RUSTIC ROADS COMMISSION
FREDERICK COUNTY, MARYLAND

30 North Market Street, Third Floor   Frederick, Maryland 21701   (301) 600-1149

MEMORANDUM

TO: Jason Stitt, Director, Division of Public Works

FROM: Rustic Roads Maintenance Subcommittee

THROUGH: Rustic Roads Commission

DATE: XXXX XX, 2025

RE: Recommendations for Standard Operating Procedures Relating to Roadside Vegetation

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Issue:

The Rustic Roads Commission has been tasked with developing recommendations for the Standard Operating Procedures (SOP) for maintenance practices that affect Rustic Roads. The Maintenance Subcommittee has created recommendations for the Division of Public Works to consider for the Tractor and Boom Mowing for Vegetation Control and Roadside Tree Trimming SOPs.

Background and Discussion:

The Rustic Roads Program has several elements that are essential for its success. It requires safe roads for multi-purpose users, it requires preservation of the scenic and historic features that contribute to the ambiance of the roads, it requires the promotion of those elements, and it requires an understanding of how design and maintenance of the roads can contribute to keeping vehicle speeds low for overall safety.

The support and knowledge within the Division of Public Works is vital to the success of the program. Leading with an ethic of care shows an appreciation of the many benefits that roadside vegetation can provide and is in harmony with other state and county initiatives such as Livable Frederick, Maryland 5 Million Trees Initiative, the Climate and Energy Action Plan for the Community, the upcoming Green Infrastructure Plan, as well as clean water and native vegetation restoration efforts throughout the County.

It is recommended that a new SOP be developed that considers the following –

1. Compliance with state and local laws such as the Maryland Roadside Tree Law and the Maryland Weed Control Law.
2. Compatibility and support of state and county initiatives mentioned previously.
3. Inclusion of the current practice of mowing 5’ or less from the edge of the public travelway for roads in the Rustic Road Program.

4. The importance of vehicle speed control in reducing injuries, deaths and property damage and seeks to incorporate practices that facilitate that. Recognizing that if non-vehicle users do not feel safe, they will not want to use these roads and a vital element of the success of the Program will be lost.
5. Best practices with respect to bank mowing and working to eliminate invasive species rather than repeated mowing.
6. A reduction in boom mowing could reduce operator accidents, save money, help the county meet its carbon reduction targets and improve water quality.
7. Develop a program that addresses replanting trees within the right-of-way. This would support the letter and intent of the Maryland Roadside Tree Law and improve tree canopy in areas where many trees have been lost due to disease, weather, and other factors.

These recommendations are offered as part of our obligations under the establishment powers of the Rustic Road Program and are not meant to be critical of current policies or procedures. A new program is an opportunity to review, update and improve on practices that have been in place for many years. We trust that the DPW leadership and personnel welcome that opportunity.

When writing the recommendations for the SOPs, the following goals and actions were considered vital to the success of the Rustic Roads Program.

1. Strategic Placement of Vegetation

Roadside Buffer Zones: Use trees and shrubs to create a native, natural buffer zone between the road and any adjacent developments or open spaces. This visual "framing" effect can subconsciously signal to drivers that they are entering a rural, tranquil area, encouraging them to slow down.

Tree Canopy: Planting trees along the edges of roads can create a natural canopy, which, especially in curves or turns, provides a visual narrowing effect, prompting drivers to reduce speed for safety. Studies have shown that a full tree canopy along low volume roads can extend pavement life by keeping pavement cooler in summer and reducing the amount of moisture negatively affecting the road surface.

Vegetative Curbs: Consider planting low shrubs or groundcover along the roadside, particularly at curves and intersections. This can subtly guide drivers to stay within lanes and reduce speed through visual cues without obstructing the driver’s sightlines.

2. Use of Native Plant Species

Adaptation to Local Conditions: Native plants are better adapted to the local climate, soil, and wildlife, reducing the need for maintenance, fertilizers, and watering. They are also more resilient and less likely to cause safety issues such as erratic growth patterns or invasive behavior.

Low-Growth Shrubs: Plant shrubs that stay below eye level to ensure they don't block sightlines for drivers. Low-growing, dense shrubs can act as soft barriers that prevent erratic driving while also reducing the temptation for drivers to "cut corners" or take wider turns.

Wildflowers and Grasslands: In rural areas, consider planting wildflowers and native grasses along shoulders and ditches. These elements can give a sense of beauty and tranquility, which may have a calming effect on drivers, encouraging slower speeds.

Preserve Native Vegetation: Retain and prioritize the growth of native grasses, shrubs, and trees. These species support local pollinators, sequester more carbon, and stabilize soil better than exotics.

3. Visibility and Sightlines

Regular Maintenance: Regularly maintain vegetation to ensure that overgrown plants don't intrude into the roadway. This maintenance ensures that the calming benefits of roadside vegetation are maintained without compromising safety.

4. Wildlife-Friendly Practices

Wildlife Corridor Creation: For rural roads that traverse areas with significant wildlife populations, managing roadside vegetation to facilitate wildlife corridors can help reduce animal-vehicle collisions. Native plants can attract birds and small mammals, while reducing the risk of larger animals like deer venturing too close to the road.

Buffer Zones for Wildlife: Creating buffer zones of taller vegetation at the edges of roads can reduce the likelihood of wildlife crossing in dangerous spots, minimizing the risk of sudden animal encounters for drivers.

5. Road Geometry Considerations

Vegetation Placement in Curves: Position taller trees or bushes further from the road at sharp curves, while using lower shrubs or grasses closer to the edge. This ensures that drivers can see ahead but still experience the calming effect of the roadside vegetation as they approach curves.

Attachments:

Attachment 1: Tractor and Boom Mowing for Vegetation Control SOP
Attachment 2: Recommendations for Tractor and Boom Mowing for Vegetation Control SOP
Attachment 3: Roadside Tree Trimming SOP

Attachment 4: Recommendations for the Roadside Tree Trimming SOP
Attachment 5: *Effects of Tree Canopy on Pavement Condition, Safety and Maintenance - Phase 2* by Bhaven Naik et al. (Abbreviated)

	Division of Public Works 355 Montevue Lane, Suite 200 Frederick, Maryland 21702	**STANDARD PROCEDURES**
	Effective Date:	**Subject:**
		Tractor and Boom Mowing for Vegetation Control
Division Director Signature:		

I. **Purpose:** To assist Office of Highway Operations (OHO) employees in the promotion of traffic and pedestrian safety, this procedure establishes guidelines for the maintenance of roadside vegetation. The goal of the maintenance effort is to provide a clear zone in the travelway to accommodate the safe operation of vehicles, cyclists, pedestrians, and others who use the right of way It also provides guidance for maintenance crews regarding safe mowing, brush cutting, and other methods to control roadside vegetation. Furthermore, this procedure addresses limits of vegetation control with respect to the public travelway, furnishes a recommended schedule for tractor and boom mowing, and provides for recognition of property owners' requests for specific action or non-action by OHO staff.

(See the *Highway Operations Mower Training Program Standard Procedures* for additional information regarding the safe operation of the mower.)

A. **Definitions**

1. **Boom mower**: Tractor with an articulating arm with a mower attachment for reaching behind guardrails or roadside banks.

2. **Clear Sight Lines**: Sight lines established along a travelway so that the driver of a vehicle can see oncoming traffic that may otherwise be obstructed.

3. **Clear Zone:** An area that is clear of obstacles such as tree limbs, branches and vegetation that may impede a vehicle on the travelway. Required dimensions with respect to this procedure are included in the attached exhibits.

4. **Dedicated right of way:** An area, typically over the surface of land, that has been dedicated to public use through plats or deeds which allows for use by others for a specific purpose subject to the fee simple property interests of the adjacent landowner

5. **Invasive species:** Plants, animals or pathogens that are not native to the ecosystem under consideration, and whose introduction causes or is likely to cause harm. Lists of invasive species may be found on the U.S. Department of Agriculture WEB site: National Invasive Species Information Center (NISIC)

6. **Noxious weed:** a weed which is considered to be harmful to the environment or animals, especially one which may be the subject of regulations governing attempts to control it. Maryland Department of Agriculture: Noxious Weeds in Maryland

7. **Prescriptive right of way:** The right to use of another's land, which has been established by exercising this right over a period of time. For many Frederick County Roads, this is the only type of right of way that exists and is generally recognized as being the width of the travelway and may also extend to include roadside ditches if maintained by the County or other public entity. This may include installed driveway culverts . The adjoining property owner(s) retain fee simple ownership of the underlying property.

8. **Public travelway:** The travel surface of a public road which may consist of concrete, asphalt tar and chip or gravel.

9. **Recovery Zone:** An area adjacent to the public travelway that facilitates the safe recovery of a vehicle that leaves the travelway.

10. **Rural Road:** Those roads listed on Exhibit "B" of Resolution No. 02-23 of the Board of County Commissioners of Frederick County, Maryland with an effective date of September 24, 2002, as amended from time to time.

11. **Safe Sight distance:** A distance which provides adequate time for a vehicle to see an object such as a pedestrian or another vehicle and take such action as required to avoid a collision. The distance required is determined by the speed of the vehicle(s). Minimum sight distance listed in the Frederick County Roads and Streets Design Manual is 200 feet for stopping and 300 feet at intersections. Required distance increases with speed.

12. **Shoulder:** An area immediate adjacent to the travelway. This area may be paved, gravel or grass, which may also constitute a Recovery Zone.

13. **Tractor mower:** A tractor with a side mounted mower deck used for roadside mowing where the terrain is relatively flat.

II. <u>**Background/Program Objectives**</u>: Highway and street agencies facilitate roadway safety with a sound maintenance program. Employees of local road agencies are responsible for reviewing their roads and rights-of-way to identify hazards and foster safe conditions for the public and employees.

Uncontrolled vegetation may be hazardous for many reasons: trees close to the road can present a fixed object hazard; tall grass, weeds, brush, and tree limbs obscure or limit a driver's view of the road ahead, including traffic control devices, approaching vehicles, wildlife, pedestrians, and bicycles. Controlling vegetation helps reduce crashes and injuries.

A. Objectives

The benefits achieved by meeting these objectives are clear sight lines, improved drainage conditions, an unobstructed travelway for all vehicles, including farm equipment, emergency responders and County snowplows, which require a clear height of up to seventeen feet for winter operations, when plow and salting operations require a raised truck bed and a safe area of refuge for bicyclists and pedestrians.

1. Clear Sight Lines - Tall grass, weeds, and brush along the shoulder, ditch, and back slope areas of a roadside can create problems. Tall grass may hide low fixed-object hazards, such as culvert headwalls, drainage inlets, guardrail ends, and the object markers in front of them, as well as wildlife and livestock. High grass can also obscure the edge of pavement and shoulder condition. OHO performs shoulder and roadside maintenance, such as grading or mowing, to define the edge of shoulder and ditch so that motorists can see the shape, condition, and limits of the roadside.

2. Horizontal Curves - On the inside of horizontal curves, vegetation growth close to the pavement edge can block a driver's view of motor vehicles, bicycles, and pedestrians traveling in the same or opposite direction. Maintaining roadsides so headlights and taillights are visible around the inside of horizontal curves increases horizontal sight distance.

3. Drainage - Weeds, turf, and sod can interfere with roadside drainage. A high shoulder creates a secondary ditch along the edge of the road which may damage the pavement. Water on the pavement due to high shoulders causes safety problems, including hydroplaning and isolated icy conditions during winter. Grading is necessary to ensure the shoulder continues the slope from the road crown smoothly.

4. Side Road Visibility - The potential for vehicle crashes increases at intersections. Safe and efficient vehicle movement through an intersection requires good visibility. As drivers approach an intersection, they need to check each quadrant of the intersection for entering vehicles. Similarly, drivers pulling out from a STOP sign need a clear view of oncoming traffic. OHO strives to maintain clear site distance at each corner of the intersection for driver safety.

5. Maintained Shoulder area – Providing a mowed shoulder along the road provides an area for vehicles to pull off the road to allow oncoming traffic to pass. It also provides a safe area of refuge for bicyclists and pedestrians from vehicular traffic on narrow roads.

B. Benefits

Mowing rights-of-way regularly and consistently:

1. Ensures regulatory and wayfinding signs are visible to drivers.

2. Ensures road users (vehicles, bicycles, and pedestrians) are visible to drivers.

3. Helps pedestrians and bicyclists see motor vehicles and provides an area of safe refuge on narrow road segments.

4. Improves driver sighting of livestock and wildlife near the road.

5. Ensures sidewalks and pedestrian paths are free and clear of overhanging vegetation.

6. Removes trees close to the roadway that may cause property damage or severe injury if struck.

7. Keeps edge-of-road shoulder area clear of obstructions to maintain a recovery area for vehicles that veer off the road.

8. Improves winter road maintenance in snow and ice areas.

9. Helps drainage systems function as designed.

10. Preserves pavements through daylighting and root system control.

11. Controls noxious weeds and invasive tree species, in accordance with local laws and ordinance, reducing the need for herbicides.

III. Techniques:

A. Bank Mowing - Mowing of banks, predominately by boom mowers towards the end of the growing season, discourages fast growing invasive tree species from becoming established. If allowed to establish, trees such as Ailanthus (Tree of Heaven), Bradford pear, and Bamboo can quickly spread, requiring considerable manual labor to keep them from overhanging the road and entering the clear zone. (See Exhibits 1 and 2.) Mowing of brush and undergrowth also provides a safe, accessible work area for tree trimming operations.

B. Roadside Mowing –

1. General - Mowing of flatter, roadside shoulder areas will be performed by tractor mowers, making single or double five (5) foot passes depending on schedule and time of year. Holding to the established frequency maintains sight distance, controls turf to maintain adequate drainage, provides a safe area of refuge for pedestrians and cyclists and provides a recovery area for vehicles.

2. Rural Roads - those roadways within the Rural Roads program, generally narrower with lower traffic count, are suitable for single pass mowing unless different treatment is warranted due to

   a) The presence of Dedicated Right of Way.

   b) Intersection sight distance

   c) An adjoining property owner request pursuant to section V.C.3, below

C. Roadside Tree Maintenance - One of the most common causes of fatal and serious injury crashes on rural roads involves vehicles leaving the road and striking a tree. The concept of a clear or recovery zone -- an area adjacent to the travelway where slope, surface, and an absence of fixed objects can permit recovery of a vehicle that leaves the roadway -- is important for providing a safe roadside. Trees are potential hazards because of their size and location with respect to vehicular traffic. Trees larger than four inches in diameter can be a hazard to a vehicle. The closer trees are to the travel lane, the more likely a vehicle is to strike them.

Isolated trees provide a better opportunity for removal compared to forest conditions, where removal involves significant cost. OHO recognizes that removing individual trees may be controversial and bases its decisions to proceed with removal primarily upon potential crash frequency and severity. OHO assigns trees closest to the road removal priority; assesses trees in critical locations, such as curves and intersections, for removal; and pays particular attention to trees that drivers have previously struck.

1. Snagging occurs when a vehicle undercarriage catches on a stump or other object. Generally, any stump higher than four inches above the surrounding ground can cause snagging.

   a) Cut trees close to the ground so that no stump remains as a fixed object or snagging hazard or schedule the stump to be ground flush.

b) Cut small-diameter trees no more than four inches from the ground.

c) Cut large-diameter trees flush with the ground.

d) Cut trees of any size growing on a slope flush with the ground.

e) Remove all trees within the clear zone when they are small saplings rather than small trees. At that time, they are easy to cut off at ground level and cause no stump problems.

2. Fell and dispose of via approved methods any dead and leaning trees within the road right-of-way that endanger the traveling public.

3. Contact property owners prior to removal of any potentially hazardous trees outside the right-of-way. Note that an emergency may warrant immediate OHO intervention. Documentation is especially important in these situations. OHO must maintain records regarding receipt of emergency notice, date of review, OHO employees involved in resolution, and other relevant facts.

D. Winter Maintenance - When trees and shrubs (particularly evergreens) in the right-of-way cast shadows on the pavement (trees growing on the south side of the road cause this issue), freeze/thaw cycles may create isolated icy patches on the pavement. Since the rest of the road is dry, drivers do not anticipate these icy patches and loss-of-control crashes result.

1. Work on the south and west sides of the roads first if time and money for brushing are limited.

2. “Daylight” by cutting taller vegetation to enable the sun to help with thawing and ice control (and generally to help preserve pavement).

3. In areas receiving heavy snow, provide vegetation clear zones for snow storage.

4. In the fall, when crews perform winter maintenance dry runs, identify dead limbs overhanging the road and remove. Dead branches overhanging roadways are problematic because winter snow and ice accumulate on the dead branches and the extra weight often causes them to fall on the roadway and traffic.

IV. Resources:

OHO utilizes tractor mowers and boom mowers, as well as mowing contractors, to control vegetation along County rights-of-way. Contractors or Homeowner's Associations primarily mow medians because the County does not have the equipment to maintain this part of the right-of-way safely, nor does it have enough median area to justify the purchase of this type of equipment.

Tractor mowers mow the flat shoulder areas. These mowers can mow a five-foot-wide pass, mowing one or two passes per mowing, depending on the time of year. Boom mowers mow hard-to-reach areas, such as behind guardrail, around culverts and headwalls, and along the steeper banks where the deck on the tractor mower cannot reach. When mowing in high-traffic or high-posted-speed roads, OHO may employ a chase vehicle with warning lights to enhance safety.

V. Operations:

OHO utilizes tractor mowers to make single or double five-foot-wide passes to the roadside to control vegetation. For those areas the tractor mower cannot reach (behind guardrail, around culverts/headwalls, and on banks), OHO will use boom mowers.

A. Various factors influence off-the-road-edge limit decisions:

1. Safe sight distance around curves and at intersections.
2. Visibility of traffic control devices, such as regulatory signs and roadside delineators.
3. Visibility of infrastructure in the right-of-way, such as culvert headwalls and bridge abutments, telephone and cable utility boxes and mailboxes.
4. Controlling the growth of trees adjacent to the roadway that may become hazardous to the traveling public due to their size and/or location.
5. Maintaining a recovery zone for vehicles that may leave the travel surface.

   (Exhibits 1 and 2 identify the optimal clear zone dimensions for the safety of the traveling public, including OHO equipment employed in snow and ice maintenance operations. OHO may not always be able to maintain the optimal clear zone, where mowing operations will need to occur outside the dedicated or prescriptive right-of-way.)

B. Frequency

1. Tractor mowing begins in April with the objective of making a pass every four to six weeks. The primary purpose of the tractor mower is to maintain clear sight distance, keep drainage swales open, and clear the recovery area of vegetation, brush, and stumps. Mowers will make a single pass while vegetation is growing rapidly. They will then make a double pass during the slower summer months, except for areas specifically exempt for Rural Roads per section III.B.2.

2. Boom mowers will mow banks and behind guardrail yearly, or more often where sight distance is a major issue. OHO may mow other locations once every two to four years due to scheduling, weather, or equipment availability.

3. Tree trimming begins early December and continues through mid-April. OHO inspects roads to identify overhanging limbs, sight distance issues at intersections, dead trees, and trees affected by scheduled road improvements. Tree trimming will continue to a lesser extent throughout the remainder of the year, as OHO identifies issues when trees are in full foliage, after storm damage, or upon receipt of citizen complaints.

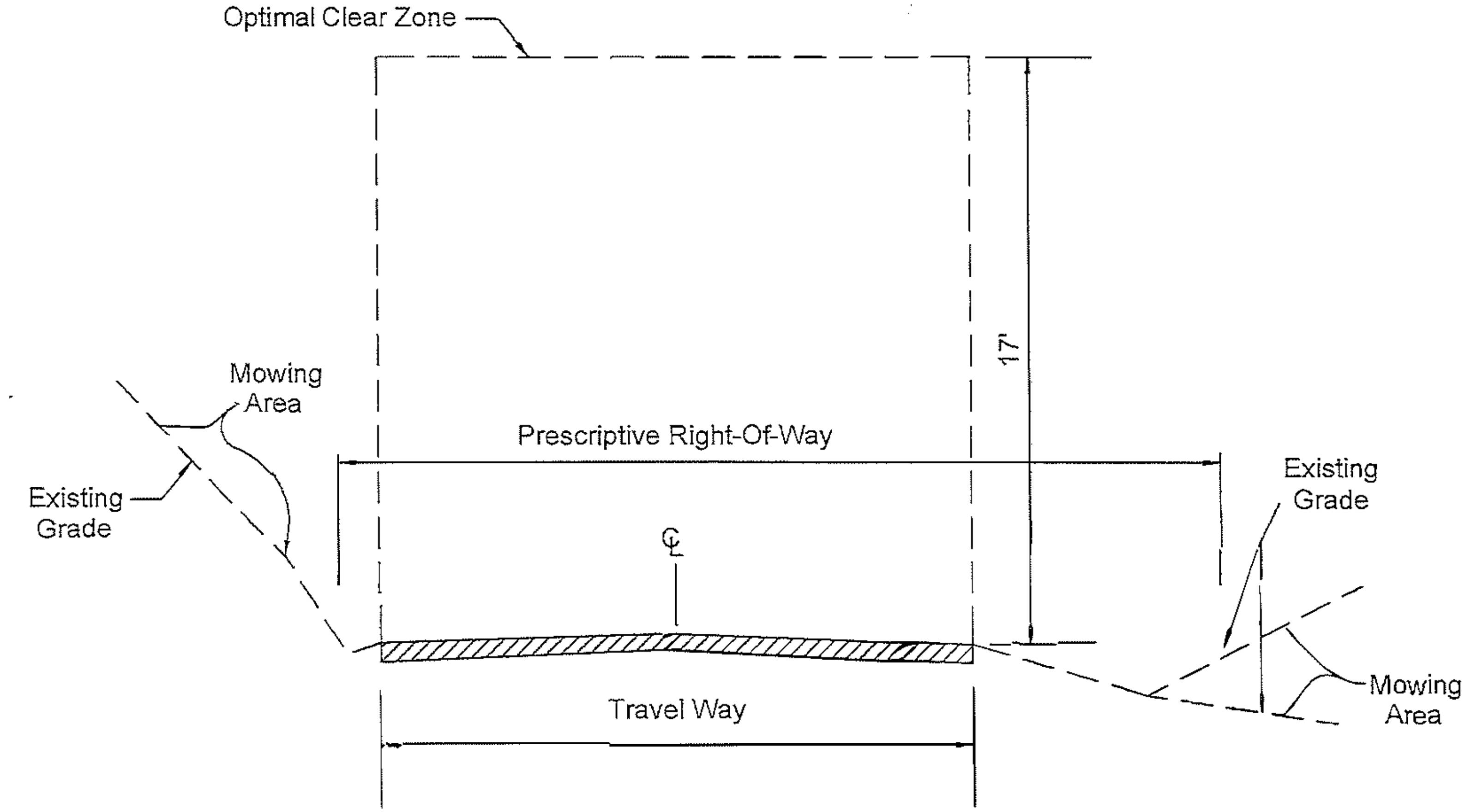
C. Property Owner Requests - OHO respects the rights of property owners and understands that some property owners may request assistance from its workforce to provide maintenance of roadside vegetation.

1. OHO does not mow outside the right of way if the area is mowed by the property owner.

2. OHO approves "no mow" requests along individual properties on a case-by-case basis if the property owner maintains their frontage to OHO standards, for the safety of all who utilize the road network. For these cases, the property owner must complete a *No Mow Request* form which must be approved by the Division of Public Works.

3. OHO approves requests to mow farther off the road edge on a case-by-case basis, when there is a definitive safety benefit to the County, such as increasing sight distance, enlarging the recovery area, or eliminating overhanging trees. For these cases, the property owner must complete a liability waiver before OHO equipment may enter upon private property.

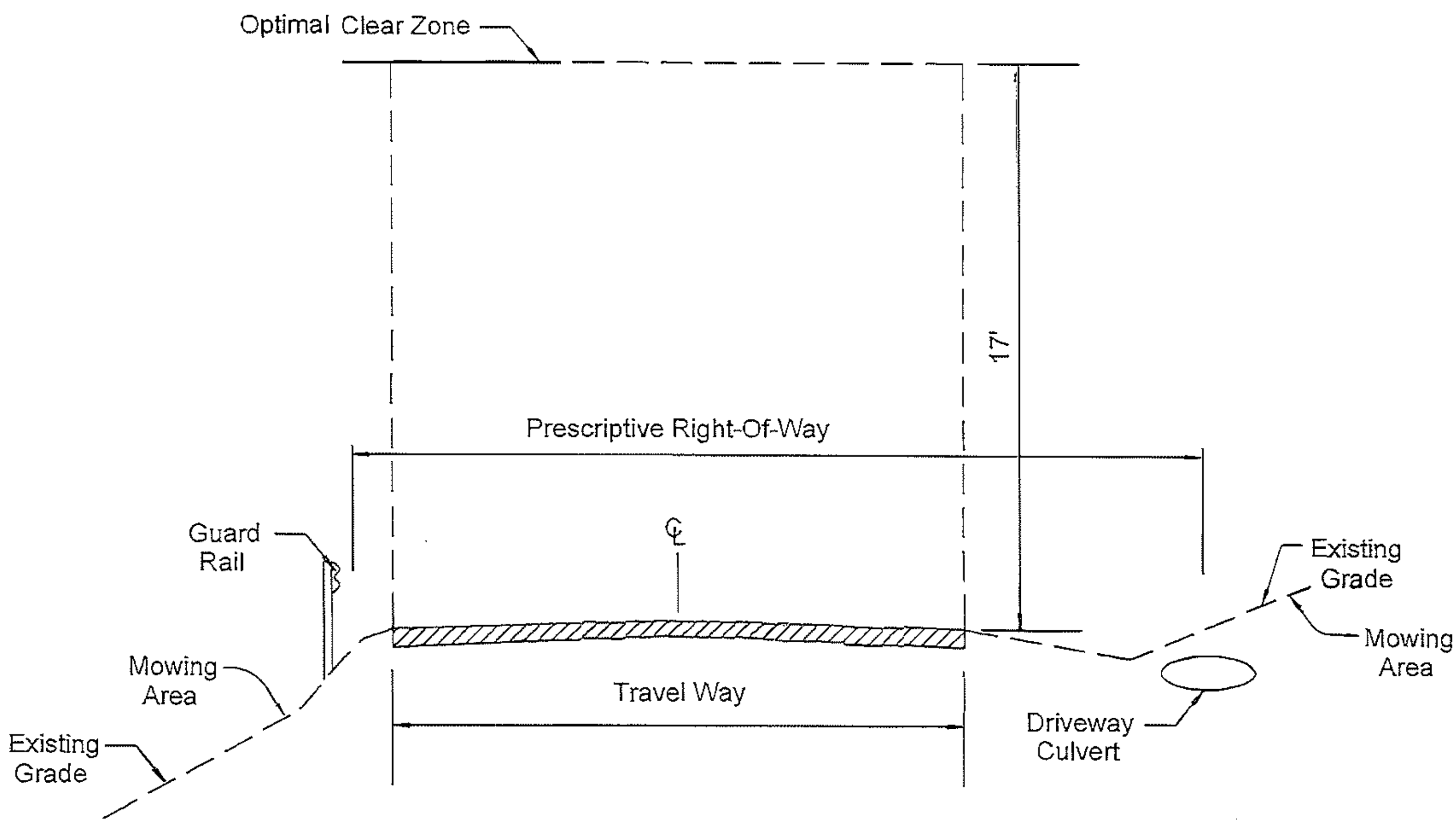
EXHIBIT 1



TYPICAL CLEAR ZONE

NOT TO SCALE

EXHIBIT 2



TYPICAL CLEAR ZONE

NOT TO SCALE

RUSTIC ROADS COMMISSION
FREDERICK COUNTY, MARYLAND

30 North Market Street, Third Floor Frederick, Maryland 21701 (301) 600-1149

Recommendations for Tractor and Boom Mowing for Vegetation Control SOP

The current SOP, Tractor and Boom Mowing Policy for Vegetation Control, appears inappropriate for roads in the Rustic Roads Program. The use of roadside vegetation along low-traffic, low-speed rural roads can be a highly effective strategy for reducing speeds and improving safety, provided it is thoughtfully planned and maintained. The combination of native plants, proper placement, and an understanding of local traffic behaviors can transform a Rustic Road into a safer and more visually appealing space, encouraging both drivers and pedestrians to interact with their environment.

It is recommended that a new SOP be developed that considers the following:

Recommendations:

1. Minimize Disturbance: Use the least disruptive methods for mowing, trimming, and clearing to reduce soil compaction, erosion, and habitat loss. Keeping mower tires on the road surface will reduce the possibility of gouging the roadside or mowing excessively deep from the road edge, while also helping to reduce soil compaction.
2. Allow Trees and Shrubs to Mature: Where safe, allow woody vegetation (especially native species) to mature to increase carbon capture.
3. Avoid Frequent Cutting of Perennials: Limit mowing of perennial grasses and forbs to allow deeper root development, which enhances soil carbon storage.
4. Maintain Vegetative Buffers: Keep dense, vegetated buffers along ditches and streams to filter runoff and prevent sedimentation.
5. Stabilize Slopes with Deep-Rooted Plants: Use native, deep-rooted species to prevent erosion and absorb excess nutrients.
6. Limit Bare Ground Exposure: After disturbance (e.g., grading), reseed with native cover to prevent erosion and nutrient runoff.
7. Train Crews in Eco-Friendly Management: Provide annual training on identifying native vs. invasive plants, pollinator habitats, and ecological mowing schedules.
8. Use Proper Equipment: Use brush cutters or flail mowers with minimal soil disturbance. Cleaning equipment can help prevent the spread of invasive seeds.
9. Track Vegetation Changes: Document changes and establish long-term maintenance plans to ensure ecological and safety goals are met.
10. Post Seasonal Mowing Notices: Inform the public and other departments about when and why mowing is limited to protect pollinators or habitat.
11. Coordinate with Conservation Groups: Partner with local wildlife or watershed groups for restoration, planting, or monitoring efforts.
12. Respect Adjacent Land Use: Coordinate with farmers, homeowners, and foresters to align roadside vegetation goals with surrounding land management.
13. Inclusion of the current practice of mowing 5’ or less from the edge of the public travelway on roads in the Rustic Road Program.

14. Mowing Limitations on Rustic Roads may be modified to allow mowing and spraying beyond the 5-foot/single pass limitation on Rustic Roads to address noxious weeds based on operator identification or complaint.

Rustic roads offer a valuable opportunity to enhance rural character while delivering real ecological benefits. Smart roadside vegetation management can protect wildlife, water, and climate without compromising the safety of travelers or the duties of work crews.

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	Division of Public Works Department of Highway Operations and Facility Management 355 Montevue Lane, Suite 200 Frederick, Maryland 21702		STANDARD PROCEDURES
	Effective Date:	November 21, 2017	Subject: Roadside Tree Trimming
Division Director Signature:			

Background Frederick County Office of Highway Operations (OHO), in the performance of their routine maintenance activities will be required to trim and/ or remove roadside trees. This work is regulated by the Maryland Department of Natural Resources (DNR) through the Maryland Roadside Tree Law (http://dnr.maryland.gov/forests/Pages/programapps/newrtlaw.aspx). All tree trimming and removal activities by OHO personnel are performed under the direction of a Licensed Tree Expert in accordance with applicable State laws and regulations.

Scope/ Purpose This policy will establish the standards by which tree trimming and removal along and within the Frederick County Right of Way will take place.

Responsibilities *Department Head-Department of Highway Operations and Facility Maintenance:* Shall provide program oversight, review and update this policy as required. *Superintendent Highway Operations:* Shall provide oversight of the minor changes to procedures and interpretation of State law as it pertains to this policy. *Maintenance Supervisor of Highway Operations:* Shall provide daily oversight regarding the implementation of the procedures as outlined in this policy and conduct a policy review every three (3) years or as needed. *Tree Crew Foreman:* Shall be the Licensed Tree Expert for the County responsible for determining when permits are required and obtaining them when called for. This position also provides daily supervision of the tree crew and provides technical expertise to the District crews as needed.

Procedure All work performed under this policy must be carried out under the supervision and direction of a licensed tree expert in accordance with Maryland law, Natural Resources, Title 5, Subtitle 4, Part I, Roadside Trees and Roadside Tree Regulations as defined in COMAR Section 08.07.02.01, Roadside Tree Care (Attachments #1 and #2).

1. A permit to prune or cut down a tree shall be required unless:
    a. The tree is uprooted or its branches are broken to contact telephone, telegraph, electric power or other wires carrying electricity, or if the tree or its branches are an immediate danger to people or property.
2. When required, Tree Crew Foreman will obtain permits for all tree removal or pruning performed by County personnel.
    a. For removed trees, the replanting of the replacement tree shall be the responsibility of the adjacent property owner.
3. Notify adjacent property owner(s) in advance of work. Confirm that wood can be left on site (in handling links) or remove wood at the conclusion of the work.
4. Follow the Standard Operating Procedures detailed in Tree Removal and Trimming (attachment #3).

NATURAL RESOURCES
TITLE 5. FORESTS AND PARKS
SUBTITLE 4. TREES AND FOREST NURSERIES
PART I. ROADSIDE TREES

§ 5-401. "Roadside tree" defined

In this subtitle, "roadside tree" means any tree or shrub growing within the right-of-way of any public road. (An. Code 1957, art. 66C, § 359; 1973, 1st Sp. Sess., ch. 4, § 1; 2009, ch. 289; 2012, ch. 66, § 6.)

§ 5-402. Powers of Department generally; establishment of State forest nurseries

The Department may plant trees along the roadsides, make rules and regulations governing the planting, care for and protect any roadside tree, and establish one or more State forest nurseries for the propagation of trees for any roadside planting.(An. Code 1957, art. 66C, § 358; 1973, 1st Sp. Sess., ch. 4, § 1; 2009, ch. 289.)

§ 5-403. Plans for planting or care of trees

(a) Application. -- If the governing body or the road supervisors of any county of the State, the Department of Transportation, the council of any municipality, or any organization or person applies to the Department to plant, care for, or protect any roadside tree, the Department shall evaluate the application and inform the applicant concerning the advisability of the requested planting, care, or protection. If, in the judgment of the Department, the requested planting, care, or protection is advisable, the Department shall prepare and submit to the applicant a plan for the same, including an estimate of the cost.

(b) Approval and implementation of plan. -- Any plan to plant, care for, or protect roadside trees may not become operative until the applicant approves the plan and has guaranteed to the Department the cost of the work. When the applicant approves a plan the Department has prepared, and the applicant has guaranteed payment of the cost in a manner satisfactory to the Department, the Department shall perform, or cause to be performed, the specified planting, care, or protection of roadside trees.

(c) Payment of unexpended balances. -- The Department, without being requested as provided in subsection (a) of this section or guaranteed as provided in subsection (b) of this section, may plant, care for, and protect roadside trees and pay for the work out of any unexpended balance of the amount appropriated for the purposes of this subtitle. However, no tree may be planted under the provisions of this section without the consent and approval of the owner of the land on which planted.

(d) More stringent local law allowed. -- Except as provided in subsection (e) of this section, a county or municipality may adopt a local law or ordinance for the planting, care, and protection of roadside trees that is more stringent than the requirements of §§

5-402 and 5-406 of this subtitle if the local law or ordinance does not conflict with the provisions of §§ 5-402 and 5-406 of this subtitle.

(e) Exceptions. -- A county or municipality may not adopt a local law or ordinance for the planting, care, and protection of roadside trees that applies to:

(1) The cutting or clearing of public utility rights-of-way or land for electric generating stations licensed under § 7-204, § 7-205, § 7-207, or § 7-208 of the Public Utilities Article, provided that:

(i) Any required certificates of public convenience and necessity have been issued in accordance with § 5-1603(f) of this title; and

(ii) The cutting or clearing of the forest is conducted so as to minimize the loss of forest;

(2) The routine maintenance of public utility rights-of-way; or

(3) The cutting or clearing of public utility rights-of-way or land for new transmission or distribution lines.

(f) Stop work order. -- A county or municipality that adopts a local law or ordinance in accordance with subsection (d) of this section may issue a stop work order against any person that violates any provision of the local law or ordinance. (An. Code 1957, art. 66C, §§ 360-362; 1973, 1st Sp. Sess., ch. 4, § 1; 2009, ch. 289; 2010, ch. 52; ch. 72, § 5; 2014, ch. 45.)

§ 5-404. Authority of enforcement

(a) Forest wardens and others. -- Forest wardens and other persons having police powers in the State, in addition to their regular duties, shall enforce the law for the care and protection of roadside trees. In the enforcement of these laws, they possess the same powers as a peace officer to arrest with a warrant.

(b) County or municipality. -- The Department may authorize a county or municipality to enforce §§ 5-402 and 5-406 of this subtitle.

§ 5-405. Payment by Department to forest warden for making required examinations, planting and care of trees, etc.; reimbursement of Department by applicant for payments

For his services in making examinations, as provided in § 5-403(a) of this subtitle, the Department shall pay the forest warden upon presentation and approval of his accounts with vouchers, for services in planting roadside trees, trimming, spraying, or otherwise caring for existing roadside trees, as provided in § 5-403(b) of this subtitle. The applicant who guarantees the cost of work shall reimburse the Department for the services of the forest warden and his helpers upon presentation of the forest warden's accounts with vouchers, and upon the approval of the Department. The applicant shall pay for the forest warden's services in examining conditions serving as a basis for permits applied for under § 5-406 of this subtitle, for issuing permits, and for supervising work authorized by the permits. The Department shall determine the rate to be paid under this section. (An. Code 1957, art. 66C, § 364; 1973, 1st Sp. Sess., ch. 4, § 1; 2004, ch. 25, § 6.)

§ 5-406. Permit to cut down or trim trees; exceptions; prohibited conduct without permit; penalty

(a) Application for permit required. -- Except as provided in subsection (b) of this section, any person who desires to cut down or trim any roadside tree shall apply to the Department for a permit.

(b) Exceptions. --

(1) A person may remove a tree or its branches without first obtaining a permit from the Department if the tree is unrooted or its branches broken so as to contact telephone, telegraph, electric power, or other wires carrying electric current, or if the tree or its branches endanger persons or property.

(2) A tree may be cut down and removed by an abutting landowner for the landowner's own use without first obtaining a permit if the tree is standing within the right-of-way of a public road which has not been surfaced with either stone, shell, gravel, concrete, brick, asphalt, or other improved surface.

(c) Prohibited conduct. -- A person may not cut down, trim, mutilate, or in any manner injure any roadside tree, except as authorized by this section, without a permit from the Department.

(d) Restriction by county or municipality to issue building permit. -- A county or municipality may not issue a building permit to an applicant for any clearing, construction, or development that will result in the trimming, cutting, removal, or injury of a roadside tree until the applicant first obtains a permit from the Department in accordance with this section.

(e) Penalty. -- A person who trims, cuts, removes, or injures a roadside tree in violation of a regulation adopted under § 5-402 of this subtitle or a permit issued under this section or who fails to obtain a permit as required by this section is liable for the imposition of a penalty:

(1) Not exceeding $ 2,000 for a first offense; and

(2) Not exceeding $ 5,000 for a second or subsequent offense. (An. Code 1957, art. 66C, § 365; 1973, 1st Sp. Sess., ch. 4, § 1; 2009, ch. 289.)

§ 5-407. Signs and advertisements along public highways and on public property

(a) State Highway Administration may authorize placing advertisements along public highways. -- The State Highway Administration may grant to any person the right to place any advertisement, sign, notice, or other writing along or upon the public highways of the State to be used only in conjunction with direction or danger signals, and subject to the limitations and restrictions imposed at the time the permit is granted. A permit may not be issued unless the need for the direction or danger signal to be erected is clearly demonstrated to the satisfaction of the State Highway Administration. Any person doing an act otherwise prohibited in this section, by virtue of a permit issued by the State Highway Administration, is immune from prosecution.

(b) Special provisions as to Kent and Queen Anne's counties. -- In Kent and Queen Anne's counties, the respective county boards of education may exhibit or display any advertisement, sign, notice, writing, or other device for the purpose of promulgating the safety of students, on or abutting any road or highway which passes near any school. However, these signs may not be displayed farther than 300 yards from any school and any designation of the donor may not comprise a space of more than 2 square feet on the sign.

(c) Placing advertisement upon public highway or private property of another without consent prohibited. -- A person, without first obtaining the written consent of the owner, may not paint, put, or fix any advertisement, sign, notice, or other writing, other than a notice posted pursuant to law, on or to any stone, tree, fence, stump, pole, building, or other structure which is in or upon either the public highway or property of another, or procure, direct, or induce the painting, fixing, or placing of the advertisement or sign.

(d) Presumption of liability of advertisement. -- For the purpose of enforcing this section, the presence of any advertisement, sign, notice, or other writing, other than a notice posted pursuant to law, upon the public highway or private property adjacent to it constitutes prima facie evidence that it was painted, placed, fixed, or erected at the direction of, or with the consent and approval of, the party or his agent or representative in the State whose name, business, location, or merchandise is advertised thereon. (An. Code 1957, art. 66C, § 366; 1973, 1st Sp. Sess., ch. 4, § 1; 1974, ch. 864, § 3.)

§ 5-408. Use of trees for planting on State forest reserve

Any trees grown in State nurseries, not required for roadside planting, may be used for planting on the State forest reserve or furnished to any landowner of the State at not more than the cost of production. The trees shall be planted for conservation purposes according to plans approved by the Secretary under rules and regulations promulgated by the Department.

§ 5-409. Liability to aggrieved parties for cutting, burning, or injuring merchantable trees or timber

(a) Written permission of owner required; damages. -- Any person, his aiders, abettors, and counsellors, who willfully, negligently, recklessly, wrongfully, or maliciously enters upon lands or premises of another without written permission of the owner of the lands or premises, in order to cut, burn, or otherwise injure or destroy, or cause to be cut, burned, or otherwise injured, or destroyed, any merchantable trees or timber on the land is liable to the party injured or aggrieved in an amount triple the value of the trees or timber cut, burned, or otherwise injured or destroyed, plus the costs of any surveys, appraisals, attorney fees, or court fees in connection with the case. The damages are recoverable in a civil action, as in any other case.

(b) Display of written permission. -- At the request of a law enforcement officer, a person on the lands and premises of another engaged in any act specified in subsection (a) of this section shall display the written permission of the owner.

(c) Exceptions. -- Notwithstanding the provisions of this section, the following shall obtain the permission of an owner before engaging in any act specified in subsection (a) of this section, but are not required to obtain the permission in writing or to display the written permission as provided in subsection (b) of this section:

(1) A public service company, as defined in § 1-101 of the Public Utilities Article; and

(2) An employee of the Department of Public Works or roads board of any county or municipality, or the State Highway Administration, performing roadside maintenance. (An. Code 1957, art. 66C, § 368; 1973, 1st Sp. Sess., ch. 4, § 1; 1980, ch. 173; 1990, ch. 6, § 2; 1996, ch. 415; 1998, ch. 653; 2010, ch. 52.)

§ 5-410. Acquisition of land for establishment of State forest nurseries

The Department may acquire land out of money standing to the credit of the Forest Reserve Fund for the establishment of any State forest nursery to grow forest trees for planting on State reserves and distribution to private landowners to encourage tree planting under the rules and regulations it promulgates. ()An. Code 1957, art. 66C, § 369; 1973, 1st Sp. Sess., ch. 4, § 1.)

§ 5-411. Levies and appropriations by counties for tree planting and care

A county may levy and appropriate money for purposes of tree planting, care of trees, and forest protection, improvement, management, and purchase.
(An. Code 1957, art. 66C, § 350; 1973, 1st Sp. Sess., ch. 4, § 1.)

Title 08 DEPARTMENT OF NATURAL RESOURCES
Subtitle 07 FORESTS AND PARKS
Chapter 02 Roadside Tree Care
Authority: Natural Resources Article, §§5-209 and 5-406, Annotated Code of Maryland

08.07.02.01

.01 Purpose.

The purpose of these regulations is to implement Natural Resources Article, §§5-401—5-406, Annotated Code of Maryland, to ensure the proper care of roadside trees in the interest of promoting and maintaining healthy trees and safe, unobstructed, and aesthetically pleasing public roads and rights-of-way.

08.07.02.02

.02 Definitions.

A. In this chapter, the following terms have the meanings indicated.

B. Terms Defined.

(1) "Director" means the Director of the Maryland Forest Service, a unit of the Department of Natural Resources, or the Director's authorized representative.

(2) "Dripline" is a line extending from the outer reaches of a tree crown vertically to the ground.

(3) "Forest Service" means the Maryland Forest Service.

(4) "Licensed tree expert" means a person licensed under Natural Resources Article, §5-415 et seq., Annotated Code of Maryland.

(5) "Person" includes the State, a county, municipal corporation, or other political subdivision of the State, or their units, or an individual, receiver, trustee, guardian, executor, administrator, fiduciary, or representative of any kind, or a partnership, firm, association, public or private corporation, or other entity.

(6) "Pesticide" means a:

(a) Chemical or biological preparation used to kill, inhibit, or regulate growth on targeted plants, their spores or seed, including:

(i) Herbicides,

(ii) Insecticides,

(iii) Tree growth regulators, and

(iv) Fungicides;

(b) Substance or mixture of substances intended for:

(i) Preventing, destroying, repelling, or mitigating pests,

(ii) Use as a plant regulator, defoliant, or desiccant, or

(iii) Use as a spray adjuvant such as a wetting agent or adhesive.

(7) "Public road" means a road the title to which, or the easement for the use of which, is vested in a public body or governmental agency.

(8) "Recommended tree list" means a list of trees approved by the Forest Service and those recommended by the Forest Service that are suitable for planting on specific sites and for specific conditions within the right-of-way of a public road.

(9) "Right-of-way of a public road" means that land the title to which, or an easement for which, is held by the State, county, or a municipality for use as a public road.

(10) "Roadside tree" or "tree" means a plant that has a woody stem or trunk that grows all, or in part, within the right-of-way of a public road.

(11) "Roadside tree care expert" means an individual representing a governmental agency who:

(a) Is designated to supervise that government's roadside tree planting and maintenance operations;

(b) Has passed the Forest Service's examination for Roadside Tree Care Experts; and

(c) Has been approved by the Forest Service as qualified to supervise that government's tree care program.

(12) "Tree care" means:

(a) Removal of a roadside tree;

(b) Planting or maintenance, or both, of a roadside tree;

(c) Application of pesticide to a roadside tree; or

(d) Treatment that may affect the health or growth of a roadside tree.

(13) "Tree care crew" means a unit from a public or private entity whose purpose is to maintain roadside trees as defined in §B(10) of this regulation, characterized by a service truck and supervised by a licensed tree expert.

(14) "Tree care standards" means tree care approved by the Forest Service and in accordance with the roadside tree care standards set forth in Regulations .07—.09 of this chapter.

08.07.02.02-1

.02-1 Incorporation by Reference.

A. In this chapter, the following document is incorporated by reference.

B. Document Incorporated. American Standard for Nursery Stock, ANSI Z60.1-2004, (American Nursery & Landscape Association, May 12, 2004).

08.07.02.03

.03 Permit Required.

A. A person may cut down or prune a roadside tree without a permit if the tree:

(1) Is uprooted or its branches are broken to contact telephone, telegraph, electric power, or other wires carrying electricity, or if the tree or its branches are an immediate danger to person or property; or

(2) Stands within the right-of-way of a public road which has not been surfaced with either stone, shell, gravel, concrete, brick, asphalt, or other improved surface material, and only if the tree is cut down and removed by, or at the request of, the abutting landowner for the landowner's own use.

B. Except as provided in §A of this regulation, a person shall obtain a permit to perform tree care to a roadside tree.

C. A person providing tree care under §A(1) of this regulation shall inform the Forest Service, by calling or writing within 1 week of the action taken, of the place or general area where that action was taken, and provide a proposed plan to upgrade the work, if necessary, to tree care standards. The Forest Service shall approve, modify, or reject a proposed plan within 2 weeks after an examination of the work.

08.07.02.04

.04 Types of Roadside Tree Care Permits.

A. Roadside tree care permits are of two types:

(1) Permits issued for a specific tree or group of trees for specific tree care operations for a term not exceeding 1 year from the date of issuance; and

(2) Permits issued for comprehensive and continuing programs of general tree care such as those administered by State agencies, counties, municipalities, corporations, and public utilities.

B. Permits issued under §A(2) of this regulation are issued only for specified types of tree care, based upon the skills of those supervising the program.

C. For tree care not authorized in a permit issued under §A(2) of this regulation, a permittee shall obtain a separate tree care permit.

D. Permits are issued for a calendar year, and may be renewed upon application.

08.07.02.05

.05 Issuance of Roadside Tree Care Permits.

A. A request for a roadside tree care permit:

(1) May be made by:

(a) A person owning title to the land on which the tree or trees are located,

(b) A governmental entity possessing an easement for the public road right-of-way in which the tree or trees are located,

(c) A person responsible for providing tree care to the tree or trees,

(d) A person whose property abuts the right-of-way at the point at which the tree or trees are located,

(e) A public utility, or

(f) An authorized agent of one of the entities in §A(1)(a)—(e) of this regulation; and

(2) Shall be made by an applicant to the appropriate office of the Forest Service.

B. For permits authorizing continued tree care programs under Regulation .04A(2) of this chapter, an examination is necessary only as specified in the permit. An examination is not required for the renewal of the permit.

C. The Forest Service may issue a permit for tree care if the applicant shows that the proposed tree care will meet one of the following conditions:

(1) Eliminate a hazard to property, public safety, or health;

(2) Improve or prevent a deteriorated tree condition; or

(3) Improve the general aesthetic appearance of the right-of-way.

D. Unless exempted by the Forest Service, if a tree is removed it shall be followed by replanting of a species on the recommended tree list that is suitable to the location.

E. Roadside tree care permits shall specify:

(1) The name and address of the permittee;

(2) The area where the tree care will occur;

(3) The particular tree or trees involved;

(4) The type of tree care permitted;

(5) The term of the permit;

(6) Whether supervision of the tree care is required; and

(7) Limitations or conditions on the tree care or planting considered advisable by the Forest Service.

F. If the Forest Service denies a permit, the Forest Service shall notify the applicant of the reasons for denial within 10 days of receipt of the application for the permit.

G. The Forest Service may:

(1) Modify the terms and conditions of a permit in accordance with provisions and objectives of the roadside tree care laws and regulations; or

(2) Suspend or cancel a permit for a violation of a:

(a) Condition of the permit, or

(b) Provision of Natural Resources Article, §5-401 et seq., Annotated Code of Maryland, or implementing regulation.

H. Request for Hearing.

(1) A person whose request for a roadside tree care permit is denied, or whose roadside tree care permit is suspended or revoked, has the right to be heard regarding the denial or suspension or revocation of the permit, after submitting a request in writing not later than 10 days after the date on which the denial or suspension or revocation notice is served.

(2) The Director shall schedule a hearing within 10 days from receipt of a request and render a decision within 10 days from the date of the hearing.

08.07.02.06

.06 Fees.

A. Fees for roadside tree care permits are calculated according to the following schedule:

(1) If Forest Service supervision of the proposed tree care is required for a permit under Regulation .04A(2) of this chapter, the fee for issuing the permit, and for supervising work authorized by the permit, is:

(a) $2,500 per year per tree care crew, or

(b) $250 per month per tree care crew;

(2) The fee for issuing the permit and for supervising work authorized by the permit under Regulation .04A(1) of this chapter is $25; and

(3) A fee is not required for a tree care permit issued to an applicant that is a government agency.

B. If a permit request is denied, a fee is not required.

C. Billing for tree care crews is made either annually or quarterly, at the option of the tree care crew.

08.07.02.07

.07 Roadside Tree Care Standards.

A. General Requirements. Unless the Forest Service grants an exception, treatment of roadside trees authorized by permit shall be performed according to the following standards:

(1) Branches to be removed shall be cut back to a live lateral branch at least 1/3 the diameter of the severed branch;

(2) Cuts shall be made sufficiently close to the trunk or parent limb without cutting into the branch collar or leaving a protruding stub;

(3) Proper pruning techniques shall be followed at all times;

(4) Except when directed by the Forest Service, pruning cuts shall be left unpainted for aesthetic reasons;

(5) If the painting of cuts is required, only materials nontoxic to the cambial layer shall be used;

(6) Dangerous deadwood and broken limbs which are located within the scope of the work as defined in the permit shall be removed;

(7) Except when authorized by the Forest Service or when the tree is being removed, climbing hooks or spurs are prohibited;

(8) Chips resulting from roadside tree care may:

(a) Be broadcast on a right-of-way except in ditches, waterways, turf, and surfaced areas, and

(b) Not exceed 6 inches in depth on the right-of-way;

(9) The wrapping or winding of cable, wires, and other attachments around a tree, fastening attachments to a tree to bruise or injure a tree, or cavity work performed on a tree, is prohibited; and

(10) When trees are removed, replacement of those trees according to a plan may be required by the Forest Service.

B. Tree Clearance for Overhead Facilities.

(1) In addition to the requirements of §A of this regulation, a person who trims a tree to provide clearance for utility wires, cables, or other facilities shall:

(a) Allow sufficient clearance for 2 years growth normally expected after trimming, unless otherwise directed by the Forest Service;

(b) Take into account the health of the tree; and

(c) Make proper cuts that direct growth away from overhead wires and facilities in compliance with safety standards and government regulations.

(2) If a trimmed tree dies within 1 year or is in poor condition of growth as a result of that trimming, the permittee shall, if required by the Forest Service, remove the tree and plant replacement trees.

(3) Replacement trees shall be:

(a) Furnished by the permittee;

(b) In good condition;

(c) Of a recommended size and species; and

(d) Properly planted at locations to be determined by the Forest Service.

C. Ground Disturbance Requirements.

(1) The requirements set forth in this section:

(a) Are intended to protect roadside trees during construction, installation, and maintenance of a structure requiring excavation;

(b) Apply to underground utilities such as:

(i) Sewers,

(ii) Water and gas pipes,

(iii) Storm drains,

(iv) Electric, telephone, and television cables or conduits,

(v) Sidewalks,

(vi) Driveways, or

(vii) Roadways or similar structures.

(2) A permittee shall take all necessary measures to protect roadside trees from damage during construction and associated activities.

(3) Damage sustained by a tree, such as broken limbs, roots, or scarred trunks, including compaction damage, shall be repaired by the permittee.

(4) The Forest Service shall supervise the measures taken to protect and repair roadside trees under this section.

D. Protection of Tree Roots.

(1) When an underground project subject to §C of this regulation encounters the roots of a roadside tree, a permittee, in accordance with the guidelines in §D(2)-----(15) of this regulation or other criteria approved by the Forest Service, shall tunnel or bore under the tree or modify the project to protect the tree's root system.

(2) For trees under 6 inches in diameter as measured 4 1/2 feet above average ground level, all machine digging shall stop at the dripline of the tree, or where specified by the Forest Service.

(3) For trees over 6 inches in diameter as measured 4 1/2 feet above average ground level, all machine digging shall stop when roots of 1 inch or more in diameter are encountered, or when specified by the Forest Service.

(4) Roots 1 inch or more in diameter may not be cut without approval of the Forest Service.

(5) A tunnel or other method of modification of the project under or around the tree shall be used if considered necessary by the Forest Service.

(6) The procedure noted in §D(5) of this regulation also shall be used to approach the tree from the opposite side.

(7) At least 24 inches of undisturbed earth shall remain over the tunnel or bore, or above other type of installation.

(8) For operations using shallow trenching techniques up to 12 inches deep, care shall be taken to minimize root damage and protect the trunk of the tree.

(9) Roots 1 inch or larger, damaged during construction, shall be sawed off close to the tree side of the ditch. Clean cuts shall be made at all times.

(10) Installations affecting roadside trees shall be completed in as short a time as possible to prevent the drying out of exposed roots.

(11) If considered necessary, the exposed root area within the ditch shall be watered and fertilized as directed by the Forest Service.

(12) Tunnels shall be refilled and the soil tamped tightly to original firmness.

(13) Trenches shall be filled to achieve and maintain original grade.

(14) Excess soil shall be removed from the site or disposed of as directed by the Forest Service.

(15) Unless otherwise directed by the Forest Service, the ground shall be fertilized and reseeded, cover shall be restored, and other procedures shall be followed as necessary to prevent erosion around trees.

E. Violations of Roadside Tree Standards.

(1) The Forest Service may require a person who fails to comply with §C or D of this regulation to:

(a) Remove and replace a tree which dies within 1 year after the treatment activity is completed;

(b) Document for 3 years the condition of a tree which shows decline within 1 year after the treatment activity is completed; and

(c) Remove and replace a tree which dies after 3 years following the completion of the treatment activity, if the tree has been the subject of the documentation in §E(1)(b) of this regulation.

(2) The value of a tree to be replaced is determined as of the date of the violation.

08.07.02.08

.08 Use of Pesticides.

A. The use or application of a pesticide to a tree on a public road right-of-way in the State is controlled as follows:

(1) A person applying a pesticide to a roadside tree shall have acquired certification and licensure required by the Maryland Department of Agriculture and shall adhere to regulations in COMAR 15.05.01;

(2) A person applying a pesticide shall apply only those pesticides registered for that use by the U.S. Environmental Protection Agency and the Maryland Department of Agriculture, and shall follow the manufacturer's label directions for proper use;

(3) Before the time of pesticide application, the Forest Service shall be notified by a permittee of the approximate time and place of application;

(4) Except when authorized by the Forest Service, a tree may not be treated with herbicides unless it is 6 feet or less in height;

(5) Dead plant material resulting from the application of an herbicide shall be removed if necessary for aesthetic or safety reasons, or both;

(6) Reasonable precautions shall be taken to:

(a) Avoid the use of herbicides on vegetation which contributes to soil retention, particularly at highway cuts and fills and other areas with steep slopes, and

(b) Prevent the pollution of streams, and damage to adjoining properties.

08.07.02.09

.09 Roadside Tree Planting.

A. Trees to be planted on a public road right-of-way are subject to the conditions in §§B and C of this regulation, in addition to conditions imposed by local ordinances.

B. Trees shall be of a species and variety from the recommended tree list, and shall conform to the American Standard for Nursery Stock.

C. Roadside tree planting shall comply with a planting plan approved by the Forest Service, which may include:

(1) Stump removal;

(2) Size and type of planting stock;

(3) Planting specifications;

(4) Spacing;

(5) Species;

(6) Proximity to overhead wires;

(7) Care and maintenance; and

(8) Other site considerations.

08.07.02.10

.10 Penalties.

Noncompliance with the provisions of this regulation constitutes a violation of law subject to the penalties provided in Natural Resources Article, §5-1301, Annotated Code of Maryland.

08.07.02.9999

Administrative History

Effective date: March 16, 1977 (4:6 Md. R. 505)
Chapter revised effective February 9, 1979 (6:3 Md. R. 149)
Regulation .06A amended effective June 27, 1980 (7:13 Md. R. 1277); September 1, 1980 (7:17 Md. R. 1669); July 5, 1982 (9:13 Md. R. 1350); June 30, 1986 (13:13 Md. R. 1490); March 20, 1989 (16:5 Md. R. 627); September 2, 1991 (18:17 Md. R. 1918)
Regulation .07A amended effective July 5, 1982 (9:13 Md. R. 1350)
Regulation .07A, C amended effective October 22, 1984 (11:21 Md. R. 1810)
Regulations .02—.09 repealed and new Regulations .02—.09 adopted effective January 31, 1994 (21:2 Md. R. 97)
Regulation .02B amended effective July 5, 2004 (31:13 Md. R. 993); March 23, 2009 (36:6 Md. R. 489)
Regulation .02-1 adopted effective July 5, 2004 (31:13 Md. R. 993)
Regulation .02-1B amended effective September 26, 2005 (32:19 Md. R. 1588)
Regulation .05 amended effective September 26, 2005 (32:19 Md. R. 1588)
Regulation .06A amended effective July 5, 2004 (31:13 Md. R. 993)
Regulation .09B amended effective July 5, 2004 (31:13 Md. R. 993)

Attachment #3

Frederick County Highway
Standard Operating Procedures & Guidelines

Tree Removal and Trimming

Objective: Remove hazardous trees and/ or limbs for site and safety of the public

PPE: Wear the required Personal Protective Equipment

- Safety glasses
- Hard hat
- Gloves
- Chaps
- Hearing protection
- Long sleeve shirt (optional)
- Face shield (optional)

Equipment: Including but not limited to

- Chipper
- Truck
- Chain saw
- Pole saw
- Gas/oil Mix
- Files
- Saw tool
- Bucket or platform (optional)
- Rope (optional)

Procedures & Guidelines

1. Determine if tree permit is required & obtain in advance if needed
2. Note reason (Work request, routine maintenance, etc.) for work in daily log
3. Document existing condition of site (photo documentation).
4. Remove underbrush with boom mower, if needed.
5. Inspect work zone
    a. Look for wires/utilities
    b. Look for other hazardous trees
    c. Look for other obstructions in work zone; signs, mailbox, fence etc.
6. Establish MOT for work zone (could be full or partial closure).
7. Call in closed road to let office know if emergency equipment can get through
8. Inspect saws (gas/oil)
9. Cut tree making sure no one is in the area of fall
10. Trim trees to road side tree specifications
11. Chip brush
12. Clean up area for limbs, saw dust, etc.
13. Remove MOT
14. Photo documentation of completed work
15. Inform supervisor of progress and/or repairs, equipment, or issues that need to be addressed
16. Before & after pictures to be stored on "R" drive organized by street name.

RUSTIC ROADS COMMISSION
FREDERICK COUNTY, MARYLAND

30 North Market Street, Third Floor Frederick, Maryland 21701 (301) 600-1149

Recommendations for the Roadside Tree Trimming SOP

The current SOP, Roadside Tree Trimming, appears inappropriate for roads in the Rustic Roads Program.

The intent of the Roadside Tree Trimming SOP is to protect, conserve and enhance the County's roadside trees through proper tree care and ensure compatibility of trees with dependable public utility systems while providing for a picturesque, scenic and safe travel way throughout the County.
Planting trees along the edge of roads and proper tree trimming can create a natural canopy which, especially in curves or turns, produces a visual narrowing effect that results in slower traffic speeds. Studies have shown that a full tree canopy along low volume roads can also extend pavement life by reducing pavement temperatures and moisture.[1]

Frederick County shall operate in full compliance with all State and Federal tree laws to include the Maryland Roadside Tree Law (NRA 5-401-5-411).

It is recommended that a new SOP be developed that considers the following:

<u>Recommended Process:</u>

1. No live tree removal, with the exception of invasive species and hazard trees.
2. Only beneficial and necessary tree trimming, root cutting, fertilization, or other maintenance practices will be done and done correctly to roadside trees.
3. Tree hazards are documented and corrective action, including removal and replacement, is done in a timely and safe manner by trained professionals (Licensed Tree Experts or Certified Roadside Tree Care Experts).
4. When a hazard tree is removed, DPW is required to replant a native MD tree in the right location (furnished by the County) thereby avoiding future problems and conflicts with sidewalks, overhead and underground utilities, and sight distances.
5. Hazard Tree removal work must be documented by the County's Certified Roadside Tree Care Expert to include:
   Daily log: reason for tree removal
   - Documentation of existing hazard condition(s) including photos
   - Documentation of completed work including photos
   - Documentation of replanting including photos
   - Documentation of replanted tree status after 1 year including photos
   - Maintain this information in an easily accessible location
6. Replacement Trees furnished by the Couty shall be:

[1] Bhaven Naik et al, *Effects of Tree Canopy on Pavement Conditions, Safety, and Maintenance- Phase 2: (Athens, OH, Ohio University Department of Civil Engineering, 2020).*

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- In good condition
- Of a recommended size and native species
- Properly planted in a location as recommended by the Forest Service
- Inspect replanted trees after 1 year
- Remove, and replace a tree that dies within one year of replanting
- Document for 3 years the condition of a tree showing decline within 1 year

7. Roadside tree removal requested by adjacent property owner(s) must be approved by DNR and the County and follow the same guidelines.
8. Tree trimming shall always follow proper pruning techniques
    - Dangerous deadwood and broken limbs located in the scope of work shall be removed
    - Take into account the health of the tree
    - Chips from roadside tree care may be broadcast in right-of-way except in ditches, waterways, turf, and surfaced areas not to exceed 6" depth
    - Inspect trimmed trees after 1 year
    - If a trimmed tree dies within 1 year or is in poor condition as a result of that trimming, the County shall remove and replace that tree as directed by #5 & #6 above.
9. Roadside tree protection. The County shall take all necessary measures to protect roadside trees from damage during construction and associated activities, damage sustained must be repaired, if not successful the tree must be replaced by the County as directed above (#5 & #6).

Roadside Tree
A plant that has a woody stem or trunk that grows all, or in part, within the rights-of-way of a public road.
Roadside Tree Care Expert
Works for a governmental agency and supervises that agency's tree care programs and is certified by the DNR.
Licensed Tree Expert
Works in the private sector and is certified by the DNR.
Live Tree
A live tree is any tree that is actively growing, transporting water and nutrients, and carrying out physiological functions. Even if the tree is dying, it would not be considered dead until it no longer has living tissue. Dead trees are exempt from replanting requirements.
Hazard Tree
A tree or part of a tree that has a defect that makes it likely to fail and potentially cause damage or injury.

Effects of Tree Canopy on Pavement Condition, Safety and Maintenance - Phase 2

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The Ohio Department of Transportation
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Final Report

OHIO UNIVERSITY

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15. Supplementary Notes

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16. Abstract

Tree canopies are common alongside and above rural highways in Ohio. Consequently, ODOT wants to know how a tree canopy affects pavement condition and road safety. A review of published research conducted for Phase I of this study suggested that tree canopies extend the life of asphalt pavement and improve road safety. Road managers and highway officials said roadside trees were believed to negatively impact the pavement surface directly below the canopy, according to the report's survey and anecdotal accounts. These impacts included increases in moisture and temperature variation, reductions of pavement longevity, and undermined road safety. These observations have not been rigorously verified, and there is a lack of prior research on the topic. This study seeks to determine if tree canopies affect asphalt pavement in Ohio, quantify any effects, and recommend best management practices. The research was approached with controlled experiments on small plots concerning microclimate and pavement condition and observations and measurements on in-service pavements covering microclimate, pavement condition, and safety.

The net results show tree canopies substantially reduce thermal loading, snow accumulation, and moisture in light to moderate rainstorms. Canopies also increase the persistence of moisture on stretches of shaded pavement. Snow and ice persistence were controlled by drainage and compaction by traffic, rather than the presence of tree canopies. In addition, a negative relationship exists between pavement surface texture and tree cover, landscape position, and traffic loading, but the effects on surface texture were apparent only under unusual conditions. No significant effects on pavement cracking were found. Crash data showed improvements in safety that can be attributed to roadside maintenance activities (trimming and pruning), but not specifically to the removal of tree canopy. There were no conclusive effects to driving behavior that can be related to tree canopy cover. Consequently, this report concludes that neither pavement condition nor driving behavior should be considered sufficient justification for removal or pruning of tree canopies as a form of routine maintenance on Ohio's rural roadways.

17. Key Words	18. Distribution Statement
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

APPROXIMATE CONVERSIONS FROM SI UNITS

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

* SI is the symbol for the International Symbol of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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- Mr. Adam Au, P.E. – ODOT Office of Pavement Engineering,
- Mr. Matt Perlik, MS. – ODOT Office of Environmental Services;
- Mr. Eric Biehl, P.E. – ODOT Office of Materials Management, and
- Mr. Aric A. Morse, P.E. – ODOT Office of Pavement Engineering.

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1.0 EXECUTIVE SUMMARY

An integral part of Ohio's roadscape is the tree canopy cover alongside and above the pavement – abundant along a significant mileage of low-to-medium-volume roads in both urban and rural areas. Research in forest microclimates, environmental effects on pavement, and urban microclimates suggests that tree canopies affect the process of pavement degradation and the drivability of the pavement surface by altering the pavement microclimate. This study seeks to determine if/how tree canopies affect asphalt pavement in Ohio's climate, to quantify such effects, and to recommend best management practices.

The research was approached in four stages beginning with controlled experiments and progressively scaling up to real management units: First, microclimate effects were documented in small plots with basic physical properties measured under controlled conditions. Second, environmental effects on pavement condition were measured in small plots under actual road conditions to determine the contribution of tree canopies relative to other environmental factors. Third, road conditions as a function of tree coverage were compared at the scale of actual management units in the field. Fourth, safety was assessed in terms of crash data from real road sections. Data were recorded over a period of 24-months in approximately 270 permanent small plots on rural roads in Athens County, OH; and at 39 selected road sections spread across Ohio DOT's eastern districts.

The small-plot data show tree canopies substantially reduce thermal loading, reduce snow accumulation, and reduce moisture in light-moderate rainstorms, potentially extending pavement life. Canopies also increase the persistence of moisture on stretches of shaded pavement, potentially decreasing service life. Snow and ice persistence were controlled by drainage and compaction by traffic and appeared to be unrelated to presence of tree canopies. The findings from road sections at the scale of management units were akin to those observed from the small plot analysis.

Observations of small plots under natural road conditions showed a significant negative relationship between pavement surface texture and tree cover, landscape position, and traffic loading. However, the influence of tree cover on surface texture was only apparent under unusual conditions: 95% canopy cover (>90% is rare on rural roads; 0-60% cover is more usual), or in pavement surfaces >10 years old and at end of service life. Road plots under moderate canopy (40-60% cover; the majority of forest roads) showed no degradation that could be linked to presence of roadside trees. In contrast to the case of surface texture, pavement cracking was not significantly related to tree proximity or canopy cover under any circumstances.

Road sections described at the scale of management units showed no significant differences in pavement condition between shaded and unshaded sections. Pavement core samples showed greater interstitial voids under tree canopies, suggesting a canopy effect, but the small sample size prevents drawing firm conclusions at this point. Crash data showed improvements in safety that can be attributed to roadside maintenance activities (e.g. trimming and pruning), but not specifically to the removal of tree canopy. Surrogate measures of safety showed no conclusive effects to driving behavior/performance that can be related to tree canopy cover.

Recommendations: Based on these observations, it is recommended in this report that removal or pruning of tree canopies should not be practiced as routine maintenance for Ohio highways as a means of extending the life of pavement. Canopy pruning or removal should only be applied to individual trees in specific cases justified by actual tree cover and pavement data. There may also be other reasons for tree maintenance which were outside the scope of this study, including health of the tree or line of sight problems. Potential reasons for removal include >95% measured canopy cover paired with degraded pavement or presence of a demonstrably dead tree likely to fall on the road. Results from this analysis support the view that, in general, tree canopies overtop rural highways should not be removed as a means of extending the life of pavement. This is consistent with the well-known economic and suggested safety benefits accruing from roadside trees, and (hence) the enormous public support that exists for protecting trees.

2.0 PROJECT BACKGROUND

An integral part of Ohio's roadscape is the trees that are abundant along a significant mileage of roads in both urban and rural settings. These trees create canopies and they are widely valued by the public, and support is often expressed in public forums [Lohr et al., 2004; Wolf, 2005]. However, within the Ohio Department of Transportation (Ohio DOT), it has been long thought that the shading from tree canopies influences the condition, safety, and maintenance of the pavement in various ways such as accelerated pavement deterioration and limited solar heating reducing the effectiveness of deicers; tree canopies are also thought to present a safety issue from falling limbs (ODOT, 2017). The Ohio DOT's current practice is to remove the tree canopy from the roadway where practical. This practice has been widely criticized by the general public, but possible effects of the tree canopy on pavement condition and safety have not been demonstrated in a rigorous scientific/engineering study.

The research team, with funding from the Ohio DOT, completed a literature review and synthesis as Phase 1 of this project (SJN No. 135320) to gain an understanding of the potential influence of tree canopy on pavement integrity, drivable surface condition, safety, and any maintenance practices [Naik et al., 2017]. This review of published research suggested that trees extend the life of asphalt pavement by reducing radiation loading, thermal cycling, and surface moisture, and improve road safety by affecting driving behavior. However, a survey of practice by Ohio DOT road managers and anecdotal reports suggested that roadside trees were believed to negatively impact the pavement surface directly below the canopy [Naik et al., 2017]. Specifically, a tree canopy is believed to cause increases in moisture and temperature variation, subsequently impairing the pavement's structural performance. The perceived impacts included accelerated moisture damage, poor density attainment, differential rutting, and raveling; all of which are believed by road managers to reduce the pavement longevity with an undesirable increase in the maintenance and rehabilitation costs. Tree canopy alongside the roadway is also believed to undermine road safety because of reduced skid resistance due to fallen leaves, limited direct sunlight promoting formation of black ice and fog; and entire trees, and branches and/or fruits falling on passing vehicles or blocking traffic lanes.

The consensus among Ohio DOT respondents is that a minimum clearance of 30 ft (0.9 m) from the centerline on both sides – available Right-of-Way (ROW) must be maintained. Some respondents mentioned removing all trees within the ROW, while others mentioned the removal of all trees except those trees having a trunk diameter of less than 12 in (300 mm). In conditions where the ROW is limited such as embankments, hills, curves and dips, and residential areas, the edge of the roadway (white line) was used to determine the clearance area. No specifics were provided on the vertical extent of the clearance, which was dependent on the reach of available trimming equipment such as a bucket truck or "sky trimmer".

Observations on tree canopy and pavement condition have been largely indirect, so there is not enough information directly addressing the tree canopy/pavement interaction. Therefore, the question of how a tree canopy alongside and overtop the roadway affects pavement condition and road safety is ripe for scientific exploration.

3.0 RESEARCH CONTEXT

The objective of this research project was to determine the effects of tree canopy on pavement in terms of pavement condition, maintenance, and safety. More specifically, this research work attempts to fill the gap in the body of knowledge pertaining to tree canopies overtop rural roadways and their effects on the pavement surface in Ohio, which has a cool-temperate climate. The research team formulated the problem in terms of four specific questions:

1. Does pavement quality differ between canopied, partially canopied, and open-sky plots?
2. How does the effect of shading due to tree canopy compare with effects of other factors which commonly contribute to pavement deterioration?
3. Do observations of microclimate and pavement condition made at the scale of individual trees also apply at the larger scale of highways and/or byways?
4. Does a tree canopy cause changes to the pavement condition that can subsequently create hazards for drivers? If 'yes', then what factors specifically contribute to the hazards?

To answer the four specific questions above, the research team set out to verify the following testable predictions (or hypotheses):

I. Tree canopy alongside and overtop the roadway influences the pavement structure. It is predicted that there will be differences in surface condition and differential setting between sections with and without tree canopies. These differences are likely to affect the life expectancy of pavement overlays, patching, and resurfacing.

II. Tree canopies act on pavement by moderating thermal cycling. In this case, there would be less block and transverse cracking under trees.

III. Tree canopies affect pavement by catching moisture on their foliage, thereby reducing the amount of moisture reaching the pavement. The research team predicts pavement under trees will have less alligator cracking in wheel tracks than exposed pavement, less debonding, and less fine-scale cracking throughout.

IV. Where the moisture from rainfall does reach the pavement, tree canopy can reduce evaporation, thereby accelerating moisture damage and water infiltration in the pavement sub-structure. This would be supported by observation of more serious edge cracking and debonding of pavement under trees than under an open sky. There will be moisture-related differences in pavement deterioration between shaded pavements and open-sky pavements.

V. Tree canopies act on pavement by absorbing soil moisture, thereby reducing the amount of moisture reaching the pavement from below. There should be less subsidence and expansion cracking of pavement under trees than under an open sky.

VI. If tree canopies cause pavement deterioration and in turn affect road safety, then all measures of deterioration and safety are expected to be proportional to the size, age, and canopy density of overhanging trees.

VII. If tree canopies influence pavement condition, this will subsequently affect the comfort and safety of the roadway. Differences between wet/dry/slick pavement surfaces will likely affect crashes or driving behavior.

The answers to the research questions and evaluations of the testable predictions then informed the development of recommendations contained in this report on tree canopy maintenance practices to maximize pavement longevity and performance while ensuring the safety of motorists.

4.0 RESEARCH APPROACH

This research was conducted as two parallel sub-projects examining canopy effects at different scales. First a detailed comparison of small patches of pavement (the "small plot study") focused on the effects on microclimate due to canopy presence and on the contribution to pavement condition by other aspects of the road environment. The second part was a comparison of larger pavement segments in a "road section study" which included microclimate impacts, pavement condition, and safety effects at the scale of real management units. Both parts involved the selection of study sites, data collection, data analysis, and interpretation of results.

This section of the report summarizes 1. Small plot evaluation of microclimate, 2. Small plot evaluation of pavement condition, 3. Road segment evaluation of microclimate, 4. Road segment evaluation of pavement condition, and 5. Road segment evaluation of safety. In each section, the method is described, and concise results are presented. More detailed and complete descriptions of methods and results are provided in the appendices.

4.1 Small Plot Study on Effects of Tree Canopy on Pavement Microclimate.

This section presents an abridged version of the research work performed at the *small plot level* to determine how tree canopy affects the pavement microclimate. A detailed presentation of the analysis can be found in Appendix A.

4.1.1 Methods

Study Sites

Microclimate was described in experimental pavement plots established on residential streets in the City of Athens, Ohio. The plots consisted of 20 in × 20 in (50 cm × 50 cm) squares that were permanently located 20 to 40 in (50 to 100 cm) from the pavement edge. The pavement was asphalt concrete placed 2 to 8 years before, with modest slope and a surface course showing only minimal wear. Plots were established in triplets – "Under" (>95% canopy cover); "Partial" (45% to 55% canopy cover); and "Open" (no canopy cover). Plots were established under 23 trees (N = 69 plots).

Experimental trees ranged from 12 to 35 in (30 to 90 cm) in diameter; and were greater than 50 years in age. All trees had a uniformly dense, apparently healthy canopy with no obvious dead tissue. Species were typical of roadside trees in the Ohio Valley region: predominantly red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), willow oak (*Quercus phellos*), and red oak (*Quercus rubrum*), with occasional sycamore (*Platanus occidentalis*), sweetgum (*Liquidambar styraciflua*), and locust (*Robinia pseudoacacia*). Most pavement variables were measured between June and September 2018 when all trees were fully leafed, presenting the maximum canopy density. Snow and ice were surveyed in January 2018 when all trees had shed their leaves and only bare branches remained. No evergreen tree species were used.

Data

- Pavement temperature; measured sequentially in experimental plots on June 6, 2018 from before sunrise (6:05AM) to after sunset (8:52PM) with an approximately 50-minute rotation. All three plots at each tree were measured within 60 seconds.
- Pavement wetness; measured as electrical conductivity at 3 to 5-minute intervals before and during natural rain showers in mid-late summer 2018. Measurement began on dry pavement, proceeded as rain began to fall, and ended when "Under" canopy plots showed wetness values comparable to "Open" plots.
- Moisture persistence; measured by experimentally wetting and then monitoring the drying of pavement plots. One liter (34 fl oz) of water was poured onto plots equivalent to a 0.39 in (1 cm) rain event. All plots were wetted before sunrise to ensure equal temperatures under all canopy conditions. Moisture was monitored in all plots at 40 to 50-minute intervals until metered moisture levels dropped to levels observed before wetting.
- Snow/Ice accumulation; measured immediately after a storm on January 13, 2018, and at daily intervals until no snow or ice remained. Snow depth was measured visually using a plastic scale inserted into undisturbed snow. Ice was assessed on the pavement as the proportion of the study plot covered.

4.1.2 Results

Pavement Temperature.

Figure 1 shows two representative examples of pavement temperature measured over the course of a day. The pavement was coolest before dawn and heated up as it absorbed solar radiation. The "open" plot pavement temperatures peaked at 113 to 122°F (45 to 50°C) during 1:00 to 3:00PM. By contrast, plots under the canopy heated substantially more slowly, with pavement temperatures peaking at only 82 to 90°F (28 to 32°C). Air temperatures ranged from 64.8°F (18.2°C) at sunrise to 78.6°F (25.9°C) at 6:00PM, normal values for a sunny day at this time of year. Peak temperatures under the canopy tended to occur early (8:00 to 10:00AM) or late (4:00 to 6:00PM) in the day as lateral radiation extended diagonally under the edge of the canopy.

Canopy classes differed significantly in maximum temperature (Kruskal-Wallis $\chi^2 = 31.577$, $p = 0.000$) and individual classes were easily distinguishable (Wilcoxon probabilities 0.0000-0.0002) increasing in proportion to canopy openness (Figure 2, left). In minimum temperature, canopy classes differed with lowest temperatures in "open" plots as depicted in Figure 2, center ($\chi^2 = 12.796$, $p = 0.002$). The greatest contrast in pavement temperature occurred between "open" and "under" plots (mean Δ=24.8±1.9°C (44.6±3.4°F)) while smaller contrasts were observed between "open" and "partial" plots (18.5 ± 4.1°C (33.3±7.4°F)), as seen in Figure 2, right.

Maples (*Acer spp.*) allowed both warmer maximum and minimum pavement temperatures than oaks (*Quercus spp.*). Site aspect and tree diameter showed no relationship with either maximum or minimum pavement temperatures.

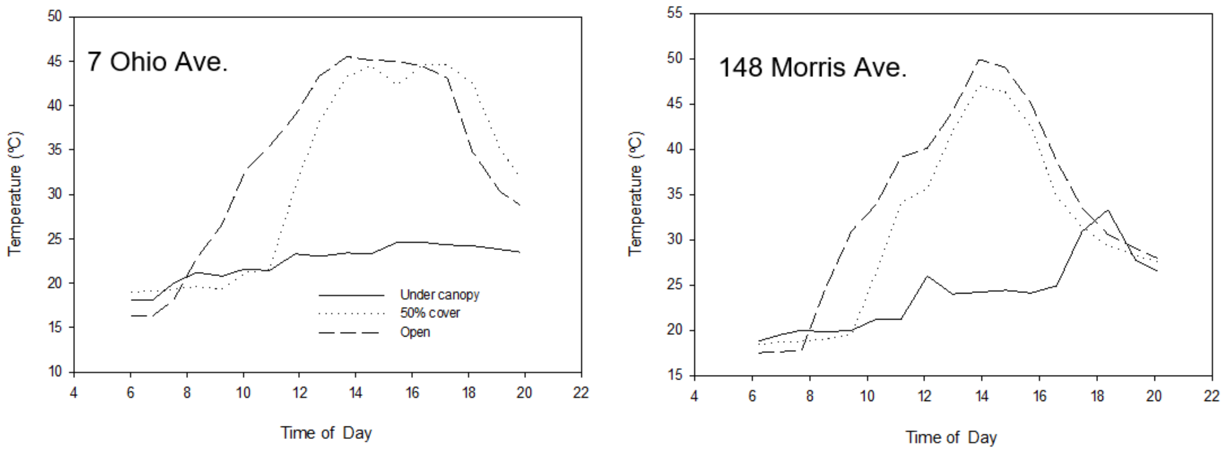


Figure 1. Pavement Surface Temperature Through the Day on June 6, 2018 in Selected Pavement Plots Under and Adjacent to two Tree Canopies.

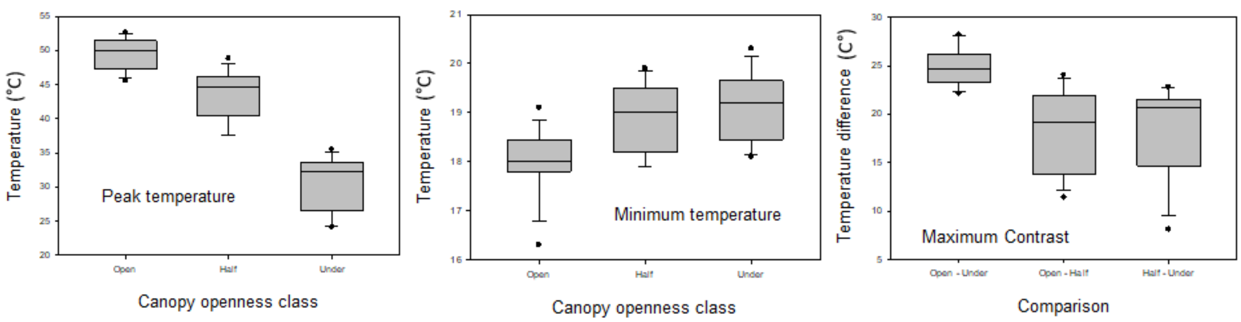


Figure 2. Temperature Extremes in Pavement Plots Under and Adjacent to Tree Canopies. Left: peak temperature between sunrise and sunset (scale range 68-131°F). Center: minimum temperature (scale range 61-70°F). Right: maximum temperature contrast (1°C = 1.8°F).

Pavement Wetting.

Wetting was measured during natural rainfall under six trees. Rain typically began with gentle sprinkling and intensity increased over a span of 30 to 40 minutes, as in the examples in Figure 3. Wetness for “under” plots was lower than for “open” plots for approximately 30 minutes (median) although there was substantial variation between trials related to the intensity and speed of development of individual rainstorms (range: 3 to 77 minutes). In “partial” plots, wetness was detected as soon as in “open” plots (median delay = 0 minutes) though, the degree of wetness in “partial” plots reached that of “open” plots after a median delay of 22 minutes (range: 0 to 74 minutes).

Very little rain was necessary to cause a wetness response in “partial” and “under” plots (unmeasurable – 0.45 mm). “Partial” plots reached levels of wetness equivalent to “open” plots after 0.029 in (0.74 mm) of rain. “Under” plots reached wetness levels equal to “open” plots after 0.050 in (1.27 mm) median.

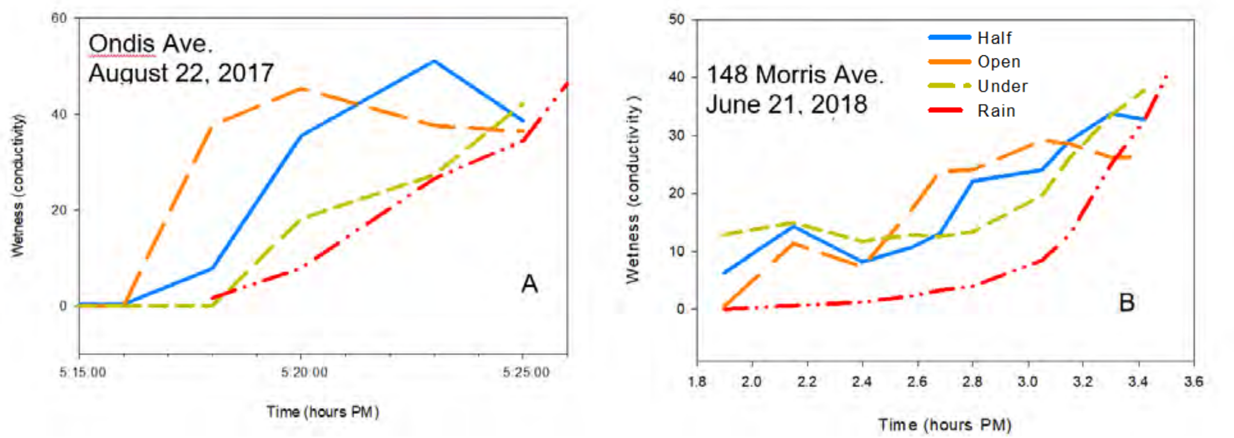


Figure 3. Accumulation of Moisture Through the Course of Rain Showers on Test Plots at trees in Athens, Ohio. Two trees are shown as examples.

Pavement Drying.

Figure 4 shows drying timelines for examples of experimentally wetted pavement plots. As expected, "open" plots dried faster than "under" plots. "Open" plots dried to 50% of the initial wetness value in 82 minutes (median), whereas "under" plots required 199 minutes. "Partial" plots required 124 minutes. Considerable variation was present within each canopy class (Figure 5). Significant contrasts were observed between canopy openness classes in 50% remaining ($\chi^2 = 11.88$, $p = 0.003$) and 10% remaining ($\chi^2 = 8.23$, $p = 0.016$). "Open" plots were distinguishable from "under" at both 50 and 10% dryness ($p = 0.004$ and 0.031, respectively). "Partial" plots were distinguishable from "open" in each measure ($p = 0.072$, 0.077), but only distinguishable from "under" at 50% dryness ($p < 0.076$).

Although pavement drainage was not quantified in this study, drainage was clearly important to drying rate. Plots with a pronounced camber (local slope within the plot) and a smooth surface drained rapidly; plots with a rough pavement surface, obvious cracks, or little slope gradient retained water longer even in full sun.

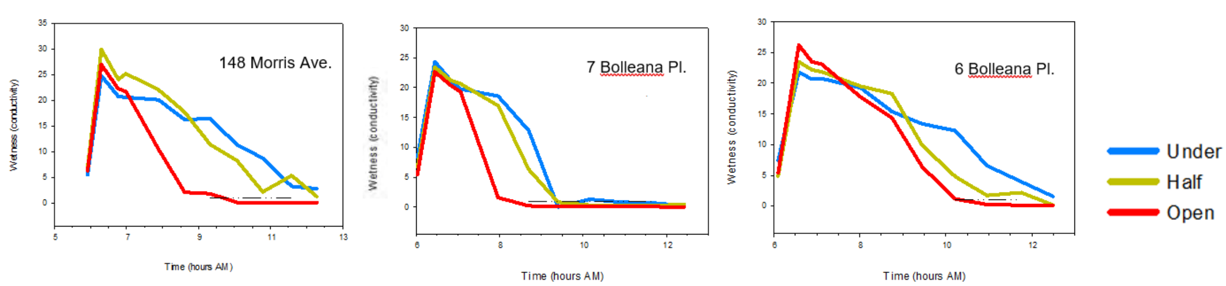


Figure 4. Drying of Experimentally Wetted Pavement Plots Under and Adjacent to Trees in Athens, Ohio. Three trees are shown as examples.

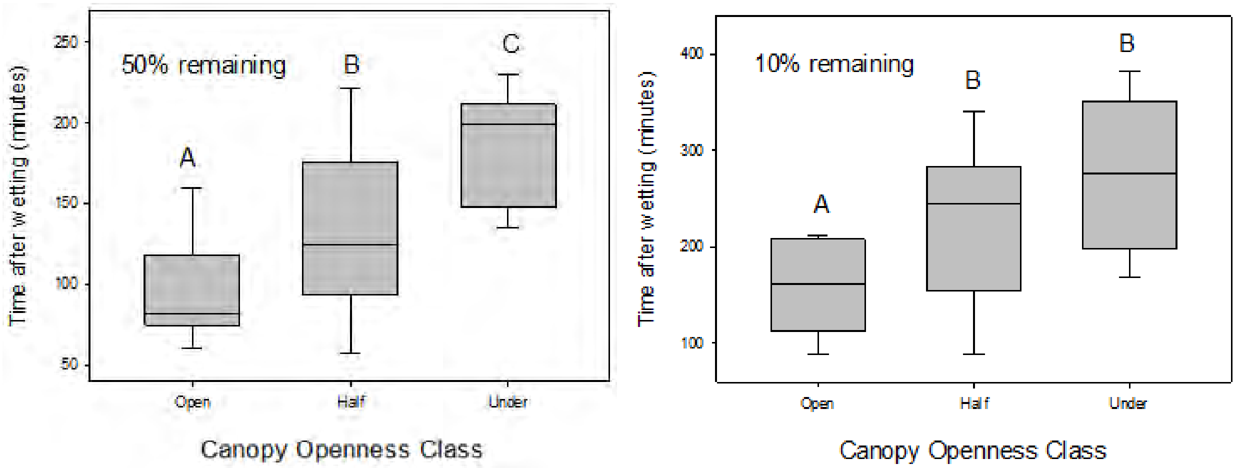


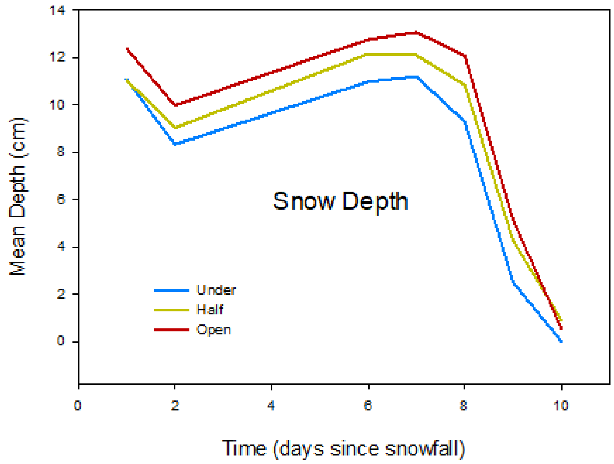
Figure 5. Drying Rates of Experimentally Wetted Pavement Under and Adjacent to Tree Canopies. Left: time to 50% of initial wetness value; Right: time to 10% of initial wetness value. Letters indicate groups distinguishable by Wilcoxon Comparisons ($p < 0.05$)

Snow and Ice.

Approximately 4 in (100 mm) of snow accumulated on January 13, 2018, supplemented by an additional 0.4 to 0.8 in (10 to 20 mm) on January 16. Maximum daily temperature remained below 32°F (0°C) though January 18 ensuring persistence of snow until January 19 (Figure 6). After the initial storm, snow depth under tree canopy was significantly less than in open plots ($\chi^2 = 6.010$, $p = 0.050$; Wilcoxon under/open $p = 0.050$) with a difference of about 21%.

No tree-canopy difference was detectable in ice cover ($p > 0.40$). After mean daily temperatures rose above freezing, snow and ice rapidly melted (Figure 6). Snow melted significantly faster under a tree canopy than under open sky ($\chi^2 = 6.122$, $p = 0.047$; Wilcoxon $p = 0.066$).

Although the research team did not systematically measure drainage or traffic volume, it became obvious that ice formation depended on two processes: packing of snow by passing vehicles and re-freezing of melt water when drainage was impeded by piles of plowed snow.



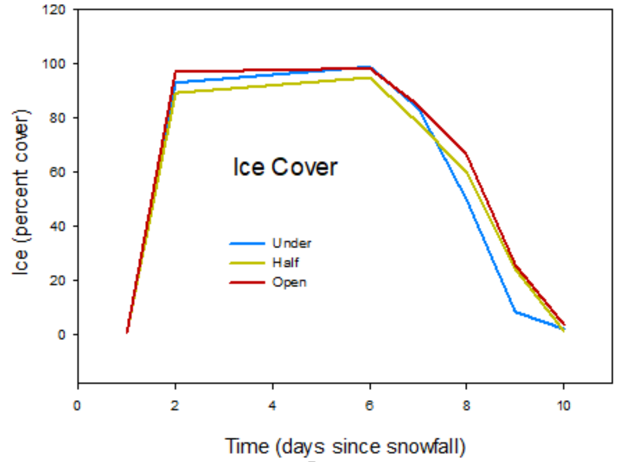


Figure 6. Snow Depth and Ice Cover on Pavement Under and Adjacent to Tree Canopies. Left: Snow depth; Right: Ice cover. (1 cm = 0.39 in).

4.2 Small Plot Study on Effects of Tree Canopy on Pavement Condition.

This section presents an abridged version of the research work performed at the *small plot level* to determine how the total road environment, including tree canopy, affects the condition of the pavement beneath. A detailed presentation of the analysis can be found in Appendix B.

4.2.1 Methods

Study Sites

Pavement condition was assessed at 75 sites in rural Athens County, Ohio. Sites were standardized to a pavement age of 10 to 12 years to ensure comparability between sites and to allow maximum opportunity for pavement degradation. All sites were surfaced with the original asphalt concrete; sites showing evidence of surface amendments such as chip-seal or patching were avoided. At each site, three 6.6 ft × 6.6 ft (2m × 2m) permanent experimental plots were established to allow comparison between canopy conditions – "under" plots (>95% canopy); "partial" plots (45% to 55% canopy), and "open" plots (no canopy). All three plots were situated on the same section of pavement.

Data

At each small plot, 14 variables related to roadway, canopy, and pavement condition were collected including:

- <u>Roadway parameters</u>
  - width,
  - proximity of plot to pavement edge, elevation of the pavement surface above soil at the edge (Dropoff),
  - cross-slope (Camber); and location of plot within any curvature,
  - location in the larger landscape (Landscape); assigned to one of five categories: "upland", "high slope", "mid slope", "low slope", and "flood plain" and
  - soil compaction; measured just outside the pavement edge.

- <u>Canopy related parameters</u>
    - tree size (Diameter),
    - number of trunks (Number) > 4 in (100 mm) diameter within 33 ft (10 m) of the plot,
    - position of tree (Nearest); in terms of distance from the plot to the nearest trunk > 4 in (100 mm) diameter, and
    - species identity of the nearest tree.
- <u>Pavement condition parameters</u>
    - texture (SUBJ); quantified as a visual estimate based on Ohio DOT PCR,
    - mean texture depth (MTD); volumetric method of measuring pavement texture (ASTM E965-96),
    - crack presence (Presence), and
    - total length (Length) of crack in each plot.

4.2.2 Results

The Width, Camber (local cross-slope), and edge Dropoff of rural roads was significantly related to their landscape position. Roads tended to be wider at mid-slope than at low-slope or floodplain positions (Kruskal-Wallis, $\chi^2 = 11.791$, $p = 0.018$); slope sites had a slightly greater drop-off at the pavement edge than uplands or flood plains ($\chi^2 = 13.015$, $p = 0.011$), and floodplain roads showed substantially less camber than any other landscape position ($\chi^2 = 45.971$, $p = 0.000$). Soil was significantly softer at mid slope than in other landscape positions ($\chi^2=12.238$, $p=0.016$). Landscape position did not affect the proximity of roadside trees, nor their size, stem density, or openness of the tree canopy (probabilities > 0.10).

Twenty-two tree species were encountered as “nearest trees”, with strong representation of sugar maple (*Acer saccharum)* (27 plots), black walnut (*Juglans nigra*) (21 plots), and hickory (*Carya* spp.) (18 plots). Species identity did not correspond with variation in any other environmental variable (Kruskal-Wallis probabilities > 0.10).

Pavement was significantly more degraded in road plots than bike path plots, which carried no car or truck traffic, in every measure of pavement condition except Crack length (Table 1).

Table 1. Comparison of pavement conditions at road and bike path (no-traffic) sites in Athens County, Ohio. Numbers indicate mean, standard deviation, and median. Comparison by Kruskal-Wallis test except in the case of Crack presence/absence, which is compared to pavement type by a χ^2 test.

Pavement measure		**Road sites**	**Bike path sites**	**χ^2**	**p**
	mean	3.114	2.164		
Subjective	std.dev.	0.461	0.347	72.33	0
	median	3	2		
	mean	4.37	2.78		
Mean Texture Depth (mm)	std.dev.	1.35	0.34	53.592	0
	median	4.04	2.74		
	mean	0.172	0.109		
Mean Texture Depth (in)	std.dev.	0.053	0.013	53.592	0
	median	0.159	0.108		
Crack presence (%)		58.3	24.2	10.553	0.0012
	mean	2502.02	33.29		
Crack length (m)	std.dev.	23528.83	24.15	0.559	0.3856
	median	38.32	34.07		
	mean	8208.73	109.22		
Crack length (ft)	std.dev.	77194.32	79.23	0.559	0.3856
	median	125.72	111.78		

Pavement condition differed significantly according to nearest tree species. The subjective PCR-derived index was highest near white oak (*Quercus alba*) and lowest near box elder (*Acer negundo*) (Kruskal-Wallis χ^2 = 14.289, p = 0.075) although the median difference was only 0.6 on a scale of 1.0 to 5.0. MTD returned the highest values (greatest degradation) near hickory (*Carya* spp.) and lowest near box elder (*Acer negundo*) (χ^2 = 19.786, p = 0.011). Road curvature, did not significantly affect any measure of pavement condition (probabilities > 0.05).

Within each road site, pavement condition differed between canopy openness classes (Table 2). Canopy openness class significantly separated plots on the basis of the subjective (PCR derived) index (Subj; Kruskal-Wallis χ^2 = 24.017, p = 0.000) with significantly higher values (more degraded pavement) in Under plots than either Open or Partial plots. However, the difference was minor (a median difference of 0.2 on a scale of 1.0 to 5.0). MTD showed greater depth under a tree canopy implying greater degradation, although the separation of median values between treatments was only 8.5% (χ^2 = 7.652, p = 0.022). Cracks were marginally more common in Under plots (68%) than in Partial (48%) or Open (59%). However, total crack length was not significantly distinguishable between the canopy treatments.

Table 2. Pavement condition under tree canopies at 162 rural road plots in Athens County, Ohio. Plots are >95% covered by leafy foliage (Under), 45-55% covered (Partial), and 0-5% covered (Open). Numbers show (top to bottom) mean value, standard deviation, and median, except in the case of Crack Presence/Absence. Highest values in each category are highlighted.

Pavement	Under	Partial	Open
Subjective			
Mean	3.260	3.166	2.921
Std dev	0.457	0.457	0.408
Median	3.2	3.0	3.0
CV	0.140	0.144	0.140
Crack length (m)			
Mean	48.88	57.06	89.67
Std dev	57.97	48.58	83.27
Median	28.66	47.96	60.53
CV	1.186	0.851	0.929
Crack length (ft)			
Mean	160.37	187.20	294.19
Std dev	190.19	159.38	273.20
Median	94.03	157.35	198.59
CV	1.186	0.851	0.929
Crack presence (percent)			
Present	66.7	47.3	55.8
Mean Texture Depth (mm)			
Mean	4.726	4.212	4.158
Std dev	1.494	1.249	1.137
Median	4.366	4.033	4.023
CV	0.3161	0.2965	0.2734
Mean Texture Depth (in)			
Mean	0.1861	0.1658	0.1637
Std dev	0.0588	0.0492	0.0448
Median	0.1719	0.1588	0.1584
CV	0.3161	0.2965	0.2734

Best models for each pavement-condition metric are listed in Table 3. The subjective index was strongly dependent on canopy openness, with higher values in more open plots suggesting less degraded pavement under a closed tree canopy. Curvature and Opposite slopes also contributed although weakly. However, median values in Under plots are only 6.7% greater than Open plots demonstrating only a minor difference in pavement condition.

Crack presence was positively affected by soil compaction, suggesting that a harder substrate is more likely to cause cracking; crack length appeared to respond to edge drop-off (more cracking at plots with a greater drop). Crack length was strongly dependent on environmental variation within sites (only 8.8% attributed to variation between sites). In contrast, Crack presence was strongly influenced by variation between sites (52.5% between).

Mean Texture Depth (MTD) responded only to canopy openness (Table 3), showing shallower crevices under an open sky consistent with Table 2. It is notable that substantially greater variation was accounted for by site than canopy condition implying a relatively weak canopy contribution (Table 3); the difference between median values in Under and Open plots was only 8.5%.

It is important to note that these results are strongly influenced by the inclusion of plots having >95% canopy cover; little difference was observed between plots with partial cover (40-60% cover) and plots open to the sky (<10% cover). Although the natural frequency of canopy cover was not quantified, two important observations emerge: First, >90% canopy cover is rare on rural roads, even in road sections running through forests (40-60% cover is much more common in forests). Thus, the actual effect of tree canopy on rural pavement condition is negligible.

Table 3. Best-fit regression models for four metrics of pavement condition at rural road sites in Athens County, Ohio. Mixed models with "site" as a random effect. Predictor variables are centered and scaled, allowing comparison of coefficients. Only predictor variables with coefficients > the respective standard errors are shown. Significance of predictor variables is tested by likelihood comparisons.

Pavement	Predictor	Coefficient	Test statistic	Probability
MTD	**Intercept**	0.437		
Site 56.9% of variance	**Open**	-0.0232	χ^2 = 6.858	0.0088
Crack length (log)	**Intercept**	8.069		
Site 8.8%	Edge	-0.23	χ^2 = 2.469	0.1161
	Dropoff	-0.25	3.098	0.0784
	Penmin	0.177	1.938	0.1639
	Opposite	1.097	1.097	0.295
	Diameter	-1.889	1.688	0.1878
Crack presence	Intercept	0.393	t = 1.617	0.1059
Site 52.5%	Open	-0.357	1.61	0.1073
Binomial	Edge	0.164	0.725	0.4683
	Penmin	0.473	1.985	0.0471
	Dropoff	-0.273	1.207	0.2275
	Diameter	-0.195	0.902	0.3669
Subjective (PCR derived)	**Intercept**	3.133		
Site 46.4%	**Open**	-0.104	χ^2 = 11.596	0.0007
	Curvature	0.045	2.085	0.1488
	Opposite	0.048	1.617	0.2035
	Adjacent	0.038	1.225	0.2684
	Edge	-0.054	2.577	0.1084

Second, canopy density changes on a scale of a few yards or meters. Thus, canopy density measurements at a single point on a rural road cannot be generalized over tens or hundreds of yards of road; an accurate description of the tree canopy must include individual canopy measurements every 5-10 yards (5-10 m).

4.3 Road Section Study on Effects of Tree Canopy on Pavement Microclimate.

This section presents an abridged version of the research work performed on *road sections* to determine how small plot results scale up to actual management units. A detailed presentation of this research work can be found in Appendix C.

4.3.1 Methods

Study Sites

Test road sections were confined to the eastern part of the state of Ohio and specifically to Ohio DOT Districts 5, 9, 10, 11, and 12. These Ohio DOT districts were selected due to (i) the climatic variations and precipitation levels, (ii) their proximity to the Ohio University Athens campus, and (iii) the perceived abundance of tree canopied roads. A total of 39 roadway segments were selected as test sites. These sites were selected first using GIS records of roadways and tree canopies, discussions of candidate sites with local Ohio DOT personnel with knowledge of the sites, and examination of sites via PathWeb (Ohio DOT's digital photolog). Canopied sections were verified by field inspection before final selection.

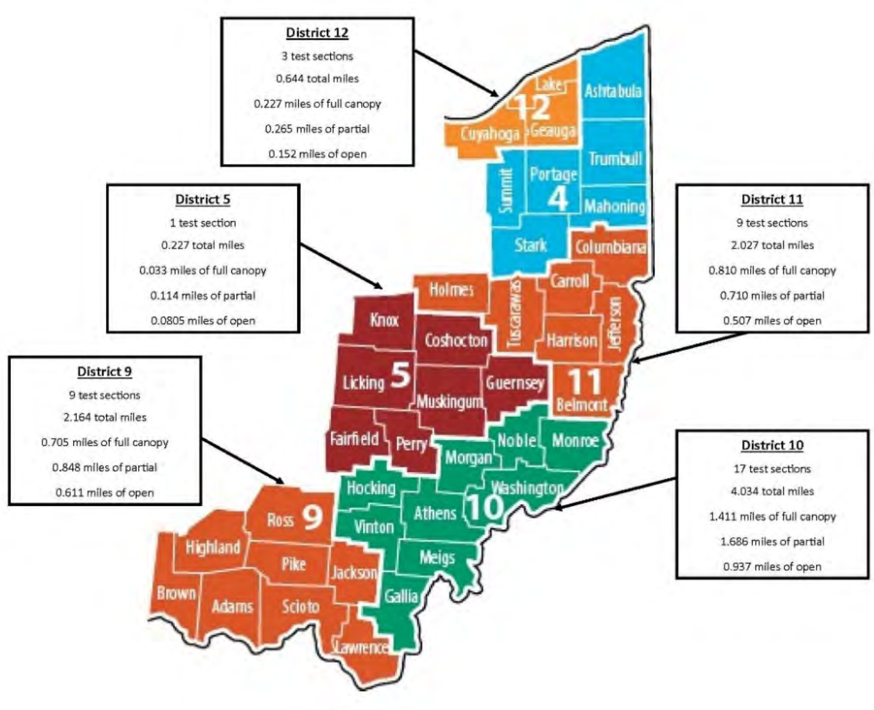


Figure 7. Summary of Selected Test Locations in Ohio DOT Districts 5, 9, 10, 11, and 12.

Each test site comprised a roadway segment with portions that had no canopy, had partial canopy, and had full canopy. Note that test segments were of different lengths and depended on the amount of tree canopy present. Figure 7 depicts the Ohio DOT Districts considered in this research study and information on the selected test segments including number of sites, total mileage, "under" (full) canopy mileage, "partial" canopy mileage and "open" (no canopy) mileage.

Data

- Pavement moisture: measured using an instrumented vehicle with GPS driven along each test segment at approximately 15 mph (24 km/h) or below and collected data every second in both directions of travel. The data were collected within 24 hours after a rain event and also includes date and time information; location information (latitude/longitude); condition of roadway (i.e., dry, wet, icy); pavement surface temperature (in °C at an accuracy of ±0.8°C (±1.4°F) at 0°C (32°F)); presence of moisture (film height) to an accuracy of 10%; and coefficient of friction of the pavement surface.
- Pavement temperature: measured along test segments with the MARWIS and a FLIR E6 infrared camera. With the FLIR E6 camera, measurements were at 25 ft (7.6 m) intervals along the center of each lane for each segment.

4.3.2 Results

Pavement Moisture.

In general, the results from Kruskal-Wallis H tests indicated that for over half of the test sites, there were statistically significant differences in moisture film height between open, partial, and full canopy sections. Additionally, some specific general conclusions based on results from Mann-Whitney U tests with Bonferroni correction include the following:

(a) difference in moisture levels between partial canopy and open (no canopy) sections was on average +3.88 µm (0.15 mil);
(b) difference in moisture levels between full canopy and open (no canopy) sections was on average +4.42 µm (0.17 mil); and
(c) difference in moisture levels between full canopy and partial canopy sections was on average +1.50 µm (.06 mil).

Note that the statistical testing was performed on the moisture data as individual sites, aggregated by Ohio DOT Districts, and for ALL sites; the results provided above were consistent. Additionally, observations of time lapse videos from sites on US-56 and US-374 showed that pavement under full canopy stayed wet for a longer time (approximately 6 to 7 hours) after a rain event relative to areas without a tree canopy.

Temperature.

In general, pavement surface temperatures were higher in open canopy compared to under both partial and full canopy. More specific conclusions based on the results include:

(a) difference in temperature levels between open (no canopy) and partial canopy sections was on average +3.29°F (+1.83°C),

(b) difference in temperature levels between open (no canopy) and full canopy sections was on average +5.09°F (+2.83°C), and
(c) difference in temperature levels between partial canopy and full canopy sections was on average +1.97°F (+1.09°C).

Note that the statistical testing was performed on the moisture data as individual sites, aggregated by Ohio DOT Districts, and for ALL sites; the results provided above were consistent.

4.4 Road Section Study on Effects of Tree Canopy on Pavement Condition.

This section presents an abridged version of the research work performed on *road sections* to determine how small plot results scale up actual management units. A detailed presentation of the research work can be found in Appendix C and Appendix D.

4.4.1 Methods

Study Sites

The set of study sites included in this analysis was that used in the microclimate analysis as noted in Section 4.3.1 above.

Data

- Pavement condition rating (PCR): measured in accordance with the Ohio DOT PCR manual [Ohio DOT, 2006]. For each test segment, the pavement was rated by direction and by canopy coverage level (i.e., PCR (by direction) for the "under", "partial", and "open" canopy portions,
- Density (air voids): extracted from pavement cores in accordance with AASHTO T269 and ODOT 1036 specifications,
- Tensile strength ratio (TSR): extracted from pavement cores in accordance with AASHTO T283 and Ohio DOT S1051 specifications, and
- Mass Loss (ML): extracted from pavement cores using Cantabro test in accordance with AASHTO TP108 specifications.

4.4.2 Results

Pavement Condition Rating.

The overall results, based on the directional average PCR values from all 38 sites, indicated there were no discernable differences in PCR between canopy levels as depicted in Table 4. By ODOT standards, these average PCR values all translate to a "GOOD" rating (i.e., 75 ≤ PCR < 90 = GOOD).

Table 4. Descriptive statistics on PCR data.

Canopy Level	N	Mean	Median	Std. Deviation
Open	76	86.13	85.59	8.49
Partial	76	84.23	84.86	9.12
Full	76	83.41	83.63	9.35

These ratings were analyzed further (refer to Horn [2019]), and the following conclusions were drawn:

(a) there was no statistically significant difference in PCR values between the different canopy levels (Kruskal-Wallis χ^2 (2) = 3.298, p= 0.193) with a mean rank PCR value of 125.23 for open, 111.91 for partial; and 106.36 for full.
(b) based on PCR values alone, the open (no canopy) sections of roadway ranked higher than partial canopy sections; and both ranked higher than full canopy sections of roadway.

Density (Air Voids).

The average densities and air voids for both canopy and no-canopy sections are shown in Table 5. The average density under canopy was found to be higher (and more consistent), 92.5%, than for no canopy, 94.1%.

Table 5. Density (air voids) test results.

Type	Number of Samples	Average Density (%)	Average Air Voids (%)	Std Dev (%)	Std Error	CoV (%)
Canopy	9	92.5	7.5	1.4	0.5	19.2
No Canopy	11	94.1	5.9	2.6	0.8	43.1

Tensile Strength Ratio.

The tensile strength, average conditioned (dry) and unconditioned (wet) tensile strength and TSR values for the canopy and no-canopy sections are summarized in Table 6. Cores from pavement under canopy exhibited higher susceptibility to moisture damage (TSR = 0.71) than the cores from pavement under no-canopy conditions (TSR = 0.85). Figure 8 depicts the

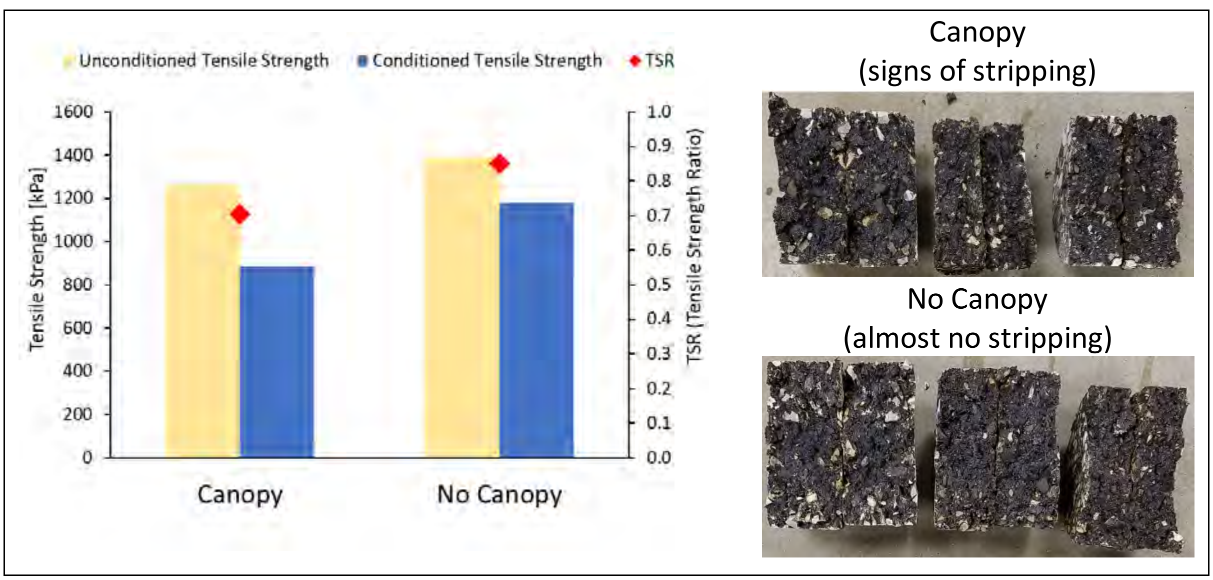


Figure 8. Tensile Strength and TSR Values for Canopy and No-canopy Conditions.

unconditioned indirect tensile strength, which was found, as expected, to be on average higher where exposure to moisture was minimized (i.e. no-canopy sections). Additionally, visual inspection of the specimens revealed the presence of stripping (physical separation of the asphalt cement and aggregate surface) where tree canopy is present.

Table 6. Moisture susceptibility TSR test results. SI units at top and English units below.

Moisture condition	Sample ID	Density (%)	Average density (%)	Air voids (%)	Average air voids (%)	Thickness (mm)	Diameter (mm)	Maximum Load (N)	Tensile strength (kPa)	Average tensile strength (kPa)	TSR
	7	92.8		7.2		33.1	100.4	7784.7	1490.6		
Dry	11	94.6	93.3	5.4	6.7	39.2	100.4	6142.3	992.9	1255.7	
	16	92.5		7.5		33.1	100.3	6691.1	1283.5		0.71
	4	94.5		5.5		43.4	100.4	7126.5	1042.7		
Wet	10	91.2	93.6	8.8	6.4	29.3	100.4	2970.1	642.2	885.9	
	12	95.1		4.9		32.4	100.2	4965.7	972.9		
	1	97.2		2.8		33.5	100.4	9242.8	1751.9		
Dry	8	90.8	95.0	9.2	5.0	30.8	100.1	6255.7	1293.1	1386.7	
	14	97.1		2.9		34.9	100.5	6146.4	1115.2		0.85
	2	98.6		1.4		42.6	100.2	11560.1	1722		
Wet	17	91.5	94.5	8.5	5.5	36.3	100.8	6375.2	1109.3	1177.6	
	18	93.5		6.5		28.9	100.3	3192.5	701.5		

Moisture condition	Sample ID	Density (%)	Average density (%)	Air voids (%)	Average air voids (%)	Thickness (in)	Diameter (in)	Maximum Load (lb)	Tensile strength (kPa)	Average tensile strength (kPa)	TSR
	7	92.8		7.2		1.30	3.95	1750	216.2		
Dry	11	94.6	93.3	5.4	6.7	1.54	3.95	1381	144.0	182.1	
	16	92.5		7.5		1.30	3.95	1504	186.2		0.71
	4	94.5		5.5		1.71	3.95	1602	151.2		
Wet	10	91.2	93.6	8.8	6.4	1.15	3.95	668	93.1	128.5	
	12	95.1		4.9		1.28	3.94	1116	141.1		
	1	97.2		2.8		1.32	3.95	2078	254.1		
Dry	8	90.8	95.0	9.2	5.0	1.21	3.94	1406	187.5	201.1	
	14	97.1		2.9		1.37	3.96	1382	161.7		0.85
	2	98.6		1.4		1.68	3.94	2599	249.8		
Wet	17	91.5	94.5	8.5	5.5	1.43	3.97	1433	160.9	170.8	
	18	93.5		6.5		1.14	3.95	718	101.7		

Cantabro Mass Loss.

The individual and average mass loss percentage (M.L.%) are presented in Table 7. In addition, Figure 9 depicts a comparison of the M.L.% against test duration for both canopy conditions. After 100 revolutions, the samples from canopy sections began to disintegrate much faster than samples from the no-canopy (open) sections. After 300 revolutions, the average mass loss was larger (69.8%) for the mixture under tree canopy than for the mixture in the no-canopy (open) section (33%). Figure 9 also shows the core remnant from the canopy section (residual) is much less than that from the no-canopy (open) section.

Table 7. Cantabro mass loss test results.

Type	Sample ID	Density (%)	Average Density (%)	Air Voids (%)	Average Air Voids (%)	Thickness (mm)	Number of Revolutions / Mass Loss (%) 100	200	300	Average Mass Loss (%)
Canopy	15	92.2	92.2	7.8	7.8	55.4	9.1	27.1	65.5	69.8
	9	92.2		7.8		46.9	33.0	64.7	74.1	
No Canopy	5	94.3	95.8	5.7	6.2	55	8.4	19.4	29.3	33.0
	19	93.2		6.8		41.4	24.7	32.9	36.6	

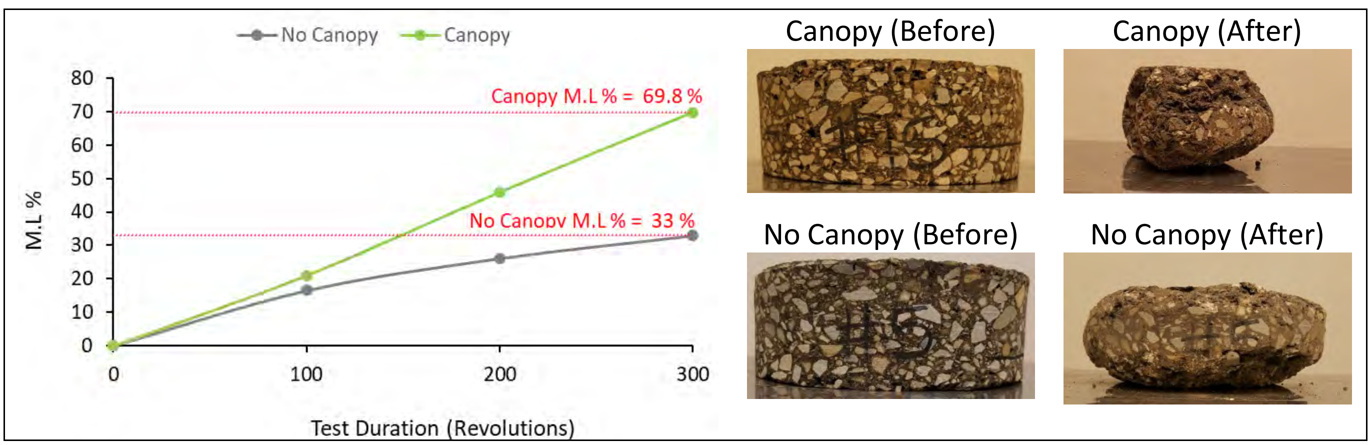


Figure 9. Cantabro Mass Loss (M.L.%) for Canopy and No-canopy Conditions.

4.5 Road Section Study on Effects of Tree Canopy on Safety.

Safety impacts from tree canopies were evaluated by comparing safety data before and after tree maintenance operations and by assessing surrogate safety measures. Full details of the safety assessment are in Appendix C.

4.5.1 Methods

Study Sites

The before-after safety analysis performed for this project included 46 low-volume road segments in Ohio DOT Districts 4, 5, 9, 11, and 12 in Eastern Ohio at which tree related maintenance operations had been performed, based on available records from Ohio DOT. The surrogate measures were obtained at study sites on SR 356 (Vinton County), SR 56 (Hocking County), and SR 374 (Hocking County), all in District 10.

Data

- Traffic crash data from 2009-2018 were obtained from Ohio DOTs GCAT system.
- Traffic volume data (per year) for the entire before-after study period were obtained from the Traffic Monitoring Management System.
- Roadway design elements, such as lane widths, shoulder widths, horizontal/vertical alignment parameters etc. were obtained using Google Earth and AutoCAD Civil 3D.
- Driver behavior, such as travel speeds and braking operations were measured as vehicles were observed travelling through study segments.

4.5.2 Results

Before-After Crash Analysis.

The results from a naïve analysis (i.e., basic comparison of observed crashes in before and after periods), showed an overall decrease in average crashes – approximately 23% for all crash types – attributed to tree maintenance (trimming/pruning). An Empirical Bayes analysis produced mixed findings, with 39 locations exhibiting safety improvements and 7 locations indicating no improvement in safety. Detailed results from the analysis are provided in Appendix C. The composite (project level) analysis found an overall 11% deterioration in safety at locations where tree maintenance operations (trimming/pruning) were performed, but this was not statistically significant at a 95% confidence level (Z-score = -1.43).

Surrogate Measures of Safety - Speed Data.

Overall, no discernable differences were observed in the average and 85th percentile speeds between canopy levels and/or day/night conditions. Additionally, a comparison of observed vehicle speeds between full and open canopy sections (see Table 8) indicated mixed findings with the 4 datasets from Hocking County exhibiting significant differences in speeds between canopy levels which the 2 datasets from Vinton County did not have. The datasets with a significant difference in speeds between canopy levels had higher average speeds within the full canopy sections.

Kruskal-Wallis H tests on the speed data under day or night conditions found some statistically significant differences under specific canopy levels for day and night conditions. Despite the statistically significant differences, interpretations cannot be made due to the mixed results. Average speeds were higher at night in some sections, but lower in others, and this is the case both for full canopy and open canopy sites.

Table 8. Kruskal-Wallis H test results (speed by canopy level).

County	Route	Direction	Canopy	N	Mean Rank	Kruskal-Wallis H	Asymp. Sig. (p-value)
Vinton	SR 356	NB	Open	66	187.29	1.59	0.207
			Full	341	207.23		
		SB	Open	71	236.64	0.41	0.522
			Full	383	225.81		
Hocking	SR 56	EB	Open	1374	1062.66	422.81	0.000*
			Full	1371	1684.02		
		WB	Open	1530	1302.16	200.69	0.000*
			Full	1524	1753.73		
	SR 374 (3)	NB	Open	3822	4094.88	106.18	0.000*
			Full	3845	3574.68		
		SB	Open	3908	3835.69	26.44	0.000*
			Full	3520	3579.95		

Note: Routes with numbers in parenthesis correspond to multiple locations on the same route
*statistically significant (α=0.05)

Surrogate Measures of Safety - Braking Data.

Braking data were collected in both directions of travel from three test locations as drivers traveled through a section of tree-lined roadway during the fall (no leaves on trees) and during the spring (leaves on trees). At each test location, video cameras (placed at 200 ft (60 m) and 400 ft (120 m)) were used to observe the tail-lights for vehicles and subsequently assess if a driver was braking (or not) as he/she traversed the sections of roadway where canopy was present. Table 9 presents results from logistic regression analysis on the observed data. The results indicated mixed findings: Half (four) of the data sets indicated drivers are *more likely* to not brake when there is no canopy (no leaves on trees) and four other datasets indicating drivers are *less likely* to not brake when there is no canopy (no leaves on trees).

Table 9. Results from braking analysis.

Leaves Present?	Number of Days monitored	Braking	No Braking	Odds Ratio	Percentage Braking	Percentage Not Braking
400 ft (120 m) South of Full Canopy on SR 356 in Vinton County						
Yes (spring)	6	23	358	1.63	6%	94%
No (autumn)	5	23	219		10%	90%
200 ft (60 m) South of Full Canopy on SR 356 in Vinton County						
Yes (spring)	5	8	307	2.59	3%	97%
No (autumn)	7	18	267		6%	94%
200 ft (60 m) North of Full Canopy on SR 356 in Vinton County						
Yes (spring)	4	3	163	0.86	2%	98%
No (autumn)	6	4	253		2%	98%
400 ft (120 m) North of Full Canopy on SR 356 in Vinton County						
Yes (spring)	4	3	408	7.68	1%	99%
No (autumn)	6	14	248		5%	95%
200 ft (60 m) East of Full Canopy on SR 56 in Hocking County						
Yes (spring)	5	33	1229	0.3	3%	97%
No (autumn)	4	4	489		1%	99%
400 ft (120 m) West of Full Canopy on SR 56 in Hocking County						
Yes (spring)	5	199	867	0.19	19%	81%
No (autumn)	4	26	589		4%	96%
475 ft (145 m) South of Full Canopy on SR 374(3) in Hocking County						
Yes (spring)	2	43	387	0.17	10%	90%
No (autumn)	4	20	1037		2%	98%
400 ft (120 m) North of Full Canopy on SR 374(3) in Hocking County						
Yes (spring)	2	40	586	1.43	6%	94%
No (autumn)	3	34	349		9%	91%

5.0 RESEARCH FINDINGS

- Tree canopies do affect the microclimate beneath them, and shading does cause temperature differentials between the pavement surface beneath the canopy and the pavement surface exposed to the open sky. Ordinary heating was substantial, leading to a 52 to 61°F (29 to 34°C) diurnal variation of exposed pavement; in contrast, pavement under-canopy only experienced a 11 to 25°F (6 to 14°C) thermal cycling. The temperature differentials due to varying canopy levels have the potential to cause pavement cracking.
- Tree canopies delay the onset of wetting in convective summer rain showers and reduce total wetness for up to 30 minutes accounting for most summer rain events in southeastern Ohio. The amount of rain retained in the foliage depends on the species of the tree, its size, and branching structure. Also, it may take up to 7 hours longer for pavement to dry under overhanging tree canopies. On average, the water-film height on pavement under canopy was +4.42 µm (0.17 mil) more than that for open sky pavement with no canopy overtop. Open sky pavement generally showed concave drying curves suggesting immediate and rapid drying on exposure to direct sunlight, while canopy covered pavement dried slowly at first (convex curves). While there are differences in moisture amounts between canopy coverage levels, in practice these differences are negligible. With moisture levels well below 0.1 in (2.5 mm), there is a very small likelihood of drivers hydroplaning and subsequently impacting safety.
- The branches of deciduous trees blocked snowfall in our trial even though no leaves were present (median 12.9% lower under trees). Ice cover and persistence on pavement appeared to be unrelated to adjacent trees. Instead, most ice was generated by compaction of snow under car tires or by nocturnal freezing of meltwater in puddles.
- Incidental observations on the small plots during drying rate experiments indicated that pavement drainage (slope and surface texture) has much more of an effect on drying rate than absence of canopy.
- Pavement damage under the three canopy coverage levels showed statistically significant differences in terms of pavement condition rating (PCR) and mean texture depth (MTD). However, differences between canopy conditions were modest (<10%) and only evident under 95% canopy cover, a rare condition on rural roads. Canopy-covered pavement had lower values of MTD indicating less damage to the surface under trees. Crack length showed no relationship to tree cover. At the scale of road sections, no significant difference in PCR was detected with canopy cover.
- An analysis of pavement cores collected from road sections under canopy have lower density (more air voids) and are more susceptible to moisture damage (showing lower TSR values and more signs of stripping in the mixture) and degradation (showing larger percentage of Cantabro mass loss) than cores from road sections in open sky (no canopy). As such the average density, TSR, and average mass loss for canopy sections were 92.5%, 0.71, and 69.8%, respectively. By contrast, for open sky (no canopy) sections the average density, TSR, and average mass loss were 94.1%, 0.85, and 33%, respectively. However, these data were collected from a very limited number of sites.
- There was no correlation of tree location or proximity with pavement damage, providing no support for the idea that root penetration causes pavement degradation. Given the very

small differences in amount of pavement distress between sections with different levels of canopy cover, it is evident that the pavement distress is generally due to non-canopy related causes. Pavement distress may be due to a variety of other factors such as poor road design, poor construction, traffic loading, etc. which are beyond the scope of this study.

- Using available crash data, the safety analysis indicated that a composite (project) level view of roadside maintenance activities (i.e., trimming/pruning of trees) does not provide safety benefits. However, individual sites showed mixed results with 39 locations exhibiting safety improvements while seven locations had no improvement in safety.
- The analysis of surrogate measures of safety (vehicle speed and braking operations) did not provide any conclusive findings.

6.0 RECOMMENDATIONS FOR IMPLEMENTATION OF RESEARCH FINDINGS

Based on the findings of this research project, including the arborist's perspective in Appendix F, the following recommendations are suggested:

1. Tree canopies should not be removed along Ohio's rural routes as a routine management practice as means of preventing damage to pavement. Cutting should **only** be done on **individual** trees and in the following circumstances:

   a. There is >90% **measured** canopy cover and **measurable** pavement degradation.

   b. Dead or decayed individual trees threaten to fall in the road.

   c. Cutting should not be applied over sections longer than 10 to 20 yards (10 to 20 m). Because canopy density varies greatly on a fine scale, Canopy density should be re-measured every 10 yards (10 m).

   d. Maintenance crews should carry simple instruments (e.g. canopy densiometers) allowing them to make on-the-spot measurements of canopy density to guide cutting decisions.

   A hemispherical densiometer is an appropriate canopy measurement instrument.

2. The incidental relationship observed between drainage, ice, and traffic suggests drainage maintenance and snow removal are more important to minimizing moisture damage on a pavement surface than is tree maintenance. Scheduled routine or seasonal inspection and cleaning of culverts and drainage features should continue per usual practice. While it is beyond the scope of this project, the value of drainage maintenance and plowing should be assessed in future research.

3. It is necessary to consider using asphalt mixes which are not susceptible to stripping when paving on tree canopied roads.

4. Trees should be maintained to ensure safety in specific locations, i.e. in spots where trimming provides unobstructed sight distance, sign visibility, and enhanced margin of safety for errant vehicles. In locations where the right-of-way or lines of sight are limited (e.g. embankments, hills, curves and dips, and residential areas), branches should be

trimmed to provide vertical top-bottom clearance at a minimum 14.5 ft (4.4 m) and a desirable clearance of 16.5 ft (5.0 m) and at least 4.5-ft (1.4 m) horizontal clearance from the edge of the roadway (white line). It should be noted that any trimming/pruning work should be limited to the specific areas where a safety problem can be demonstrated.

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