil drainage characteristics (i.e., excessively drained - 4 roadside mixes, well to moderately well drained - 9 roadside mixes or somewhat poorly to poorly drained - 5 roadside mixes). The standards also allow use of additional seed mixes if recommended by NRCS or Rutgers Cooperative Extension (RCE) and approved by the SCD.

There is a Pine Barrens seed mixture that consists of native warm and cool season grasses along with Partridge Pea, but the Standards do not specifically recommend this mixture for roadsides. Several seed mixes contain species that may be considered invasive in the Pine Barrens including Sericea Lespedeza (a.k.a. Chinese Bushclover, *Lespedeza cuneata*) and Weeping Lovegrass (a.k.a. African lovegrass, *Eragrostis curvula*). Native and non-native species listed in seed mixes that may increase soil fertility and alter native Pine Barrens soils include Partridge Pea (*Chamaechrista fasciculata*, native), Crownvetch (*Coronilla varia*, non-native), Flatpea (*Lathyrus sylvestris*, non-native), Sericea Lespedeza (*Lespedeza cuneata*, non-native), Bird's Foot Trefoil (*Lotus corniculatus*, non-native), and White Clover (*Trifolium repens*, non-native).

The permanent vegetative cover standards require mulching of all seed applications. The standards provide a wide variety of materials and application practices including straw or hay with various mechanical (e.g., netting) or chemical (e.g., liquid binders) anchoring techniques. Wood- or paper-fiber mulch and pelletized mulch are also acceptable mulch materials. Compliance with the mulching requirement is based upon the “existence of vegetation sufficient to control soil erosion” and is not specific to the presence of mulch (i.e., the applicant is deemed to be in compliance if the end result is the presence of vegetation at the disturbed location).

The permanent vegetative cover standards provide guidance on mowing and other maintenance levels. Four levels (A through D) describe the return frequency of mowing events and associated recommendations on the application of fertilizer and lime, pest control and irrigation. Level D is recommended for roadsides and suggests infrequent or no mowing, and fertilizer and lime applications only in the first year of establishment. The Standards do not provide specific mowing regimes (e.g., mowing height, seasonal timing).

New Jersey Department of Transportation and other State Roadway Authorities

The New Jersey Department of Transportation (2008) publishes its own “Soil Erosion and Sediment Control Standards”. This document is very similar to the document promulgated by the SSCC, but it applies only to NJDOT roadsides and NJDOT right-of-ways (this includes federal highways maintained by NJDOT). The NJDOT certifies to SCD’s that appropriate standards are applied for all NJDOT construction and maintenance projects through an interagency agreement with the New Jersey Department of Agriculture (NJDA). If necessary, NJDOT Standards allow their engineers to design soil erosion features that differ from the Standards after consultation and approval of internal subject matter experts and/or the Manager of the Bureau of Landscape Architecture and Environmental Solutions. NJDOT directly manages 244 miles of roadways in the Pine Barrens.

NJDOT standards list five unique seed mix options following construction activities. The majority of species listed in seed mixes are non-native cool season grasses. One recommended species is invasive in the Pine Barrens (Weeping Lovegrass, a.k.a. African Lovegrass, *Eragrostis curvula*). One non-native species listed in seed mixes, White Clover (*Trifolium repens*), may increase soil fertility and alter native Pine Barrens soils. The application of straw mulch with binding agents (e.g., vegetable-based gel), synthetic plastic emulsion, fiber mulch or vegetable-based gels are required over seedings. NJDOT Standards specify fertilizer application at initial sowing and approximately six months after sowing. Liming requirements specify increasing soil pH to 6.5. “Standards for Topsoiling” allow stripping, storage and re-application of topsoil from the construction site, but the pH must be greater than 5.8. When any topsoil has a pH less than 5.8, it is required to be amended to reach a pH of 6.5.

NJDOT “Standards for Maintaining Vegetation” suggests that maintenance occur on a regular basis. Maintenance programs should include: maintenance of grass height between 3 - 12 inches, application of fertilizer as needed to maintain a dense stand of desirable species and addition of lime as determined by soil testing every 2-3 years. Other relevant standards include “Standards for Topsoil Stabilization Matting”, “Standards for the Preparation of Existing Soil” and “Standards for Land Grading”.

Other state authorities manage 135 miles of roadways (South Jersey Transportation Authority’s Atlantic City Expressway = 58 miles, New Jersey Turnpike Authority’s Garden State Parkway = 77 miles). The NJTA and SJTA require direct project review through the SCD’s. Part of the GSP mission is to provide an attractive greenbelt along the roadway. NJTA initiatives include the “Going Green Task Force” and “Go Wild Areas” that emphasize reduction of mowing in areas that are difficult / dangerous to mow. In some places, it is possible that clear zone distances will require widening to meet current road traffic volumes.

County and Municipal Roadside Management

There are six counties (Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, and Ocean) and 56 municipalities within the Pinelands (See Appendix B). Collectively, counties manage 744 miles and municipalities manage 1,937 miles of roadways in the Pine Barrens. County and municipal road projects are directly reviewed by the SCD’s. In addition, many counties and municipalities have entered into MOA’s with the New Jersey Pinelands Commission regarding road maintenance practices (see above under New Jersey Pinelands Commission).

State Parks, Forests and Wildlife Management Areas Roadside Management

Roadsides along state-owned land are maintained by the New Jersey Department of Environmental Protection - Division of Parks & Forestry (state parks and forests) and Division of Fish & Wildlife (state wildlife management areas). The NJDEP is responsible for funding and executing roadside maintenance along their lands in agreements with state, county and municipal road authorities. In general, state-managed roadsides are mowed once per year in fall or winter. Park superintendents indicate that rare plant locations are known to staff that mow roadsides or may be marked by volunteers to avoid inadvertent mowing during the growing season. Areas adjacent to entrance driveways/roadways are generally maintained as regularly mowed (ca. 5 times per year) cool season grasses to facilitate easy public recognition.

Review of Costs for Roadside Management Practices

The practice of Integrated Roadside Vegetation Management (IRVM) has been gaining acceptance around the country and there are many states that have adopted the objective of reducing mowing

frequency and/or maintaining native plant communities to minimize maintenance costs and conserve our natural heritage. NCHRP (2005) reports that Florida, Maine, Maryland, Minnesota, Montana, and Washington have statutes mandating an Integrated Pest Management (IPM) approach to roadside vegetation management. Arkansas, Florida, Illinois, Maryland, Minnesota, New York, Ohio, Pennsylvania, Texas, and Washington have policies that require an integrated approach to vegetation management. Some specific examples include:

- Iowa: For over 30 years, Iowa counties have been practicing IRVM to reduce costs and allow the establishment and maintenance of native prairie vegetation that provides both aesthetics and soil erosion control (Ehley 1990).
- New York: Implemented Conservation Alternative Mowing Plans (CAMPS) to foster native grassland birds along major roadways. The protocol consists of four management regimes including: High Management Zone, Frequently Mowed Zone, Annually Mowed Zone and No-Mow Zone (Weiskotten 2003).
- Missouri: Reduced mowed roadside acreage by nearly 20% or 100,000 acres from 2000-2004 (Hillis 2005).

However, NCRHP (2005) also reports that data on maintenance costs for IRVM and traditional roadside management is sparse and reported cost estimates vary widely, which challenges accurate cost comparisons. Reported mowing costs (fine mowing to maintain turf grasses) ranged from \$20/acre/cut in West Virginia to \$190/acre/cut in Florida. Coarse mowing (for non-turf grasses) ranged from less than \$3/acre/cut in Washington to \$130/acre/cut in Maryland. Annual mowing costs in South Carolina were estimated at approximately \$24 per acre (Dlesk and Bell 2006). The number of cuts per year is a significant variable that often confounds cost comparisons between states (e.g., Florida may require 10 cuts per year while Maine requires 1 cut per year).

The New Jersey Department of Transportation (NJDOT) initiated the Grassland Eco Mow Zone (GEMZ) program in 2005. Under the GEMZ program, vegetated roadside areas beyond 6-8 feet from the edge of the paved road shoulder are mowed annually in mid to late fall (vegetated areas closer to the paved road/shoulder edge are mowed whenever vegetation height reaches 8-10 inches). The ecological, environmental, economic and aesthetic benefits of this program include:

- Reduced gas consumption and material wear and tear
- Reduced air pollution and runoff, increased groundwater recharge and facilitates litter removal
- Improved seasonal landscape interest from wildflowers and grasses
- Increased habitat for flora and fauna, creation of habitat corridors

The NJDOT maintains detailed records through their MMS (Maintenance & Management System). The NJDOT South Region estimated mowing effort and expenditures from 2005 - 2008 (Scott Oplinger, personal communication). Mowing costs (including labor and equipment operation) ranged from \$182 to \$318/acre (mowing frequency was 4 - 6 cuts per year, presumably based upon precipitation patterns). Importantly, NJDOT's South Region has decreased their total mowed acreage by 38% since 2006 (from 3,300 to 2,040 acres), which has conferred significant savings. Total costs for 2008 (after full implementation of the GEMZ program) were 33% lower than the average costs for 2005 and 2006 (prior to GEMZ implementation in the South Region).

Other commendable examples of roadside management in New Jersey include the conversion from multiple growing season mows to an annual mowing regime along roadside portions of Brendan Byrne State Forest. This change has helped to conserve the Federally endangered American chaffseed (*Schwalbea americana*).

The Burlington County Highway Department recently reduced their mowing regime to once per year in the early spring along Country Route 563. This will encourage native plant communities while simultaneously reducing management costs. Reduced mowing along Burlington County Route 563 is expected to save taxpayers approximately \$3,000 annually in personnel costs* (fuel costs and equipment wear and tear were not calculated). If annual dormant season mowing was implemented along all 178 miles of Burlington County routes within the Pine Barrens, then costs savings would be approximately \$27,000 annually. Depending upon individual organizational needs, cost savings may be secondary to time savings that would allow personnel to perform other vital tasks. In this example, Burlington County would gain over 130 days of personnel time for other tasks – and save fuel and equipment wear and tear costs.

*Assumptions included: 50 acres mowed (20 mile road x 20 feet mowed, 5 work days to cut), one annual mow compared to four mowing events per year, \$35,000 salary and 35% benefit rate.



Diverse mix of native Pine Barrens wildflowers, grasses and ferns.

Section II. Specific Examples of Pine Barrens Roadside Management

A small number of sites were surveyed for this report to demonstrate a range of existing roadside management practices. Representative sites include those with potential for improvement and those that currently support healthy native Pine Barrens plant communities. As a general rule, roadsides that have been filled with non-native soil types and/or composts (i.e., “fill”) support weedy plant assemblages consisting of non-native invasive species or species native to New Jersey that are not typical of the Pine Barrens. The problem of past fill events is especially prevalent where roads traverse wetland communities where significant amounts of fill were utilized to improve grading and drainage.

Table 2. Evaluation of Sample Pine Barrens Roadside Management Practices

Road Name	Road Stretch Examined	Manager	Management Regime
Atlantic City Expressway	ca. 2 miles South of intersection with State Highway 54	South Jersey Transportation Authority	Repeated growing season mowing
Franklin Parker Preserve	Along Airstrip	New Jersey Conservation Foundation	Annual dormant season mowing
Garden State Parkway	Between Atlantic County Route 561 Alternate and Burlington County Route 539	NJ Turnpike Authority	Repeated growing season mowing
Ocean County Route 528	Between Stump Tavern Road and Ocean County Route 640	Ocean County Department of Transportation / NJDEP Division of Fish & Wildlife	Repeated growing season mowing, Examined area of recently dumped fill material
State Highway 70 – Site A	ca. 2 miles south of Lakehurst circle	NJDOT	Northbound side was recently seeded with cool-season grasses, Southbound side was native vegetation
State Highway 70 – Site B	Intersection of Spring Lake Blvd. (ca. 0.5 miles North of Mt. Misery Road)	NJDOT, Brendan Byrne State Forest	Repeated growing season mowing along road, annual dormant season mowing in alcoves
State Highway 70 – Site C	ca. 1 mile south of Mt. Misery Road	NJDOT, Brendan Byrne State Forest	Repeated growing season mowing along road, annual dormant season mowing in alcove
State Highway 70 – Site D	Intersection with Sooy Place and Big Hill Road	NJDOT	Road intersection area with repeated growing season mowing
State Highway 70 – Site E	Intersection with New Road	NJDOT	Road intersection area with repeated growing season mowing

Atlantic City Expressway

General Roadside Description: Roadsides have 15-30 foot wide strips receiving repeated growing season mowing and are composed of non-native cool season grasses and typical lawn weeds. The cool season grasses appear to be dark green, which may indicate that high nutrient non-native fill material was utilized during road construction (it was determined that fertilizer application is not performed as part of normal maintenance) – native Pine Barrens soils are sandy and have low nutrient content. Some median areas are seeded with wildflower mixes and mowed less frequently. Wildflower mixes, however, evidently consist of non-native plants. The narrow grassed roadsides are punctuated with wider (> 50 feet) central median areas and roadside alcoves that are also repeatedly mowed during the growing season.

Specific Road Stretch Field Observations: An alcove located approximately 2 miles south of the intersection with State Highway 54 was visited on 10 October 2008. Cool season grasses and typical lawn weeds dominated along the regularly mowed 15-30 feet area closest to the road. There were large areas where sparse native species cover was predominant despite past growing season mowing events. The presence of native species may indicate that mowing is less frequent in the alcove than immediately along the roadside. Alternatively, the presence of native species in alcoves may track areas where non-native soils were not applied or where past soil amendments (e.g., fertilizer, lime) have leached away on steeper slopes. The dominant native species in these areas was a species of *Aristida* (Three-Awn Grass), which typically grows 6-12 inches in height (See Appendix C - Photo #5). Lichens and mosses were present over some bare sandy areas. There were a variety of native species along a narrow strip where the regularly mowed area meets native forest communities (presumably this area is mowed less frequently). Native species observed along the forest edge included: Three-Awn Grass, Little Bluestem, Broom sedge, Pennsylvania Sedge, Stiff Aster, Field Aster, Goats Rue and Yellow-Eyed Grass. Small diameter (< 10 feet) circular tracks were noted in multiple locations (presumably from turning mowers) along with some minor areas where soil erosion was occurring due to repeated mowing on slopes. See Appendix C for photographs of the examined road stretch (Photos 1 - 5).

Recommendations to Improve Native Plant Communities: The primary recommendations are to reduce the mowing regime to one cut per year in late winter / early spring, and apply no soil amendments. This will allow existing native species to expand and prevent potential soil erosion, while inhibiting the establishment of woody species. Repeated growing season mowing will be required within the current operational zone, which may be reduced to 8 feet in width from the edge of the traveled paved roadway. In some areas, the operational zone may need to exceed 8 feet to incorporate existing drainage swales.

Franklin Parker Preserve

General Roadside Description: This area is not a typical roadside, but unpaved roads are maintained on either side of an unpaved airstrip. Native Pine Barrens plant communities are maintained along roadsides through annual dormant season mowing and overhanging branches are removed to maintain the integrity of the roads and the adjacent airstrip. The two roadways are approximately 0.5 miles long.

Specific Road Stretch Field Observations: The existing management regime of a single dormant season mow has resulted in a healthy early successional Pine Barrens plant community consisting of sparse cover of Little Bluestem along with a variety of low growing wildflowers, grasses and sub-shrubs (See Appendix C – Photos 5, 7, 18, 19, 27 and 31 for examples of low growing native plants). It is likely that one or more annual mowing events were not performed in the past because pitch pine sprouts were present in particular areas (annual mowing would likely result in preventing seedling establishment). See Appendix C for photographs of the examined road stretch (Photos 6 - 7).

Recommendations to Improve Native Plant Communities: The current management regime of annual dormant season mow does not require any modifications. However, the currently established pitch pine sprouts may be removed as necessary to maintain the integrity of roadsides free from potential vehicle hazards. Removal may be accomplished through targeted foliar application of herbicide or physical removal of sprout stumps.

Garden State Parkway

General Roadside Description: The majority of the roadway consists of approximately 10-20 foot wide regularly mowed grass strips consisting of non-native cool season grasses and typical lawn weeds. Some median areas are seeded with wildflower mixes and mowed less frequently. Wildflower mixes, however, evidently consist of non-native plants. The cool season grasses appear to be dark green, which may indicate that high nutrient non-native fill material was utilized during road construction (it was determined that fertilizer application is not performed as part of normal maintenance) – native Pine Barrens soils are sandy and have low nutrient content. The narrow grassed roadsides are punctuated with wider (> 50 feet) mowed central median areas and roadside alcoves. Many central median areas consist of narrow forests. Overall, the Garden State Parkway roadsides are maintained similarly to the Atlantic City Expressway.

Specific Road Stretch Field Observations: A fifteen mile stretch between Atlantic County Route 561 Alternate and Burlington County Route 539 was observed on 10 October 2008. The general roadside description above adequately describes this portion of the Garden State Parkway. Specific plant communities or species identifications were not performed but are suspected to be similar to observations made along the Atlantic City Expressway.

Recommendations to Improve Native Plant Communities: See above recommendations under Atlantic City Expressway.

Ocean County Route 528

General Roadside Description: Portions of the roadway consist of approximately 10-15 foot wide regularly mowed grass strips consisting of non-native cool season grasses and typical lawn weeds. Other portions of the roadside consist of very narrow areas (< 5 foot wide) and consist of regularly mowed native species (mowing is suspected to be less frequent in these areas, which may allow persistence of particular native plants). Alternatively, the presence of native species may track areas where non-native soils were not applied or where past soil amendments (e.g., fertilizer, lime) have leached away on steeper slopes.

Specific Road Stretch Field Observations: There were five locations where approximately 3-6 inches of rich topsoil/compost fill was recently applied. In addition, the fill contains common household trash. The fill was added to increase the grade to improve roadside parking adjacent to Colliers Mills Wildlife Management Area. This highly enriched fill is facilitating the establishment of numerous non-native weeds (e.g., Crabgrass, Foxtail Grass, Lady's Thumb Knotweed, etc.). Native Pine Barrens plant communities grow on nutrient poor sandy soils and are outcompeted by weedy invasive species when soils contain high nutrient contents. See Appendix C for photographs of the examined road stretch (Photos 8 - 12).

Recommendations to Improve Native Plant Communities: The applied non-native fill requires removal and replacement with native Pine Barrens fill material. Native fill material should be limited to the minimum amount required to provide safe vehicular access to the roadside. Natural colonization of the area by local plants should occur over time. If seeding is deemed necessary, it should be with native Pine Barrens species (as available) and should be supplemented by lightly raking the mulch layer of adjacent unaffected areas of native vegetation into the impacted area. This may provide native plant seeds and mulch (e.g., oak leaves, pine needles) that can accelerate re-vegetation of the impacted area. This restoration approach should be considered experimental and monitored periodically for success. See Section III for detailed post-disturbance restoration recommendations.

State Highway 70

General Roadside Description: This roadway has multiple roadside management regimes. Portions are managed similarly to the Atlantic City Expressway and Garden State Parkway. Other areas have regular growing season mowing regimes along relatively narrow strips (10-15 feet along the paved roadway) with less intense mowing regimes beyond these areas that support healthy native Pine Barrens plant communities. Roadside alcoves are also present in particular road stretches. Recently modified areas may be graded with non-native fill materials and seeded with non-native cool season grasses along with additions of fertilizer and lime to facilitate establishment. Illegal off road vehicle (ORV) traffic has resulted in long stretches of unsightly, unofficial ORV tracks along many miles of the road shoulders, with obvious impacts to the native plant communities.

State Highway 70 - Site A

Specific Road Stretch Field Observations: An approximately 6 foot wide recently disturbed roadside area had been graded and seeded with cool season grasses (It is unclear, but probable that non-native fill material was added – See Appendix C, Photo #13). An approximately 2 - 5 foot strip of native Pine Barrens vegetation was left undisturbed along the forest edge. Species in the undisturbed area included Bearberry, Wintergreen, Pine Barrens Heather, Purple Lovegrass, Pussy-Toes, Three-Awn Grass, Broomsedge and Little Bluestem. Overall vegetative cover was sparse with lichen and mosses covering bare sand in many areas. The opposite roadside was not impacted and consisted of sparse cover of a diverse mix of native Pine Barrens species growing on a low slope (soil erosion was not evident). Species composition was similar to the undisturbed areas on the impacted roadside. See Appendix C for photographs of the examined road stretch (Photos 13 - 19).

Recommendations to Improve Native Plant Communities: If applied, non-native fill material should be removed and replaced with native Pine Barrens fill material. The mowing regime (repeated growing season mowing) should allow maintenance within the operational zone, which would include approximately 7 feet of paved road shoulder and only 1 foot of the impacted unpaved area. The remainder of the unpaved area may be treated as described above for Ocean County Route 528. Enforcement of traffic regulations should be sought from appropriate law enforcement agencies.

State Highway 70 - Site B

Specific Road Stretch Field Observations: Alcoves located along the east- and westbound lanes near the intersection with Spring Lake Boulevard were visited on 10 October 2008. The alcoves consisted of a diverse mix of native Pine Barrens species including Little Bluestem, Pine Barrens Heather, Pinweed, Orange Grass, Pennsylvania Sedge, *Dichanthelium* sp. and *Aristida* sp. Bare sand was present along with areas covered with lichens and mosses that held the soil in place. Both sides of the road were flanked with approximately 10 foot wide regularly mowed cool season grasses with typical lawn weeds. Soil erosion was not present despite the sparse vegetative cover in some areas. A small area in the vicinity of the alcove was dominated by non-Pine Barrens species including the non-native invasive African Lovegrass and Asiatic Bittersweet. It is likely that this area contains enriched fill that is not native to the Pine Barrens because typical Pine Barrens soils do not support these plant species. See Appendix C for photographs of the examined road stretch (Photos 20 - 27).

Recommendations to Improve Native Plant Communities: The current management regime of annual dormant season mowing does not require any modifications, but the regularly mowed operational zone should be reduced to an 8 foot width from the traveled lane edge. However, there are minor occurrences of currently established pitch pine sprouts that may be removed as necessary to maintain the integrity of

roadsides free from potential vehicle hazards. Removal may be accomplished through targeted foliar application of herbicide or physical removal of sprout stumps. Adjacent areas containing invasive and other non-Pine Barrens species should be mowed with a brush hog and treated with herbicide to prevent spread (See Section IV for details). The extent of suspected non-native fill should be examined and removed to prevent re-infestation. At a minimum, African Lovegrass should be eradicated, through the application of herbicides, because it can invade adjacent areas.

State Highway 70 - Site C

Specific Road Stretch Field Observations: An alcove located along the eastbound lane approximately 1 mile south of Mt. Misery Road was visited on 10 October 2008. The paved road was flanked with a 10 foot wide strip of cool season grasses mixed with typical lawn weeds that receive repeated mowing during the growing season. There were large areas where sparse to dense native species cover was predominant. These areas receive an annual mowing during the dormant season. The dominant native species were Broomsedge along the moist woodland edge grading toward Little Bluestem on drier areas closer to the paved road. See Appendix C for photographs of the examined road stretch (Photos 28 - 29).

Recommendations to Improve Native Plant Communities: The current management regime of annual dormant season mowing does not require any modifications, but the regularly mowed operational zone should be reduced to an 8 foot width from the traveled lane edge. This site should be evaluated by the NJ Forest Fire Service to determine fire hazard risk because of the dense growth of native grasses. If the area is considered high risk, then the annual dormant season mowing should occur in autumn to minimize the amount of time that cured grass stems are present. If fire hazard risk is considered low, then annual mowing should occur in early spring to allow seeds to remain on dried stems, which will allow natural seed dispersal and provide a food source for winter resident birds. Autumn mowing would also reduce the aesthetic beauty of the site by removing the attractive cottony seed heads and autumn and winter stem colors (usually russet and tan).

State Highway 70 - Site D

Specific Road Stretch Field Observations: The road intersection with Sooy Place / Big Hill Road was visited on 10 October 2008. There was a 5 foot strip that receives repeated growing season mowing and consists of non-native cool season grasses and typical lawn weeds. The cool season grasses appear to be dark green, which may indicate that high nutrient non-native fill material was utilized during road construction – native Pine Barrens soils are sandy and have low nutrient content (NJDOT reports that this area is not fertilized as part of normal maintenance, so non-native fill is strongly suspected). The remaining area was predominately a mowed mixture of native and non-native species (probably receiving less frequent growing season mowing). The non-impacted forest edge was dominated by a dense stand of low growing native Pennsylvania Sedge. See Appendix C for photographs of the examined road stretch (Photos 30 - 31).

Recommendations to Improve Native Plant Communities: The applied fill requires removal and replacement with native Pine Barrens fill material. Fill should be limited to the minimum amount required to provide safe emergency vehicular access to the roadside. Natural colonization of the area by local plants should occur over time. If seeding is deemed necessary, it should be with native Pine Barrens species (as available) and should be supplemented by lightly raking the mulch layer of adjacent unaffected areas of native vegetation into the impacted area. This may provide native plant propagules (e.g., seeds, stolons, rhizomes) and mulch (e.g., oak leaves, pine needles) that can accelerate re-vegetation of the impacted area. This restoration approach should be considered experimental and monitored periodically for success. See Section III for detailed post-disturbance restoration recommendations.

State Highway 70 - Site E

Specific Road Stretch Field Observations: The road intersection with New Road (north and southbound side of New Road) was visited on 10 October 2008. There was a 10-15 foot strip that receives repeated growing season mowing and consists of non-native cool season grasses with typical lawn weeds. The cool season grasses appear to be dark green, which may indicate that high nutrient non-native fill material was utilized during road construction – native Pine Barrens soils are sandy and have low nutrient content (NJDOT reports that this area is not fertilized as part of normal maintenance, so non-native fill is strongly suspected). The remaining area was predominately a mowed mixture of native and non-native species. The invasive Japanese Stiltgrass and Canada Thistle along with numerous other weedy species were present. See Appendix C for photographs of the examined road stretch (Photos 32 - 35).

Recommendations to Improve Native Plant Communities: Existing fill requires removal and replacement with native Pine Barrens fill material. Fill should be limited to the minimum amount required to provide safe emergency vehicular access to the roadside. Natural colonization of the area by local plants should occur over time. If seeding is deemed necessary, it should be with native Pine Barrens species (as available) and should be supplemented by lightly raking the mulch layer of adjacent unaffected areas of native vegetation into the impacted area. This may provide native plant seeds and mulch (e.g., oak leaves, pine needles) that can accelerate re-vegetation of the impacted area. This restoration approach should be considered experimental and monitored periodically for success. See Section III for detailed post-disturbance restoration recommendations.

Other Sites Containing Rare Plants and Unique Plant Communities

Louis Hand and Ted Gordon pioneered efforts to protect roadside plant populations in the early 1970's. Initial efforts focused on protecting *Schwalbea americana* (American Chaffseed) near Whitesbog. Although there were setbacks through the years (untimely mowing, road widening, utility pole replacements, etc.), this population still exists and is relatively healthy due to continuing efforts of the Office of Natural Lands Management in cooperation with NJDOT. Other early pioneers included Howard Boyd, Lou Phallon and Betty Woodford who communicated the need to protect roadside plant communities with various road agencies.

In addition to the threat of direct loss of rare species, there are numerous examples of diverse assemblages of native Pine Barrens wildflowers being degraded by the application of non-native fill materials and/or untimely and repeated growing season mowing. Over the years, Pine Barrens naturalists and researchers feel that thousands of roadside miles have lost their unique native flora (Ted Gordon and Joseph Arsenault, personal communications). Particular examples include:

- New Lisbon Road (Burlington County) – This road is considered the “Gateway to the Pines”, but is regularly mowed during the growing season.
- State Highway 55 – Planting of invasive African Lovegrass, which is now spreading throughout Pine Barrens roadsides.
- State Highway 70 (Four Mile to Lakehurst) – non-native fill material (Piedmont Triassic shale) installed following road construction
- State Highway 72 (through Pine Plains) – extensive colony of bearberry (maximum height typically six inches) was repeatedly mowed to extinction
- U.S. Highway 206 (near Atsion) – Past management included dormant season mowing only, which resulted in large displays of Wand Goldenrod, Ladies' Tresses and Lobelias. Current growing season mowing will ultimately eliminate these native species.

- County Route 539 (Warren Grove to Tuckerton) – significant dumping of leaf compost leading to replacement of native species with native cool season grasses that require significantly more maintenance mowing
- County Route 563 (multiple locations) – There are numerous locations containing many species of Pine Barrens plants. There have been repeated efforts over many years to protect particular road stretches, but growing season mowing events have reduced quality in some areas. In 2008, Burlington County agreed to an annual dormant season mowing, which should significantly improve the health of native roadside plants.
- Dover Road (Ocean County) - In November 2008, non-native fill was applied to increase roadside grade to match the height of a newly paved roadway. Unfortunately, this fill was spread over an existing population of Pine Barrens Gentian located along the eastern road shoulder of Dover Road near the entrance to Dover Forge. According to Ocean County personnel, the initial fill material was removed and replaced with native fill that included sand, compost and Pinelands grass seeds. However, the precise nature of the new fill, in terms of pH and nutrient levels, is not known, and it is not known whether the Gentian population will survive.



The invasive Chinese silvergrass beginning an infestation along a Pine Barrens roadside.

Section III. Recommended Best Management Practices

Recommendations in this section are intended to inform future revisions and current interpretations of existing soil erosion control standards (Standards) utilized by NJDOT and SSCC as well as informing proposed changes to MOA's between the Pinelands Commission and the State and Pinelands counties and municipalities. In addition, recommendations encourage changes to roadside mowing regimes, development of native seed mixes, initiation of pilot roadside restoration projects, and management of invasive species. Each recommendation is prefaced by a brief discussion. Additional background information to support recommendations is provided in other plan sections.

Regulatory Framework

The overarching goal of existing soil erosion Standards is to retain soils on site and reduce off-site sedimentation. Although a generic statewide approach has led to attempts to improve roadside soils through additions of nutrient rich fill materials, fertilizer, lime and seeding with non-native cool season grasses, this suite of measures is not necessary to reduce soil erosion in the Pine Barrens. In fact, these Standard recommendations and requirements are counter to the health and natural attractiveness of native Pine Barrens roadside plant communities. Particular improvements are possible utilizing the existing Standards, but new interpretations by NJDOT and SCD's will be required to ensure conformance while bringing increased protection to native roadside plant communities. Currently, NJDOT Standards allow their engineers to design soil erosion features that differ from the Standards after consultation and approval of internal subject matter experts and/or the Manager of the Bureau of Landscape Architecture and Environmental Solutions. However, greater clarity and consistency would be obtained through the creation of specific NJDOT and SSCC Standards that shift focus from soil stabilization to ecological restoration that stabilizes soil.

Recommendation #1 – Modify existing NJDOT and SSCC Standards: NJDOT and SSCC Standards should specifically account for the uniqueness of the Pine Barrens (e.g., reduced soil erosion potential and ecological value of native roadside plant communities). The SSCC is expected to revise their existing standards within the next 2-3 years. The NJDOT revised their standards in 2008, but inclusion of specific requirements for the Pine Barrens should be considered during their next revision. Overall, new standards should shift focus from soil stabilization to ecological restoration that stabilizes soil.

Key recommendations and requirements of the Standards are listed in Section I. Statewide soil erosion control recommendations and regulations that should be altered for Pine Barrens' applications include: vegetative cover requirements, topsoiling requirements, use of soil amendments including fertilizer and lime, seeding with non-native species, and standards for maintaining vegetation. Specific recommendations for changes to the Standards are provided in Recommendations 3, 4, and 5. Recommendation #5 should be considered especially important for guiding future revisions of the Standards and is presented as "Summary Best Management Practices for Pine Barrens Roadside Plant Communities" after the executive summary of this report. All other recommendations should be considered as additions to existing Standards that will further the health of roadside plant communities.

Recommendation #2 - Modify existing NJ Pinelands Commission MOA's: MOA's should clearly distinguish between road maintenance and other activities that impact roadsides that would trigger the formal Commission application procedures. Items that should require application to the Commission include:

1. Any grading or scraping that impacts the existing vegetation community of the road shoulder
2. Any fill material that changes soil chemistry (e.g., pH, nutrients, etc.)
3. Any soil amendments, especially lime and fertilizer
4. Any non-native seed mix

The Pinelands Commission is currently considering modification to their MOA's with state agencies, counties and municipalities regarding roadside management (See Section I), which provides an opportunity to improve roadside management practices that are not addressed in the current Standards. The protections afforded through the Pinelands Comprehensive Management Plan allow the Pinelands Commission to establish protocols that allow improved management of roadsides (e.g., permit requirements for vegetation disturbance, prohibiting non-native plantings, protections for rare plants - See Section I).

Road Construction and Drainage Materials

Road construction, re-surfacing and widening along with drainage and utility maintenance, and other roadway improvements may involve intensive practices that alter roadside plant communities. The selection of materials for pavement underlayment, drainage improvements (especially concrete washouts), and road bank stabilization can involve materials that raise roadside soil pH (native Pine Barrens surface soil pH ranges from 3.6 to 4.0 and sub-surface soils range from 4.2 to 5.0 - Markley 1998). Some materials of concern include gravel, particularly trap rock gravel. These materials do not have a basic pH, but may be significantly more basic than natural Pine Barrens soils. For example, preliminary studies show that typical gravel, sourced from outside of the Pine Barrens, can raise local soil pH values to approximately 6.5 and may encourage invasive species proliferation, especially under disturbed conditions (Walter Bien, personal communication). The use of pulverized concrete underlayment and concrete drainage systems should be expected to produce even greater alteration of roadside soil pH. Freshly poured concrete has a pH value of 11-12, while aged concrete has a pH value of 8-9 (NASA 2009). One known example of pulverized concrete underlayment occurs on State Highway 55 near its intersection with State Highway 322, but soil pH impacts have not been measured. Native Pine Barrens plants adapted to low pH soils are more likely to be outcompeted by invasive species and other non-native plants in the vicinity of the roadway due to increases in soil pH.

Recommendation #3 – Road Construction and Drainage Materials: The practice of utilizing pulverized concrete or any other potentially pH-altering roadside construction materials should be discontinued. Locally sourced gravel underlayment and plastic-lined washouts should be utilized to avoid increasing roadside soil pH (see Appendix D for listing of local sources of gravel).

Post-Disturbance Restoration Regimes

This section contains sub-sections on the following topics: fill materials and amendments, soil erosion considerations, and development of native Pine Barrens roadside seed mixes. In all cases, it is ideal to minimize soil disturbance related to any project to avoid the need for soil erosion control measures or other remediation.

Fill Materials and Amendments

The use of non-native fill material continues to be the norm in the Pine Barrens. Leaf compost and non-native topsoil have been considered useful amendments to aid the establishment of non-native cool season

grasses following roadside construction projects and road re-surfacing. Unfortunately, these practices have seriously degraded native Pine Barrens roadside plant communities in numerous locations (e.g., County Route 539 from Warren Grove to Tuckerton, State Highway 70 from Four Mile to Lakehurst). Enriched non-native fill material allows the establishment of invasive species that normally cannot compete with native Pine Barrens species on native, nutrient-poor soils.

Recommendation #4 - Fill Material and Amendments: The nutrient deficient A-horizon of Cohansey and Kirkwood formations is a unique feature of the Pine Barrens, which will require fill materials from local sources only. Sub-soils of these formations may contain elevated minerals, but it is not expected that pH would vary significantly from topsoils (Markly 1998). Within the Kirkwood-Cohansey formation, there are belts of other formations (e.g., Potomac-Raritan-Mahothy sands) that may have sub-soils with relatively higher amounts of organic matter, clay or green sand (Robert Canace, personal communication). Only topsoils from soil formations matching the local roadside conditions should be utilized as fill material (if sub-soils are utilized as fill material, then testing should be performed to assure a chemical and texture match to topsoils in the impacted locality). There are 80 sand and gravel mines located on either Kirkwood or Cohansey geological formations (Appendix D, Figure 2). Fertilizer, lime or other amendments that increase nutrient content or alter soil pH should be eliminated or solely restricted to a single application coinciding with appropriately determined seeding events (see below).

Soil Erosion Considerations

The Universal Soil Loss Equation (USLE) is utilized to determine the sediment yield from construction sites (SSCC 1999, NJDOT 2008). The equation ($E = R \times K \times LS \times C$) incorporates factors including rainfall (R), soil-erodibility (K) and slope gradient and length (LS) where vegetative cover (C) plays an important mitigating role in minimizing potential erosion losses. Fifteen soil series have been identified in the Pine Barrens (Markley 1998) and soil erodibility factors (K) are considered “Low” for seven soil series, “Medium” for six soil series and “High” for one soil series (SSCC 1999, Table 3). It is important to note that for each soil series, the K-value is based upon soil in a cultivated continuous fallow situation on a 9% slope that is 73 feet long. In general, the majority of roadsides slopes in the Pine Barrens are significantly less than 9% and/or considerably shorter than 73 feet long. Therefore, K-values reported in this table are conservative (i.e., soil erosion potential is lower than reported whenever the slope gradient is less than 9% or shorter than 73 feet). Currently, the Standards do not stipulate an acceptable range of estimated soil loss derived from the USLE, but generically require establishment of vegetative cover to reduce soil erosion potential (See Section I).



Native boneset flowers in bud.

Table 3. Soil Erodibility Factors for Pine Barrens Soils¹

Soil Erodibility Class	Percentage of Pine Barrens Land Area (Markley 1998)	Soil Series Names	Notes
Low K = 0.17 – 0.24	44	Atsion, Berryland, Evesboro, Fort Mott, Klej, Lakehurst and Woodmansie	
Medium K = 0.28 – 0.37	41	Downer, Fallsington, Hammonton, Pocomoke, Sassafras and Woodstown	Each of these soil series has a K-value of 0.28, which is the minimum value to be considered “Medium”.
High K = 0.43 – 0.49	5	Aura	
Total	90		Total is less than 100% because it excludes the “Muck” soil series described by Markley (1998) that is not included in Standards Table A1-2 (SSCC 1999).

¹Erodibility values of the top strata for each soil series are reported in this table.

Recommendation #5 - Soil Erosion Decision Guidelines and Procedures: The calculation of estimated soil loss through the USLE should be determined on a site-by-site basis, because the lack of strong slopes and relatively low soil erodibility classes suggest low erosion potential throughout large portions of the Pine Barrens. In general, natural early successional Pine Barrens plant communities that would form on bare soils are typified by a mixture of sparse herbaceous vegetative cover with lichens/mosses reducing the amount of exposed sand. This natural vegetative cover, along with low potential soil erodibility, should mitigate the need for rapid establishment of vegetative cover or allow reduction of the current statewide standard of 80% permanent vegetative cover in much of the Pine Barrens.

1) If USLE calculations suggest low soil erosion potential, then unassisted natural colonization should be allowed following soil re-grading or disturbance. When applicable, the re-application of stockpiled topsoil from the impacted area can provide natural seed sources for revegetation. Additionally, a light raking of the mulch layer from adjacent non-impacted areas is likely to introduce propagules and a light layer of pine needles / oak leaves that would facilitate germination and seedling establishment. This recommendation is optimal and should be utilized whenever possible.

2) If USLE calculations suggest moderate or high erosion potential, then the following step-wise, prioritized decisions are recommended after soil re-grading. Recommendations of Step A are considered optimal in cases where soil erosion is a potential risk. If these recommendations are not adequate, then recommendations of Step B, followed by recommendations of Step C should be considered. Discretion of soil erosion control specialists should be utilized to minimize impacts and inputs.

- A) Utilize biodegradable erosion control products that hold soil during natural colonization and allow establishment of native species that require sunlight for germination. Erosion control may be achieved with multiple products detailed in SSCC (1999) and NJDOT (2008). If erosion control products are not an acceptable solution, then proceed to B.

- B) As available, apply appropriate native ecotype Pine Barrens seed mixes (see below for detailed considerations). The use of a “nurse crop” of non-native annual grasses may be considered. If vegetation establishment time is not conducive to reducing immediate soil erosion concerns, then proceed to C.
- C) Apply customary non-native cool season grass mixes at minimally acceptable application rates as a nurse crop along with seed of native species. If specific native ecotype Pine Barrens roadside mixes are not available, then utilize Pinelands native species that are more commonly available (e.g., Little Bluestem, Panic Grass, Indian Grass - See Table 4). If necessary, an initial addition of minimally required fertilizer may be considered to facilitate establishment of cool season grasses. Note: It is suspected that a lack of regular mowing may allow a transition from planted cool season grasses to a native Pine Barrens plant community if non-native fill is not utilized. However, this speculation should be corroborated with either detailed field observation or experimentation.

Developing Native Ecotype Pine Barrens Roadside Seed Mixes

Early successional plant communities that form on bare sand develop over longer periods of time in the Pine Barrens than in other parts of New Jersey. This is because native soils are low in nutrients and often droughty, which slows plant establishment and growth. However, relatively sparse vegetation, developing cover of lichens and mosses and porous sandy soils with little slope generally do not result in significant soil erosion even in the very early stages of succession.

In some cases, rapid establishment of vegetation may be required for aesthetic or regulatory purposes and seeding with native Pine Barrens plants would accelerate plant establishment. Nationally, there are only several large seed suppliers (Ernst Conservation Seeds, Meadville, PA is the nearest source). Currently, there is very limited availability of most Pine Barrens species and there are no suitable commercially available seed mixes because large seed suppliers require large, stable demand for particular seed mixes to retain economic viability. Additionally, original source locations for seeds of particular native species (ecotypes) are distant to the Pine Barrens and should not be considered for use in New Jersey when the primary goal is to promote diversity (species and genetic) of our native flora. The uniqueness of the Pine Barrens and relatively low potential demand for native seed mixes (from the viewpoint of very large seed suppliers) suggests the need to encourage the participation of smaller, local seed suppliers (i.e., niche markets or diversified growers). Assistance from governmental agencies or non-profit organizations will be especially important during seed mix development when demand is relatively low and there is significant need for development of efficient production methodologies.

The Natural Resource Conservation Service (NRCS) Cape May Plant Materials Center can potentially provide support for development of native ecotypes of Pine Barrens species. The Plant Materials Center has extensive expertise, seed cleaning equipment, seed storage facilities and ample land base to develop new seed mixes (founder plots are typically 100 - 1000 square feet, while production plots may encompass 1 - 20 acres). In recent years, the Center has worked with Pine Barrens ecotypes of native species such as Bearberry, Little Bluestem and Panic Grass. Recently, the Center has become interested in developing several species of native, cool season grasses that would be appropriate for Pine Barrens roadsides. However, personnel and budget constraints limit their development capacity to several species at any given time and the Center must be responsive to regional projects from Massachusetts to North Carolina.

Potential State involvement could include resources (i.e., expert personnel, land base) of the Forest Resource Education Center in Jackson or existing farmland located in state parks, forests and wildlife

management areas within the Pine Barrens. Non-profit land trusts may also consider allowing use of their existing farmland for testing or production purposes. Because of federal and state government spending constraints, private fundraising efforts may be necessary to leverage the full potential of private growers and government agencies to jump-start seed production of native Pine Barrens plants. The participation by government or non-profit entities may also assist potential private growers by cushioning potentially uneven or relatively light demand for native seed mixes specific to the New Jersey Pine Barrens.

As an example of current efforts, the Pinelands Preservation Alliance plans to establish demonstration plots at the New Jersey Conservation Foundation's Franklin Parker Preserve to test establishment rates of several species and there is some area to establish founder or small production plots at the preserve (Emile DeVito, personal communication). Two private growers, Clemenson Farms Native Plant Nursery (Estell Manor) and Rare Find Nursery (Jackson) are contract growing or experimenting with ecotypes of native species, but these are small-scale preliminary efforts that require additional investment by numerous entities before Pine Barrens seed mixes can become readily available.

There is considerable need to conduct research to identify candidate species and develop seed mixes. Research should include seed collection locations/ripening time, seed extraction techniques, assessment of germination rates, seed production rates and seed application requirements (quantity and application type - drilling or surface sow). Generally, moving a new species from initial seed collection through generating enough seed for production growers requires 5-10 years (Chris Miller, personal communication).

The best candidate species would produce large amounts seed, be amenable to easy harvest and seed cleaning, have high germination rates and be adapted to roadside conditions. Ideally, seed mixes containing annual and perennial species including native grasses (cool and warm season) along with wildflowers to support pollinators. Effort should be made to assure species diversity with the goal of restoring native plant communities rather than solely focusing on producing vegetative ground cover. The components of any mix should be compatible (e.g., species germination times are similar or early germinating species will not inhibit later germinating species). For proposed native plantings within the operational zone, determination of mowing tolerance for species that will exceed 6 inches in height will also be necessary. Another important consideration is the maintenance of genetic diversity throughout long-term seed production, which will require careful record keeping practices that note initial native source populations and on-going seed sources to maintain production plots. Initially, soil erosion considerations may require species with rapid establishment rates, but other species will also ultimately naturally colonize roadsides to create a healthy and diverse roadside plant community.

The Pinelands Preservation Alliance has assembled a comprehensive database of Pine Barrens plants that includes references to their status as a characteristic Pine Barrens species, flowering and fruiting times, wetland indicator status, growth form, life history and habitat descriptions (South Jersey Vascular Plant Database created by Russell Juelg). This database should be utilized to assess whether a particular species should be considered a candidate for roadside seed mixes. A preliminary list of candidate species was created based upon interviews with numerous professionals with natural history and/or plant propagation experience (Table 4). See Appendix E for a more extensive list of potential roadside species compiled by Russell Juelg.

Table 4. Potential Candidate Species for Native Pine Barrens Roadside Seed Mixes

Species Grouping	Species	Notes
Grass - Annual	Six Weeks Fescue (<i>Vulpia octoflora</i>), Three-Awn Grass (<i>Aristida longispica</i> and other <i>Aristida</i> species)	
Grass - Perennial Cool Season	Blackseed Speargrass (<i>Piptochaetium avenaceum</i>), Pennsylvania Sedge (<i>Carex pennsylvanica</i>), Poverty Oat Grass (<i>Danthonia spicata</i>), Silky Wild Oat Grass (<i>Danthonia sericea</i>), Ticklegrass (<i>Agrostis hyemalis</i>)	
Grass - Perennial Warm Season (> 12 inch height)	Crinkled Hair Grass (<i>Deschampsia flexuosa</i>), Little Bluestem (<i>Schizachyrium scoparium</i>)	
Grass - Perennial Warm Season (< 12 inch height)	<i>Dichanthelium</i> species (formerly <i>Panicum</i>)	Group of short-statured panic grasses
Herbs - Annual	Rough Buttonweed (<i>Diodia teres</i>)	
Herbs - Perennial	Clasping Milkweed (<i>Asclepias amplexicaulus</i>), Wild Indigo (<i>Baptisia tinctora</i>), Maryland Goldenaster (<i>Chrysopsis mariana</i>), Trailing Tick-Trefoil (<i>Desmodium rotundifolium</i>), Hyssop-Leaved Boneset and other Bonesets (<i>Eupatorium hyssopifolium</i>), Bush Clover (<i>Lespedeza capitata</i> or <i>L. hirta</i>), Hairy Blazing Star (<i>Liatris pilosa</i>), Toothed Whitetop Aster and other asters (<i>Sericocarpus asteroides</i>), Sweet Goldenrod and other Goldenrods (<i>Solidago odora</i>)	Rough Buttonweed (above), Toothed Whitetop Aster and Clasping Milkweed are utilized by bees that also pollinate commercial blueberries and cranberries (Rachael Winfree, personal communication).
Sub-shrubs (6 - 12 inch height)	Bearberry (<i>Arctostaphylos uva-ursi</i>), Pine Barrens Heather (<i>Hudsonia ericoides</i>), Wintergreen (<i>Gaultheria procumbens</i>)	

Recommendation #6 - Native Ecotype Seed Mix Development: Partnerships will be critical toward the development of native seed mixes. The relatively long development timeline necessitates immediate action starting with initiation of seed collection, germination trials and establishment of founder plots. Non-profit or state entities should immediately begin seed collection even if seeds cannot be immediately grown (This may be feasible if an arrangement can be made with the Green Belt Nursery, who participates in the Millennium Seed Bank project and has facilities to preserve seeds for long periods of time).

Prior to initiating seed production, it will be crucial to complete a market analysis that involves determination of approximate annual quantity of seed required for Pine Barrens roadsides or other restoration efforts. These estimations are vital to developing a market viability analysis that would allow private growers to determine the economic viability of participating in seed mix development. This task would initially involve estimation of impacted roadside acreage, but would also require estimating seed production rates and seed application rates. As an example, Coastal Panic Grass can produce 150 pounds of seed per acre annually and seed application rates range from 5-10 pounds per acre (therefore one planted acre may produce enough to seed for 15-30 acres). Cool season native grasses produce significantly less seed per acre and require twice the seeding rate and will therefore require significantly larger production areas (Chris Miller, personal communication).

The New Jersey Pinelands Commission should provide signals to public agencies and private growers that local ecotypes of native species will ultimately be required for restoration activities. This would stimulate required research and notify growers of anticipated economic benefits from producing native seed mixes.

The development of native ecotype seed mixes should include creation of a certification process. Iowa and other states have developed a seed certification processes for the production of local ecotypes (AOSCA 2009, ICIA 2009). Locally, the Green Belt Nursery (part of New York City Parks Department) is currently in the process of developing protocols for restoration of the Fresh Kills landfill (Timothy Chambers, personal communication).

The NJDOT and SCD soil standards both include seed mix recommendations that include invasive species and species that increase soil fertility (nitrogen-fixing species) - See Section I, Review of Current Regulations and Management Practices. Although there are some native species that fix nitrogen, seed mixes should avoid planting densities that would lead to excessive amounts of nitrogen-fixing plants because high soil nitrogen shifts the competitive balance to non-native plants. Seed mixes should not include any non-native plants that fix nitrogen or species that are considered invasive.

Mowing and Maintenance Regimes

Current mowing practices are detrimental to the health of native Pine Barrens roadside plant communities. Frequent mowing, mowing large distances from the edge of traveled lane edges, and low mowing heights are key practices that should be stopped. Section I of this report defined roadside zones (i.e., operational, clear, transitional and undisturbed zones) that will be referred to in this section. Refinement of roadside zone distance definitions and other mowing recommendations are provided below. Examples of current and past roadside management practices are provided in Section II.

Operational Zone - This zone is defined as an 8 foot distance from the edge of the traveled roadway. This zone includes the paved, gravel or vegetated road shoulder beyond the typical road area utilized by vehicles. The purpose of this zone is to provide safe emergency vehicle pull-off areas and allow road maintenance activities including maintenance of drainage swales and access to utilities. In limited cases, this zone may have to be wider than 8 feet to allow required maintenance activities.

Recommendation #7 - Operational Zone Mowing and Maintenance Regime: The operational zone should be mowed as necessary to maintain its practical functions. Because typical roadside mowers have 5-6 feet cutting width and paved/gravel portions of road shoulders may be 2-3 feet wide, it is expected that one pass will be required during each mowing event. Vegetation heights must be maintained below 10 inches at all times to prevent contact with the bottom of vehicles, which may cause ignition of the vegetation under certain conditions. Vegetation in these areas is typically non-native cool season grasses that can withstand repeated growing season mowing. However, maintaining a mowing height greater than 6 inches can allow the establishment and maintenance of a suite of native Pine Barrens species (numerous short grasses and sub-shrubs - See Appendix C, Photographs 5, 7, 18, 19, 24 and 31). Future development of native, cool season grasses may provide suitable substitutes for non-native grasses (see above). In general, the presence of nutrient rich fill material necessitates more frequent mowing requirements (up to 3 - 4 times per year) than would be required of native plants growing on unaltered native soils. Fertilizer or other soil amendments should not be utilized to avoid impacts on native plants growing in any zone. There should be no mowing in areas of any zone that are currently sparsely vegetated. This will reduce mower-generated soil erosion.

There are two recommended special exceptions to regular mowing within the operational zone. The first involves the presence of rare plant species and the second involves narrow road shoulders. Regular mowing has eliminated numerous roadside rare plant populations. Sites with rare plants require the mowing regime described under the clear zone below (i.e., annual dormant season mowing only). Areas requiring this special exception are relatively small compared to the entire roadway length (e.g., less than 5,000 square feet). These areas should be marked with signage to facilitate communications with

roadside managers and avoid untimely mowing that would degrade or eliminate rare plant populations. Signage should be placed on either side of the sensitive areas and include language that specifies acceptable mowing dates (i.e., after November 30th and before March 30th).

Many smaller roadways (e.g., county and municipal) have narrow vegetated road shoulders less than 8 feet wide. Undisturbed zones are close to the traveled roadway and do not allow typical zonation. In these cases, there is no provision for safe vehicle pull-off areas. These narrow road shoulders should be mowed as described under the clear zone recommendations below unless regular mowing is required for maintenance functions described for the operational zone. Where emergency vehicular access is desired in the future, the removal of trees and shrubs will be required and maintenance regimes should follow recommendations in this section.

Clear Zone - Clear zone distances vary based on safety considerations and is kept free of all woody plants or other large obstructions that present a hazard to errant vehicles. The installation of guide rail is required when sufficient clear zone distances cannot be obtained due to unmovable obstructions. Intersection site lines may be considered an extension of the clear zone concept whereby vegetation height must be maintained below 30 inches at all times to allow visibility (David Earl, personal communication).

Recommendation #8 - Clear Zone Mowing and Maintenance Regime: The clear zone should be mowed on an annual basis during the dormant season. Whenever possible, all mowing should occur in March (ca. late winter / early spring) to allow the full, uninterrupted life cycle of plants including growth, flowering, seed production, seed dispersal and seedling establishment. Annual mowing will remove the tops of any woody plants that may have sprouted during the previous year and will weaken root systems to stunt future growth. Mowing height should be 6 inches above the ground to avoid damage to a suite of short-statured woody native species (e.g., Bearberry, Wintergreen, and Pine Barrens Heather which are excellent ground cover for roadsides - See Table 4). Fertilizer or other soil amendments should not be utilized to avoid impacts on native plants growing in any zone. Areas of any zone that are currently sparsely vegetated should not be mowed. This will reduce mower-generated soil erosion.

Practical considerations of a condensed mowing schedule may necessitate a wider mowing window (i.e., after November 30th and before March 30th) because personnel may not be able to perform all necessary mowing during a one month period. Currently, many annual mowing efforts are conducted from September to mid-November. Even though personnel time constraints may not allow all mowing to occur in March, effort should be taken to delay mowing into late autumn to allow late-flowering species (e.g., Pine Barrens Gentian, Asters, Bonesets, and Goldenrods) to produce and begin dispersing their seeds. The flowering and fruiting of Pine Barrens plants indicates a number of potential roadside species that begin flowering as early as April and flower/produce fruit through October (Boyd 1991 and South Jersey Vascular Plant Database). It is critical that mowing regimes preserve both early blooming and late fruiting plants.

Exclusive use of dormant season mowing may not be adequate to completely eliminate recalcitrant woody species, especially where establishment is already underway (e.g., pitch pine sprouts - See Appendix C, Photo 6). In these cases, it may become necessary to mechanically or chemically remove woody species (See guidelines in Section IV). Prescribed burning during the dormant season should also be considered a useful option to reduce woody plant establishment. However, low intensity prescribed burning should not be utilized on an annual basis and care should be given to understand the impacts of repeated burns on reducing desirable native species and/or increasing invasive species (e.g., Chinese bushclover). Annual, low intensity prescribed burning has documented negative impacts on soil microfauna and related natural

food chains (Boyd and Marucci 1979). Potential for increased fire hazard risk from particular types of roadside vegetation is described below under Special Considerations.

Transitional Zone - The “alcove” and wide median areas along major interstate and state roadways may be considered an extension of the transitional zone concept and are common on the Garden State Parkway and Atlantic City Expressway. Alcoves were designed to provide visual interest for drivers and typically exceed clear zone distance requirements. They are kept clear of woody vegetation and can be utilized to foster healthy, attractive native Pine Barrens plant communities.

Recommendation #9 - Transitional Zone Mowing and Maintenance Regime: The transitional zone should be managed in the same manner as the clear zone recommendations detailed above. These areas have potential to greatly expand early successional habitat that is becoming increasingly uncommon throughout the Pine Barrens, while simultaneously filling their original intended purpose of creating visual interest for drivers.

Undisturbed Zone – This zone begins at the tree line of adjacent forest cover and its distance from the roadside is defined by clear zone requirements (or modified by the inclusion of alcoves – see above). This zone typically extends to the edge of the roadside right-of-way.

Recommendation #10 – Undisturbed Zone Mowing and Maintenance Regime: Mowing is not recommended in this zone. However, some major roadways may not currently provide required clear zone distances (original clear zones may have become obsolete due to increased speed limits and traffic volumes), which will necessitate future removal of woody plants within the right-of-way. Recommended mowing regimes detailed above should be utilized for any newly enlarged clear zones.

Invasive Species Management

Section IV provides background information on invasive species in the Pine Barrens. In general, roadsides are at increased risk to infestation relative to core areas of the Pine Barrens. This is due to modified soils, regular disturbance, direct seeding of particular species, and unintentional spread through mowing equipment.

Recommendation #11 – Invasive Species Management: A summary of invasive plant stewardship recommendations is provided in Table 6 (Section IV). The primary tenets involve prevention, early detection and rapid response to newly forming infestations, and thoughtful control and restoration techniques. In all cases, the use of herbicides should be restricted or minimized to avoid impacts to non-target species. Although mechanical control (e.g., hand pulling) is more labor intensive than chemical control methods, it is recommended that cooperative efforts of all stakeholders be organized to control most emerging infestations. This will require an organized pool of volunteers and staff members from a variety of organizations.

Pilot Restoration Projects for Impacted Roadsides

The restoration of impacted roadsides is considered beyond the scope of this report. However, roadsides that have received nutrient-enriched fill materials should not be expected to recover solely with changes to mowing regimes. Instead, invasive species (and other species not native to the Pine Barrens) will continue to dominate without remedial efforts.

Recommendation #12 - Restoration Demonstration Project and Research: The Pinelands Preservation Alliance and the NJDOT have begun discussions regarding the potential restoration of two

areas along State Highway 70 (see Section II). Successful restoration will require removal of enriched fill materials and replacement with native fill to maintain the existing grade with the roadway. Decisions regarding seeding with native species should follow the recommendations outlined above based upon erosion control considerations.

The long-term goal of restoring all areas that have received non-native fill materials should be guided by careful mapping in highest priority areas, careful determination of restoration strategies, and funding opportunities. Mapping should be guided by knowledge of local naturalists (searching areas previously known to have healthy native plant communities) and careful observation of existing vegetative cover (i.e., non-native species cover will likely indicate areas of non-native fill materials).

Special Considerations

There are several additional considerations regarding the establishment of management regimes that favor native Pine Barrens roadside communities. Factors include fire management, site line safety considerations, deer-vehicle collisions, impacts of road salting, and aesthetics / public opinion.

Fire management is considered an important component regarding mowing regimes on roadsides by the New Jersey Forest Fire Service (NJFFS). The presence of dense stands of tall, native warm season grasses could reduce the effectiveness of roads acting as firebreaks. High fuel loads of cured grasses may increase fire risk from discarded cigarettes or blown catalytic converters. Additionally, it is feared that high fuel loads along roadsides may attract arsonists in the brief autumn and traditional spring fire seasons. The mowing of tall dense stands of grass in autumn (prior to curing - i.e., drying out) is recommended by the NJFFS. Warm season grasses and fallen oak leaves begin to cure in October-November, but wildfire risk is generally highest from March - May (Horace Some, personal communication). Additionally, the presence of dense, tall grasses is not the desired goal for healthy native Pine Barrens roadside plant communities and seed mixes should not contain significant amounts of tall warm season grasses such as Indian Grass and Switch Grass. Open communication between roadside managers and the NJ Forest Fire Service must be maintained to reduce any potential conflicts between the species composition of roadside vegetation, timing of mowing, and fire risk.

Site line safety considerations must be considered for roadside management regimes that foster native plant communities. There are many herbaceous plants that will not grow taller than 30 centimeters (ca. 1 foot) and these species must be utilized whenever site lines must be maintained. As native species are evaluated for roadside seeding, a special 'site-line' seed mix should be developed.

The Deer Vehicle Crash Information Clearinghouse (www.deercrash.com) provides reviews regarding the impacts of roadside vegetation and maintenance regimes on the frequency of collisions (DVCIC 2009a, DVCIC 2009b). These reviews conclude that there is no current literature suggesting a strong correlation between roadside maintenance regimes or vegetation types and frequency of deer-vehicle collisions. DVCIC 2009a suggests that road configurations related to reducing driver speeds (e.g., narrow lanes, road curvature, etc.) are more significant in reducing deer-vehicle collisions and also suggests herd reduction as an important tool. In general, white-tailed deer are considered "edge species" that are likely to forage on herbaceous vegetation found on roadsides (Martin et al. 1951). These potential foraging areas are necessitated by safety through the creation of clear zones. This dilemma may be resolved by fostering native Pine Barrens plant communities instead of non-native cool season grasses. Cool-season grasses become green and begin growing early in the spring and are utilized by deer when other foods (e.g., native warm-season grasses, native wildflowers) are not available. Many native Pine Barrens species are resistant to deer browse and make less attractive food sources. Additions of fertilizer or non-native, nutrient-rich fill materials also lead to more lush deer browse, as well as a high number of non-native

forbs that may attract deer to roadsides, and these additions should be avoided to potentially minimize deer-vehicle collisions. Overall, taller herbaceous roadside vegetation is not expected to pose a significant visibility risk leading to increased deer-vehicle collisions because the height of deer exceeds the height of any potential herbaceous vegetation.

The necessary salting of roadways during winter months may alter roadside vegetation, but is not suspected to cause significant harm to native roadside plant communities. The two common salts, calcium chloride and sodium chloride, both add chloride ions that most plants cannot tolerate in excess. This can facilitate dominance by weedy/tolerant species such as crabgrass along the immediate paved road edge (i.e., 1-2 feet). Additionally, calcium addition from road salt may increase soil pH levels along the immediate road edge, which may also facilitate non-native species. The existence of healthy plant communities in areas where non-native fills are absent suggests that road salting may not pose a significant risk.

Roadside managers that have minimized mowing are occasionally subject to complaints from some members of the general public that perceive non-turf roadsides as a sign of neglect. Public outreach in the form of road signage and website messages will be required to mitigate public concerns. Messaging should include concepts of restoring natural ecosystems and reducing taxpayer costs through reduced mowing. Fear of encountering ticks or chiggers during emergency care pull-offs has also been cited as a public concern. However, this concern is mitigated by the recommended provision of 8 feet of regularly mowed area within the operational zone. Reduced deer use from elimination of non-native cool season grasses should also reduce populations of ticks and chiggers (see above). The benefits of encouraging native plant communities (e.g., reduced maintenance costs, improved biodiversity) should outweigh minor complaints from a limited number of people. Additionally, the number of citizens unhappy with natural vegetation on roadsides may actually be outweighed by the number that enthusiastically welcomes such views. Appendix F provides sample language utilized by NJDOT to address aesthetic complaints posed by the general public in response to its GEMZ program. This language has provided an effective communication tool for NJDOT (Scott Oplinger, personal communication).



Native asters provide attractive roadside scenery.

Section IV. Invasive Plant Management

Invasive Plants in the Pine Barrens

The uniqueness of Pine Barrens soils has largely protected the region from serious infestations of invasive plants that are rampant in other parts of New Jersey and across much of the world. Characteristics such as low nutrient content, low soil pH and low water holding capacity, alone or in combination, makes the Pine Barrens inhospitable to most invasive plants. However, roadside areas that have received or continue to receive inputs such as non-Pine Barrens fill material, lime and/or fertilizer are susceptible to a host of invasive plants (and native plants that are typically found only outside of the Pine Barrens) that do not tolerate harsher growing conditions. The use of basic or relatively basic construction materials (underlayment, erosion control, drainage structures, etc.) could increase soil pH and shift the competitive balance from native species to invasive species. In addition to changes in soils, roadsides are subject to infestation through introduction of seeds from intentional nearby plantings of invasive species and unintentional spreading of seeds from mowers and other roadside maintenance equipment.

The most threatening invasive species that are found within the Pine Barrens include Chinese Bushclover (*Lespedeza cuneata* -- a.k.a. Sericea Lespedeza), African Lovegrass (*Eragrostis curvula*, a.k.a. weeping lovegrass) and Common Reed (*Phragmites australis*). Chinese Silvergrass (*Miscanthus sinensis*) is an emerging invasive species in the Pine Barrens and should be eradicated immediately upon detection. A serious invasive pest commonly found outside of the Pine Barrens, Japanese Stiltgrass (*Microstegium vimineum*), is also beginning to establish emerging populations along edges of wetlands, especially along roadsides and other disturbed habitats. Occurrences of stiltgrass should also be eradicated immediately upon detection. Other invasive species that are widespread in New Jersey, but relatively uncommon in the Pine Barrens include Asiatic Bittersweet, Japanese Honeysuckle, Japanese Wisteria, Multiflora Rose and Reed Canary Grass. These species should also be treated as encountered on roadsides. Treatment recommendations for all species listed in this paragraph are included as Appendix I.

Other relatively common non-native roadside species include Sheep Sorrel (*Rumex acetosella*), Mimosa (*Albizia julibrissin*), Common Yarrow (*Achillea millefolium*), White Sweet Clover (*Melilotus alba*), Queen Anne's Lace (*Daucus carota*), several Hawkweed species (*Hieracium* spp.), Cypress Spurge (*Euphorbia cyparissias*), Spotted Knapweed (*Centaurea stoebe*) and Canada Thistle (*Cirsium vulgare*). In general, this pool of non-native species (and others), thrive along roadsides that have significant and repeated human disturbances and/or compaction from regular vehicular traffic or thrive in areas where non-native fill materials are present. At present, these species do not appear to pose a significant risk, but many invasive species have a significant lag time before they become truly invasive (i.e., invasive species may be present in low numbers for decades before forming significant infestations across a large area).

Overview of Invasive Plant Management

The underlying philosophical context for invasive species management is the obligation to counteract negative human impacts on natural systems, which is often referred to as “stewardship”. The guiding principal of stewardship is fostering health of native plant communities that support our flora and fauna, which is indirectly accomplished through the management of invasive species. Management of invasive species is generally achieved through targeted control measures that minimize, but do not eradicate, particular invasive species. Eradication within pre-defined boundaries should only be considered a valid goal when populations are relatively small and the threat of continued spread is significant. In all cases, invasive species management should aim to stimulate native plant communities to resist infestation and minimize the use of pesticides and any other intervention. However, human impacts on natural systems

are diverse and perpetual, which will necessitate continuing stewardship of natural resources within the context of a human-dominated environment in order to support healthy native plant communities.

There are two general approaches related to invasive species management. These involve a species-based approach or a site-based approach. A species-based approach should be employed when an invasive or potentially invasive species can either be eradicated or contained to reduce impacts across the entire Pine Barrens or within smaller specific areas. This approach is warranted for invasive species that are emerging regionally (e.g., Chinese Silvergrass) and for widespread invasive species with limited distribution in the Pine Barrens (e.g., Japanese Stiltgrass).

A site-based approach should be employed when conservation targets within a defined area are threatened by invasive species that are widespread throughout the Pine Barrens (e.g., Chinese Bushclover). This approach involves holistic strategies to promote native plant species assemblages that reduce overall invasive species cover through direct competition for light and soil nutrients. The ultimate goal is to foster native plant communities that resist future infestations.

Control Methods

The management of invasive species can be classified into five broad methods referred to as mechanical, chemical, biological, cultural and ecological control (Table 5). Each control method utilizes multiple techniques and control methods may be used alone or in combination depending upon the resource to be protected and practical constraints (Appendix G - Overview of Invasive Plant Control Methods).

For Pine Barrens roadsides, the single largest factor facilitating invasive species is the use of non-native, nutrient enriched soils and soil amendments. The majority of non-native species in the Pine Barrens cannot compete with native species on unaltered soils, but see above for a small number of invasive species that are problematic within the Pine Barrens.

Chemical control is the most commonly utilized method. It can be used in concert with mechanical control (e.g., cutting plants and applying herbicide to the stump) or alone (e.g., basal bark applications). However, herbicide use to control invasive species should be judicious to avoid impacts to non-target plants and animals. In all cases, herbicide use should involve the most benign formulations and application methods that effectively control the invasive species being treated. Appendix H - Summary of Herbicide Characteristics provides a summary of eleven herbicides that includes target species classes, persistence in the environment, toxicity to humans and wildlife and estimated material cost. Each herbicide was placed into a recommended use grouping that considers all of the above mentioned factors.

In all cases, the use of herbicides should be restricted or minimized to avoid impacts to non-target species. Mechanical control should be utilized as the primary control method (especially for newly emerging populations of invasive species) to reduce potential non-target impacts from herbicides. Methods involve physical removal or cutting of invasive species. Although mechanical control is more labor intensive than chemical control methods, it is recommended that cooperative efforts of all stakeholders be organized to control most emerging infestations. This will require an organized pool of volunteers and staff members from a variety of organizations.

Table 5. Description of Invasive Plant Control Methods

Control Method	Description	Pros	Cons	Notes
Biological	Introduction of a biocontrol agent (e.g., insect, pathogen) from the invasive species' native range	Dramatic reduction in abundance with minimal costs; minimal accessibility issues	Limited number of invasive species have agents; potential for unintended consequences if the biocontrol agent 'switches' to non-target species	Requires extensive time and effort to provide effective host-specific agents; Numerous federal regulations provide significantly reduced risk of impacts to non-targets species
Mechanical	Physical removal of all or portions of an invasive species	No requirement for specialized training; can be performed by volunteers	Very labor intensive; may require specialized equipment; site accessibility issues, impractical for large infestations; re-sprouting or further invasive species dissemination may occur	Common techniques include mowing, cutting, pulling and girdling
Chemical	Application of herbicide to all or portions of a plant	Most effective and efficient method in most cases; staff can be assisted by volunteers	Labor intensive; site accessibility issues; requires specialized training/license and equipment; may require repeated applications for more difficult species	Common applications include foliar, cut stump, basal bark and injection; Mechanical and chemical controls may be combined for cut stump and hack-and-squirt methods
Cultural	Removal of invasive species through broad land use activities	Very cost effective	Does not apply well to forest habitats	Primarily applies to agricultural or horticultural systems, but may apply to the maintenance of early successional natural systems including grasslands; Techniques include prescribed fire and prescribed grazing
Ecological	Allowing natural ecological processes (e.g., competition for light and soil resources, predator-prey relationships, etc.) to reduce invasive species over time	Very cost effective; utilizes natural processes	May not occur in many systems due to persistent or continuing human impacts (e.g., overabundant deer, continual physical disturbance, habitat fragmentation, etc.)	Primarily applies to forest systems; As an example, very strong anecdotal evidence suggests that overabundant deer facilitate infestations by Japanese stiltgrass and other invasive species in forests

Roadside Invasive Plant Stewardship Recommendations

A primary goal of stewardship activities is the maintenance or enhancement of healthy plant communities that resist future infestation by invasive species. A comprehensive effort to reduce the impacts of invasive species should include elements of prevention, control and restoration. An outline of recommended activities is provided in Table 6.

Table 6. Summary of Roadside Invasive Plant Stewardship Recommendations

Stewardship Element	Stewardship Activity	Stewardship Goal	Note
Prevention	Follow suggested BMP guidelines (See Section III)	Promote healthy native Pine Barrens plant communities	The exclusion of non-native fill material and soil amendments is the most important prevention strategy.
Prevention	Regular cleaning of roadside maintenance equipment	Reduce unintentional spread of invasive species	This is particularly important when mowing is performed at infested sites
Control	Map areas prone to invasive species	Prioritize mapping activities.	Assessment of infestation susceptibility by mapping areas suspected of having non-native fill, pH alterations and/or higher human disturbance frequency & intensity.
Control	Map roadsides to determine distribution and intensity of infestations	Formulate a clear operational plan that prioritizes control work based on existing infestations	This could serve as a proxy for mapping soil additions and alterations mentioned above.
Control	Regularly perform Early Detection & Rapid Response to newly forming infestations	Prevent small infestations from becoming too large to control.	This is the most efficient and effective control method to prevent the growth of large infestations.
Control	Develop treatment control options including the use of herbicides or mechanical treatments	Reduce impacts and potential spread of invasive species	See Appendix I
Restoration	Whenever practicable, remove non-native fill material and restore native plant communities	Reduce site susceptibility to prevent future infestations	See Section III

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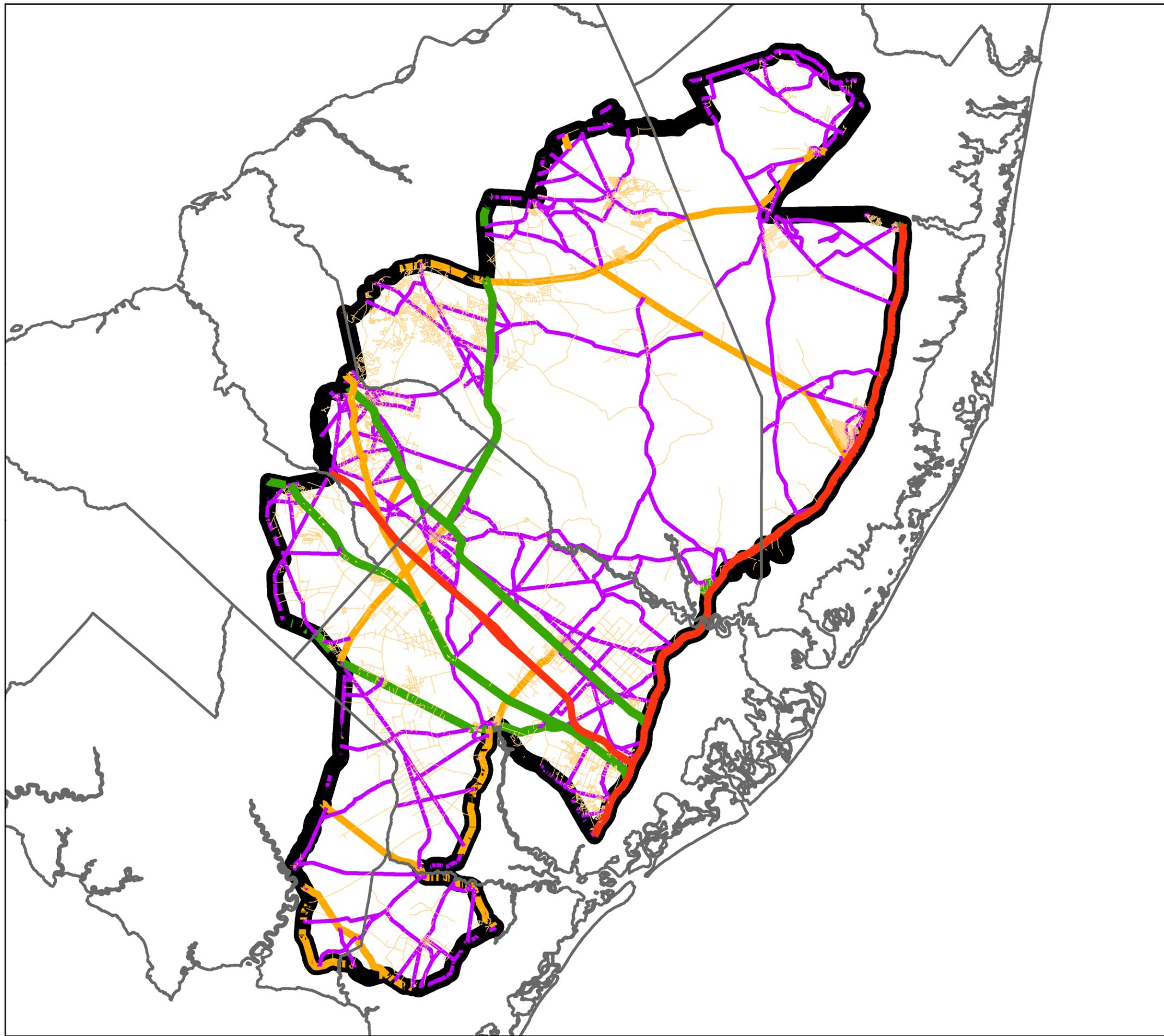


Figure 1.
Pine Barrens Road Network
Best Management Practices
for Pine Barrens Roadside
Plant Communities

Map prepared by Michael Van Clef, Ph.D.
Ecological Solutions, LLC

Legend

-  County Boundary
-  Pinelands Boundary
- Road Type**
-  US Highway
-  State Highway
-  State Toll Road
-  County Routes
-  Local Road
-  Interchanges

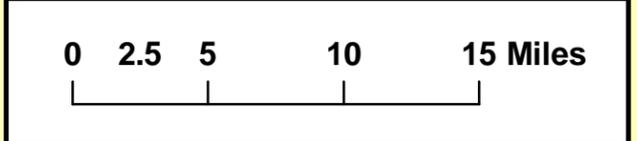


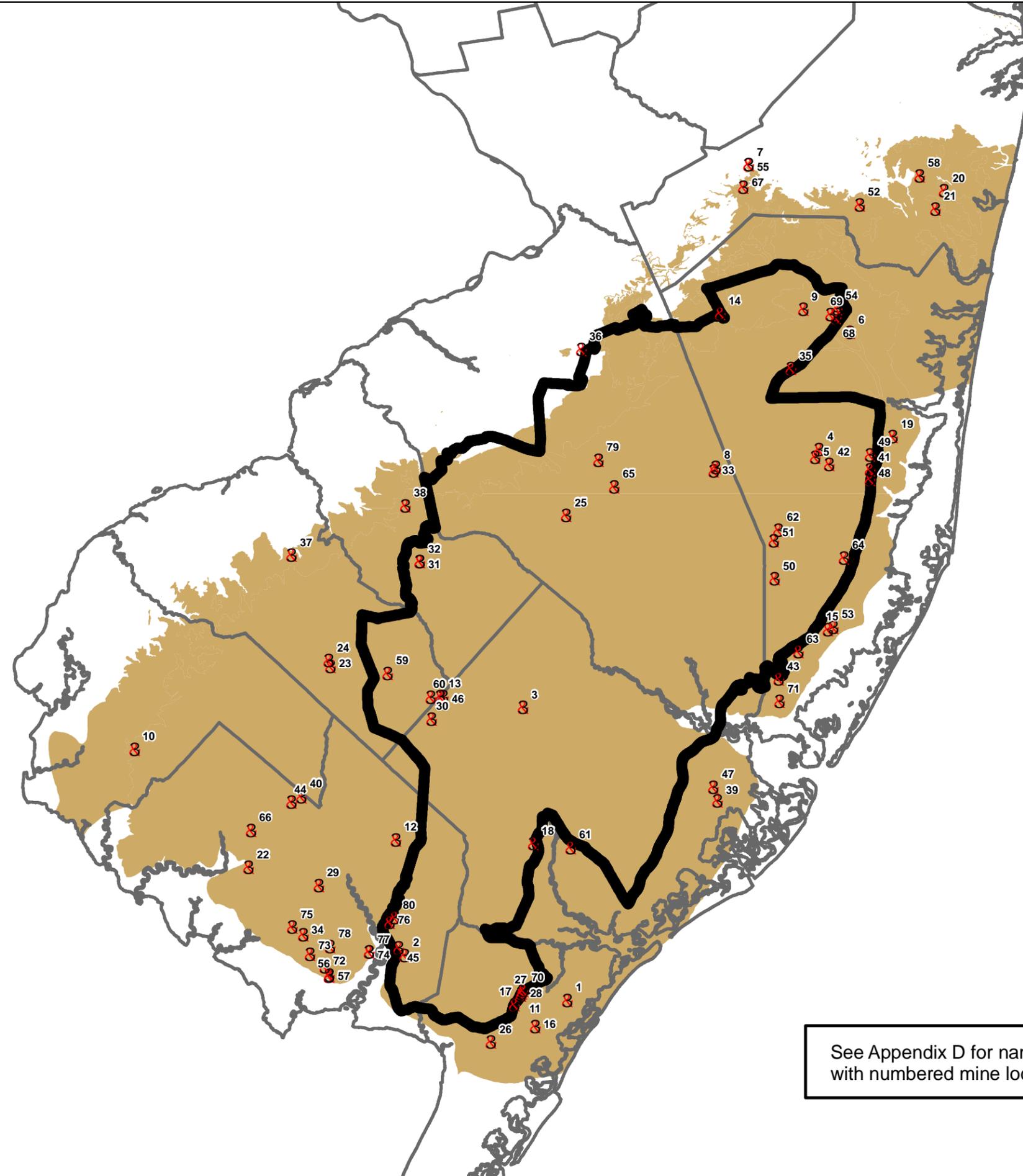
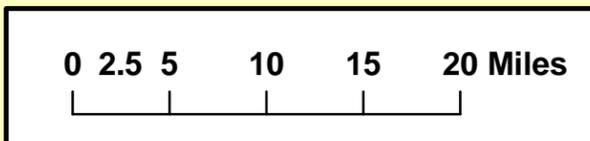
Figure 2.
Locations of Pine Barrens
Mining Operations

Best Management Practices
for Pine Barrens Roadside
Plant Communities

Map prepared by Michael Van Clef, Ph.D.
 Ecological Solutions, LLC

Legend

-  County Boundary
-  Pinelands Boundary
-  Mines
-  Cohansey/Kirkwood Formations



See Appendix D for names associated with numbered mine locations.

**Appendix A. List of Interviewed Professionals
Best Management Practices for Pine Barrens Roadside Plant Communities**

Name	Organization
Arsenault, Joe	Private Consultant
Asadpour, Jo Ann	New Jersey Department of Transportation
Austin, Jason	Rare Find Nursery
Bethmann, Chris	Brendan Byrne State Forest
Bien, Walter	Drexel University
Brubzichesi, Ralph	New Jersey Turnpike Authority
Canace, Robert	Formerly NJDEP - Geological Survey
Caruso, George	New Jersey Department of Transportation
Chambers, Tim	Green Belt Native Plant Center
Coritz, Cynthia	Bass River State Forest
DeFelice, Gary	New Jersey Turnpike Authority
DeVito, Emile	New Jersey Conservation Foundation
Earl, David	New Jersey Department of Transportation
Gordon, Ted	Private Consultant
Horner, Chuck	New Jersey Pinelands Commission
Juelg, Russell	Pinelands Preservation Alliance
Lewandowski, Rick	Mt. Cuba Center, Inc.
Miller, Chris	USDA-NRCS Cape May Plant Materials Center
Minch, Frank	State Soil Conservation Committee
Mortellite, Carl	Atlantic County Department of Public Works, Division of Roads and Bridges
Murphy, Rebecca	County DOT - Ocean
Nooney, Erin	Burlington County Highway Department
Oplinger, Scott	New Jersey Department of Transportation
Porutski, Ray	NJDEP - Division of Fish & Wildlife, Central Region Office
Scelsi, Paula	New Jersey Department of Transportation
Showler, John	State Soil Conservation Committee
Somes, Horace	NJ Forest Fire Service
Widjeskog, Lee	NJDEP - Division of Fish & Wildlife, Southern Region Office

Appendix B. Pine Barrens Municipalities
Best Management Practices for Pine Barrens Roadside Plant Communities

County	Municipality	Total Area (acres)	Pine Barrens Area (acres)
ATLANTIC	Buena Borough	4865	2298
ATLANTIC	Buena Vista Township	26507	23850
ATLANTIC	Corbin City	5107	55
ATLANTIC	Egg Harbor Township	7281	7281
ATLANTIC	Egg Harbor City	43729	18117
ATLANTIC	Estell Manor City	34610	22248
ATLANTIC	Folsom Borough	5410	5410
ATLANTIC	Galloway Township	57456	26408
ATLANTIC	Hamilton Township	72179	70237
ATLANTIC	Hammonton Township	26509	26509
ATLANTIC	Mullica Township	36220	36220
ATLANTIC	Port Republic City	5015	1638
ATLANTIC	Weymouth Township	7817	6550
BURLINGTON	Bass River Township	49290	43169
BURLINGTON	Evesham Township	19001	10466
BURLINGTON	Medford Township	799	799
BURLINGTON	Medford Lakes Borough	25532	19772
BURLINGTON	New Hanover Township	14360	13042
BURLINGTON	North Hanover Township	10946	473
BURLINGTON	Pemberton Borough	395	2
BURLINGTON	Pemberton Township	40296	36640
BURLINGTON	Shamong Township	28910	28910
BURLINGTON	Southampton Township	28028	20362
BURLINGTON	Springfield Township	18726	217
BURLINGTON	Tabernacle Township	31718	31718
BURLINGTON	Washington Township	65067	65067
BURLINGTON	Woodland Township	61174	61174
BURLINGTON	Wrightstown Borough	1328	957
CAMDEN	Berlin Borough	2332	238
CAMDEN	Berlin Township	2090	334
CAMDEN	Chesilhurst Borough	1098	1098
CAMDEN	Voorhees Township	7430	0
CAMDEN	Waterford Township	23147	23147
CAMDEN	Winslow Township	37284	30097
CAPE MAY	Dennis Township	39761	15661
CAPE MAY	Upper Township	40749	14276
CAPE MAY	Woodbine Borough	5111	4870
CUMBERLAND	Maurice River Township	59856	42118
CUMBERLAND	Vineland City	44154	3239
GLOUCESTER	Franklin Township	36138	12866
GLOUCESTER	Monroe Township	29996	20715
OCEAN	Barnegat Township	21890	14144
OCEAN	Beachwood Borough	1783	496
OCEAN	Berkeley Township	27590	10445
OCEAN	Dover Township	26667	13
OCEAN	Eagleswood Township	10477	2472
OCEAN	Jackson Township	64433	30308
OCEAN	Lacey Township	53984	42592
OCEAN	Lakehurst Borough	644	562
OCEAN	Little Egg Harbor Township	31313	11469
OCEAN	Manchester Township	52921	38603
OCEAN	Ocean Township	13833	8247
OCEAN	Plumsted Township	25648	13745
OCEAN	South Toms River Borough	766	371
OCEAN	Stafford Township	30577	14023

Appendix C. Photographs of Selected Road Stretches
Best Management Practices for Pine Barrens Roadside Plant Communities



Photo #1
Atlantic City Expressway: Representative roadside alcove that is mowed regularly during the growing season.



Photo #2
Atlantic City Expressway: A crust of lichens and mosses growing between native wildflowers and grasses protect against soil erosion.



Photo #3
Atlantic City Expressway: Regular mowing may leave tracks that lead to soil erosion on slopes by breaking up the natural crust of lichens and mosses and inhibiting growth of native plants.

Appendix C. Photographs of Selected Road Stretches
Best Management Practices for Pine Barrens Roadside Plant Communities



Photo #4
Atlantic City Expressway: Native vegetation thriving along an infrequently mowed narrow strip at the forest edge. Annual non-growing season mowing can maintain native grasses and wildflowers without interfering with clear zone safety requirements.



Photo #5
Atlantic City Expressway: Native species of three-awn grasses are naturally short and do not require growing season mowing to maintain clear zone or intersection site line safety requirements. These species may be developed for use in native roadside seed mixes. Species of *Dichanthelium* and many other naturally low-growing native species can serve the same purpose (See Photos #7, 18, 19, 24, and 31).



Photo #6
Franklin Parker Preserve: Native plant community consisting of sparse cover of little bluestem, wildflowers, mosses and lichens. Pitch pine sprouts are maintained at low heights through mowing, but may be treated with herbicide if complete removal becomes necessary.

Appendix C. Photographs of Selected Road Stretches
Best Management Practices for Pine Barrens Roadside Plant Communities



Photo #7
Franklin Parker Preserve: Native species of *Dichantheium* (formerly *Panicum*) that is naturally very low growing (See text associated with Photo #5).



Photo #8
Ocean County Route 528: Non-native fill material was added to increase the grade for hunters parking along the roadside to gain access to Colliers Mills Wildlife Management Area.



Photo #9
Ocean County Route 528: The depth of fill added was approximately several inches, which will smother existing native plants and allow weeds to outcompete native Pine Barrens plants that cannot tolerate high nutrient levels.

Appendix C. Photographs of Selected Road Stretches
Best Management Practices for Pine Barrens Roadside Plant Communities



Photo #10
Ocean County Route 528: A tomato plant, along with numerous weedy plants emerged from the fill, which replaced a native Pine Barrens plant community (See Photo # 11).



Photo #11
Ocean County Route 528: A healthy native Pine Barrens plant community adjacent to the fill area.



Photo #12
Ocean County Route 528: In addition to smothering existing native plants and adding harmful nutrient inputs, unsightly trash was mixed with the fill.

Appendix C. Photographs of Selected Road Stretches
Best Management Practices for Pine Barrens Roadside Plant Communities



Photo #13
State Highway 70 – Site A: Recent utility work along the paved shoulder led to the suspected installation of non-native fill material and subsequent hydro-seeding of non-native cool season grasses.



Photo #14
State Highway 70 – Site A: Photo showing probable addition of non-native fill material.



Photo #15
State Highway 70 – Site A: The roadside was hydro-seeded with a non-native cool season grass mixed with a newsprint carrier containing fertilizer to facilitate establishment.

Appendix C. Photographs of Selected Road Stretches
Best Management Practices for Pine Barrens Roadside Plant Communities



Photo #16
State Highway 70 – Site A: Adjacent roadside contains a healthy native Pine Barrens plant community (hydro-seeded area seen across highway as bright green strip).



Photo #17
State Highway 70 – Site A: Close-up of adjacent roadside across highway from impacted roadside. There is evidence of vehicles pulling off the paved roadway, but soil erosion does not occur.



Photo #18
State Highway 70 – Site A: Sparse cover of native grasses and very low growing "sub-shrubs" (bearberry) along unaffected roadside.

Appendix C. Photographs of Selected Road Stretches
Best Management Practices for Pine Barrens Roadside Plant Communities



Photo #19
State Highway 70 – Site A: Other low growing “sub-shrubs” include wintergreen.



Photo #20
State Highway 70 – Site B: Approximately 10 feet along the paved roadway are mowed regularly during the growing season, but the remainder of the alcove is mowed once per year during the dormant season, which allows native Pine Barrens plants to flourish.



Photo #21
State Highway 70 – Site B: Distant view of regularly mowed roadsides with annually mowed alcoves allowing habitat for early successional Pine Barrens natives.

Appendix C. Photographs of Selected Road Stretches
Best Management Practices for Pine Barrens Roadside Plant Communities



Photo #22
State Highway 70 – Site B: Little bluestem and other native grasses and wildflowers can provide attractive roadside cover.



Photo #23
State Highway 70 – Site B: Mosses and lichens fill gaps between sparsely growing native plants to prevent soil erosion.



Photo #24
State Highway 70 – Site B: Another native “sub-shrub”, Pine Barrens Heather, forms small, low growing clumps.

Appendix C. Photographs of Selected Road Stretches
Best Management Practices for Pine Barrens Roadside Plant Communities



Photo #25
State Highway 70 – Site B: An immediately adjacent area is suspected to have non-native fill material that supports invasive species such as African lovegrass.



Photo #26
State Highway 70 – Site B: Other invasive species present included Asiatic bittersweet.



Photo #27
State Highway 70 – Site B: A New Jersey native plant, pokeweed, that typically cannot grow in the unique Pine Barrens soils is also present.

Appendix C. Photographs of Selected Road Stretches
Best Management Practices for Pine Barrens Roadside Plant Communities



Photo #28

State Highway 70 – Site C: The mowing regime for this site is the same as Site B, but moister conditions provide habitat for broom sedge (seen in foreground with cotton-like seed heads). This area provides an attractive roadside plant community, especially in autumn when cottony seed heads are perched on russet and tan stems (fall colors are just beginning to become evident in this photo).



Photo #29

State Highway 70 – Site C: As at drier sites, mosses and lichens fill gaps between plants and prevent soil erosion.



Photo #30

State Highway 70 – Site D: This area, located at a road intersection, has received non-native fill that promotes weedy species such as the invasive Canada thistle. This site is a primary candidate for restoration efforts.

Appendix C. Photographs of Selected Road Stretches
Best Management Practices for Pine Barrens Roadside Plant Communities



Photo #31
State Highway 70 – Site D: Although the majority of this site is degraded, a dense stand of low growing Pennsylvania sedge occurs along the forest edge. This species is an excellent native species to foster in areas where the maintenance of site lines are necessary.



Photo #32
State Highway 70 – Site E: This road intersection must be maintained with low growing vegetation to maintain site lines. It is very likely that non-native fill materials were utilized to help maintain the non-native grasses. This site is maintained through regular growing season mowing and consists of cool season grasses with typical lawn weeds such as English plantain (See Photo #33). This site is a primary candidate for restoration efforts.



Photo #33
State Highway 70 – Site E: Typical lawn weeds (e.g., English plantain) occur throughout the regularly mowed portions of the site.

Appendix C. Photographs of Selected Road Stretches
Best Management Practices for Pine Barrens Roadside Plant Communities



Photo #34
State Highway 70 – Site E: Non-native fill has allowed the establishment of Japanese stiltgrass, which is a very aggressive invasive species.



Photo #35
State Highway 70 – Site E: In areas immediately adjacent to the degraded site, native ground pines flourish. These plants are ancient relatives to species that dominated forests during the age of dinosaurs.

Appendix D. Pine Barrens Mining Operations

Best Management Practices for Pine Barrens Roadside Plant Communities

Source: NJDEP (2009)

Reference Number ¹	Name	Mine Location			Products
		County	Municipality	Street Address	
1	Action Supply	CAPE MAY	UPPER TWP	1413 Stagecoach Road	Sand & gravel
2	Albrecht & Heun Inc.	CAPE MAY	MIDDLE TWP	Stage Coach Road	Sand & gravel
3	Arawak Paving Co., Inc.	ATLANTIC	HAMILTON TWP	2nd Road and Chestnut Ave.	Sand & gravel
4	Atlantic Gravel Inc.	OCEAN	LACEY TWP	2321 Lacey Road	Sand & gravel
5	Brick Wall Corporation	OCEAN	LACEY TWP	2215 West Lacey Road	Sand & gravel
6	Brick Wall Corporation	OCEAN	MANCHESTER TWP	2498 Route 70	Sand & gravel
7	Buck Mining and Materials, Inc.	MONMOUTH	MILLSTONE TWP	North Pinehill Road	Sand, gravel, fill dirt
8	Clayton Sand Company	BURLINGTON	WOODLAND TWP	Pasadena Road	Sand & gravel
9	Clayton Sand Company	OCEAN	JACKSON TWP	1143 Route 571	Sand & gravel
10	Continental Aggregates Corp. LLC	SALEM	QUINTON	Route 49	Sand, gravel, fill dirt
11	Daley's Pit	CAPE MAY	UPPER TWP	1701 Route 610(Dennisville-Petersburg Road)	Sand & gravel
12	Dun-Rite Sand and Gravel Co.	CUMBERLAND	VINELAND	Broad Street	Sand, gravel, fill dirt
13	Dun-Rite Sand and Gravel Co.	ATLANTIC	BUENA VISTA TWP	Dutch Mill Road (Jackson Road)	Sand & gravel
14	E.M.E. Inc.	OCEAN	PLUMSTED TWP	849 Route 539	Sand, gravel, crushed stone
15	Eagles Lake Reserve Inc.	OCEAN	EAGLESWOOD TWP	942 South Main Street (Route 9)	Sand, gravel, fill dirt
16	Earthwork Associates Inc.	CAPE MAY	DENNIS TWP	384 Woodbine - Oceanview Road	Sand, gravel, crushed stone
17	Earthwork Associates Inc.	CAPE MAY	WOODBINE BORO	CR 610 Petersburg-Dennisville Road	Sand, gravel, fill dirt
18	Estell Manor Sand And Gravel	ATLANTIC	ESTELL MANOR CITY	Maple Avenue	Sand, gravel, fill dirt
19	Fisher Sand and Gravel Inc.	OCEAN	BERKELEY TWP	342 Northern Boulevard	Sand & gravel
20	Fred McDowell, Inc	MONMOUTH	WALL TWP	Schoolhouse Road	Sand & gravel
21	Fred McDowell, Inc.	MONMOUTH	WALL TWP	Hurley Pond Road	Sand, gravel, fill dirt
22	George Griner	CUMBERLAND	FAIRFIELD TWP	570 Elmer Road	Sand, gravel, fill dirt
23	Grochowski Excavating, Inc.	GLOUCESTER	FRANKLIN TWP	Fries Mill Road	Sand, gravel, fill dirt
24	Grochowski Excavating, Inc.	GLOUCESTER	FRANKLIN TWP	Fries Mill Road	Sand, gravel, fill dirt
25	Haas Sand and Gravel	BURLINGTON	TABERNACLE TWP	Forked Neck Road	Sand, gravel, fill dirt
26	Hanson Aggregates BMC, Inc	CAPE MAY	DENNIS TWP	1714 State Highway 83	Sand, gravel, industrial sand
27	Hanson Aggregates BMC, Inc	CAPE MAY	UPPER TWP	Dennisville Petersburg Road	Sand, gravel, industrial sand
28	Hanson Aggregates BMC, Inc	CAPE MAY	UPPER TWP	Dennisville Petersburg Road	Sand, gravel, industrial sand
29	Hanson Aggregates BMC, Inc	CUMBERLAND	MILLVILLE CITY	Route 555, Dividing Creek Road	Sand, gravel, industrial sand
30	Hanson Aggregates BMC, Inc	ATLANTIC	BUENA VISTA TWP	311 Unexpected Road	Sand, gravel, industrial sand
31	Hanson Aggregates BMC, Inc	CAMDEN	WINSLOW TWP	409 New Freedom Road	Sand, gravel, industrial sand
32	Hanson Aggregates BMC, Inc	CAMDEN	WINSLOW TWP	409 New Freedom Road	Sand, gravel, industrial sand
33	Hanson Aggregates BMC, Inc	BURLINGTON	WOODLAND TWP	160 Woodmansie Road	Sand & gravel
34	Hanson Aggregates BMC, Inc.	CUMBERLAND	DOWNE TWP	191 Railroad Avenue	Industrial sand
35	Heritage Mineral	OCEAN	MANCHESTER TWP	Mile Marker 41 Route 70	
36	Herman Liedtka Inc.	BURLINGTON	SPRINGFIELD TWP	Juliestown-Arneys Mount Road	Sand, gravel, fill dirt
37	Inversand Company	GLOUCESTER	MANTUA TWP	650 Woodbury-Glassboro Road	Greensand
38	J.D.M. Materials Co.	CAMDEN	VOORHEES TWP	1236 Haddonfield-Berlin Road	Sand & gravel
39	JBT Building Company	ATLANTIC	GALLOWAY TWP	223 South New York Road	Sand, gravel, fill dirt, crushed stone
40	Koering Excavation Inc.	DEERFIELD	CUMBERLAND	Stillman Avenue	Sand & gravel
41	Lacey Holdings Ocean View	OCEAN	FORKED RIVER	2011 West Lacy Road	Sand, gravel, fill dirt
42	Lacey Natural Sand LLC	OCEAN	LACEY TWP	2006 Lacy Road	Sand & gravel

Appendix D. Pine Barrens Mining Operations
Best Management Practices for Pine Barrens Roadside Plant Communities
Source: NJDEP (2009)

Reference Number ¹	Name	Mine Location			Products
		County	Municipality	Street Address	
43	Mathis Construction Company Inc.	OCEAN	LITTLE EGG HARBOR	4th Avenue	Sand, gravel, industrial sand, fill dirt
44	Maurice Dilibetra	CUMBERLAND	DEERFIELD	437 Maxon Avenue	Sand, gravel, fill dirt
45	Mays Landing Sand and Gravel	CUMBERLAND	MAURICE RIVER TWP	State Highway 347	Sand & gravel
46	Mays Landing Sand and Gravel	ATLANTIC	BUENA VISTA TWP	Jackson and Malaga Roads	Sand & gravel
47	Ole Hanson and Sons Inc.	ATLANTIC	GALLOWAY TWP	Route 9	Sand, gravel, fill dirt
48	Parker Associates Inc. Pit # 1	OCEAN	LACEY TWP	North side of Lacy Road	Sand & gravel
49	Parker Associates Inc. Pit # 2	OCEAN	LACEY TWP	North side of Lacey Road, 4miles west of GSP	Sand & gravel
50	Phoenix Pinelands Corporation	OCEAN	LITTLE EGG HARBOR TWP	Route 539 Mile post 9	Sand & gravel
51	Pinnacle Materials, Inc.	OCEAN	BARNEGAT TWP	201 Route 539 South	Sand, gravel, fill dirt, crushed stone
52	Pinnacle Materials, Inc.	MONMOUTH	HOWELL TWP	West Farms Road	Sand & gravel
53	R.W.V. Land and Livestock	OCEAN	EAGLESWOOD TWP	942 South Main Street	Sand, fill dirt
54	Ralph Clayton and Sons	OCEAN	JACKSON TWP	Route 547	Sand & gravel
55	Raymond Preston Inc.	MONMOUTH	MILLSTONE TWP	Pine Hill Road	Sand & gravel
56	Ricci Bros. Sand Co., Inc.	CUMBERLAND	COMMERCIAL TWP.	2099 Dragston Road	Sand & gravel
57	Ricci Bros. Sand Co., Inc.	CUMBERLAND	DOWNE TWP	Dragston Road to Route 553	Sand & gravel
58	Rosano Trucking Inc.	MONMOUTH	HOWELL TWP	West Hurley Pond Road	Sand & gravel
59	Sahara Sand of Franklin	GLOUCESTER	FRANKLIN TWP	Corner of Coles and Blue Bell Road	Sand, gravel, fill dirt
60	Sahara Sand of Monroe	GLOUCESTER	MONROE TWP	Piney Hollow and Jackson Road	Sand & gravel
61	Santore Sand And Gravel Co.	ATLANTIC	HAMILTON TWP	4555 Thelma Avenue	Sand & gravel
62	Shore Sand and Gravel LLC	OCEAN	BARNEGAT TWP	560 Route 72	Sand & gravel
63	Shoreline Grading, Inc.	OCEAN	LITTLE EGG HARBOR TWP	Thomas Avenue	Sand, gravel, fill dirt
64	Shoreline Sand and Gravel LLC	OCEAN	BARNEGAT TWP	1111 West Bay Avenue	Sand, gravel, fill dirt
65	South Jersey Materials Inc.	BURLINGTON	TABERNACLE TWP	South Park Road and Sooy Place Road	Fill dirt
66	South State Inc.	CUMBERLAND	FAIRFIELD TWP	202 Reeves Road	Sand, gravel, crushed stone
67	Stavola Asphalt Co. Inc.	MONMOUTH	MILLSTONE TWP	Old Backbone Road	Sand, gravel, crushed stone
68	Stavola Sand and Gravel	OCEAN	MANCHESTER TWP	Route 547	Crushed stone
69	Stavola Sand and Gravel	OCEAN	JACKSON TWP	East side of Lakehurst-Whitesville Road Route 547	Sand & gravel
70	Tuckahoe Sand and Gravel, Inc.	CAPE MAY	UPPER TWP	Route 610 and Sharp Road	Sand & gravel
71	Tuckerton Sand and Gravel, Inc.	OCEAN	LITTLE EGG HARBOR TWP	Off Center Street	Sand & gravel
72	U.S. Silica	CUMBERLAND	DOWNE TWP	James Moore/Tom's Bridge Road	Sand, gravel, industrial sand
73	U.S. Silica	CUMBERLAND	DOWNE TWP	Narrow Lane Road	Sand, gravel, industrial sand
74	U.S. Silica	CUMBERLAND	COMMERCIAL TWP	1101 Railroad Avenue	Sand, gravel, industrial sand
75	U.S. Silica	CUMBERLAND	DOWNE TWP	Ackley Road	Sand, gravel, industrial sand
76	U.S. Silica	CUMBERLAND	MAURICE RIVER TWP	Estell Manor Road	Sand, gravel, industrial sand
77	U.S. Silica Company	CUMBERLAND	MAURICE RIVER TWP	9035 Noble Street	Sand & gravel
78	Unimin Corporation	CUMBERLAND	DOWNE TWP	Whitehead Road	Sand, gravel, industrial sand
79	Ward Sand and Materials Co.	BURLINGTON	WOODLAND TWP	223 Sooy Place Road	Sand & gravel
80	Whibco Inc.	CUMBERLAND	MAURICE RIVER TWP	377 Port Cumberland Road	Sand, gravel, industrial sand

¹ See Figure 2 for locations of each operation.

Appendix E. Pine Barrens Roadside Plant Species
Best Management Practices for Pine Barrens Roadside Plant Communities
Compiled by Russell Juelg

Common Name	Scientific Name	Whitmer Stone Notes	Habit	Duration	Wetland Indicator Status	Habitat
Thread Agalinis	Agalinis setacea (J.F. Gmel.) Raf. ~	(SPA). "Frequent throughout the Pine Barrens" -Stone.	herb	Annual	--	"Dry, sandy ground of woods and edges, fields, roadsides, sandhills" - Hough
Ticklegrass	Agrostis hyemalis (Walt.) B.S.P. `		graminoid	Perennial	FAC	dry ground
Pearly Everlasting	Anaphalis margaritacea (L.) Benth. ^	occasional; throughout	herb	Perennial		dry, open;
Broom Sedge	Andropogon virginicus L. var. virginicus `		graminoid	Perennial	FACU	dry
Plantain-pussytoes	Antennaria plantaginifolia (L.) Richards. 0^	Landisville, Palermo; N, MD, CM	herb	Perennial		dry ground, open woods
Ground-nut	Apios americana Medik. `		herb	Perennial	FACW	moist
Spreading Dogbane	Apocynum androsaemifolium L. ^		herb	Perennial	--	dry, open
Wild Sarsaparilla	Aralia nudicaulis L. ^	Rather rare in PB; N, MD, Coast	herb	Perennial	FACU	damp to dry
Bear-berry	Arctostaphylos uva-ursi (L.) Sprengel ~		sub-shrub	Perennial	NI	dry sand
Slender Three-awn	Aristida longespica Poir. var. longispica `		graminoid	Annual	--	moist or dry
Blunt-leaved Milkweed	Asclepias amplexicaulis Sm. `		herb	Perennial	--	dry fields, open woods
Butterfly-weed	Asclepias tuberosa L. ssp. tuberosa 0^		herb	Perennial	--	dry, open
Bushy Aster	Aster dumosus L. var. dumosus ~		herb	Perennial		dry or moist
Slender Aster	Aster gracilis Nutt. ~		herb	Perennial	FACU	dry, sandy
Stiff-leaved Aster	Aster linariifolius (L.) `		herb	Perennial	--	dry, open
Late Purple Aster	Aster patens Ait. var. patens `		herb	Perennial	--	dry, open
Showy Aster	Aster spectabilis Ait. ~		herb	Perennial	--	dry, sandy
Fern-leaved False Foxglove	Aureolaria pedicularia (L.) Raf. `		herb	Annual	--	dry woods
Wild Indigo	Baptisia tinctoria (L.) R. Br. ex Ait. f. `		herb	Perennial	--	dry, sandy, open

Appendix E. Pine Barrens Roadside Plant Species
Best Management Practices for Pine Barrens Roadside Plant Communities
Compiled by Russell Juelg

Common Name	Scientific Name	Whitmer Stone Notes	Habit	Duration	Wetland Indicator Status	Habitat
Dense-tuft Hair-sedge	<i>Bulbostylis capillaris</i> (L.) Kunth ex C.B. Clarke ssp. <i>capillaris</i> ^	rare, along RR; prob intr. in PB	graminoid	Annual		dry, open
Pennsylvania Sedge	<i>Carex pensylvanica</i> Lam. `		graminoid	Perennial	--	dry, open
Umbel-like Sedge	<i>Carex tonsa</i> (Fern.) Bickn. var. <i>tonsa</i> `		graminoid	Perennial	--	dry to moist; shade or sun
Maryland Golden-aster	<i>Chrysopsis mariana</i> (L.) Ell. `		herb	Perennial	UPL	dry, sandy
Gray's Sedge	<i>Cyperus grayi</i> Torr. {{{(^	common, PB & Coast	graminoid	Perennial	--	dunes, dry, sandy:
Pine Barren Sedge	<i>Cyperus retrorsus</i> Chapman var. <i>retrorsus</i> ~		graminoid	Perennial	FAC-	sandy barrens
Silky Wild Oat Grass	<i>Danthonia sericea</i> Nutt. `		graminoid	Perennial	FACU	Dry openings and woods edges.
Wild Oat Grass	<i>Danthonia spicata</i> (L.) Beauv. ex Roemer & J.A. Schultes `		graminoid	Perennial	--	Dry openings and woods edges.
Trailing Tick-trefoil	<i>Desmodium rotundifolium</i> DC. `	"Our only trailing species" -Stone.	herb	Perennial	--	dry woods, barrens
Rough Buttonweed	<i>Diodia teres</i> Walt. var. <i>teres</i> `	<i>Diodia virginiana</i> is S1, E	herb	Annual	UPL	dry
White Boneset	<i>Eupatorium album</i> L. var. <i>album</i> ~		herb	Perennial	--	dry, open woods
Hyssop-leaved Boneset	<i>Eupatorium hyssopifolium</i> L. var. <i>hyssopifolium</i> `		herb	Perennial	--	dry, open
Hairy Boneset	<i>Eupatorium rotundifolium</i> L. var. <i>ovatum</i> (Bigelow) Torr. `		herb	Perennial	FAC-	dry
Slender Bushy Goldenrod	<i>Euthamia caroliniana</i> (L.) Greene ex Porter & Britt. `	(SPA). Apparently, recent scrutiny of the complex has yielded the conclusion that <i>E. tenuifolia</i> and <i>E. microcephala</i> are conspecific with <i>E. caroliniana</i> .	herb	Perennial	FACU	Wetlands. "Open, moist to wet, sandy soils, lake shores and dunes" -FNA
Milk-pea	<i>Galactia regularis</i> (L.) B.S.P. `		herb	Perennial	--	dry, open, sandy

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Common Name	Scientific Name	Whitmer Stone Notes	Habit	Duration	Wetland Indicator Status	Habitat
Teaberry	<i>Gaultheria procumbens</i> L. `		subshrub	Perennial	FACU	dry or moist woods
Carolina Crane's-bill	<i>Geranium carolinianum</i> L. var. <i>carolinianum</i> 0^	Not common in PB, prob intr; throughout	herb	Annual		dry, barren, sandy
Sweet Everlasting	<i>Gnaphalium obtusifolium</i> L. var. <i>obtusifolium</i> `		herb	Annual/Winter-Annual	--	dry open ground
Purplish Cudweed	<i>Gnaphalium purpureum</i> L. var. <i>purpureum</i> `		herb	Annual/Biennial	UPL	sandy
Frostweed	<i>Helianthemum canadense</i> (L.) Michx. `		herb	Perennial	--	Dry, open, well drained sand.
Hairy Hawkweed	<i>Hieracium gronovii</i> L. `		herb	Perennial	UPL	dry, open
Vein-leaf Hawkweed	<i>Hieracium venosum</i> L. `		herb	Perennial	--	dry
Hudsonia	<i>Hudsonia ericoides</i> L. ~		subshrub	Perennial	--	Dry, open sand.
Orange-grass	<i>Hypericum gentianoides</i> (L.) B.S.P. `		herb	Annual	UPL	Sandy, sun-baked sand.
Yellow Stargrass	<i>Hypoxis hirsuta</i> (L.) Coville `		herb	Perennial	FAC	dry open woods
Wild Potato	<i>Ipomoea pandurata</i> (L.) G.F.W. Mey. ^	"nearly all parts of the State, but nowhere very common" -Stone.	vine	Perennial	FACU	dry
Slender Rush	<i>Juncus tenuis</i> Willd. `	"Plentiful throughout ... except in the Pine Barrens, where it apparently does not occur except rarely as a weed." -Stone.	graminoid	Perennial	FAC-	dry or moist
Dwarf Dandelion	<i>Krigia virginica</i> (L.) Willd. `		herb	Annual	UPL	dry
Tall Lettuce	<i>Lactuca canadensis</i> L. 0^		herb	Biennial	FACU-	fields, waste places
Oblong-fruited Pinweed	<i>Lechea racemulosa</i> Michx. ~		herb	Perennial	--	dry
Bush-clover	<i>Lespedeza capitata</i> Michx. 0^	common; throughout	herb	Perennial		dry, open
Hairy Bush-clover	<i>Lespedeza hirta</i> (L.) Hornem. ssp. <i>hirta</i> `		herb	Perennial		dry woods, fields
Creeping Bush-clover	<i>Lespedeza repens</i> (L.) W. Bart. `		herb	Perennial	--	dry woods, fields
Grass-leaf Blazing-star	<i>Liatis pilosa</i> (Ait.) Willd. var. <i>pilosa</i> ~		herb	Perennial	--	dry, open, sandy

Appendix E. Pine Barrens Roadside Plant Species
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Common Name	Scientific Name	Whitmer Stone Notes	Habit	Duration	Wetland Indicator Status	Habitat
Cow-wheat	Melampyrum lineare Desr. var. pectinatum (Pennell) Fernald `		herb	Annual	FACU	damp to dry
Pine Barren Sandwort	Minuartia caroliniana (Walt.) Mattf. ~		herb	Perennial	--	Dry sugar sand.
Horse-mint	Monarda punctata L. ssp. punctata ^	"appears as a weed"; MD, Coast, CM	herb	Perennial	UPL	dry
Blue Toad-flax	Nuttallanthus canadensis (L.) D.A. Sutton `		herb	Annual	--	sandy
Cut-leaf Evening-primrose	Oenothera laciniata Hill 0^	a weed in cultivated ground; MD,	herb	Annual	FACU-	dry
Eastern Prickly Pear	Opuntia humifusa (Raf.) Raf. var. humifusa 0, {^		cactus	Perennial	--	Dry, well drained sand.
Columbia Panic-grass	Panicum columbianum Scribn. var. columbianum `		graminoid	Perennial	FACU	"Dry (or moist) sandy soil of open woods, fields" Hough.
Ashe's Panic-grass	Panicum commutatum Schultes var. ashei (Pearson) Fern. `	"Plentiful in dry sandy woodland of the Pine Barrens and Cape May districts..." -Stone.	graminoid	Perennial	FACU+	"Open, usually dry, sandy to rocky soil of open woods and edges" -Hough.
Starved Panic-grass	Panicum depauperatum Muhl. 0^		graminoid	Perennial	--	"Dry sandy or rocky ground" -Stone.
Forked Panic-grass	Panicum dichotomum L. var. dichotomum 0^	Found mostly along railroads in Stone's time.	graminoid	Perennial		Dry openings, thin woods, and woods edges.
Lindheimer's Panic-grass	Panicum lanuginosum Ell. var. lindheimeri (Nash) Fern. `		graminoid	Perennial	FAC	moist or dry
Gray Panic-grass	Panicum meridionale Ashe ~		graminoid	Perennial		"Dry ground" -Stone.
Commons' Panic-grass	Panicum ovale Elliot var. ovale ~		graminoid	Perennial	FACU	Dry openings, thin woods, and woods edges.
Hemlock Panic-grass	Panicum sabulorum Lam. var. patulum (Scribn. & Merr.) C.F. Reed `		graminoid	Perennial		"Dry (or moist) sandy soil of open woods, fields" Hough.

Appendix E. Pine Barrens Roadside Plant Species
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Common Name	Scientific Name	Whitmer Stone Notes	Habit	Duration	Wetland Indicator Status	Habitat
Round-fruited Panic-grass	<i>Panicum sphaerocarpon</i> Ell. var. <i>sphaerocarpon</i> `		graminoid	Perennial	FACU	"Sandy, usually dry soil in light shade..." -Hough.
Smoothish Panic-grass	<i>Panicum villosissimum</i> Nash var. <i>pseudopubescens</i> (Nash) Fern.`		graminoid	Perennial	--	"Dry, usually sandy soil of open woods and shaded edges..." -Hough.
Switchgrass	<i>Panicum virgatum</i> L. var. <i>cubense</i> `	Along salt marshes and rivers, and farther inland than <i>P. virgatum</i> acc. to Stone.	graminoid	Perennial	FAC	Uplands and wetlands.
Smooth Forked Chickweed	<i>Paronychia canadensis</i> (L.) Wood ^		herb	Annual	--	Dry
Hairy Forked Chickweed	<i>Paronychia fastigiata</i> (Raf.) Fern. var. <i>fastigiata</i> ^	SPA? Stone cites a Mays Landing record from the New Brunswick herbarium.	herb	Annual	--	"Well-drained, dry, rocky or sandy, open ground of woods and shaded edges" - Hough.
Slender Paspalum	<i>Paspalum setaceum</i> Michx. var. <i>setaceum</i> `		graminoid	Perennial	FACU+	Dry openings and woods edges.
Black Oat Grass	<i>Piptochaetium avenaceum</i> (L.) Parodi 0^	prob not typical PB	graminoid	Perennial	UPL	dry sandy ground
Jointweed	<i>Polygonella articulata</i> (L.) Meisn. `((herb	Annual	--	Well-drained, sterile, sandy.
Rattlesnake Root	<i>Prenanthes serpentina</i> Pursh `		herb	Perennial	--	dry
Hispid Swamp Blackberry	<i>Rubus hispidus</i> L. `	Highly technical genus.	herb	Perennial	FACW	dry to wet, often in shaded swamps
Little Bluestem	<i>Schizachyrium scoparium</i> (Michx.) Nash var. <i>scoparium</i> `		graminoid	Perennial	FACU-	dry
White-top Aster	<i>Sericocarpus asteroides</i> (L.) B.S.P `		herb	Perennial	--	dry
Narrow-leaved White-top Aster	<i>Sericocarpus linifolius</i> (L.) B.S.P. `		herb	Perennial	--	dry, open
Coastal Blue-eyed-grass	<i>Sisyrinchium atlanticum</i> Bickn. `		herb	Perennial	FACW	fields, meadows, open woods

Appendix E. Pine Barrens Roadside Plant Species
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Common Name	Scientific Name	Whitmer Stone Notes	Habit	Duration	Wetland Indicator Status	Habitat
Glaucus-leaved Greenbrier	<i>Smilax glauca</i> Walt. `		vine	Perennial	FACU	moist to dry
White Goldenrod	<i>Solidago bicolor</i> L. `		herb	Perennial	--	dry, open
Slender Goldenrod	<i>Solidago erecta</i> Pursh ~		herb	Perennial	FAC	dry woods
Field Goldenrod	<i>Solidago nemoralis</i> Ait. `		herb	Perennial	--	dry
Fragrant Goldenrod	<i>Solidago odora</i> Ait. `		herb	Perennial	--	dry, open
Downy Goldenrod	<i>Solidago puberula</i> Nutt. ~		herb	Perennial	FACU-	"open places" sandy
Wrinkle-leaved Goldenrod	<i>Solidago rugosa</i> P. Mill. ssp. <i>rugosa</i> var. <i>rugosa</i> `		herb	Perennial	FAC	damp to dry
Indian Grass	<i>Sorghastrum nutans</i> (L.) Nash 0^	rare or casual in PB	graminoid	Perennial	UPL	moist or dry
Goat's Rue	<i>Tephrosia virginiana</i> (L.) Pers. `		herb	Perennial	--	dry, sandy, open
Blue Curls	<i>Trichostema dichotomum</i> L. `		herb	Annual	--	dry, old fields
Venus' Looking-glass	<i>Triodanis perfoliata</i> (L.) Nieuwl. var. <i>perfoliata</i> 0^		herb	Annual	FAC	dry, open areas
Bird's-foot Violet	<i>Viola pedata</i> L. 0^	Rare in PB; N, MD, Coastal, CM	herb	Perennial	UPL	dry, open
Slender Fescue Grass	<i>Vulpia octoflora</i> (Walt.) Rydb. var. <i>octoflora</i> `		graminoid	Annual	UPL	Dry, sterile, open sandy spots.

Appendix F. NJDOT Sample Language Addressing Roadside Aesthetic Complaints
Best Management Practices for Pine Barrens Roadside Plant Communities

The following text represents the standard written response NJDOT provides to the general public regarding aesthetic complaints related to their GEMZ program:

The New Jersey Department of Transportation (NJDOT) is responsible for the maintenance of our highways and the surrounding areas; an obligation that we take very seriously. Most recently, budgetary constraints have forced us to closely examine the use of limited resources, both financial and human.

The aesthetic benefit of mowing all of the grass along our roadways, while desirable, is no longer practical considering the cost to do so. The demand on manpower, the wear and tear on an aging fleet of equipment as well as the increasing price of fuel dictate that we explore alternatives to mowing. At the same time, there is a growing recognition of the need to improve aesthetics and to enhance our environment.

To that end, the Department has decided to facilitate a program referred to as Grassland Ecological Mow Zone (GEMZ). The intent of this program is twofold; first, reduce total mowable acreage to the fullest extent possible, second, in the areas that will be mowed, cut the grass when it reaches approximately eight to ten inches to a height of no lower than four inches. Both of these strategies will tend to reduce manpower requirements and the second will help the grass eventually overcome unattractive weeds, reach a stable, manageable height, and fill in other areas made barren by our past practices which tended to cut the grass too low resulting in “scalped” areas.

Decisions on where to allow the grass to grow and on which areas will be mowed on a routine basis are made based upon several considerations. The location, the type of facility as well as drainage and sight requirements are predominate factors in the selection process. Most interstate or major highways with wide grass medians and huge infields within the interchanges are primary candidates for this program. However, this is not to say that other land service type roadways are excluded. At a minimum, we will continue to mow along the edges of roadways and in areas required to support appropriate drainage and visibility. Areas that are not mowed routinely (GEMZ areas) will be mowed at the end of the season, sometime in mid to late fall, which will help facilitate growth of healthy grasses and wild flowers in the Spring. It should be noted that it is expected to take approximately two to three years before we will realize the full benefit of these changes.

While I recognize that our efforts have changed the appearance of our roads; we ask for your patience and support as we are working to develop turf management strategies to assist us in controlling roadside vegetation. This allows us to dedicate resources to routine activities such as improving roadway surfaces, monitoring and unclogging drainage lines, and clearing vegetation from our signs. You should be seeing improvements in those areas as we change how and when we cut our grass.

Appendix G. Overview of Invasive Plant Control Methods
Best Management Practices for Pine Barrens Roadside Plant Communities

Method Name	Method Type(s)	Method Code	Typical Herbicide Concentrations	Target Type(s)	Basic Technique	Pros	Cons	Notes
biological control	Biological Control	BC	N/A	few selected species	Release of approved biological control agents that attack only target species	Method can provide effective control and is cost effective	There are no species in the Pine Barrens with an available biological control agent.	A biological control agent for <i>Phragmites</i> is being researched.
basal bark	Chemical Control	BB	15 - 25%	woody species	Application of herbicide within a 6-12 inch band around entire stem approximately 12 inches above base of plant	Method provides effective control and is cost effective	Some suggested oil diluents are not environmentally friendly, but vegetable or citrus oils with triclopyr can be effective (Rathfon 2006)	Herbicide application is performed using a backpack sprayer. Method used for woody stems ≤ 6" in diameter. This is an effective and efficient method, but will have limited use for mowed roadsides.
foliar spray	Chemical Control	FS	1-3%	Any plant less than 4 feet tall	Application of herbicide using a backpack sprayer to wet all leaves	Method provides effective control and is cost effective	Method has potential to injure non-target species and cannot be used on taller plants due to increased risk to applicator and non-target species (i.e., spraying upward increases risk of drift); Method can be sensitive to weather conditions (e.g., heat may dry spray before effective absorption)	Foliar applications generally include use of a backpack sprayer (Recommend use of Thinvert system ¹). Some foliar application methods include wipe-on applications (e.g., "bloody glove"), but these methods are not recommended because they are extremely time consuming and increase likelihood of exposure to the applicator. The use of boom applications is not recommended, but may be useful in the establishment of native warm season grasses where all existing vegetation must be removed prior to seeding.
pre-emergent spray	Chemical Control	PS	1-3%	herbaceous species	Application of herbicide to prevent seed germination	Method can provide effective control	Requires a broad application in areas known or suspected to contain invasive species; Timing of application can vary between years for targeted species; Suppresses germination of all species	This method may be useful in areas with Japanese stiltgrass (an annual) and native species are already established.
hack-and-squirt	Chemical & Mechanical Control	HS	15 - 25%	woody species	Make downward cuts with a hand axe (one cut per inch of diameter) and apply herbicide to cuts	Method provides effective control and is cost effective; Volunteers can assist with stem cutting	Stem cutting may be difficult for thick-barked plants	Herbicide applied with squirt bottle or paint brush. Herbicide should be applied immediately after cutting.

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Method Name	Method Type(s)	Method Code	Typical Herbicide Concentrations	Target Type(s)	Basic Technique	Pros	Cons	Notes
stem injection	Chemical & Mechanical Control	SI	15 - 25%	woody species	E-Z-Ject Lance loaded with herbicide pellets	Method provides effective control	Equipment is difficult to operate under field conditions; Injection for thick-barked trees requires significant force; Equipment is expensive	A modified approach using a drill and manual insertion of herbicide may be more practical.
cut stump	Chemical & Mechanical Control	CS	15 - 25%	woody species	Cutting stems just above ground level followed by targeted application of herbicide to cut stems	Method provides effective control; Volunteers can assist with stem cutting	Mechanical removal of stems is very time consuming	Cutting is performed by loppers, handsaws or chainsaws depending upon size of stems. Herbicide applied with a squirt bottle, paint brush or backpack sprayer. Herbicide should be applied immediately after cutting.
prescribed fire	Cultural Control	PF	N/A	many species	Must follow a site-specific Prescribed Burning Plan.	Method provides effective control of woody species and is cost effective.	Requires highly trained personnel; Insurance requirements may restrict range of applicators	Prescribed fire is most effective for grasslands with dense stands of native warm season grasses that provide ample fuel to eliminate woody seedlings; Prescribed fire may be utilized to remove dense thatch before application of herbicides (e.g., common reed, reed canary grass) in wetland habitats. The effectiveness of prescribed fire to control some invasive species is uncertain (e.g., fire may stimulate Chinese bushclover).
prescribed grazing	Cultural Control	PG	N/A	many species	Rotational system using multiple livestock species	Method may be effective; Method can be assisted by volunteers	Method requires significant expertise in selection of livestock species, density of animals per unit area and timing of grazing; Method requires installation of fencing; Method may spread some invasive species through feces; Trampling of vegetation may encourage invasive species	This method is impractical for roadsides.

Appendix G. Overview of Invasive Plant Control Methods
Best Management Practices for Pine Barrens Roadside Plant Communities

Method Name	Method Type(s)	Method Code	Typical Herbicide Concentrations	Target Type(s)	Basic Technique	Pros	Cons	Notes
soil tilling	Cultural Control	ST	N/A	herbaceous species and woody seedlings	Turning of soil using typical farm equipment	Method may provide effective control and is cost effective	Method destroys native species along with invasive species; Method may increase invasive species through extensive soil disturbance	This is an extreme method with limited use in natural areas. Successive tilling events may be used to exhaust weed seed bank prior to re-planting native species.
mulching	Cultural Control	MU	N/A	herbaceous species	Application of a thick layer (3-4 inches) of organic materials	Method is effective for herbaceous species within cultivated garden beds or roadsides; Method can be assisted by volunteers	Method is not practical in natural areas where vehicle access is limited	Only effective on species with small seeds or weakly growing plants that cannot germinate/grow through the mulch. Japanese stiltgrass is sensitive to heavy mulching.
solarization	Cultural Control	SO	N/A	herbaceous species	Application of plastic sheeting over infested areas	Method may be effective in some situations; Method can be assisted by volunteers	Method may alter soil chemistry and biology more significantly than herbicides	Plastic sheeting increases soil temperature to kill seeds and plants. Method may be combined with
girdling	Mechanical Control (may be combined with Chemical Control)	GI	N/A	woody species	Cutting and removing a ≥ 3 inch band of bark from a trunk	Method can provide effective control; Method can be assisted by volunteers	Method may be ineffective on species with re-sprouting ability; Method is time consuming and difficult for thick-barked species; Method cannot be utilized where the risk of standing dead trees is unacceptable	chemical control (i.e., apply herbicide to girdled area); Do not attempt on species such as black locust, tree-of-heaven or Japanese angelica tree, which will vigorously re-sprout multiple stems in response to girdling (hack-and-squirt may be effective on these species)
mowing	Mechanical Control	MO	N/A	many species	Cutting tops of plants using a mower, brush cutter or weed whacker	Method may be used as a pre-treatment for herbicide application to cut stumps or foliar applications to re-sprouts using a backpack sprayer	Method is ineffective for most species because of re-sprouting ability	Japanese stiltgrass can sustain itself as a "lawn" by producing seeds on plants that are two inches or smaller
pulling	Mechanical Control	PU	N/A	small woody plants and herbaceous species	Removal of entire plant by hand or use of specialized tools such as a "Weed Wrench"	Method can provide effective control; Method can be performed by volunteers	Method is extremely time consuming and ineffective when root system cannot be completely removed; Method creates soil disturbance that stimulates germination of invasive species such as Japanese stiltgrass	This method should only be considered on a limited basis.

Appendix G. Overview of Invasive Plant Control Methods
Best Management Practices for Pine Barrens Roadside Plant Communities

Method Name	Method Type(s)	Method Code	Typical Herbicide Concentrations	Target Type(s)	Basic Technique	Pros	Cons	Notes
hot foam spray	Mechanical Control	HF	N/A	herbaceous species	Rental of Waipuna Hot Foam System	No herbicides are required	System rental cost is \$700/month with a two-year lease commitment and there are other related equipment costs; system can only be used within 200 feet of a vehicle that carries the specialized hot foam generator, many herbaceous plants require multiple treatments	This is an innovative system, but has significant financial and practical limitations.

¹Thinvert system involves use of specialized spray nozzles combined with a thin invert emulsion spray fluid (instead of using water to mix with herbicides). The primary advantage is less herbicide drift to non-target plants and an overall lower volume of spray required to treat a given area. Although the system is more expensive than typical spray systems, it is ultimately cost effective because of labor-savings generated through reduction of re-filling of sprayers.

Appendix H. Summary of Herbicide Characteristics
Best Management Practices for Pine Barrens Roadside Plant Communities
Sources: Tu et al. 2001, CDMS 2007

Herbicide Common Name ¹	Recommended Use Grouping ²	Examples of Trade Names	Target Species	Half-life in Soil (days)	Half-life in Water (days)	Estimated Cost per Gallon	Wildlife Risk Category		Human Risk	
							Birds and Mammals	Aquatic Species	Signal Word ³	Notes
2,4-D ¹	Infrequent	Navigate, 2,4-D L.V. 4 Ester, 2,4-D Amine 4, Aqua-kleen, Barrage	herbaceous broadleaf plants	10	hours to months	\$40 (Weed Ho)	Moderately toxic	Not reported, but may bioaccumulate	Caution or Danger	Inconclusive evidence implicates 2,4-D as a potential endocrine disrupter; Eye and skin irritant
Clopyralid	Infrequent	Reclaim, Curtail, Transline, Stinger, Lontrel	herbaceous broadleaf plants	40	8-40	\$ 410 (Transline)	Practically non-toxic	Low toxicity	Caution or Danger	May cause serious eye damage
Fluazifop-p-Butyl	Limited	Fusilade DX, Fusion, Ornamec, Horizon 2000	grasses	15	stable	\$300 (Fusilade)	Slight toxicity to practically non-toxic	High toxicity	Caution	Eye and nasal irritant - toxic if inhaled
Fosamine	Limited	Krenite S	woody plants, some herbaceous broadleaf plants	8	stable	\$60 (Krenite)	Very slight toxicity	Low toxicity	Caution	Eye and skin irritant
Glyphosate ¹	Typical	Round-Up, Rodeo, Accord, Glypro, Glyphomax, Touchdown	any plant	47	12 days to 10 weeks	\$40 (Accord); \$80 (Rodeo)	Low toxicity	Moderate toxicity ⁴	Caution	Eye and skin irritant
Hexazinone	Infrequent	Velpar L	herbaceous broadleaf plants, some grasses & some woody plants	90	3 days to 9 months	\$95 (Velpar)	Low toxicity	Slight toxicity	Danger	May cause serious eye damage
Imazapic	Infrequent	Plateau, Cadre	some grasses, some herbaceous broadleaf plants	120-140	< 8 hours	\$350 (Plateau)	Low toxicity	Moderate toxicity	Caution	Eye and skin irritant
Imazapyr ¹	Limited	Arsenal, Chopper, Stalker, Habitat	any plant	24-141	2 days	\$410 (Arsenal)	Low toxicity	Low toxicity	Caution	Eye and skin irritant

Appendix H. Summary of Herbicide Characteristics
Best Management Practices for Pine Barrens Roadside Plant Communities
Sources: Tu et al. 2001, CDMS 2007

Herbicide Common Name ¹	Recommended Use Grouping ²	Examples of Trade Names	Target Species	Half-life in Soil (days)	Half-life in Water (days)	Estimated Cost per Gallon	Wildlife Risk Category		Human Risk	
							Birds and Mammals	Aquatic Species	Signal Word ³	Notes
Picloram	Typical	Tordon K, Tordon 22K, Grazon PC	herbaceous broadleaf plants, woody plants	90	2-3 days	\$120 (Tordon)	Slight toxicity to practically non-toxic	Slight to moderate toxicity	Caution	Eye and skin irritant
Sethoxydim	Limited	Poast, Torpedo, Ultima, Vantage, Conclude	grasses	5	hours in sunlight	\$230 (Poast)	Slight toxicity	Slight toxicity	Warning	Eye and skin irritant
Triclopyr	Typical	Garlon 3A, Garlon 4, Remedy, Pathfinder II, Crossbow	herbaceous broadleaf plants, woody plants	30	4 days	\$130 (Garlon)	Slight toxicity	Slight toxicity	Caution or Danger	Garlon 3A can cause severe eye damage and is labeled "Danger"; Most other formulations are labeled "Caution"

¹ Denotes that some formulations of this herbicide are registered for aquatic applications.

² Groupings were based upon risks to humans or wildlife, relative cost compared to other similarly effective products and frequency of use by natural area managers.

³ Signal Words include "Danger" (highly toxic or highly corrosive), "Warning" (moderately toxic) and "Caution" (slightly toxic or relatively non-toxic). Please note that signal words are assigned to specific formulations and may vary within particular herbicide common names (CDMS 2007).

⁴ Glyphosate is essentially non-toxic when using aquatic formulations (e.g., Rodeo with a surfactant registered for aquatic applications).

**Appendix I. Invasive Species Phenology¹ and Treatment Recommendations²
Best Management Practices for Pine Barrens Roadside Plant Communities**

flowering period
period of flowering and fruiting
fruiting period

Scientific Name	Common Name	January	February	March	April	May	June	July	August	September	October	November	December	Treatment Recommendation Notes ^{3,4,5}
<i>Celastrus orbiculatus</i>	Asiatic bittersweet													Options: BB,FS,CS; Species has an extensive root system and pulling is ineffective; Glyphosate recommended for foliar applications; Triclopyr recommended for non-foliar applications
<i>Eragrostis curvula</i>	African lovegrass													Options: FS; Species may be difficult to control; Glyphosate recommended for foliar applications - apply prior to flowering; Repeated mowing is only somewhat effective and would harm native species mixed with infestations
<i>Lespedeza cuneata</i>	Chinese bushclover													Options: FS, CS; Species has an extensive root system and pulling is ineffective; Triclopyr recommended for foliar applications - apply prior to flowering; Cut-stump applications only feasible for very small populations; Repeated mowing is only somewhat effective and would harm native species mixed with infestations; Prescribed fire is reported to stimulate growth
<i>Lonicera japonica</i>	Japanese honeysuckle													Options: FS,MO,PU; Foliar application is the only practical solution - hand-pulling very difficult as species roots at multiple leaf nodes; Mowing may be performed in July and September to weaken plants prior to spraying; Spraying may occur in non-growing season because species is semi-evergreen; Glyphosate recommended
<i>Microstegium vimineum</i>	Japanese stiltgrass													Options: FS,MU; Long-lived seed bank requires 3-5 years of treatments; Species has extremely dense growth of individuals - pulling is impractical; Glyphosate recommended
<i>Miscanthus sinensis</i>	Chinese silver grass													Options: FS,PF; Species has extensive root system - pulling is ineffective; Glyphosate recommended; Prescribed fire has unknown impacts
<i>Phalaris arundinacea</i>	reed canary grass													Options: FS,PF; Very difficult to control - may require multiple cutting and herbicide treatments; Glyphosate recommended; Prescribed fire has unknown impacts
<i>Phragmites australis</i>	common reed													Options: FS,PF,PG,MO; Very difficult to control - may require multiple cutting and herbicide treatments; PF,PG and MO are helpful to remove old stems or reduce height of living stems prior to FS; Glyphosate recommended
<i>Rosa multiflora</i>	multiflora rose													Options: BB, FS,PF,PG,CS,MO,PU; Glyphosate recommended for all methods except BB, where triclopyr is recommended
<i>Wisteria floribunda</i>	Japanese wisteria													Options: BB,FS,CS; Species has an extensive root system and pulling is ineffective; Glyphosate recommended for foliar applications; Triclopyr recommended for non-foliar applications

¹Phenology information collected from Hough (1983), MOBOT (2007),PFAF (2007) or Brand (2007) and is intended to guide timing of control efforts.

²Treatment recommendations from Zerbe et al. (2003), multiple websites, personal experiences of author and fellow colleagues.

³Optimal treatment methods vary by size of individual plants and extent of infestation in selected treatment areas. See Appendix G for additional information.

⁴For bark applications, triclopyr should be used in its ester form (e.g., Garlon 4).

⁵See below for a sample of invasive species control and species information websites:

- Plants for a Future <http://www.pfaf.org/index.html>
- Flora of North America http://www.efloras.org/flora_page.aspx?flora_id=1
- USDA PLANTS <http://plants.usda.gov/index.html>
- Invasive Plant Atlas of New England <http://www.lib.uconn.edu/webapps/ipane/search.cfm>
- Plant Conservation Alliance - Alien Plant Working Group <http://www.nps.gov/plants/alien/fact.htm>
- Plant Invaders of Mid-Atlantic Natural Areas <http://www.invasive.org/weeds.cfm>
- The Nature Conservancy's Global Invasive Species Initiative <http://tncweeds.ucdavis.edu/control.html>
- National Invasive Species Information Center <http://www.invasivespeciesinfo.gov/plants/control.shtml>