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Roadside Right-of-Way Maintenance Strategies



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16. Abstract <p>The Indiana Department of Transportation's (INDOT) roadside management program is tasked with multiple items across the state's 39,000 lane miles. Roadside maintenance is an essential task that keeps INDOT's rights-of-way (ROWs) safe and functional for drivers. Most roadside vegetation maintenance work for INDOT is outsourced, and INDOT's in-house staff perform any follow-up vegetation maintenance as needed. INDOT needs to focus on cost-efficient solutions due to budgetary constraints from increased labor, equipment, and contractor costs and no budgetary increases.</p> <p>INDOT contracted Davey Resource Group, Inc. (DRG) to provide recommendations for updates to INDOT's roadside ROW vegetation maintenance strategies. DRG completed a literature review, interviewed regional DOTs, and performed an analysis of the identified gaps within INDOT's vegetation maintenance program. DRG then provided implementation recommendations. The benefits and timeline of each of these implementation items were provided, including costs and return on investment (ROI) estimates when possible.</p> <p>Issues identified included a reactive vegetation management approach, staff who lack familiarity with INDOT's vegetation maintenance operations standards, a lack of access to appropriate equipment/technology, a limited number of contractors bidding on vegetation work, and contractors taking on more work for which they have capacity. DRG recommends the development of specialized vegetation crews in each district. Purchase of specialized equipment and mapping technology is recommended for those crews, along with improvements to prequalification requirements, design standards, and engineering division communication to make vegetation maintenance easier and safer for maintenance staff. Alternative recommendations are provided where available.</p>			
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EXECUTIVE SUMMARY

Introduction

The Indiana Department of Transportation's (INDOT) maintenance operations division is responsible for completing various tasks across the state's 39,000 lane miles. Roadside right-of-way (ROW) maintenance is an essential duty that keeps Indiana ROWs safe and functional for drivers. The majority of roadside vegetation work in Indiana is completed by contractors, while INDOT's in-house maintenance staff focuses primarily on road and pavement maintenance, performing vegetation maintenance follow-up or addressing customer complaints as needed. Cost-effective solutions are a priority with the increasing labor, equipment, and contractor costs, and the lack of additional funding available. Departments of Transportation (DOTs) must prioritize which assets are provided funding for maintenance and replacement. As maintaining safe roadways is a DOT's main priority, ensuring structural asset condition and sight distance through vegetation management is a high priority for DOTs. Given the sporadic and often unpredictable nature of vegetation work completed in-house, most INDOT maintenance operations staff do not have access to enough appropriate equipment and technology for completing vegetation maintenance tasks, and are undertrained to perform the vegetation maintenance tasks, resulting in reduced efficiency. To uncover these challenges and find solutions, INDOT contracted Davey Resource Group, Inc. (DRG) to provide recommendations for updating INDOT's roadside ROW vegetation maintenance strategies.

To carry out the research, DRG completed a literature review of current and emerging roadside vegetation maintenance strategies; conducted interviews with INDOT and regional DOT staff; performed a strengths, weaknesses, opportunities, and threats (SWOT) analysis; and performed a gap analysis of INDOT's roadside vegetation management program. DRG then provided implementation recommendations including costs and return on investment (ROI) estimates when possible. Following the Study Advisory Committee's (SAC) review of implementation recommendations, DRG assessed the selected implementation items in further detail and developed technical memorandums providing next steps and cost savings information.

Findings

DRG found a variety of challenges to INDOT's roadside vegetation management strategies.

- These issues include a vegetation management approach based on reactivity, maintenance operations staff that lack familiarity with INDOT vegetation maintenance operations standards, and a lack of access to the best available equipment and technology for the required vegetation maintenance tasks, all of which contribute to reduced efficiency.
- Maintenance staff are often not included in construction design phase leading to issues where maintenance is not feasible along the ROW.

- INDOT staff within specialized vegetation management crews are more cost-effective and efficient than those staff who are not a part of a specialized vegetation management (generalized) crew. This may be due to training and increased amount of experience of specialized crews versus generalized crews.
- Districts with equipment for vegetation management, such as forestry bucket trucks, are more efficient than those without vegetation management specific equipment.
- Additionally, INDOT is challenged by a limited number of pre-qualified contractors bidding on vegetation work, leading to contracts being awarded to prequalified contractors for more work than they have the capacity for without safeguards in place to prevent such issues.

Implementation

To address these issues, DRG developed technical memorandums that provide steps that INDOT should implement to improve roadside management. These technical memorandums include:

- Roadside Safety Appurtenances Preliminary Recommendations: Research revealed that some newer approaches to managing vegetation beneath currently installed guardrail and cable rail systems may be cost-prohibitive for DOT implementation. Despite these initial findings, the lack of consideration for vegetation maintenance in INDOT's current guardrail and cable rail designs meant further research into improvements was necessary. DRG recommends further research on concrete mow strips and concrete barriers, along with other long-term vegetation management assets under appurtenances.
- Culvert and Ditch Maintenance: INDOT should begin using culvert and ditch markers in conjunction with standard drawings, provide staff access to Global Positioning Systems (GPS) that contain culvert and ditch locations, reduce the variation in distance from pavement within individual ditches, and reduce ditch bank slopes.
- Pre-Qualification Recommendations: Contractors who submit an audited or a reviewed statement should have the period between the pre-qualification review increased to 16 months from 12 months. Also, the pre-qualification period should begin at the time of approval, not the time of application.
- Sound Barrier Recommendations: Barriers can be placed against the ROW boundary to reduce maintenance needs. Maintenance agreements should be made with adjacent property owners to maintain the area behind barriers. Barriers should be located a minimum of 15 ft off the ROW edge if utility access is needed. Access doors should be large enough to allow equipment access, with traversable grades.
- Contract Language Recommendations: There are recommended updates to contract language and recommendations for tracking contractor work.
- Improving Maintenance Operations' Involvement in Design and Construction Recommendations: INDOT should assign specific maintenance staff to attend meetings with alternatives, as needed.
- Work Standards Recommendations: Language updates were provided, along with recommended updates to production guidelines to assist INDOT staff in budget and work plan development.
- In addition to the technical memorandums, it was recommended that specialized vegetation crews be developed using Highway Technician 2 maintenance staff, with dedicated vegetation maintenance equipment in each district, and for specialized equipment and mapping technology be purchased.

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1. INTRODUCTION

1.1 Problem Statement

Indiana Department of Transportation (INDOT) is charged with maintaining more than 39,000 lane miles and more than 100,000 acres of roadsides and medians. As safety is the main driver behind Departments of Transportation (DOT) right-of-way (ROW) management, ensuring sight distance through vegetation maintenance is the main priority of DOTs, but managing ROW vegetation is a complex challenge. With an ever-increasing workload, rising costs for labor, equipment, and contractors, and a lack of additional funding available with budgets growing increasingly tighter each year, INDOT is considering strategic changes to their vegetation management program. The majority of INDOT's roadside vegetation management is completed via cyclical mowing and herbicide application by contractors, but the way DOTs manage the ROW is rapidly changing. Opportunities exist to incorporate new and alternative vegetation control methods, landscape asset designs, roadside safety asset designs, roadside operation specifications, and design and construction specifications into INDOT programs that could reduce maintenance costs while maintaining a safe travel corridor.

1.2 Objectives

The research sought to address key challenges that affect INDOT roadside management from a broad perspective, including vegetation management, construction, design, customer service, and administration while taking costs into account. The research team explored current and completed research on ROW maintenance tools and processes to assess existing conditions and needs within INDOT departments related to roadside vegetation management.

This included assessing roadside safety appurtenance specifications, noise barrier specifications, contractor pre-qualification requirements, contract language, INDOT in-house performance guidelines, new and emerging vegetation management equipment and technology, and inter-departmental cooperation between maintenance operations and the engineering divisions. The research team sought to identify the best practices and recommended strategies for improving INDOT's roadside management. The research objectives included:

- Understanding the challenges INDOT faces when managing vegetation along the roadside.
- Identifying tools and technology that will improve maintenance practices, design, and the planning and prioritization of work.
- Identifying ways to improve management, design standards, and operational protocols for vegetative and structural assets that impact vegetation.
- Synthesizing information from various sources to advance INDOT's roadside vegetation management program.

The project's goals were to conduct short-term implementation tasks and provide long-term implementation recommendations that could be completed statewide.

1.3 Project Approach

Davey Resource Group, Inc. (DRG) researched various tools, technology, equipment, and specifications that could be used by INDOT to improve roadside maintenance strategies and develop recommendations for implementation.

1.3.1 Phase I

1.3.1.1 Literature Review. DRG completed a literature review of domestic and international sources. The literature review investigated current vegetation management specifications and relevant design standards of INDOT and other DOTs, as well as general strategies and benefits of vegetation management, vegetation management strategies around specific types of structures, the design of ROW structures and how they impact vegetation management, new and emerging technology and equipment for vegetation management, and public outreach strategies for DOTs. When appropriate, DRG solicited vendors for additional information.

1.3.1.2 INDOT Site Visit Meetings. To gain an understanding of the issues and struggles of maintenance operations, DRG met in person with INDOT staff from each district. These meetings occurred in Paoli, Indianapolis, and Plymouth, with staff from two districts represented at each meeting. Prior to the meetings, INDOT staff were provided with a survey to direct conversation during the meetings. Following these meetings, DRG staff met with Bedford and Greenfield management units to assess equipment and facilities. During these meetings, INDOT staff provided information on the vegetation management challenges they face. Staff from various departments within INDOT attended the meetings, including maintenance, construction, customer service, environmental services, design, and hydrology, among others. In between district meetings and management unit visits, DRG toured the INDOT ROW following routes suggested by district staff to observe existing roadside conditions and issues firsthand.

1.3.1.3 Regional DOT Interviews. The research team conducted targeted interviews with regional DOTs focusing on issues revealed during the site visits. Based on prior knowledge of the INDOT Study Advisory Committee (SAC) Technical Advisor and DRG, state DOTs known to implement vegetation management processes that could benefit INDOT and that either shared a border with Indiana or had similar topography were chosen for targeted interviews.

Thirty-four questions were developed to evaluate the regional DOTs' vegetation management practices. They focused on items such as zonal maintenance regimes, in-house versus contracted vegetation maintenance operations, vegetation maintenance practices around structural assets, design/construction specifications, staffing and training requirements, use of innovative technology and equipment, and public outreach procedures. The DOT survey questions and responses are included in Appendix A.

The research team and SAC Technical Advisor met with staff from the Illinois Department of Transportation (IDOT), Iowa Department of Transportation (Iowa DOT), Kentucky Transportation Cabinet (KYTC), Minnesota Department of Transportation (MnDOT), Missouri Department of Transportation (MoDOT), and Wisconsin Department of Transportation (WisDOT). A synopsis of the interviews was provided to the SAC project panel following the completion of the surveys.

1.3.1.4 Strengths, Weaknesses, Opportunities, and Threats Analysis. A Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was completed. This describes INDOT's strengths and weaknesses, opportunities for INDOT to improve their vegetation management practices, and potential threats that may continue to impede the adoption of these improvements. Information collected during the literature review, site visits, regional DOT interviews, and additional DOT specification research was used to complete the analysis. Weaknesses identified in the SWOT analysis were further expanded upon, and recommended solutions were provided in a gap analysis.

1.3.1.5 Gap Analyses. The gap analysis examined internal deficiencies within INDOT concerning personnel, equipment, planning, and implementation of vegetation management. The gap analysis matrix compared INDOT's current processes and operations to those of interviewed DOTs and to general industry standards or new and innovative practices found in the literature. Differences in work efficiency and cost-effectiveness between the various INDOT districts were also explored. The gap analysis matrix includes summaries of the main issues identified with INDOT's vegetation management processes, potential solutions, and expected benefits of implementing changes.

1.3.2 Phase II

1.3.2.1 Implementation. The research team developed a comprehensive list of implementation options. An extended analysis of these options was completed including timeline, potential benefits, costs, and ROI, when possible. Additionally, decision trees outlining implementation benefits, as well as the possible effects of rejecting certain implementation recommendations, were created. Flow charts were created to highlight the reasoning behind each implementation option's benefits. The research team met with the SAC to review the implementation options and determine the next steps within the current project and those that would set the stage for future research and implementation. Five areas were recommended for implementation from the initial implementation list, including updates to prequalification processes, contract language, work standards, noise barrier specifications, and roadside culvert and ditch marking and design. To supplement design specification recommendations, DRG also examined ways for INDOT to improve the communication between maintenance and construction/design personnel and explored new and innovative approaches to address vegetation maintenance issues around roadside

appurtenances. Technical memorandums were developed for each of these items that included background information on other state practices, recommendations and benefits for INDOT, and future costs and savings, where applicable. In addition to the implementation option analysis, the research team provided feedback on equipment as requested by the SAC Technical Advisor throughout the project.

2. FINDINGS

2.1 Literature Review

2.1.1 Native Plant Benefits

The successful re-establishment of roadside vegetation following construction can turn a site with bare soil into a functional community that can provide ecosystem services such as: reducing the extent of noxious weeds and invasive plants along the ROW, providing erosion control, increasing water infiltration, providing a carbon sink, and more (Armstrong et al., 2019; Jakobsson et al., 2018; Lazaro-Lobo & Ervin, 2019; Mills et al., 2021; Milton et al., 2015; National Academies of Sciences, Engineering, and Medicine [National Academies], 2023c). The use of native plant communities reduces mowing needs, provides habitat for pollinators, and increases aesthetic appeal. The reduction in mowing helps to reduce greenhouse gases and maintenance costs (National Academies, 2023c). Several agencies have begun using native vegetation species more frequently for revegetation. The Federal Highway Administration (FHWA) promotes the use of native species along the ROW to combat the potential spread of invasive species and promote ecological health (FHWA, 1999).

Regional native species have evolved to grow in the local climate and soils, which results in a higher establishment rate than non-native species (Tinsley et al., 2006). Due to native species having denser and deeper root systems than non-native species (Wilsey & Wayne Polley, 2006), native vegetation may help to reduce erosion more than non-native species. When utilizing native vegetation, it is important to use suitable seed mixes, such as wetland seed mixes for wetland/ditch sites. Using appropriate species will increase establishment success and reduce erosion, ultimately reducing costs.

2.1.2 Invasive Plant Control Strategies

Roadsides can act as a corridor for the spread of invasive species. Soils with excess macronutrients are typically more susceptible to invasive encroachment, although some invasive plant species thrive in areas with lower nutrient levels (Mills et al., 2021; Sardans et al., 2016). To ensure desirable species have the best opportunity to thrive, it is recommended to use appropriate levels of fertilizers for the desired plants to achieve the correct macronutrient levels. Native grasses and forbs require less macronutrients than turfgrass species. Using excess fertilizer is expensive, wasteful, and can be harmful as it can increase the abundance of invasive species and excess macronutrient runoff in stormwater.

Chemical and/or mechanical control is commonly used for invasive species management in affected areas. Chemical control often involves synthetic herbicides but can also utilize alternatives such as clove oil (Barker & Probst, 2014). Mechanical control involves the physical manipulation of vegetation such as with mowing and string trimming (Weidlich et al., 2020). Mechanical control needs to be completed at the appropriate time, for example, cutting invasive species after seed production can inadvertently increase their dispersal. Mechanical cutting may also help certain species such as Japanese knotweed (*Reynoutria japonica*) spread by relocating plant fragments, which can take root and grow new plants from small stem cuttings (Ito & Ito, 2021). Chemical control needs to be completed following herbicide labels and be timed for the type of vegetation and application method.

For example, foliar application needs to be completed when the plant is actively growing and leaves are present, whereas a cut stump treatment can be completed any time of the year apart from early spring due to the strong upward flow of sap in vegetation at that time of year. The timing must also be appropriate for the herbicide being utilized (e.g., using oil-based formulas in freezing temperatures instead of water-based).

Preventing invasive species growth is easier than controlling invasive species after establishment (Early et al., 2016). Invasive species can be prevented at newly seeded or planted sites by removing native soil in areas with a history of invasive plant coverage and replacing it with furnished soil to remove invasive species from the seedbank or reducing the amount of fertilizer applied to reduce soil macronutrients, when applicable. Control of emerging and established invasive species can be accomplished through repeated broadcast treatments or through targeted applications of selective herbicides applied at the appropriate stage of the plant life cycle in combination with mechanical removal as dictated by plant species.

2.1.3 DOT Vegetation Management Strategies

Each state DOT has specific vegetation maintenance requirements and guidelines. Some published guidelines or requirements include Texas Department of Transportation's (TxDOT) *Landscape and Aesthetics Design Manual* (TxDOT, 2017), Ohio's *Guidelines for Mowing Reduction Outside Clear Zones for Compliance with the Candidate Conservation Agreement with Assurances (CCAA) for the Monarch Butterfly* (Ohio Department of Transportation, 2019), and Wisconsin's *Highway Maintenance Manual* (Wisconsin Department of Transportation, n.d.). Vegetation management strategies depend on the DOT's goals. If vegetation is desired but safety requirements need to be met, mechanical mowing or plant growth regulator (PGR) application may be beneficial.

For DOTs, the maintenance of undesirable species can consist of a combination of mowing, vegetation removal, and herbicide application. The strategy used depends on the species being targeted, the timeframe of control, and the rules and regulations of the DOT (National Academies 2023d; Weidlich et al., 2020). Common vegetation management strategies include broadcast and spot treatment applications of herbicide, mowing, string

trimming, brush hogging, and tree removal through manual or mechanical means. In addition, DOTs can design the ROW to reduce the amount of vegetation growth in specific areas, such as using concrete mow strips under guardrails and cable rails to reduce maintenance needs (Bligh et al., 2004).

2.1.4 Vegetation Management for Roadside Drainage and Structural Assets

Vegetation management practices around structural and safety features in the ROW, such as guardrails, slopes, medians, or other features that may cause access difficulties for maintenance, were researched. Given vegetation's ability to influence erosion near structures, sight distances, and other issues in the ROW, vegetation management and vegetation health are intrinsically tied to the integrity of structural and safety assets within the ROW. Proper vegetation maintenance around these assets should be considered in DOT asset management plans.

Vegetation management systems, such as fiber or rubber mats, used in conjunction with select safety features, such as guardrails or cable rails, are designed to prevent vegetation growth along safety features and increase visibility of these assets (California Department of Transportation [Caltrans], 2023). These vegetation management systems can, in turn, reduce management and construction project costs for the DOT. The use of these systems does not entirely preclude these areas from regular maintenance, as fiber or rubber mats and even concrete mow strips under rails require annual debris removal maintenance to prevent weeds from growing in the debris that accumulates on the surface.

Culverts and other aspects of stormwater systems are safety features that directly impact drainage along the ROW. To ensure drainage is achieved, these systems often incorporate vegetation and structural aspects, also known as green infrastructure (Lee et al., 2018). Stormwater systems are regularly inspected and maintained as vegetation can help stabilize the surrounding soil, slow down the flow of stormwater, and act as a filter to allow suspended solids to drop out of the stormwater. As culverts are part of the stormwater system, when they become blocked by excessive vegetation or siltation, there can be significant impacts to the ROW through flooding, and over time this can damage structural assets.

2.1.5 New and Emerging Technology and Equipment

New and existing tools and technology capable of being incorporated into vegetation management programs, designed for both DOTs and related organizations were researched. Remote sensing technologies through satellites and the use of GPS are examples of technology that have been in use for decades. These technologies have been incorporated by several DOTs for structural management and snow and ice removal primarily, but the inclusion of these technologies for vegetation maintenance tasks can vastly improve efficiency and effectiveness by tracking areas that require maintenance (National Academies, 2013, 2023a, 2023b). The use of artificial intelligence (AI) and unmanned aerial vehicles (UAV), on the other

hand, are new and emerging technologies with applications in a variety of fields that can potentially further automate processes that GPS and remote sensing have improved upon for roadside vegetation management (National Academies, 2023b). Contractors, such as Greehill and Cyclomedia®, have developed systems that allow their staff to drive along roadways to map vegetation, such as trees (Cyclomedia, 2025; Greehill, 2024).

The shapefiles can be used by clients to layer with their internal mapping and tracking system. Greehill's AI is capable of identifying the species of trees and determining the relative condition of individual trees based on existing health metric data on that species (Greehill, 2024).

Without proper equipment, vegetation in areas with access challenges can be difficult to control. This can include vegetation growing around safety appurtenances such as guardrails, noise barriers, or overhanging limbs from trees. There are new and established pieces of equipment that are designed to assist with these vegetation management problem areas. Several DOTs incorporate the use of forestry bucket trucks, with an extended reach up to 100 ft (30.48 m) into the tree canopy, into their vegetation management operations (DRG, 2022). These units are limited to working on firm ground such as frozen soil or the road edge. Arborist-tracked lifts can provide more flexibility with the terrain they can access, while being able to reach similar heights (DRG, 2022). Reaching vegetation around roadside structures requires even further maneuverability. Additional articulation of the machinery may be necessary, and this can be provided by machines such as chassis-mounted, articulated knucklebooms with grapple saws, or a Sennebogen® 718 E (DRG, 2022).

2.1.6 DOT Vegetation Management Personnel

Proper staffing is just as essential to vegetation management as the right equipment. One important position within the DOT is served by landscape architects (LA). The duties of LAs include: promoting public safety, stewardship of natural and cultural resources, mitigation of impacts to resources, and enhancing ROW beautification. In some states, LAs sign off on planting plans and design landscapes for ROW projects (National Academies, 2025).

LAs' work can include public engagement, bridge project design, Intelligent Transportation Systems (ITS) box placement, roadside planning and maintenance, development of erosion control measures, and overall project management. Having LAs on staff can ensure that the landscape design is compatible with the roadside, including drainage and sight requirements, while maintaining the aesthetic of the ROW.

DOTs should also have access to staff or contractors certified by the International Society of Arborists (ISA). Wiseman and Harvey (2017) interviewed multiple DOTs in the Mid-Atlantic region to determine the extent of ISA certified staff for roadside tree risk management. They found that the majority of states interviewed had few, if any, ISA certified employees maintaining trees along the ROW (Wiseman & Harvey, 2017). However, in many states, DOT maintenance staff are tasked with assessing, identifying, and removing trees that pose an unacceptable

level of risk or trimming trees to prevent hazardous situations from developing along the ROW (DRG, 2017). Performing tree risk mitigation and tree removal without proper training can lead to mistakes that pose a safety risk to employees and the traveling public.

2.1.7 DOT Public Outreach and Involvement

DOTs are expanding public outreach to include online public participation in addition to traditional in-person outreach (Griffin & Jiao, 2019). Online outreach allows DOTs to increase their geographic reach and the public's involvement. DOTs have different methods for the public to reach out with ROW complaints, including phone systems, email, and websites. DOTs are using technology to change the ways public outreach is completed to help ensure all members of the community are reached when desired, including avenues such as social media. One study indicated that cell phones were used more equally across various demographics within the study to provide feedback to the DOT over more traditional methods such as in-person meetings (Griffin & Jiao, 2019).

2.2 INDOT Site Visit Meetings

INDOT staff highlighted a variety of challenges with roadside vegetation maintenance during the district office visits. DRG addressed several of these issues within the gap and SWOT analysis (see Section 2.4). Several issues were shared by multiple districts, but some challenges mentioned were unique to certain districts.

2.2.1 Vegetation Management Processes and Standards

2.2.1.1 Contracted Work. INDOT contracts the majority of vegetation management work. Southern and northern district staff noted that contractors are not mowing back far enough or around fixed objects within the ROW to meet INDOT specifications. Central district staff mentioned customer complaints regarding contract herbicide spraying. Across the state, staff indicated that there were not enough contractors bidding on vegetation management contracts, and this may lead contractors to receive more work than they can reasonably complete within INDOT's timelines and may also affect bid pricing. The quality control issues identified may be a result of the low number of contractors receiving excessive work. INDOT Central Office staff stated that the lack of prequalified contractors was not exclusive to vegetation management but was noticed across most contract types. In addition, some INDOT field staff and district commissioners are unaware that mowing and herbicide contracts are not intended to replace all in-house vegetation maintenance work, leading to in-house work not being completed as needed.

Staff from the central districts described issues with inexperienced contractors. For example, one staff member indicated that in a recently awarded contract, the selected contractor was not familiar with how to complete the grubbing and other vegetation work awarded.

An additional concern is that contract herbicide application timelines listed in contracts are not always being met. Interviewed INDOT staff mentioned the small number of contractors potentially may be causing this issue as the contractors are awarded more herbicide contract work and do not have enough equipment or staff to meet contract application timelines. Other complaints regarding the quality of contractor work included:

- Not mowing the 500-foot (152.4-meter) transitional area at intersections
- Not mowing full contracted widths (15 feet/4.57 meters) along road segments
- Sections of ditch lines not being mowed
- Saplings not being cut and/or sprayed
- Additional areas needing to be sprayed

Conversely, staff in a district with a specialized vegetation management crew indicated that they did not have any complaints about contractor spraying or mowing and believe their current system is working well. The lack of competition due to too few contractors bidding in addition to increased labor and equipment costs may be driving up vegetation management pricing. INDOT has combatted this issue by switching to a two-year herbicide application cycle (odd-numbered roads sprayed in odd years, even-numbered roads sprayed in even years). This practice may be reducing herbicide effectiveness in years when herbicide is not sprayed, since invasive species are allowed to complete their lifecycle and go to seed, allowing invasive species populations to grow and spread. INDOT tracks herbicide applications using a combination of manual spreadsheet methods and geotagged maps, with contractors utilizing geotagged maps.

Currently, INDOT contracts out broadcast herbicide application for half of the ROW each year. This is being done to help reduce costs. INDOT staff, with the exception of the specialized vegetation management crews, do not apply broadcast herbicide.

2.2.1.2 In-House Work. When developing annual maintenance work plans with technical services, maintenance operations staff drive the road once per year to develop the plan of work and assign it to be completed by contracted forces or in-house staff. At this frequency, they are unable to identify all vegetation-related issues that will appear later in the growing season. Vegetation issues that are identified after the annual plan is set and budgeted for and cannot wait until the following year to be completed typically must be completed by in-house roadside maintenance operations crews. This vegetation work, such as brush cutting, herbicide applications, and sight distance mowing, is often reactionary in response to internal work requests and customer complaints. INDOT has a Deficiency Application tied to ArcGIS Survey123 to proactively track roadside issues, but this program does not have a specific recording option for vegetation management deficiencies. INDOT is planning on replacing this application.

Most maintenance staff in INDOT districts spend most of their time focusing on pavement and structural work and a small amount of their time performing vegetation maintenance.

However, Seymour and Fort Wayne Districts have a small number of specified maintenance operations staff who spend a large proportion of their time on vegetation management. These staff can focus on honing their vegetation management skills by performing the work daily. They understand the performance standards better, can use the equipment more efficiently and safely, and the districts generally have more of the equipment needed to complete work more efficiently than other districts that do not have these specialized crews.

Fort Wayne District has three inspectors who perform vegetation maintenance tasks when contract inspection duties are light. As such, Fort Wayne can get a large proportion of the required vegetation management work completed; however, staff expressed that they could use additional specialized staff to help complete additional tasks that are not required. Seymour District's specialized five-person vegetation management crew complete primarily vegetation management, and state they are able to complete most in-house vegetation management work needed across the district. Similar to Fort Wayne, Seymour's specialized crew was previously tasked with completing contractor inspections as their main priority, but due to supervisor turnover, these efforts have more recently been realigned to focus on completing vegetation maintenance tasks.

2.2.2 Design Specifications, Construction, and Erosion Control

2.2.2.1 Vegetation Maintenance Coordination with Construction Activities. During district meetings, it was clear that communication between INDOT maintenance staff and roadside designers and construction staff during the design and pre-construction phases could be improved. Construction engineers do not typically consider vegetation management needs or maintenance staff access during the design phase. This leads to issues such as ROWs that are too narrow, thereby necessitating slopes be constructed that are too steep for most vegetation to establish well, leading to the development of erosion and slope failures that need to be repaired. INDOT maintenance operations staff often install rip rap for these repairs. For vegetation that does establish, maintenance crews have difficulty accessing it due to the steep slopes. Rip rap does not prevent vegetation from growing but does make access by maintenance crews more difficult for vegetation management.

Maintenance staff are occasionally contacted to provide input to identify problem areas at some sites, but this is typically during the construction pre-final or pre-construction meetings—with exceptions in some of the districts, after the maintenance challenges in the construction plans can be mitigated.

INDOT staff agreed that it would be beneficial to be able to provide input during the scoping stage to address design issues with slopes, noise barriers, culverts, and other difficult-to-access areas prior to the finalization of design plans. It was mentioned that operations staff turnover makes it difficult for construction staff to identify who within the maintenance division to invite to the pre-construction meetings, and that it is also difficult for the maintenance operations staff who attend these pre-construction meetings to identify items that could be issues

for their department since they are not always familiar with how to read structural or other design plan sets.

2.2.2.2 Slope Maintenance, Seeding, and Soils. Southern Districts' staff mentioned that INDOT's ROWs have issues with erosion and slides on steep slopes; northern districts also identified erosion as an issue. The seed mixes being selected may contribute to these stabilization issues. Seed mixes for capital projects are prescribed in the INDOT Standard Specifications and are typically cool-season turfgrass, not native species that would be better suited to local conditions and capable of being established more successfully. There are pay items in construction contracts for the use of soil amendments if needed, but this option is usually not utilized. Soil testing, if completed, is typically for larger roadway construction projects, and only includes soil boring to test topsoil depth. Plant growth layer specifications are rarely met due to cost constraints. Based on experience of the research team working with roadsides in multiple states, existing soil along ROWs is typically not ideal for growing vegetation due to high pH and calcium levels and low phosphorus levels often caused by the road building process, and high salinity levels in states that treat roadways for ice in the winter. This is further complicated by the mixing of soil layers during the construction process, leading to low organic content and high compaction. Soil amendments can help minimize poor soil conditions to promote vegetation growth. Repair projects completed by INDOT maintenance operations staff and any outside permitted work in the ROW are typically seeded with turfgrass due to seed availability at the INDOT garages and staff inexperience using native seed mixes.

Due to the slope failures observed across the state, staff expressed interest in testing alternative stabilization practices such as GeoWeb® for erosion control. Possibly because of issues with steep slopes, soil nutrients, soil texture/particle size, and insufficient topsoil depths, INDOT staff continually must reseed areas or replant trees—one area on I-69 was reportedly reseeded 18 times.

2.2.3 Staffing and Training for Vegetation Maintenance

For most INDOT maintenance operations staff, vegetation management training is completed on the job, with few staff obtaining herbicide applicator licenses. Highway Technician 2 (HT-2) contract inspectors within the maintenance division previously were expected to attain Category 6 herbicide application licenses. The expectation for a Category 6 license was discontinued after the reclassification of maintenance operation's HT-2s. As a result, when inspectors are asked to apply for licenses now, there may be pushbacks that create issues for the Human Resources Department. Given the infrequency that maintenance operations' staff in most districts conduct vegetation management tasks, compared to other roadside maintenance tasks, even staff with herbicide applicator licenses have low confidence in their ability to safely and correctly apply herbicide. Staff with applicator licenses receive annual continuing credit hour seminars to maintain their certifications, but some would prefer more frequent hands-on training demonstrating the use of various INDOT equipment used to treat invasives.

INDOT Operations Memorandum 14-05 (OM 14-05) details in-house vegetation management practices; however, few staff were aware of this document. Staff expressed uncertainty about who is responsible for knowing maintenance performance standards, who should be mentoring and teaching staff, and generally what aspects of vegetation maintenance in-house staff are responsible for versus contractors.

2.2.4 Equipment/Technology

Vegetation management equipment is shared between management units, leading some units to be unaware of all equipment available to them. For instance, at one of the southern management units, staff stated their two Gradall® units were in disrepair, so they could not perform vegetation maintenance requiring this equipment. These staff were not aware that they could coordinate for the use of six other units. The equipment database which is intended to assist in the coordination of equipment access between management units and subdistricts was reported to have issues tracking equipment accurately. Some staff indicated they could not find certain pieces of equipment in the system to find their location or when they would be available for use.

INDOT staff lack certain specialized equipment for performing specific vegetation maintenance activities (e.g., districts with noise barriers lacking equipment to access and efficiently manage vegetation behind those structures). INDOT's equipment used for herbicide applications and tree removal are used infrequently by most maintenance operations staff and, as such, staff are often inefficient with using it, except for the specialized vegetation maintenance staff in Fort Wayne and Seymour.

While workloads have increased over the years, the technology available to maintenance operations staff to assist with the work has not kept up with their needs. Staff agreed that tools to help plan, predict, and track maintenance would be helpful. There is currently no internal mapping or tracking of herbicide application or other vegetation maintenance issues, or any use of AI or drone technology to aid in scouting or investigating customer complaints. INDOT staff drive the roads and map any observable issues with staff physically highlighting district maps with problem areas and adding the location to a spreadsheet to be shared with contractors or other INDOT personnel.

Due to the limitations and lack of efficiency with these processes, improvements to Automatic Vehicle Location (AVL) and GPS tracking and reporting of work are desired.

Another area where this lack of mapping technology has caused problems is in the identification of ROW limits. INDOT staff stated that there are times the ROW boundary is unknown as the ROW width is inconsistent between properties, particularly in areas that used to be county properties that the state has taken over. INDOT has received complaints and has been sued by landowners over trees removed that were outside of ROW limits. INDOT currently has a team in the Central Office that is working to digitize ROW boundaries for the state, but this will likely take another 20 years to complete. Fort Wayne District has begun to digitize their county records as well, but they are waiting on some county parcel data.

2.2.5 Public Outreach

INDOT staff expressed that there is a need to manage customer expectations. The number of customer complaints related to vegetation management is too high for staff to handle all issues, and it has become clear that the public does not understand INDOT's maintenance processes and vegetation management goals.

2.3 Regional DOT Interviews

A comparison is provided below of the responses provided by the six interviewed regional DOTs for various categories. A summary table is included as Appendix A to compare these regional DOT responses to INDOT practices.

2.3.1 Vegetation Management Processes and Standards

2.3.1.1 Vegetation Management Regime and Planning.

Each DOT interviewed follows a different vegetation management regime with each one using a combination of chemical and mechanical control. The amount of vegetation maintenance work completed by DOT staff varies with some states using contractors for much of the work, while others complete most vegetation maintenance in-house. Apart from KYTC and WisDOT, DOTs interviewed complete the majority of mowing in-house. Most DOTs interviewed use zonal maintenance where the type and amount of maintenance completed is determined by the proximity to the roadway. The amount of vegetation maintenance completed proactively versus reactively varies between states, and in some cases, across districts within a state, depending on the activity. Typically mowing and some herbicide application in the clear zone, otherwise known as operational zone or safety zone—unobstructed, traversable roadside areas up to 30 ft from the pavement edge—are planned activities, whereas brush cutting and issues related to sight distance, hazards, and customer complaints are reactionary.

2.3.1.2 Mowing Schedule. Many states have a mowing cycle that is completed on a predetermined schedule over the course of 1–5 years. The clear zone is mowed at least once per year; however, areas outside of the clear zone may not be mowed regularly, with some states not mowing outside of the 15-foot clear zone except to control trees and other undesired vegetation (Iowa DOT). Any mowing Iowa DOT completes outside of the clear zone is to help maintain culverts, ITS boxes, weed control, control trees, and maintain areas for the Monarch Candidate Conservation Agreement with Assurances (Monarch CCAA), per Iowa DOT staff. IDOT, KYTC, and MnDOT complete a full mow-back to the edge of the ROW regularly; this varies from twice a year (KYTC) to once every 4 years (IDOT). MoDOT and WisDOT mow an additional 15 ft (4.57 m) beyond the clear zone. WisDOT does this on a 3-year cycle (one-third of the state every year), while MoDOT mows an additional 15 ft (4.57 m) annually on all interstates in the fall.

2.3.1.3 Tree and Shrub Maintenance. To minimize the risk associated with trees that pose an unacceptable level of risk from vehicle crashes, the majority of the DOTs interviewed do not allow trees to grow along the ROW within 30 ft (9.14 m) of pavement on interstates. IDOT and WisDOT stated that sometimes trees are allowed to grow behind guardrails, but that it is not preferred. Iowa DOT, KYTC, and MoDOT stated they strive to proactively remove trees with an unacceptable level of risk or remove trees before they grow tall enough to reach the pavement should they fail. The majority of DOTs conduct tree removal and maintenance in-house, with contractors hired in cases where a tree is beyond the capabilities of in-house staff to handle due to safety concerns associated with size, tree health, proximity to overhead utility lines, and similar reasons. For example, MnDOT contracts out their mechanical brush cutting and debris removal due to the emerald ash borer (*Agrius planipennis*), while continuing to complete tree trimming and removal and manual brush cutting in-house.

2.3.1.4 Vegetation Maintenance Around Roadside Assets and Appurtenances.

Guardrails, cable rails, and other appurtenances account for a considerable amount of vegetation management, as the visibility of these assets is required for the public and inspectors and vegetation can impact the effectiveness and longevity of these assets. The DOTs interviewed use various pieces of equipment to complete routine vegetative asset maintenance. Despite this, there were several similarities in the difficulties and successes in completing vegetation maintenance. IDOT and KYTC indicated that bare ground treatments using residual herbicide applications were used under cable rail and guardrails. Mowing, herbicide application, rock, and non-bonded aggregates were the most commonly identified items for vegetation management strategies. Multiple DOTs researched weed mats and other long-term management approaches, but the return on investment (ROI) was not large enough for them to justify utilizing these strategies.

2.3.1.5 Ensuring Access for Maintenance and Inspections.

Each state interviewed had access issues with certain assets, particularly noise barriers. The states that indicated their staff do not have access issues behind noise barriers were Iowa DOT (equipment-sized gates in noise barriers) and IDOT (noise barriers at the edge of ROW—requiring no maintenance behind them). The remaining DOTs indicated that they do not complete maintenance behind noise barriers, unless complaints become numerous, due to the difficulty in accessing these locations.

Many of the DOTs interviewed stated that drainage assets (culverts, ditches, and underdrains) were kept clear with mowing. Mowing of these assets is completed either during the regular mowing cycles (IDOT, Iowa DOT, KYTC, MnDOT, and WisDOT) or when requested by inspectors (MoDOT). Some of the DOTs interviewed stated that the culverts/ditches are placed within the clear zone whenever possible to ensure maintenance access and that the culvert/ditch must be accessible by mowers to ensure mowing is completed. In addition to mowing, IDOT, Iowa DOT, and MoDOT physically mark culverts in the field to increase awareness of their location. MoDOT also has all culverts

mapped within their GIS system. WisDOT maps all culverts so county contractors can locate culverts and ditches for mowing.

IDOT stated that ITS boxes are mounted on concrete pads that are mowed around. The concrete pad may extend into a walkway to help staff identify where the boxes are located. Iowa DOT stated that ITS boxes are located on poles with sleeves to prevent damage from mowers and to enable staff to locate the boxes during inspections.

Regular mowing and installation of physical markers were the most common methods identified to ensure that inspectors can locate assets. Where these options are not feasible, enabling staff access to specialized equipment appears to be effective in ensuring that staff can access assets to complete maintenance.

2.3.1.6 ROW Boundaries Identification. DOTs were asked about the identification of ROW boundaries and how maintenance was completed in areas with unclear boundaries. IDOT, Iowa DOT, MoDOT, and WisDOT use survey teams in these instances.

The DOTs interviewed have fences along the ROW edge of limited-access roads, and many DOTs indicated that staff can tell where the property boundaries are along two-lane roads due to farming activities.

2.3.2 Design Specs, Construction, & Erosion Control

2.3.2.1 Vegetation Maintenance Coordination with Construction Activities. Questions were developed to determine where updates should be made to design specifications and how to enhance communication with construction staff to enable safer and more efficient vegetation maintenance. IDOT, Iowa DOT, MnDOT, and WisDOT provide as-builts to maintenance staff or provide access to the information upon request. IDOT, KYTC, MoDOT, and WisDOT currently include, or have included in the past, staff to attend pre-scoring and scoping meetings. However, DOTs who do not have maintenance staff attend pre-scoring or early-stage scoping meetings (before 30% plan completion) stated that the timing of maintenance staff inclusion is often not ideal and often large changes are not possible at the stage where maintenance staff review is completed. Multiple DOTs interviewed stated that they would like maintenance staff to be included in pre-scoring and scoping meetings, as the inclusion of maintenance staff with field experience at these meetings can prevent the development of ROWs that restrict maintenance equipment access.

2.3.2.2 Drainage for ROW. All DOTs interviewed use underdrains or drainage tiles. In extremely wet areas, drainage tiles and underdrains do not reduce the number of ditches. In states with drainage tiles or underdrains installed, there has been little to no reduction in the number of ditches present along the ROW. KYTC stated that the use of drainage tiles or underdrains in cities have reduced the number of ditches, thus reducing the amount of ditch maintenance needed, but that the hours and required funds transferred to drainage tile and underdrain maintenance. Overall, the drainage tiles and underdrains did

not reduce the overall maintenance needed, just the type of maintenance.

2.3.2.3 Soil Management. Most DOTs interviewed stated that soil for post-construction restoration efforts mostly comes from topsoil stripped and salvaged on site during construction unless additional soil is needed to complete the project. When that is the case, soil will be brought in from existing stockpiles or purchased. IDOT, Iowa DOT, and KYTC have some districts that maintain stockpiles at maintenance yards for this purpose. MnDOT has stockpiles of ditch cleanings that are occasionally screened for reuse, but this practice varies throughout the state. WisDOT indicated that new soil is not brought in unless planting of trees and shrubs is involved. To help improve soil quality for herbaceous seed establishment while providing cost savings, WisDOT has started a pilot project using biochar made from trees removed from the ROW. Most states do not test topsoil for macronutrients; it is only tested for pH and organic composition. Fertilizer and lime are then applied at pre-determined amounts as listed in the DOTs specifications, often without using the soil test results to determine appropriate amounts to add. MoDOT completes soil testing before projects start; however, the soil layers are mixed during the construction process, leading the soil testing to be less helpful than desired.

2.3.2.4 Slope Maintenance & Design. The creation and maintenance of roadside slopes has presented challenges for several DOTs. IDOT indicated that district Roadside Managers are contacted to determine seed mix selection for some construction projects, but erosion problems during construction are left to the construction contractors to correct, and they typically do not opt to use native seed to help stabilize slopes. MnDOT expressed difficulty with vegetation establishment on slopes and are currently working on providing improved technical support for post-construction seed establishment.

WisDOT is also having slope maintenance challenges and are currently becoming dependent on rip rap to manage these issues. Staff indicated that many of their slope issues are the result of WisDOT's reluctance to purchase additional real estate, thereby requiring steep slopes that often result in erosion.

Iowa DOT did not mention any major issues with erosion on slopes. Iowa DOT has their Resident Construction Engineer (RCE) ensure vegetation is established before closing permits, and maintenance staff are often cross utilized with construction projects. These staff with maintenance backgrounds are better able to identify stabilization issues in the field during the construction process. KYTC conducts inspections with erosion control staff who are trained on plant species identification prior to releasing construction contractors from the permits, and have contractors reseed if necessary.

2.3.3 Staffing and Training for Vegetation Maintenance

Three DOTs interviewed have vegetation management specialists. The number of staff who specialize in vegetation management varies between states. KYTC has a specialty crew in

each of its 12 districts as does MnDOT in its eight regions. MoDOT has specialized staff to operate Utility Terrain Vehicles (UTV), however, the remainder of maintenance staff perform a wide variety of jobs.

KYTC was reorganized in 2004 as part of SB 39 to create specialized vegetation management crews. These crews complete the majority of vegetation management work, use the DOT’s specialized equipment, and assist the general operations maintenance crews to complete snow and ice removal in the winter. After the development of these crews, vegetation maintenance quality improved in Kentucky.

MnDOT stated that specialized crews were essential for the operation of the DOT. MoDOT stated an agreement with the Missouri Department of Conservation led to UTV operators becoming specialized staff. Each DOT or district with specialized vegetation management crews reported an increase in efficiency for vegetation maintenance tasks.

Apart from manufacturer training for new equipment or software, and pesticide licensing, the majority of DOTs complete training for vegetation maintenance in-house. Most of the DOTs interviewed stated that annual training is completed formally and additional training is completed informally in the field.

2.3.4 Equipment/Technology

KYTC stated that staff use plant identification applications that are AI-based to identify species when needed. No DOT interviewed for this project is currently using UAV technology

for vegetation management. IDOT had a UAV demonstration completed; however, the amount and type of training necessary was found to be cost prohibitive. WisDOT uses UAVs for structural inspections and researched using AI and UAVs to identify invasive species along the ROW.

MnDOT is using inventory systems to track work progress using data from sprayers and work orders, and MoDOT is tracking equipment and materials used for vegetation management in their MoDOT Maintenance Management System (MMS). IDOT, KYTC, and MoDOT have remote control mowers for use along steep slopes to ensure vegetation maintenance is completed, while ensuring staff safety.

2.3.5 Public Outreach

IDOT, KYTC, MoDOT, and WisDOT all reported having a public information program. MnDOT staff interviewed were unsure if their state DOT has a public information program. The states who responded positively about having a public information program highlighted mowing practices as one of the items the program addresses.

2.4 Strengths, Weaknesses, Opportunities, and Threats (SWOT) and Gap Analyses

2.4.1 SWOT Analysis Results

Table 2.1 outlines the SWOT analysis results.

TABLE 2.1
SWOT Analysis Results.

Strengths	Weaknesses	Opportunities	Threats
<ul style="list-style-type: none"> INDOT is reviewing and has begun investing in select new tools and technology. Moving forward with technology—herbicide trucks ordered via spring 2024 letting will have mapping capabilities. Field staff have a desire to learn about and begin using new equipment. Field staff have a desire to complete vegetation management following INDOT’s needs and goals. Field and office staff have a lot of the same priorities for vegetation management. INDOT has a comprehensive vegetation management plan. INDOT has a strong fleet vehicle maintenance tracking system where maintenance units check out equipment as they need it. Organizational structure is well defined, and all staff know they should turn to the roadside maintenance specialist for assistance in matters related to vegetation management. 	<ul style="list-style-type: none"> Equipment needs are not met. Lack of understanding between INDOT local staff and contractors regarding the breakdown of workload tasks. Disconnect between Central Office staff and vegetation management field staff. Operators lack consistent experience and refresher training on the specialized equipment. Generalist staff lack consistent application of vegetation management knowledge, such as vegetation identification. Field staff not familiar with OM 14-05. Lack of staff with herbicide applicator licenses. Reactive vegetation management style reduces efficiency. Limited number of contractors bidding which can inflate costs due to lack of competition. Contractors may be awarded jobs above their capacity. Perceived barrier to entry for new contractors. 	<ul style="list-style-type: none"> DOT research is increasing the use and availability of tools and technology for roadside vegetation asset management (RVAM). Mapping capabilities have increased exponentially in recent years. Technology designed for agriculture and tree services can be adapted or used as is by DOT staff. Use of AI and other tools and technology can complete work with fewer personnel due to budget decreases. By following the outreach and bidding processes found to be effective by other DOTs, INDOT can: <ul style="list-style-type: none"> increase contractor competition limit the number of contracts (acreage) individual vendors that can be awarded at one time, thus contract compliance. Other DOTs have found that dedicated vegetation management crews improve efficiency and effectiveness of work. 	<ul style="list-style-type: none"> Increased costs of materials (such as herbicide, sprayer tanks, trucks, and more), personnel, and contracting combined with budget decreases. Competitors (contractors) may pay more money, thus recruiting current DOT staff and reducing the number of applicants to the DOT; this is especially true of highly trained personnel. Large leaps forward in new technology and equipment are difficult for employees to learn. The increased reliance on technologies may cause a loss of entry-level positions. By not addressing hazard trees, INDOT is opening themselves up to potential lawsuits caused by injury or loss of life. Low quality of mapping due to low technology opens INDOT up to potential lawsuits due to a lack of timestamps for herbicide application locations.

2.4.2 Gap Analysis Results

DRG developed a gap analysis matrix to describe the main issues identified with INDOT’s vegetation management processes, potential solutions, and expected benefits of implementing changes (Appendix B). A summary of the gap analysis follows.

2.4.2.1 Vegetation Management Processes and Standards.

Contractors perform INDOT’s proactive vegetation management work. Yet, there are not enough pre-qualified contractors bidding on vegetation management contracts to keep the work competitive, resulting in a small number of contractors being awarded more work than they have the capacity for in the time frames provided within the contracts. INDOT’s in-house vegetation management is reactionary with a lack of planning or production goals by which the districts are held accountable. Additionally, in-house staff often lack clarity on contractor roles and responsibilities, leading to confusion among INDOT staff about which vegetation management tasks for which they are responsible.

Daily estimated production rates for in-house crews completing some vegetation management activities are below the daily production guidelines that are outlined in the INDOT Division of Maintenance Work Performance Standards (WPS), as shown in Figure 2.1, Figure 2.2, and Figure 2.3. The WPS provides INDOT staff a way to determine costs for vegetation management activities through providing possible production rates but does not constitute daily production goals. In the dataset reviewed for this project, districts only met 55.1% of the daily production guidelines for manual brush cutting on average. Similarly, all districts met 71% of the production guidelines on

average for mechanical brush cutting. Individually, Fort Wayne and Seymour Districts (both of which have specialized vegetation management crews) are meeting the mechanical brush cutting production guidelines. For spot seeding activities, all districts are below production guidelines, meeting only 24% of the guidelines on average.

DRG did not identify any major issues with INDOT’s vegetation management OM 14-05 draft currently under revision regarding existing maintenance zonal definitions or the general methodologies for the vegetation management work tasks described. However, there are no specific guidelines for small culvert maintenance or vegetation removal within ditches provided in OM 14-05 or in the WPS. Culvert inlets and outlets obstructed by woody vegetation and invasive herbaceous vegetation growth is of particular concern and should be called out to prevent impediments to flow and avoid the associated roadside maintenance challenges caused by flooding.

2.4.2.2 Design Specs, Construction, and Erosion Control.

There is a disconnect between INDOT design standards, construction personnel, and staff who conduct vegetation maintenance. Maintenance staff in four INDOT districts are often not included in the scoping phase, which leads to areas where maintenance of vegetation is extremely difficult due to how the areas were designed.

Without maintenance staff input at the appropriate time of the construction process, areas of the ROW may not be able to be maintained as required due to safety concerns, a lack of access for staff or equipment (i.e., a slope greater than 3H:1V (Horizontal to Vertical)), vegetated medians too narrow to safely access, and noise barriers without adequate access behind the

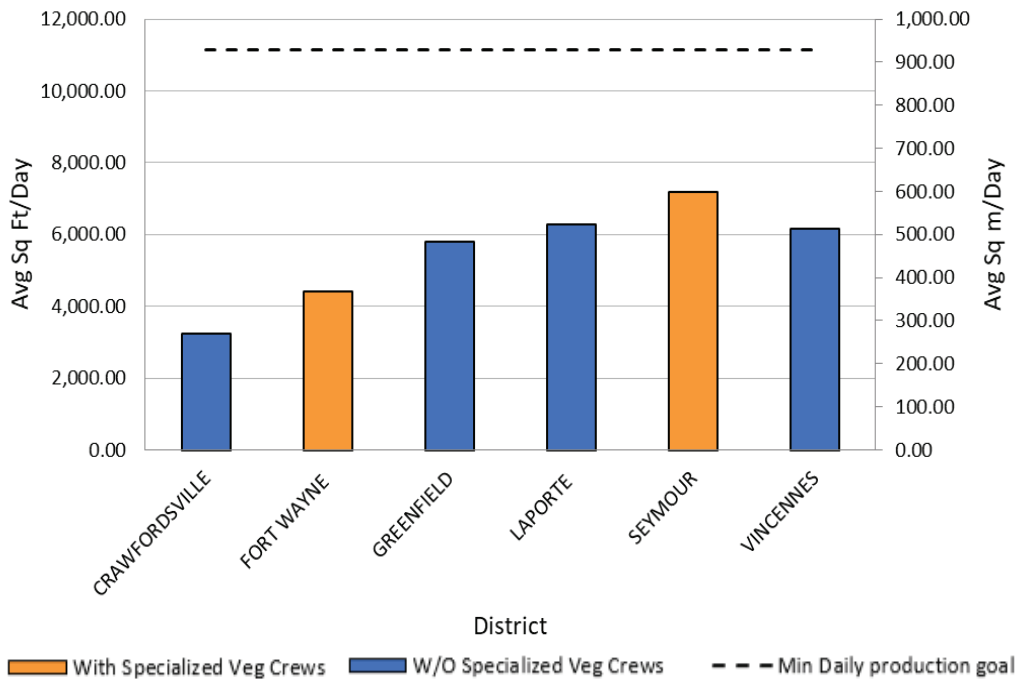


Figure 2.1 2023 Average Manual Brush Cutting Production Rates.

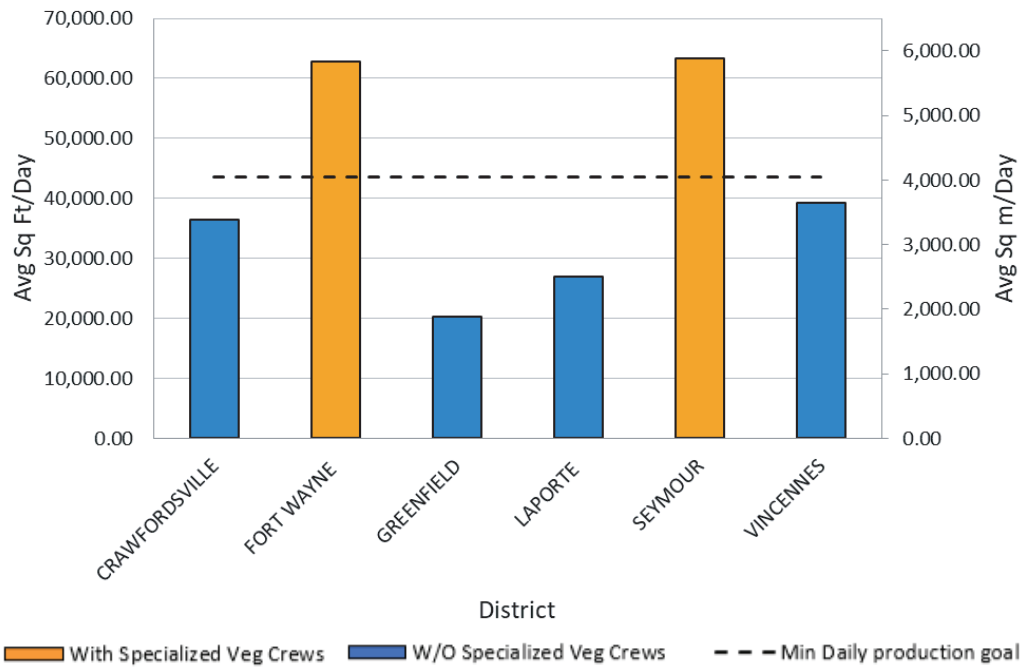


Figure 2.2 2023 Average Mechanical Brush Cutting Production Rates.

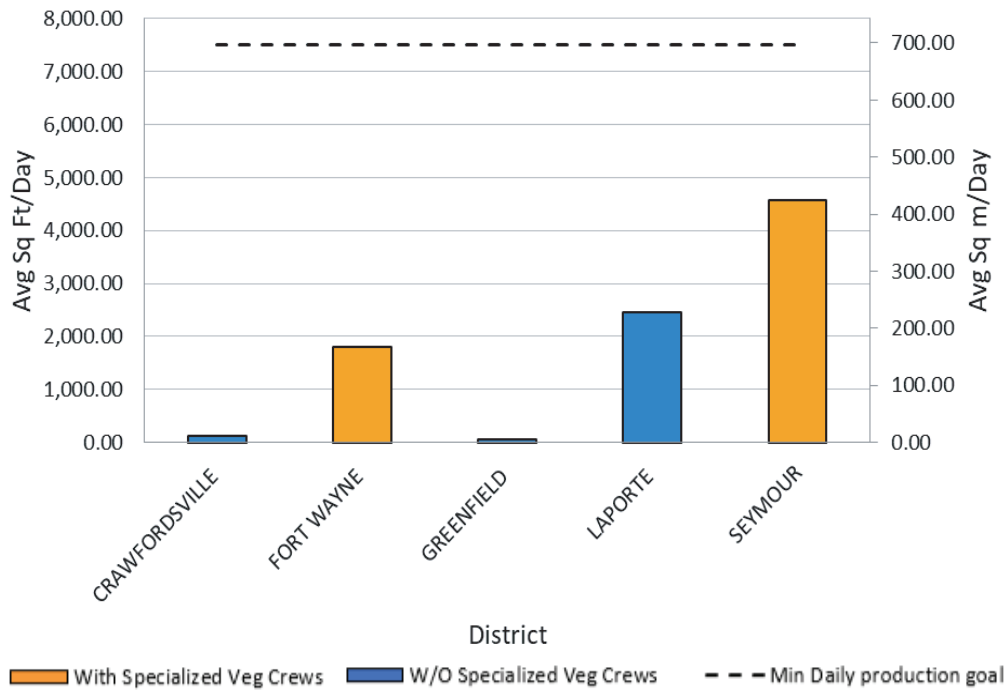


Figure 2.3 2023 Average Spot Seeding Production Rates.

barrier (Figure 2.4). INDOT noise barriers typically only contain fire hydrant access doors which are not adequately sized to allow access for large equipment such as mowers or tractors (Figure 2.5). Instead, staff need to travel to the end of the barriers to obtain access, then travel the length of the barrier to where

maintenance is needed, if the area behind the barrier is not too steep or washed out to traverse. INDOT field staff also have issues locating culverts and ditches as they are not designed to be consistent distances from pavement and are not denoted with field markers. Overall, it was found that INDOT maintenance



Figure 2.4 Noise Barrier With Vegetation Growth Over Wall and Access Difficulty Along I-465.



Figure 2.6 A Slope Along US 31 Just North of Indianapolis in January 2024.



Figure 2.5 Noise Barrier With Fire Hydrant Access Door Along I-465.

staff do not have access to as-builts, do not meet with construction staff to determine where new assets will be located, and field staff do not always have ready access while in the field to computers/tablets to access GIS databases where structural assets are mapped, making it difficult to ensure maintenance is possible with roadway designs.

Two INDOT districts (Greenfield and La Porte) invite maintenance staff to scoping meetings. Greenfield District has a document that was developed in 2020 that lists staff members, by position title, who should be invited to specific meetings during the design and construction process. This guidance document includes various maintenance staff members to be included at meetings and has helped Greenfield District staff to ensure that construction projects have maintenance staff review plans prior

to the pre-final check when modifications to the plan can no longer be made.

Additionally, habitat-appropriate seed mixes are not being utilized by contractors or INDOT staff. Without standards requiring the use of native, habitat-appropriate seed mixes, turf-grass seed mixes U and R are routinely selected for seeding all areas. These seed mixes are installed without conducting soil tests to check for organic matter and other key characteristics and are sometimes installed at inappropriate times in the year that do not allow time for germination or only allow for minimal development prior to winter weather, both of which can result in lower establishment rates. Soil stabilization methods implemented are not always appropriate for sites, with loose straw sometimes used in place of hydroseeding or erosion control blankets along slopes, resulting in vegetation not establishing after seeding. For example, the research team observed that vegetation was not established on slopes along US 31 prior to the 2024 dormant season and straw was sparse, exposing bare soil (Figure 2.5). Proper seed dissemination practices and seed mixes not being used on slopes can result in difficulties with stabilization and vegetation establishment.

2.4.2.3 Staffing and Training for Vegetation Maintenance.

Specialized vegetation management operations staff numbers range from zero to five across the six districts. Seymour District has five specialized vegetation management operations staff, while Fort Wayne only has three. Crawfordsville District recently hired a Vegetation Management Supervisor to help the district move in the same direction as Fort Wayne and Seymour, with staff specializing in vegetation management. Within Fort Wayne and Seymour, the specialized vegetation management operations staff complete contract inspections and vegetation management. The remaining districts, as of early 2025, did not have specialized crews. Assuming five field staff and a team lead—or six staff members—within each district, there is a gap of 21 specialized vegetation management staff within INDOT. Reallocation of HT-2 maintenance staff to focus on contract inspections and vegetation maintenance will help close this gap.

Districts that have fully formed specialized vegetation management crews (Seymour and Fort Wayne) are more efficient and cost-effective than districts without specialized staff.

For example, with manual brush cutting, Seymour District has 38.5% higher work efficiency and 44.1% lower costs per square foot, compared to the average across other districts. The average work efficiency between Seymour and Fort Wayne is more than double other districts for mechanical brush cutting, with half the average costs per square foot of other districts. The average work efficiency between Seymour and Fort Wayne is 2.6 times greater than other districts for spot seeding activities with an average cost per square foot 95% lower than the costs per square foot for other districts.

The difference in cost and efficiency may be driven by the fact that the only training available for special equipment or general vegetation maintenance procedures is the initial training and annual refreshers, when completed. As a result, staff may not understand how to operate specialized equipment or have reduced efficiency due to unfamiliarity. Conversely, the specialized crews can focus on honing their vegetation management skills by performing the work more regularly. They understand the WPS better and can use the equipment more efficiently and safely. The specialized crews also have ready access to more of the necessary equipment as they use it on a regular basis, whereas the districts without these specialized crews need to transport and gather the equipment they need from the last office to use it each time the equipment is needed for a scheduled work type.

In addition, some management units do not have a licensed herbicide applicator, and some do not have trained service people or registered technicians for herbicide application. This may not only be impacting the effectiveness of INDOT's in-house vegetation maintenance work but also the quality of inspections made by contractor herbicide application since HT-2 contract inspectors are no longer expected to attain Category 6 herbicide application licenses.

Combined with the small amount of in-house vegetation management training, the lack of inspectors who are also certified herbicide applicators likely impacts the quality of contract inspections.

2.4.2.4 Equipment/Technology. Districts that lack specialized equipment (e.g., bucket truck for tree removal) are less efficient at certain tasks. For example, districts with forestry bucket trucks (trucks with a reach over 46 ft (14 m)—Seymour, Fort Wayne, Crawfordsville—are able to remove more than double the number of trees per day than districts without forestry bucket trucks. The four forestry bucket trucks within these three districts account for 67% of in-house statewide tree removal work. Seymour and Crawfordsville are almost three times more cost-effective than the districts without forestry bucket trucks. No district has the proper equipment for large-scale tree removal or the ability to reach over, under, or behind structural assets such as bridges and noise barriers (e.g., removing trees with a chassis-mounted, articulated knuckleboom with grapple saw or Sennebogen® 718 E). Additionally, herbicide spray trucks utilized for spot spraying activities are not outfitted with GPS technology to track application timing/location.

2.4.2.5 Public Outreach. INDOT's communication division is not effectively communicating vegetation management information to the public. As a result, the public is not aware of INDOT's current vegetation management practices, or any new policies they implement.

2.5 Implementation

Based on the results of the SWOT and Gap Analysis, DRG developed 12 action items to improve INDOT's roadside management (Appendix C). These items were presented to the SAC, and seven implementation items were identified. DRG developed Technical Memorandums detailing background information, findings, and recommendations for each of the seven implementation items selected for identifying INDOT's needs and next steps for implementation (Appendix D).

3. DISCUSSION

3.1 Recommendations

Based on the results of the literature review, INDOT meetings, DOT interviews, gap and SWOT Analyses, and project implementation, DRG developed the recommendations described in Section 3.1.1.

3.1.1. *Vegetation Management Processes and Standards*

3.1.1.1 Proactive Planning. In-house vegetation management work is typically reactionary for INDOT. Proactive maintenance can have many advantages over reactive maintenance, most significantly the reduced risk to the public. A reactive approach is not an effective means of targeting areas with the highest maintenance needs. For example, DRG conducted an urban forest study in 2016 in Largo, Florida, a city that relied heavily on responding reactively to customer requests for tree maintenance. DRG found that this approach was ineffective for tree care and roadside safety improvements since the area's most frequent calls were not from locations where trees required the most maintenance. Conversely, proactive systems ultimately improve roadside safety because potential problem areas are visited, assessed, and maintained on a regular basis (DRG, 2016). Other benefits of proactive maintenance include:

- Increased staff efficiency due to methodically working through a priority list
- More predictable budgets and projectable workloads
- Reduced long-term maintenance costs
- Increased environmental and economic benefits from properly maintained vegetated areas as they mature (Harrison, 2014)
- Complaints that can be addressed, prioritized, and often worked into the planned workload quickly by office staff with access to the schedule
- Increased consistency of data reporting for customer complaint work orders

One form of proactive maintenance is the application of Plant Growth Regulator (PGR) to vegetation along the ROW to slow

vegetation growth by inhibiting plant cell elongation. INDOT currently has contractors broadcasting broadleaf weed control herbicide every other year in the spring and fall (odd numbered roads during odd numbered years, even numbered roads during even numbered years), but these treatments do not contain PGR and would only provide seedhead suppression if the current prescribed application rates were increased. Although INDOT has chosen to avoid PGR treatments due to the possibility of thinning grasses after repeated use, we recommend that PGR be applied every other year during the period in spring when cell elongation occurs. This gap will allow seed heads time to form and disperse during years PGR is not used, minimizing the impact on vegetation health that can result when PGR is applied too frequently. Successful PGR treatment will provide a longer window until the mow cycle is needed in the years that PGR is used, allowing INDOT to defer mowing by a couple of weeks. Note that this will then necessitate alternating mowing schedules every year, which districts will need to account for when managing mowing contracts. In addition to PGR, broadleaf weed control should be applied to all roads annually in the spring and fall.

Even if only applied in areas frequently mowed due to site distance issues and related complaints, the application of PGR and broadleaf weed control will reduce the number of mows needed per year in the areas where it is applied. We recommend that areas that receive frequent customer complaints be the highest priority for the PGR treatments, though use throughout the Operational Zone is ideal. The annual application of herbicide can also increase invasive plant species control and reduce their spread along the ROW. Both of these treatments will reduce the overall amount of work needed by INDOT and contractors for invasive species control each year over time and will ultimately offset the initial increased costs of additional spraying.

3.1.1.2 Establish Performance Goals for In-House Crews.

Given the challenges a reactionary approach can cause for vegetation management planning and coordination across the state, DRG recommends that INDOT integrate additional specific vegetation management goals into annual work plans to enhance “targeted maintenance efforts” as described in the OM 14-05 draft currently under revision. Currently, INDOT annual maintenance work plans contain little to no vegetation maintenance. As a result, if the work is not in the work plan, there is no staff accountability for the completion of the work. In conjunction with improved tracking of vegetation maintenance needs (see Section 3.1.3), specific vegetation management tasks should be integrated into work plans as annual “Tracked Activities.” This will ensure districts will be held accountable to carry out a set amount of pre-planned vegetation management every year in areas that have been confirmed to need it (e.g., areas not covered by contracts, sight-distance problem areas, etc.).

3.1.1.3 Update Contracting Processes. INDOT has a shortage of pre-qualified contractors, so DRG recommends updating contracting processes and pre-qualification requirements to attract additional bidders. Increasing the number of bidders will increase competition for contracts, which may help

decrease bid prices. The competition may enhance the quality of contractor work and contractor adherence to goals and timelines to improve chances of being awarded future work. DRG would also expect that with more vendors under contract, vegetation treatment timelines will be more likely to be met, thereby increasing the quality of work.

Based on the practices of other DOTs, DRG recommends that INDOT begin using two pre-qualification periods. Contractors who submit either an audited statement or reviewed statement should have the period between the pre-qualification review increased from 12 to 16 months. It is recommended that the age of the financial statement, after INDOT’s acceptance of the financial statement, does not factor into the length of the pre-qualification period. Well-established companies (i.e., 10 years plus experience) with no issues in fulfilling contract(s) or newly formed companies with key staff who have 10 years or more of experience in the field for which they are applying for INDOT pre-qualification should be given the opportunity to apply for a reduction in pre-qualification requirements where they would only need to provide financial statements for pre-qualification. This reduction would last as long as the key successful personnel remain with the contractor (e.g., field supervisor remains with the company) and so long as the contractor shows the capability to rectify work that is underperformed or shows the ability to pay for any financial or legal liabilities. Financial statements should continue to be provided annually. Simplifying the pre-qualification requirements for vegetation management contractors would be helpful to attract and retain additional qualified bidders.

Although vegetation maintenance is often associated with constructed projects, it is not a construction activity and should be treated as a separate activity. This would reduce the instances of qualified vendors being barred from bidding on this work due to restrictions that are only relevant to construction projects (e.g., training requirements of journeymen).

3.1.1.4 Improve Quality Control/Quality Assurance of Contractors.

Another way to increase the quality of contracted vegetation management work and reduce the need for INDOT’s in-house off-cycle work is to have specific HT-2s with herbicide applicator licenses that are well-versed in the contract language and performance standards perform contract inspections as their primary work task. When inspection work is light, these staff should assist in-house vegetation maintenance staff as their secondary work task. If contractors are aware that their efforts are being more closely monitored, quantified, and evaluated, and that they will have an impact on future contracts, they may improve the quality of their work. Other general language improvements to clarify contractor responsibilities are also needed, as described in the Contract Language Recommendations.

Contract inspectors and contractors should be aware of how frequently herbicide calibration demonstrations should be completed. Mowing inspections should include width, intersections, and fixed objects along the ROW to ensure all assets are mowed as stated in the contract. This information should be included in the contract and match INDOT’s internal standards.

3.1.2 Staff and Training Updates

During the gap and SWOT analysis, it became clear the reassignment of some generalized maintenance operations field staff to specialized vegetation management crews in each district would improve performance and efficiency. This is demonstrated by the two districts that currently operate with specialized crews and a crew supervisor.

For brush cutting and seeding activities in 2023, the districts with specialized crews were more efficient (i.e., the amount completed per labor hour), with costs 33.5% less per unit area. This increased efficiency may be tied to the fact that the specialized crews have ready access to all needed equipment and have more experience working with specialized equipment, such as herbicide application equipment. The use of specialized crews across the state would mean training on specialized equipment would be contained to only six individuals within each district, and specialized equipment would only be needed for those staff as opposed to the majority of INDOT's maintenance staff needing the training, thereby reducing costs and increasing staff safety. The creation of specialized crews will allow non-specialized crews to maintain focus on non-vegetation-related tasks, such as crack sealing, instead of being pulled off to address customer service complaints related to vegetation. Vegetation management will also be more effective long term as those staff will have a better understanding of OM 14-05 and can hone their skills in identifying vegetation management issues to address them more quickly and effectively, thereby reducing future complaints.

DRG also noted that specialized crews complete work on a more proactive schedule which results in more efficient use of staff and equipment and fewer customer complaints. This was supported by data from 2023 where for every work order related to a complaint in a district with specialized crews, a district with non-specialized crews receive nine complaints. The specialized crew's supervisors will also be able to provide input at design and construction meetings. This may reduce instances when structural assets make vegetation maintenance more difficult due to roadway design issues. As shown in the extended analysis (Appendix C), enhanced efficiency and cost-effectiveness of specialized crews will result in nearly a 700% ROI within the first year (ROI is met within 1.5 months).

If INDOT decides not to implement specialized vegetation management crews, there are alternative training and staffing related steps that are recommended to aid non-specialized staff with vegetation management:

- Develop one-pagers and videos to provide additional training/information on proper equipment use and OM 14-05, along with conducting additional herbicide training. With better trained staff, DRG would expect to see the time needed for vegetation maintenance decrease, equipment damage because of staff misuse and the resulting repair/maintenance costs decrease, and the need for annual follow-up visits for herbicide work at previously treated sites and at sites where herbicide was not applied after manual or mechanical control also decrease.
- Implement pay progression or incentives for staff who attain certifications related to vegetation management (e.g., herbicide applicator license), such as making these requirements for a promotion to the next position level (i.e., HT-3 to HT-2). This will

help increase the number of experienced staff in each district wanting to complete additional vegetation management training and would reduce the need for onboarding of new staff because of increased employee retention. INDOT previously stated that pay progression outside of promotions is not feasible due to funding; however, tying these certifications to promotions may help to remove this barrier.

3.1.3 Equipment and Technology Purchases

DRG recommends INDOT purchase forestry bucket trucks for general tree work, as well as arborist tracked lifts, chassis-mounted articulated knucklebooms with grapple saws, or Sennebogen® 718 E to help with maintenance behind and over noise barriers and other difficult-to-reach areas such as under bridges.

Having the proper equipment to complete these kinds of tasks will increase the cost-effectiveness of tree maintenance and removal and provide the ability to maintain vegetation behind existing noise barriers. Increased efficiency is already being seen across INDOT districts with the three districts that have access to forestry bucket trucks. Based on differences in cost-effectiveness between districts with forestry bucket trucks and those without, annual savings for tree removal and tree trimming activities would total \$245,632.60 if all districts had a forestry bucket truck. Tree maintenance can also be completed more proactively, as staff will be able to reach trees to trim or remove them as needed before they fall and become a roadway hazard. With the ability to provide proper and timely maintenance around noise barriers, vegetative damage to these structures will decrease, resulting in an increased lifespan of these assets.

In addition to large equipment purchases, increased usage of mapping and inventory tools and technology would greatly improve INDOT vegetation management. The use of inventory and mapping systems improves the ability of DOTs to measure the amount of work their staff are performing and to measure the benefits of performing the work, thereby enabling a quantification of cost of deferring the work to make a case for funding. Mapping and inventory tools have been found to increase DOT staff productivity by allowing staff to track vegetation maintenance on both a local and statewide scale. The inclusion of field staff in the mapping and tracking of assets increases field staff morale and retention. DRG suggests that INDOT develop or adopt an existing inventory mapping system for vegetation management, utilizing GIS or similar tool, and integrate this data into the current INDOT deficiency application or the "DMO" system in development to replace it. This inventory system could be developed for INDOT specifically or the mapping could be completed by contractors to collect information on ROW trees and other assets.

Currently, issues noted in the INDOT deficiencies application are tied to a single survey file generated using the ArcGIS Survey123 inventory program that allows collection of location and deficiency type, location, photos, and general comments (Figure 3.1). Staff expressed that this program is currently overloaded with deficiency layers, so vegetation issues have not been integrated, and most complaints are reported and handled manually rather than through application.

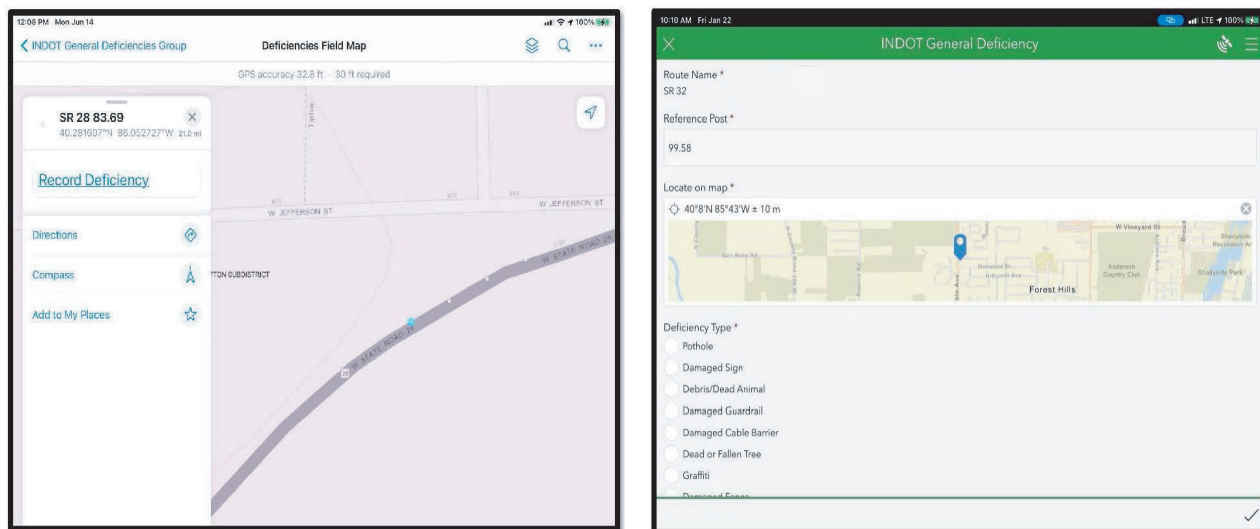


Figure 3.1 Screenshots from INDOT’s Deficiencies Application (to be Replaced by the New “DMO” System).

A more streamlined system that focuses solely on vegetation management issues and has the capacity to capture geospatial information and assign items to work orders will improve vegetation management integration into work plans and allow for greater quality control over maintenance tasks that are already completed. INDOT will be more aware of the location and timing of vegetation management needs and will have a greater capacity to complete vegetation management to reduce customer complaints.

3.1.4 Design/Specification Updates

3.1.4.1 Guardrail and Cable Rail Specifications.

Vegetation under and around guardrails, cable rails, and other roadside safety structures require maintenance but require labor-intensive methods to access. To alleviate this issue, it is recommended INDOT consider updating safety feature specifications (guardrail, cable rails, etc.) to use alternate non-vegetative materials where vegetation maintenance is difficult or a safety hazard (e.g., areas where median width causes safety concerns). These materials would reduce the need for vegetation maintenance around guardrails and cable rails, and the associated costs and safety concerns. Many of the materials available for long-term vegetation management under structural roadside assets are considered cost-prohibitive by many DOTs, except for concrete barriers as an alternative to guardrail. Research indicates that despite their higher initial construction costs, concrete barriers have lower lifetime costs and can provide the same vegetation growth reduction benefits as other forms of mow strips under guardrail at a fraction of the time for the ROI. Future research should analyze in greater detail current and future guardrail positioning along INDOT roadsides and evaluate the costs and benefits of utilizing concrete barriers in these areas.

3.1.4.2 Noise Barrier Specifications. DRG also recommends updating noise barrier design specifications to reduce the need for future maintenance. Noise barriers should be

placed at the edge of the DOT ROW to reduce the need for maintenance behind the barriers. INDOT should implement agreements with adjacent landowners for the landowners to maintain and use the areas behind the wall at their own risk. As the adjacent property owners have easier access and an interest in the area’s appearance, these types of agreements have been successful for Caltrans. In areas where utility access will be needed, or in areas where excessive vegetation growth could impact noise barrier integrity, but landowner maintenance agreements are not feasible, a minimum gap of 15 ft (4.57 m) from the ROW edge is recommended for INDOT to allow utility and/or maintenance access.

Access doors in noise barriers should be large enough to allow access for commonly used vegetation management equipment that will be safe for use behind noise barriers, such as UTVs and pickup trucks (i.e., 10 ft [3.05 m] wide, with drop-offs behind them prevented. Iowa DOT, for example, has double door gates built into noise barriers to allow access by tractors or pickups. A recent study completed for Ohio Department of Transportation (ODOT) that also explored current DOT practices for noise barrier maintenance provides these same recommendations regarding access (Croasmun et al., 2023). The gates should be made with alternative materials such as fiberglass that will not run the risk of rusting shut as INDOT’s current fire access doors do but would maintain the same sound-reducing qualities as the current doors. TxDOT has begun using plastic noise walls with double door gates which can be up to 10 ft wide (Atlantic Industries Limited, 2024). Where access doors are not feasible, sufficient gaps (2.5:1–3:1 overlap length to gap width ratio, as suggested by AASHTO) between the ends of adjacent noise barriers should be provided to allow for equipment access.

3.1.4.3 Slope Stabilization Materials. It is recommended that INDOT test innovative technologies to help improve slope stabilization effectiveness. DRG recommends testing GeoWeb® or a similar alternative slope stabilization technique that has

been shown to reduce slope failures and improve vegetation establishment. They will be particularly valuable on slopes that are too steep for maintenance activities such as mowing (greater than 2.5:1 or 40%). Costs will depend on the total acreage of slopes along Indiana roadsides that fall between 40% and the maximum slope for GeoWeb® (1:1 or 100%).

It is recommended that INDOT use native seed mixes on backslopes that are 30 ft (9.14 m) or more from the edge of pavement to help reduce erosion. The deeper and more complex root systems of these species will penetrate the soil better and help to stabilize the slopes better than turfgrass. Turfgrass seed mixtures (seed mix U and R) should continue to be used in the Operational Zone to help ensure line of sight. Native species require less pounds per acre for establishment, making the overall cost of the native mixes less than or equivalent to the price of non-native turfgrass mixes, even with the per pound cost of native seed being higher than that of turfgrass. Additional savings from the use of native seed mixes will be realized due to reduced need for straw or mulch application, decreased fertilizer application amounts, and reduced watering needs when compared to the installation requirements of turfgrass.

3.1.4.4 Culvert and Ditch Locating. Another design related issue for INDOT is that culverts and ditches are not clearly visible for inspection or maintenance staff. DRG recommends that INDOT mark culverts in the field and, similar to IDOT and MoDOT, develop standard drawings for the markers. These can be some form of marking posts, flagging, or other optic marker. These markers will assist inspectors and maintenance staff locate culverts and will also reduce instances of equipment, such as mowers, damaging culverts. Note that maintenance staff will need to complete maintenance on these markers to ensure they remain visible in the future. As a supplement to field markers, it would also be helpful to make culvert and ditch locations accessible to field staff and supervisory staff via a GIS system on mobile devices, such as the updated INDOT deficiency application. Ditch and culvert location data for integration into this GIS system can be collected via mobile LiDAR, which is a cost-effective alternative to field surveys for prioritizing and planning ditch maintenance (Habib et al., 2021).

3.1.4.5 Design Process Recommendations. It is recommended that individual ditches maintain a consistent distance from the road, where feasible depending on terrain, and ROW property boundaries. Culverts should not be designed with slopes that inhibit maintenance activity. Chapter 203 of INDOT's Design Manual (2013, p. 86) states that "channel side slopes should not exceed the soil or lining's angle of repose and should be 3H:1V or flatter." We recommend this slope should be updated to 6H:1V. Creating gentler slopes may require the purchase of additional ROW, but the savings that result from having ditches better designed for maintenance and slopes that are more stable may outweigh these ROW purchase costs. INDOT staff indicated that they aim for 6H:1V slope in practice, so implementing a reduced slope requirement should be feasible.

During the project, it was revealed that increased communication between the maintenance and design divisions should be improved. Maintenance staff input during the design and construction stages of projects can help to prevent maintenance challenges. DRG recommends that statewide INDOT incorporate similar requirements to the Greenfield District, Caltrans, or at a minimum, suggestions in their Design Manual to integrate maintenance staff into the design process. Maintenance reviews should ideally occur no later than the 30% design stage. INDOT can utilize the Transportation Program Meeting Attendees—Greenfield-INDOT District chart created in 2020, follow a similar model to Caltrans and break down their design review personnel into various teams/committees with varying responsibilities during design administration, or develop a more flexible structure to accommodate district and project specific needs.

3.1.5 Soil Management

Given the challenges that INDOT has been experiencing with seed establishment, particularly on construction project sites, DRG strongly recommends soil testing of all construction sites and as needed per results, the incorporation of soil amendments prior to seeding. At a minimum, soil testing should consider cation exchange capacity (CEC), pH, organic matter, macronutrients (nitrogen, phosphorus, potassium), and particle size, as described in Indiana Test Method (ITM) 515-15. In areas where vegetation establishment has historically been an issue, soil salinity should also be tested. Stockpiled soil from road construction often does not support vegetation unless amended with organic matter. In a recent study of seed mix establishment along Ohio roadsides (DRG, 2023), both turfgrass and native seed mixes failed to establish without the use of amendments in areas where soil test results showed organic content, phosphorus, pH, calcium and sodium levels outside thresholds compatible with life for species seeded.

Soil amendment types and amounts should be determined based on soil sample results, this can include compost, fertilizers, lime, biochar, sustainable, engineered soil mixes, and other engineered products to alter soil chemistry. If the soil testing lab is provided with the types of plants to be planted/seeded (e.g., native grasses and forbs, turfgrass, etc.), recommendations can be provided for the proper amount of amendments needed for the selected plant types to have their soil macronutrient requirements met. Soil scientists can be contacted from organizations such as university extension offices or from local National Resources Conservation Service offices to provide specific recommendations on the quantities of macronutrients to use to achieve the recommended levels.

INDOT can consider adopting similar soil amendment methodologies to the Maryland Department of Transportation (Maryland DOT). Maryland's Soil Special Provisions Insert 920 Landscaping Materials (2024) provides specific soil test values and recommended amendments for existing topsoil on construction sites. The requirements consider quantity of prohibited weeds, debris, grading analysis results, textural analysis, pH, organic matter content, nutrient content, soluble salts,

and harmful materials and provide amendment guidelines based on these metrics. For example, the standard requires that limestone be applied to topsoil that has a pH of 4.8–6.1, while sulfur should be applied to topsoil with pH 7.1–7.6. Compost is to be applied if organic matter is between 1 and 3.7.

Soil amendments can be expensive, but failure to use them when needed can result in the failure of vegetation to establish that may result in slope failure. To enhance roadside soil while expanding material reuse statewide to save on costs, DRG recommends that INDOT explore the use of sustainable, engineered soil mixes. Engineered soil mixes can be designed to support plant establishment and be made from common agriculture or industrial waste and by-products such as dredged sediment, recycled concrete aggregate, biochar, and sawdust, among others. These engineered soil mixtures offer benefits such as sustainable material reuse, reduced costs for sand and compost, lower transportation expenses, and diminishing environmental impacts associated with material transport (Saftner, 2024). Soil mixes made from industrial by-products such as biochar have shown success for MnDOT and are currently being piloted by WisDOT.

As an alternative to soil amendments, furnished topsoil should be used. Furnished topsoil is free of grass, brush, and roots and consists of loose, friable, loamy material without a mixture of subsoil or refuse. The use of furnished topsoil reduces the need for soil amendments, reduces invasive species presence, and improves the growth of desirable species as this soil meets all DOT macronutrient and soil composition requirements (DRG, 2023). DRG recommends that INDOT create a furnished topsoil specification and that a qualified vendors list with contacts be available to construction contractors to assist them in obtaining furnished topsoil. The use of furnished topsoil is standard practice on all construction projects for Maryland DOT and specifications are provided in Maryland Soil Special Provisions Insert 920 Landscaping Materials (Maryland DOT, 2024), and specifications for furnished topsoil are given in Item 653 of Ohio DOT's Standard Specifications (ODOT, 2025).

INDOT's (2025) Recurring Special Provision 629-R-30 (Plant Growth Layer) already integrates topsoil specifications, testing requirements in accordance with ITM 515-15, and recommendations of alternative soil amendments. Recurring Special Provision 629-R-30 should be transitioned to the Standard Specifications for use in all construction contracts, with ramifications for contractors who fail to comply with INDOT's specifications.

3.1.6 Public Outreach Improvement

Roadside maintenance should coordinate with INDOT's communications division to send out informative press releases and/or social media blurbs seasonally, when changes to vegetation management practices occur, or to educate the public on INDOT's vegetation management program as it relates to driver safety, landscape aesthetics, pollinator benefits, etc. Customer service complaints are currently a large portion of INDOT's annual vegetation management workload, and a more informed public may help to reduce this workload.

3.2 Conclusions

INDOT's vegetation management program faces various challenges that can be addressed with the recommended implementation items. Several of INDOT's challenges with vegetation management can be resolved with the implementation of specialized vegetation management crews. INDOT roadside maintenance data demonstrated that districts with specialized vegetation management crews were more efficient and cost-effective than districts without specialized crews. The inclusion of specialized vegetation management crews does not preclude the use of contractors but is intended to supplement their work as needed. These specialized vegetation management staff should prioritize completing contract inspections for maintenance operations activities and completing vegetation maintenance tasks when needed and can assist with other general maintenance operations tasks when vegetation inspections and maintenance are caught up. INDOT should strongly consider this option to improve roadside vegetation management.

DRG did not identify any major issues with INDOT's OM 14-05 with regard to zonal definitions or the general guidelines and methodologies for the vegetation management activities described. However, this document is meant to be the primary guidebook for INDOT staff for conducting vegetation management, and a large proportion of INDOT field staff interviewed were unaware of the document. The creation of one-pagers readily accessible to vegetation maintenance staff will increase awareness of the guidelines in this critical document. These one-pagers should be placed within vehicles and other places within INDOT facilities to increase staff awareness of INDOT's vegetation management policies. The creation of these one-pagers would assist both specialized vegetation management crews and generalized crews.

Quality control for completed vegetation maintenance, including contractors, can be improved. Improving contractor quality control would ensure that all areas are mowed or have herbicide applied as described in the contract. Inspectors should also be apprised of the upcoming planned work locations to be able to communicate with INDOT staff as to whether sight distance or other customer service issues can wait until the contractor's planned maintenance date and can update customer service personnel on the decision. Mapping and inventory of maintenance activities completed by both contractors and in-house staff (e.g., length/width of ROW mowed, percentage of plants sprayed, etc.) will also assist with tracking vegetation management work to ensure all goals are met. Work by contractors should be closely monitored and tracked to ensure maintenance goals are being met. Proper tracking of work completed by contractors and in-house staff via GIS technology and enforcing liquidated damages when contract deadlines are not met could help to remedy these issues.

The reactionary nature of in-house vegetation management is not ideal for long-term programmatic vegetation management along the ROW. The need for reactionary work can be mitigated with the aid of mapping and inventory technology that can help INDOT better track areas in need of maintenance. This includes areas of off-cycle work, or problem areas not already assigned

to contractors. This will not remove all reactionary work, such as unexpected sight distance issues, customer complaints, and other unplanned work will always be needed, no matter how proficient a DOT's inventory processes are. Regardless, identifying as many vegetation management issues as possible in advance and addressing them accordingly can prove invaluable to the efficiency, effectiveness, and even public perception of INDOT staff.

Current INDOT design standards for roadside appurtenances like guardrails and noise barriers require updates to facilitate vegetation maintenance around them. Other ROW assets with maintenance challenges are roadside drainage features. Drainage features such as ditches, culverts, and underdrain under pavement that are clear of vegetation, debris, etc., are essential structures that help maintain the structural integrity of the ROW; proper and timely maintenance of them is crucial. Installing markers near these structures is a simple and inexpensive solution to locate them, allowing both maintenance staff to complete maintenance and inspectors to access them when needed. Multiple states have used this method to track culvert and ditch maintenance and integrate marker locations into their GIS-based asset management systems.

3.2.1 Future Research Projects

Exact costs and monetary ROI could not be determined for several recommended action items identified during this project. This was due to a lack of data or previous studies on these items by INDOT, other DOTs, or academic groups. Determining costs for the action items without a monetary ROI estimate should be a focus in follow-up projects to this study. For example, INDOT needs a more detailed study of noise barrier vegetation management costs.

The amount and cost of vegetation management efforts at INDOT specifically for noise barriers is not currently tracked. Regarding the GeoWeb® recommendation, the costs of re-seeding efforts and failed slope maintenance would need to be determined in order to calculate cost savings provided by GeoWeb® or a similar technology for slope stabilization.

When completing a nationwide study on tools and technology utilized by DOTs, DRG was unable to obtain data comparing efficiencies or cost effectiveness of roadside crews before and after a mapping and inventory system for vegetation management tasks was implemented. Therefore, a savings estimates or ROI for this action item could not be completed during this project. A pilot study within INDOT that compares efficiency and cost-effectiveness of crews with and without a new inventory system could be conducted to determine savings and the resulting ROI.

It is unknown what percentage of INDOT's time is spent on activities or calls that could be resolved or avoided by a more informed public. To DRG's knowledge there is no data on this within INDOT, and this was not explored by DRG on other DOT projects. It would be helpful to collect more detailed data on this to determine INDOT's annual savings if more public education on vegetation management activities was explored. This would likely take the form of a survey asking residents about

their current knowledge of INDOT's vegetation management practices, as well as their current questions/concerns followed by focus groups where messages could be tested to determine if complaints would be reduced with adequate information.

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APPENDICES

Appendix A. DOT Survey

Appendix B. Gap Analysis

Appendix C. Extended Analysis Recommendations With ROI

Appendix D. Technical Memorandums

References

Appendix A. DOT Survey

Topic		Illinois	Indiana	Iowa	Kentucky	Minnesota	Missouri	Wisconsin
Vegetation Management Implementation	<i>Regime and Planning</i>	<ul style="list-style-type: none"> • Zonal maintenance. • Spraying and plantings contracted out. • Mowing, brush cutting, and tree removal tasks done in-house. • Mowing, guardrail/cable rail, and some of the weed control is proactive • 5-10% of time spent addressing customer complaints. 	<ul style="list-style-type: none"> • Zonal maintenance. • Mowing and spraying initially completed by contractors, with in-house staff following up and dealing with site distance and customer complaints. • In-house maintenance is very reactionary and relies on customer service complaints. 	<ul style="list-style-type: none"> • Zonal maintenance. • Brush cutting and mowing activities in-house. • Plantings and spraying are contracted 80-90% of the time. • Trying to be more proactive and plan ahead better with spraying contracts. • About 10% of their work is customer service complaints. 	<ul style="list-style-type: none"> • Zonal maintenance. • Herbicide applications are conducted in-house 50% of the time. • Brush cutting is mostly in-house (75% mechanical brush cut in-house) as well as plantings (90%). • Contractors complete 100% of guardrail trimming and culvert/ditch trimming, 75% of tree removal and trimming activities, and 75% of ROW mowing. • Most mowing and herbicide is planned, with an added push to improve roadside appearance before Memorial Day, July 4th, and Labor Day. • Try to be proactive on the trees that pose an unacceptable level of risk before they fall. 	<ul style="list-style-type: none"> • Zonal maintenance. • Mechanical brush-cutting activities (for ash trees), tree removals that are tied to bats, and most plantings are contracted out. All other VM activities are in-house. • Mowing along the clear (operational) zone and for culverts is proactive. • Clearing for structural assets is reactive. 	<ul style="list-style-type: none"> • The majority of VM activities are conducted in-house. Large reseeding efforts are contracted out. • Clear (operational) zone mowing, some of the guardrail spraying, and looking for trees that pose an unacceptable level of risk is proactive. • Receive a lot of customer service requests that are also reactive. 	<ul style="list-style-type: none"> • Zonal maintenance. • All vegetation maintenance is contracted out. • Most spraying and brush cutting activities are reactionary.
	<i>Mowing Schedule</i>	4-6 times per year 15 ft off shoulder, 4-year mow rotation (Year 1 - Interstate medians, Year 2 - SB/WB interstates, Year 3 - NB/EB interstates, Year 4 - non-interstate routes)	<ul style="list-style-type: none"> • Urban interstates 5 cycles per year, 15 ft off shoulder. • Rural interstate 3 cycles per year, 15 ft off shoulder. • Other 2 cycles per year, 15 ft off shoulder. 	<ul style="list-style-type: none"> • 2-3 cycles per year 15 ft off shoulder. • No mowing before July 15th to benefit nesting ground birds (e.g., pheasants). 	Most of the state routes receive a minimum of 3 mowing cycles. The 1st mowing cycle will be a full-width mowing cycle to mow any reachable areas. The 2nd mowing cycle takes place ~July 4th and is a 15-ft-wide shoulder mowing; to conserve pollinators, the entire ROW is not mowed on this cycle. The 3rd mowing cycle is in late August/early September and will be a full-width mowing.	2 mows/year, for safety. 1st mow is in the spring, the 2nd ~ 4th of July. There is a full mow-back every 3-4 years depending on if they have brush problems.	Row is mowed 15 ft for the clear (operational) zone 3x/year. More mowing occurs in urban areas. The last mowing in the fall will mow an additional 15 ft along the ROW on interstates.	<ul style="list-style-type: none"> • First 15 ft are mowed 1x/year, an additional 15 ft are mowed to equal 30 ft on a 3-year cycle. • Additional mowing rotates around the state with only 1/3 of the state being mowed the additional 15' each year.
	<i>Tree and Shrub Maintenance</i>	They try to eliminate trees along the ROW unless it's behind a guardrail.	Contractors are supposed to clear woody vegetation 30' from pavement, but often this distance is shorter.	All trees/woody vegetation within 30' of pavement are cut.	<ul style="list-style-type: none"> • The superintendent of the maintenance crews develops a list of the trees that pose an unacceptable level of risk and sends the list to the district agronomist and to the contractor unless it is something the KYTC crews can handle. Most trees that pose an unacceptable level of risk are taken down by contractors due to a shortage of KYTC staff availability. • All trees cleared within 30' of pavement. 	<ul style="list-style-type: none"> • All trees within clear (operational) zone removed. • Only left in areas where they won't impact travel. 	<ul style="list-style-type: none"> • Trees cannot grow within the first 30 ft of the ROW. The clear (operational) zone is to be cleared of trees and other obstructions. • There's probably some within 30 ft behind guardrails, but they try to use boom mowers to mow behind these. 	<ul style="list-style-type: none"> • Do not do tree inventories. • No trees permitted in 30 ft of clear (operational) zone.

Topic		Illinois	Indiana	Iowa	Kentucky	Minnesota	Missouri	Wisconsin
Vegetation Management Implementation (Cont'd.)	<i>Maintenance Around Roadside Assets and Appurtenances</i>	<ul style="list-style-type: none"> Guardrail sprayed to achieve bare soil. Rocks/gravel underneath guardrail in some locations. No procedures for vegetation maintenance around noise barriers. 	Combination of string trimming, boom mowers, and broadleaf herbicide around guardrails.	Articulated mowers and herbicide around cable rails.	<ul style="list-style-type: none"> Contractors are expected to weed-eat around the assets on the regular mow cycles. Herbicide for bare ground under guardrails. Have looked into matting but have not been implemented due to expense. Do not maintain areas behind noise barriers. 	Use guardrail mowers, string trimmers, spraying, and have tried mats under guardrails.	<ul style="list-style-type: none"> Aggregate under the guardrail along with some oil, it's effective if done correctly. Most of the cable rail posts directly next to the lane are built into asphalt. Little maintenance completed around noise barriers. 	<ul style="list-style-type: none"> Historically guardrails had bonded non-aggregate put in place during construction. Currently spray under guardrails. Areas behind noise barriers are never maintained, turn into a mess.
	<i>Ensuring Access for Maintenance and Inspections</i>	<ul style="list-style-type: none"> Mowing around culverts, ditches, and ITS boxes during regularly scheduled mowing. Culverts marked with posts. Noise barriers at the edge of ROW to reduce maintenance. Noise barriers have 7ft by 3ft access openings. 	<ul style="list-style-type: none"> Inspectors will report back to maintenance if they are having access issues. If inspectors don't mention anything, maintenance tries to keep culverts and ditches clear approximately once a year depending on issues they notice during planned road work activities. Have doors in noise barriers, but they rust shut. There are sometimes drop-offs on the opposite side of these doors. Maintenance will ignore difficult-to-access areas like behind noise barriers unless a complaint comes in. 	<ul style="list-style-type: none"> Mowing. Double door gates in sound walls which can fit a tractor or pickup. Some sound walls right on ROW boundary to avoid maintenance behind it. Culverts delineated with markers. Conduct biannual inspections of culverts and ditches and conduct appropriate cleaning and mowing. 	<ul style="list-style-type: none"> There are access issues to complete maintenance behind the noise barriers. Will have man-sized doors, or staff can go to the end of the wall for equipment accessibility. Ditches and culverts get cleaned out when contractors are hired to clean them out as needed. 	<ul style="list-style-type: none"> Mowing, spraying, resetting culvert aprons, working on culverts. Before culvert inspections, the inspectors ask maintenance to come out and mow and remove debris and buildup. Noise barrier inspections can include issues with shrubs and trees. The vegetation is included as issues and incorporated into the rating of the noise barrier system. There is 10-15 ft behind noise barriers for access. 	<ul style="list-style-type: none"> Used to clear under bridges before the inspectors came out. Clearing for access as needed. There's usually openings at the end of the noise barriers where equipment can gain access. Some districts use optic (reflective) markers. There is an inventory of all the culverts in the state, and it is available on the GIS system. Some state crews use this data to locate the culverts and ditches. 	<ul style="list-style-type: none"> There are regular maintenance practices on the interstate systems where culverts are located. Mowing. Culverts and possibly ditches are mapped so they can be easily found.
	<i>ROW Boundaries Identification</i>	<ul style="list-style-type: none"> Most of the ROW is fenced off on interstates. On two-lane roads, you can usually tell where the boundaries are. For tricky areas, the county garages refer to their property line maps, or they call their survey crew. The survey crew has all the maps and the monitoring equipment to map it out in 2-3 weeks 	<ul style="list-style-type: none"> A lot of uncertainty with ROW limits. Fort Wayne District has digitized the ROW records they have but have not received records from all counties. 	<ul style="list-style-type: none"> Will survey and locate ROW boundaries if they are in question. Currently creating a digital ROW layer that will be ready in 3-4 years. 	<ul style="list-style-type: none"> If ROW is in question, they go to the district and the district staff look at really old records to figure it out. 	Unknown, not answered.	<ul style="list-style-type: none"> There are ROW markers or there's fencing. When they are not, the MoDOT survey team places markers on the ROW to indicate the boundaries. The width of the ROW can be a set distance but varies based on the terrain. 	<ul style="list-style-type: none"> Rely on real estate boundary estimates. Surveyors sometimes mark the property when they are contacted.
Design Specs, Construction, & Erosion Control	<i>Vegetation Maintenance Coordination with Construction Activities</i>	<ul style="list-style-type: none"> Plan sets go through multiple districts before going out for bid. Maintenance can review if they want. 	<ul style="list-style-type: none"> Operations staff are usually invited to pre-cons. Difficult for staff to give feedback when they aren't familiar with engineered plan sets. 	<ul style="list-style-type: none"> Maintenance staff cross-utilized with construction staff. They can look at construction projects during the process so they can identify issues as they arise during construction. They have a good field relationship between maintenance and construction. 	Typically, if maintenance is involved, it's not until late in the process and a lot of the decisions have already been made.	Unknown, not answered.	Maintenance supervisors and superintendents are contacted at some point in the project and are provided with plan sets.	Has ebbed and flowed over the years. Sometimes, there is no involvement, and other times, a maintenance staff member has to be in the meetings.

Topic		Illinois	Indiana	Iowa	Kentucky	Minnesota	Missouri	Wisconsin
Design Specs, Construction, & Erosion Control (Cont'd.)	<i>Drainage for ROW</i>	All highways have an underdrain on each side of the highway, and they lead to the culverts wherever they drain.	Underdrains, which do occasionally get clogged.	Use underdrains but are not using drainage tiles to reduce the number of ditches. The use of underdrains has had no impact on the number of ditches.	They have installed underdrains and have reduced the need for ditches, but maintenance is still needed on the underdrains, so it has not reduced overall maintenance need.	<ul style="list-style-type: none"> They have a performance measure around culvert maintenance because it is in the Enterprise Asset Management System (EAMS). Need to meet 80% of maintenance needs within a certain time frame. They are not sure of the exact cycle but have targets for culvert inspections. Use of drainage tiles has not reduced the number of ditches. 	Underdrains mostly in urban areas; have not reduced the need for ditches.	Have underdrains; it is unknown if this has reduced the need for ditches.
	<i>Soil Management</i>	<ul style="list-style-type: none"> Usually, all the soil for maintenance projects is brought in from the yard. If they do not have enough, they might need to purchase. This varies district by district. Do not test soils. 	<ul style="list-style-type: none"> Do not bring in soil or use amendments. Have had issues with soil quality. Soil is only tested during construction projects. 	<ul style="list-style-type: none"> Can use soil from ditches for maintenance activities, but not construction. Use on-site topsoil. Will fertilize when they stabilize and seed. 	<ul style="list-style-type: none"> A combination of bringing in new soil and using furnished soil. Some maintenance yards have topsoil stockpile. There are specifications to add lime. If it's low in fertility and the pH is low, they add in a bunch of fertilizer and lime to create conditions for the grass to grow. Sometimes add organic amendments like compost or lime to adjust pH. 	<ul style="list-style-type: none"> Topsoil usually stockpiled on site, will bring in soil if needed. Will occasionally use soil from ditches. Tests imported soil for physical characteristics but not nutrients. They are currently discussing reviving a soil testing process that has fallen out of practice, including testing topsoil for depth, physical characteristics, pH, salts, and nutrients. 	<ul style="list-style-type: none"> Try to use native soil. Soil tests are done for nutrients, pH, and organic matter. Fertilizers are different in specs for cool-season grasses and natives. 	<ul style="list-style-type: none"> Do not bring in new soil, the projects try to balance the sites through stockpiling. They will spec compost soil mixes for plantings if they are included for trees and shrubs. They have been experimenting with biochar. They are looking into ways to make their own biochar from their trees they remove. A lot of their seed failures are due to poor soil. No soil testing.
	<i>Slope Maintenance & Design</i>	<ul style="list-style-type: none"> Interim Roadside Manager is contacted about the type of seed only. Contractors responsible for slope failures on construction projects. 	<ul style="list-style-type: none"> Heavy reliance on rip rap for slopes if there are issues with seed establishment. Seed mixes are determined by seed commissioner. 	<ul style="list-style-type: none"> Resident Construction Engineer (RCE) makes sure the vegetation is established - before signing off on permit. 	<ul style="list-style-type: none"> Erosion control staff inspect all construction projects to make sure erosion control has been done correctly and they check to make sure the desirable vegetation has been established. Use rip rap as a last resort. 	<ul style="list-style-type: none"> They try to get all of the ditches to be traversable, they have reduced the slope to 4H:1V in a lot of cases. In a few cases they have reduced this further to 6H:1V slopes. Successful seeding and prevention of slope failures is difficult. 	<ul style="list-style-type: none"> 5 regions in the state each have different standard seed mixes. Use a lot of blankets on the slopes. Most of the seeding on slopes is done with hydroseeding now and they haven't had any issues with this. 	<ul style="list-style-type: none"> Have trouble with slopes. Becoming dependent on rip rap.
Staffing and Training for Vegetation Maintenance	<ul style="list-style-type: none"> Used to have specialized landscape crews, but not anymore. Not everyone certified to spray; those who are get pay bump if they are actively spraying. Most have chainsaw certification. Recurrent training for vegetation maintenance in-house. 	<ul style="list-style-type: none"> Fort Wayne District has staff that inspect contractor maintenance and complete vegetation work. Seymour District has specialized "Corridor Crew" that completes vegetation management and follows up on contractor work. All other districts do not have specialized vegetation management staff. Annual herbicide application refreshers. 	<ul style="list-style-type: none"> Do not have specialized vegetation management crews. All maintenance staff are certified herbicide applicators. The DOT also provides chainsaw, chipper, and general equipment training. They recently re-initiated a formal training program. Completing mentoring/training on the job as needed. 	<ul style="list-style-type: none"> They have a specialty crew in each district that only does everything related to vegetation. Specific people are trained on the specialized equipment. Everyone who sprays needs to be fully licensed based on state requirements. Training is a mixture of in-house and University of Kentucky (pesticide training). These used to be done mainly in person but have moved to 	Have specialized vegetation management crews.	Most vegetation management is completed by generalist crews, but they do have some specialized crews, especially the UTV crews. UTV crews are trained to be certified applicators.	Landscape architects provide high-level policy trainings to patrol and superintendents. Now they can do virtual presentations. The counties do the training for equipment and vegetation identification training on their own.	

Topic	Illinois	Indiana	Iowa	Kentucky	Minnesota	Missouri	Wisconsin
	<ul style="list-style-type: none"> Manufacturer brought in for initial trainings for equipment. 	<ul style="list-style-type: none"> Some staff have Category 6 spray licenses, but have concerns over infrequency of use. A lot of training is on the job. 		<p>more online CEU classes since 2020.</p> <ul style="list-style-type: none"> Annual herbicide applicator training and for staff that work on trees. There is a tree management workshop with equipment vendor demonstrations. When new equipment is delivered, vendors run through the equipment with staff. 			
Equipment/Technology	<ul style="list-style-type: none"> Not using AI, intelligent inventory, or UAVs. Have a "green climber" which is remotely controlled and can traverse steep slopes. Use boom mowers to get extra 20' reach. 	<ul style="list-style-type: none"> Not using AI or intelligent inventory. There are drone pilots in each district, but the drones do not have a definitive application. Seymour District has remotely controlled mowers. Some districts have boom mowers. 	Not using AI, intelligent inventory, UAVs, or remotely controlled mowers.	<ul style="list-style-type: none"> Not using AI, intelligent inventory, or UAVs. One district has a robotic mower for steep slopes. 	Using data from sprayers and work orders to track progress.	<ul style="list-style-type: none"> Some trucks have geometrics (GPS tracking), including some UTVs. There is an inventory system, staff have to charge out what they use each day. They enter into a computer in the MMS (MoDOT Maintenance System). No AI is used. Drones are being used for structural management, not vegetation. They have used some remote mowers for slope mowing, excavators & skid steers with forestry heads, boom mowers. They have contracted out the work that requires forestry heads or leased the equipment, particularly for specialized equipment. 	Not using AI, intelligent inventory, UAVs, or remotely controlled mowers.
Public Outreach	<ul style="list-style-type: none"> Mowing information is sent out at the beginning of the mowing season. IDOT has a YouTube video detailing the reasons for the reduced mowing. A new law will require that when they are spraying, they need to notify landowners through multiple sources, e.g., door hangers or signs along the road. 	Staff felt the public were generally unaware of INDOT's maintenance processes, and had a different perception as to what site distance issues were.	No public information program associated with vegetation management.	<ul style="list-style-type: none"> When they initiated the reduced mowing maintenance cycles, they sent out press release over social media. Maintenance has a good relationship with the public affairs office. 	Unknown, not answered.	<ul style="list-style-type: none"> Most vegetation management is completed by generalist crews, but they do have some specialized crews for vegetation management, especially the UTV crews. UTV crews are trained to be certified applicators. New equipment training is provided by vendors. A lot of recurrent trainings are done in-house. In the past chainsaw training was contracted out. Timing depends on the training. The safety division does a lot of the training. 	<ul style="list-style-type: none"> An online map was created relating to turf and pollinator areas to help with public education through the office of public affairs. The office of public affairs has put videos together; they have an educational video planned for Earth Day. - - Public affairs is trying to promote the DOT's expectations and the reasons vegetation management is completed. WisDOT is doing this through social media, press releases, and a website page about pollinators and mowing.

Appendix B. Gap Analysis

Processes/Operations	Problems to Address	Gap	Recommended Steps/ Materials	Expected Outcome Safety, Efficiency, Effectiveness, Cost Effectiveness
Staffing	Roadside crews do not have enough time to complete vegetation management that is needed outside of contracts.	Need 5 people per district, currently have 0-5 per district. There is a gap of 22 specialized vegetation management staff.	Create specialized vegetation management crews consisting of 5 staff members. The crews can be created by pulling staff across the subdistrict maintenance staff or by filling dormant vacant PCNs within the maintenance department.	<ul style="list-style-type: none"> Increased time for roadside crews to complete non-vegetation management items. Increased work efficiency, effectiveness, and reduced costs for both vegetation management and non-vegetation management activities.
Equipment	Staff do not have trucks/equipment that allows them access to larger trees that need trimmed or cut.	3 districts currently use forestry bucket trucks (Fort Wayne, Seymour, and Crawfordsville); these districts account for majority of tree work across the state. There were 4, 46'+ bucket trucks that accounted for 67% of statewide tree removal work. 2 of these bucket trucks were disposed.	Purchase additional forestry bucket trucks or arborist tracked lift.	Increased effectiveness of tree removal activities.
	Staff do not have proper equipment to access behind noise barriers for large-scale vegetation maintenance (i.e., removing trees).	Equipment cannot access trees and other vegetation behind the majority of noise barriers.	Purchase equipment that will allow access behind noise barriers such as chassis-mounted, articulated knuckleboom with grapple saw or Sennebogen® 718 E.	Reduce vegetation management issues behind noise barriers (staff safety, efficiency, and effectiveness).
Training	Staff may not understand the operations of specialized equipment that is new to the department. They also may not remember initial training in specialized equipment/processes (e.g., bucket truck operation, herbicide mixing, etc.) due to infrequency of use.	There is no training available for special equipment or general vegetation management procedures besides the initial training and annual refreshers (when completed).	<ul style="list-style-type: none"> Staff should have access to vendors who can troubleshoot equipment issues and provide supplemental training. Create one-pagers to be kept in the truck to allow staff access to training when using the equipment. This will reduce the number of errors in the use of equipment. Create specialized vegetation management crews who will use equipment more consistently. 	<ul style="list-style-type: none"> Increased success for implementation of new equipment when it is initially rolled out. Successful integration of new equipment into INDOT vegetation management practices in the long term. More efficient day-to-day vegetation management operations. Reduced maintenance and repair costs.
	Lack of familiarity with requirements and specifications for vegetation management.	Staff are either not aware of or do not follow the protocols and specifications outlined in OM 14-05.	<ul style="list-style-type: none"> Annual training should continue to be conducted. This training should be expanded to include protocols (e.g., OM 14-05), mowers, bucket trucks, and other specialized pieces of equipment. One-pager documents should be created detailing OM 14-05 for further reference throughout the year once updates are finalized. 	More consistent adherence to vegetation management specifications outlined in OM 14-05.
Vegetation Management Planning, Inventory, & Implementation	Maintenance staff are not included in the construction design phase, leading to issues where maintenance is not possible.	Many districts do not invite maintenance staff to meetings. If maintenance staff are invited, representatives are not trained in providing feedback in this setting.	Appropriate maintenance staff should be included at every scoping meeting.	Reduce instances where structural assets prohibit vegetation management due to a factor that could have been addressed during design review.
	Staff are unaware of where maintenance is needed.	The maintenance team do not have access to as-builts, do not meet with construction staff to determine where assets are located, nor is there an inventory of all assets.	<ul style="list-style-type: none"> Appropriate maintenance staff should be included at every project's scoping meeting. Implement a more comprehensive inventory of vegetation assets to identify problem locations prior to failure. 	Vegetation management planning will be more proactive since INDOT will have a better understanding of what structural assets will require future vegetation management.
	Culvert and ditch maintenance is not adequate.	There are no specific guidelines for culvert and/or ditch maintenance in OM 14-05 or Work Performance Standards.	Add specific guidelines/policy for culvert and ditch maintenance procedures to OM 14-05 (such as mowing 2x/yr), and methods to achieve the goals for culvert/ditch maintenance should be outlined in the Work Performance Standards.	Reduce the likelihood of ditches or culverts getting backed up with vegetation.
	In-house vegetation management is very reactionary.	Lack of annual planning or goals set for in-house vegetation management.	Integrate vegetation management goals into annual Work Plans. Selected vegetation management tasks should be included as "Tracked Activities" in the Work Plans.	Districts will be held accountable to carry out a set amount of pre-planned vegetation management every year.

Processes/Operations	Problems to Address	Gap	Recommended Steps/ Materials	Expected Outcome Safety, Efficiency, Effectiveness, Cost Effectiveness
Certifications	Inadequate number of staff licensed for specialized work such as pesticide and herbicide application. Insufficient number of staff obtaining certifications due to lack of interest in taking on additional responsibilities without being enticed.	Some management units do not have a licensed herbicide applicator, some do not have trained service people. Not all management units have licensed applicators or registered technicians.	To ensure adequate levels of licensed herbicide applicators in each management unit provide: <ul style="list-style-type: none"> • Pay progression should be provided for each optional license obtained by staff. • Pay progression should be used when the activity is actively being completed: a DOT applicator spot treating brush that had been cut down will receive additional compensation only during the activity. • or • Create specialized vegetation management crews. 	<ul style="list-style-type: none"> • Increased number of licensed applicators. • Increased efficiency to complete follow-up herbicide treatments to brush-cut areas.
Contracting	Not enough contractors bid on vegetation management contracts that meet the prequals.	The number of contractors working on vegetation management in the state is currently low.	<ul style="list-style-type: none"> • Alter pre-qual standards to increase the number of contractors eligible for bidding • Update outreach and bidding processes to 1) increase contractor competition, 2) limit the number of contracts (acreage) individual vendors can be awarded at one time. 	<ul style="list-style-type: none"> • Increase competition between bidders for vegetation management contracts, which will reduce bid prices. • Reduce conflicts caused by vendors taking on more contracts than they can work at one time. • Increase contract compliance.
	Contractor roles and scope are not always clear in contracts.	DOT staff and contractors may not understand the tasks of the other party.	Clearly defined roles will be outlined in vegetation management contracts; contracts will designate acreage to be treated while providing flexibility for vegetation management staff to request specific areas be treated based on contracted spray acreage. Legal will review.	More efficient overall vegetation management processes for both contractors and in-house staff since all parties will know what they need to accomplish.
Design Specs, Construction, & Erosion Control	Maintenance is not always possible or dangerous to complete based on roadway design.	<ul style="list-style-type: none"> • Areas of the right-of-way cannot be maintained as required due to safety concerns, a lack of access, lack of equipment that can be used to maintain the area, i.e., a slope greater than 3H:1V right along the ROW where staff and contractors cannot maneuver mowers due to safety concerns. • Vegetated medians are too narrow in some areas. 	<ul style="list-style-type: none"> • Appropriate maintenance staff should be included at every scope meeting to address potential vegetation management issues with construction/design teams. • Noise barriers should be built on the edge of the ROW, where feasible. If setback distance would impact the required sound wall height at a particular site, access doors large enough for machinery to pass through should be installed. • Ensure medians that must be maintained can be accessed safely by requiring minimum width where grass is installed. 	<ul style="list-style-type: none"> • Reduce instances where structural assets or other design decisions inhibit vegetation management due to a factor that could have been addressed during design review. • Increase safety of maintenance staff and contractors.
	Vegetation is not establishing after seeding.	<ul style="list-style-type: none"> • Appropriate seed mixes are not always being used. • Seed dissemination practice is not always ideal for site conditions. • Soil is not being adequately tested. • Not enough topsoil being used. 	<ul style="list-style-type: none"> • Use alternative seed mixes and dissemination techniques more appropriate to site conditions. • Test native and imported soil for pH, soil nutrient, and organic content. • Ensure minimum depth of topsoil is met consistently throughout sites. • Update seeding specification to provide a minimum of 6"+ of topsoil. 	Improved plant establishment after seeding.
	Culverts and ditches are not visible for inspection or maintenance staff.	<ul style="list-style-type: none"> • Culverts and ditches are not consistent distances from roads. • No visible markings for culverts. 	<ul style="list-style-type: none"> • Update specifications to create culverts and ditches a set distance from roadway, where feasible based on topography. • Place physical marker in field to denote inlets and outlets. 	Inspections and maintenance will be completed more efficiently and reduce follow-up visits.
	Slope failures occur frequently.	Erosion control and slope stabilization procedures are not adequate to prevent landslides and slope failures in some areas.	<ul style="list-style-type: none"> • Test GeoWeb® or other appropriate slope stabilization item. • Update seeding specification by creating slope specific seed mix and remove invasive species from seeding specification. • Inventory vegetation assets to identify problem locations prior to failure. 	Reduced likelihood of roadside slope failures.

Processes/Operations	Problems to Address	Gap	Recommended Steps/ Materials	Expected Outcome Safety, Efficiency, Effectiveness, Cost Effectiveness
Vegetation Management Work Efficiency & Cost Effectiveness	Actual daily production rates for some vegetation management activities are below the daily production guidelines that are outlined in the Work Performance Standards.	<ul style="list-style-type: none"> • <i>Manual Brush Cutting</i>: All districts below minimum. 55.1% of the minimum guideline on average. • <i>Mechanical Brush Cutting</i>: Only Seymour and Fort Wayne meet guidelines. Others are 71% of the guideline on average. • <i>Seed & Fertilization</i>: All districts below minimum. 77% of production guideline on average. • <i>Spot Seed & Fertilization</i>: All districts below minimum. 24% of production guidelines on average. • <i>Tree Removal</i>: All districts except LaPorte above production guideline. LaPorte 90% of guideline. • <i>Spot Mowing</i>: All districts except Crawfordsville above minimum production guideline. Crawfordsville 77% of guideline. 	Create specialized vegetation management crews to increase efficiency to meet current goals, and/or lower production guidelines to more closely align with what is actually getting accomplished. Purchase specialized equipment that will enable staff to work more efficiently for vegetation management.	Updated daily production guidelines, particularly for manual brush cutting and spot seeding/fertilization, will more accurately reflect what is being accomplished in the field, allowing for more accurate estimation of labor hours needed in the Work Management System.
	Districts that do not have specialized crews are not as efficient at brush cutting (manual and mechanical) or spot seeding as districts with specialized vegetation management crews.	<ul style="list-style-type: none"> • <i>Manual Brush cutting</i>: Seymour District 38.5% higher work efficiency and 44.1% lower costs/sq ft compared to the average across other districts. • <i>Mechanical Brush Cutting</i>: The average work efficiency between Seymour and Fort Wayne is more than double other districts. The average cost/sq ft between Seymour and Fort Wayne is half the average cost/sq ft of other districts. • <i>Spot Seeding</i>: The average work efficiency between Seymour and Fort Wayne is 2.6 times greater than other districts. The average cost/sq ft between Seymour and Fort Wayne is 95% lower than the cost/sq ft for other districts. 	<ul style="list-style-type: none"> • Create specialized vegetation management crews to increase efficiency and reduce costs. • Purchase specialized equipment that will enable staff to work more efficiently and safely on vegetation management tasks. 	50-100% increase in work efficiency and cost effectiveness for brush cutting and spot seeding activities.
	Districts that lack specialized equipment for each task (e.g., bucket truck for tree removal) are less efficient and cost effective at certain tasks.	<i>Tree Removal</i> : Districts with 46'+ bucket trucks (Seymour, Fort Wayne, Crawfordsville) are able to remove more than double the number of trees/day than districts without bucket trucks. Additionally, Seymour and Crawfordsville are almost 3x more cost-effective than the districts without bucket trucks.	Replace short, ineffective bucket trucks for the districts that don't have access to 46'+ forestry bucket trucks.	<ul style="list-style-type: none"> • Double the trees/day removed for districts that didn't have a bucket truck. • Triple the cost effectiveness of tree removal work in those same districts.
Public Outreach	The public is not aware of INDOT's current vegetation management practices, or any new policies they implement.	INDOT does not have any public information program associated with vegetation management.	Coordinate with the public affairs office or similar group at INDOT to send out informative press releases and/or social media blurbs when changes to vegetation management practices occur, or to generally educate the public on INDOT's vegetation management program as it relates to driver safety, landscape aesthetics, pollinator benefits, etc.	<ul style="list-style-type: none"> • More informed public with regard to INDOT's vegetation management practices. • Potential reduction in customer service calls.

Appendix C. Extended Analysis Recommendations With ROI

Table C.1 Vegetation Crews & Equipment.

Action #	Action	Timeline	When/How to Complete	Problems Addressed	Benefits	Benefit Validation/Cost Savings & Assumptions	Other State DOTs Completing This	Anticipated Cost (\$)	Total Annual Savings (\$)	First Year Return on Investment (%)	Time to ROI	Explanation of Anticipated Costs
1	Create Specialized Vegetation Management Crew (5 people and a crew supervisor per district)	1-5 years	Follow-up project to current project due to timeline and budget	<p>Staff do not have time to complete both vegetation management activities and non-vegetation management activities.</p> <p>Lack of appropriate maintenance staff attending design/construction meetings</p> <p>Operations staff are unfamiliar and undertrained in the requirements and specifications (i.e., OM 14-05) for vegetation management and specialized equipment operation.</p>	<p>Non-specialized crews can focus on pavement and other maintenance needs, and can be more efficient at them, while specialized crews can focus on vegetation.</p> <p>Appropriate staff (e.g., vegetation management crew supervisor) will be available to give input at design/construction meetings. Reduce instances where structural assets prohibit vegetation management due to a factor that could have been addressed during design review (such as right-of-way width causing steep slopes, narrow vegetated medians, or other areas that result in maintenance difficulties due to their design).</p> <p>Increased work efficiency and reduced costs for vegetation management tasks.</p> <p>Vegetation management will be more effective long term as staff will use the proper herbicide mixtures and application techniques (i.e., applying herbicides to ALL brush cut areas).</p> <p>Less equipment breakdowns due to experienced workers on equipment.</p>	<p>On average across all non-vegetation management activities, both the districts with specialized vegetation management crews and those without specialized crews exceeded the amount of work scheduled for 2023 in the Work Plan. However, districts with the vegetation management crews exceeded the planned amount of work much further. On average across the non-vegetation management activities, districts with specialized vegetation management crews accomplished 16.9 X more than the planned work, while districts without VM crews accomplished only 4.4 X more. Furthermore, an estimated \$12,455,181.50 of savings can be achieved from cost savings on non-vegetation management tasks. Districts with specialized vegetation management crews were 10.1% more cost effective than districts without vegetation management crews when completing non-vegetation management tasks.</p> <p>There is no INDOT maintenance data that specifically notes what work was done for issues that were a result of specific design choices, such as slopes that are too steep, structural features that make access difficult, incorrect seed mixes/stabilization methods, narrow grassed medians, etc. Therefore, calculating an ROI for this or determining changes in crew efficiency as a result is not feasible at this time.</p> <p>For brush cutting and seeding activities in 2023, the districts with specialized crews were more efficient (amount completed/hour). Specialized crews' costs were also 33.5% less per acre or sq ft. Annual savings are 33.5% of the total cost of work for the non-specialized crews in 2023 (\$5,134,309.88 total, \$1,718,866.3 in savings).</p> <p>The annual cost for brush cutting activities that did not indicate treatment with herbicide was \$3,072,973.79. From a previous study with ODOT, treating cut brush reduced costs by 33.7% on average over two years (assuming all non-sprayed sites would require annual follow-up, and the sprayed sites would not need this due to the low % of undesirable cover the following year). Applying this to INDOT costs, spraying all sites following brush cutting would save \$1,035,592.17 annually.</p> <p>This was not supported by existing data and is an assumption. Equipment maintenance data actually showed that maintenance costs were higher for districts with specialized crews, even when accounting for hours worked on vegetation management activities (\$115.28/hr. for districts with specialized crews, and \$62.33/hr. for districts w/o specialized crews). This may indicate existing specialized crews need more training/refreshers. This may also be a result of certain equipment being utilized for other roadside tasks beyond vegetation management or getting transferred between offices more frequently. Additionally, we do not know the equipment utilization for each specific piece of equipment that requires maintenance, just overall hours on vegetation management tasks, which may have biased the cost/hr. estimate.</p>	Kentucky, Minnesota, and Missouri (in-part), ODOT for specific pieces of equipment	\$2,214,636.00 DRG Cost: Unknown	\$15,419,574.96	696.26%	~1.5 months	Costs are the annual salaries and benefits costs for 4 new specialized vegetation management crews. 5 members per district, with four being HT2 (\$51,506 mid-range of salary) and one being HT1 (\$57,500 mid-range salary). The salary for the manager of this crew (\$53,222) is also included. The salary total was then doubled to account for the benefits costs.

Action #	Action	Timeline	When/How to Complete	Problems Addressed	Benefits	Benefit Validation/Cost Savings & Assumptions	Other State DOTs Completing This	Anticipated Cost (\$)	Total Annual Savings (\$)	First Year Return on Investment (%)	Time to ROI	Explanation of Anticipated Costs
				Crews complete vegetation work on a reactive basis which causes inefficiency.	Crews can complete work on a proactive schedule which results in efficient use of staff and equipment and fewer customer complaints.	In 2023, the average number of WOs that were noted as customer complaints/requests in districts with specialized crews was 4. In districts without specialized crews, the average was 35.25. Additional savings (\$200,661.99) come from this difference in customer complaint WOs for districts with specialized crews.						
				Some staff with vegetation management certifications/training are not frequently conducting vegetation management tasks and applying this training.	Less vegetation management related training needed statewide for operations crew new hires.	121 staff over the past 5 years (2019-2023) completed the online training related to roadside vegetation management (chainsaw, revegetation during construction, and weed recognition). This would be reduced to 36 with specialized crews (5 crew members, 1 supervisor in each of the six districts). 123 hours total were spent on the revegetation during construction and weed recognition courses (only 7 hours were spent on the weed recognition). If the 36 specialized staff all take both courses (1 hour per course, 72 hours total), this would be just a little over half the previous total hours. Assuming \$33/hr. rate (\$30/hr. with 10% overhead), this is a savings of \$1,683.						
					Reduced need for additional staff with vegetation management certifications (e.g., herbicide applicator), leading to reduced staff needing annual refresher training.	Over the past 5 years, 105 staff have taken the Purdue herbicide applicator training; whereas, with the specialized crews, this would only be 36 individuals. With the course being \$110, this could be a savings of \$7,590.						
2	Purchase forestry bucket trucks for general tree work or arborist tracked lift, as well as a chassis-mounted, articulated knuckleboom with grapple saw or Sennebogen® 718 E to help with maintenance behind noise barriers	3-6 months	During the current project, DRG can help develop/review the bid sheets to ensure the equipment will be appropriate. Testing/training of equipment/staff outside of timeline of current project.	Staff cannot reach upper tree branches with current equipment.	Tree management can be completed more proactively as staff will be able to reach upper branches and safely trim trees as needed before they fall and become a hazard.	This is an assumption based on the abilities of the recommended equipment.	This was not a DOT survey question. ODOT has purchased forestry bucket trucks, an articulated knuckleboom with grapple saw and a Sennebogen® 718 E	\$1,150,000.00 DRG Cost: \$5000 per unique piece of equipment	\$277,104.11	24.10%	4.15 years	The anticipated costs are a sum of 4 Altec bucket trucks at \$145,000 each and \$570,000 is the cost of 1 Sennebogen® 718 E with grapple attachment. Alternatively, the cost for an articulated knuckleboom with grapple saw is \$466,737.24 (total \$1,046,737.24 for this and bucket trucks). Assuming this would result in the same cost effectiveness increases as the Sennebogen® 718 E, first year ROI would be 26.47%, with a time to ROI of 3.78 years.
				Staff cannot reach vegetation behind noise barriers.	Increased lifespan of noise barriers.	We are assuming that improved vegetation management around noise barrier structures will help preserve their structural integrity. We do not have Sennebogen® 718 E use data from INDOT, but we do have cost differences between INDOT crews that use forestry bucket trucks vs those that do not use forestry bucket trucks for tree removal as shown in the item above. To substitute for the lack of INDOT Sennebogen® 718 E data, we took the % difference in costs between Sennebogen® 718 E and forestry bucket truck crews from a different project (ODOT Ash tree removal project; 40.27% difference), and then applied both cost reductions to the total cost of INDOT noise barrier work for 2023 (\$45,944.82). The total of savings from these cost reductions is \$31,471.51.						

Table C.2 Vegetation Crew Alternatives.

Action #	Action	Timeline	When/How to Complete	Problems Addressed	Benefits	Benefit Validation/Cost Savings & Assumptions	Other State DOTs Completing This	Anticipated Cost (\$)	Total Annual Savings (\$)	First Year Return on Investment (%)	Time to ROI	Explanation of Anticipated Costs
3	Develop one-pagers and videos for equipment use and operations memorandum, along with additional herbicide training.	6 months	DRG will develop one-pagers for specialized equipment, INDOT field staff can review one-pagers to ensure information is understandable by INDOT staff.	Staff do not have documents detailing how to use infrequently used/specialized equipment.	Time needed for vegetation management will decrease.	Total labor costs for 2023 vegetation management work was \$3,325,514.26. Assuming one-pagers will speed up mobilization times by 1%, annual savings from implementing one-pagers will total \$33,255.14 . This 1% is a reasonable assumption after looking at differences in mobilization times between crews that received specific equipment training those that did not in a previous ODOT study. Mobilization for crews that had gotten familiar with equipment was 5 minutes faster than crews earlier in the year.	Illinois - do "recurrent training in-house" (does not specify if this includes herbicide application) Iowa - all maintenance staff are certified applicators; they recently re-initiated a formal training program for veg management activities. Missouri - "a lot of recurrent training conducted in-house (unclear if this includes herbicide)" Wisconsin - high level policy training to patrol and superintendents.	DRG - \$110,000	\$1,068,847.31	871.68%	~1 month	Costs included are just DRG costs to produce the one-pagers and additional training.
					Equipment damage as a result of staff misuse and the resulting repair/maintenance costs will decrease.	This benefit was not supported by existing data and is an assumption. Equipment maintenance data actually showed that maintenance costs were higher for districts with specialized crews, even when accounting for hours worked on vegetation management activities (\$115.28/hr. for districts with specialized crews, and \$62.33/hr. for districts w/o specialized crews). This may indicate existing specialized crews need more training/refreshers. However, this may also be a result of the equipment being utilized for other roadside tasks beyond vegetation management and differences in wear-and-tear between equipment being used. Additionally, we do not know the total work hours on each specific piece of equipment that requires maintenance, just overall hours on vegetation management tasks, which may have biased the cost/hr. estimate.						
					Decreased annual follow-up herbicide work at previously treated sites (or sites that should have been treated during the first visit, but weren't).	We assume that additional training will increase staff's familiarity with proper herbicide procedures, application protocols, etc. which will ultimately lead to more effective work. This includes knowing that follow-up herbicide treatment should be completed for ALL brush cut activities to reduce/eliminate need for follow-up annual treatments (which is the cost savings). This was demonstrated in a prior study DRG conducted with ODOT. The annual INDOT cost for brush-cutting activities that did not indicate treatment with herbicide was \$3,072,973.79. From a previous study with ODOT, treating cut brush reduced costs by 33.7% on average over two years (assuming all non-sprayed sites would require annual follow-up, and the sprayed sites would not need it based on the low % cover the following year). Applying this to INDOT costs, spraying all these sites following brush cutting would save \$1,035,592.17 annually.						
4	Implement pay progression/incentives for staff to attain certifications related to vegetation management (e.g., herbicide applicator license)	2-3 months for development 6-18 months for approval	DRG will work with INDOT to identify all relevant certifications to include in the pay progression/incentive program.	Not enough staff with training beyond the required new hire training for vegetation management.	More experienced staff in each district who will be willing and motivated to apply additional vegetation management training in the field.	We assume that pay progression and other incentives will motivate staff to invest more effort in vegetation management work and to attain related certifications. We cannot calculate an ROI for this at this time as a pay progression plan would need to be further developed. If this is implemented, pay progression systems will also be applied to other maintenance departments.	Illinois provides pay incentives only during herbicide application, unknown for other states as this was not a DOT survey question.	INDOT Cost: Unknown DRG Cost: \$20,000	Unknown	Unknown	Unknown	Costs cannot be estimated at this time without a more detailed pay progression plan.
					Reduced need for onboarding of new hires.	We assume that these pay progression incentives will increase employee retention and reduce the need to train new hires.						

Table C.3 Design/Specification Updates.

Action #	Action	Timeline	When/How to Complete	Problems Addressed	Benefits	Benefit Validation/Cost Savings & Assumptions	Other State DOTs Completing This	Anticipated Cost (\$)	Total Annual Savings (\$)	First Year Return on Investment (%)	Time to ROI	Explanation of Anticipated Costs
5	Update safety feature specs (guardrail, cable rails, etc.) to use alternate non-vegetative materials where maintenance is difficult or is a safety hazard (e.g., in areas where median width would be too narrow to safely access).	2 years	Follow-up project to current project due to the budget and timeline.	Vegetation under/around guardrails, cable rails, and other roadside safety structures needs to be reduced and is difficult to access when maintenance is needed.	<p>Increased lifespan of guardrails, cable rails, etc.</p> <p>Reduced need for vegetation management around guardrails, cable rails, etc., and a subsequent reduction in the costs and safety concerns associated with it.</p>	<p>We are assuming that improved vegetation management around guardrails, cable rails, and similar roadside safety features will help preserve their structural integrity.</p> <p>Vegetation management work that was noted as being conducted around guardrails totaled \$27,114.15 in 2023, which would be minimal savings if this was to be eliminated. However, the labeling of work as guardrail specific was just taken from employee comments in the roadside data summary, which may not be reflective of the full extent of in-house guardrail work. Additionally, none of these savings include the costs for contractors spraying/clearing brush around guardrails, which likely totals in the millions.</p>	Kentucky (researched but not implemented), Minnesota (mats), Missouri (aggregate under the rails, researched under but decided against it), Wisconsin (bonded non-aggregate)	DRG Cost: \$200,000 for upcoming appurtenances project	TBD with upcoming appurtenances project	TBD with upcoming appurtenances project	TBD with upcoming appurtenances project	This task is looking at specifically reducing vegetation management needs; however, most states indicated that many of these items are cost prohibitive. With INDOT's 3,232 miles of guardrail and cable rail barriers, installing something like semi-rigid interlocking plastic panels around existing guardrails would cost an estimated \$444,883,507.20. This is based on cost per linear ft estimates from a previous study by DelDOT (note, this was one of the more expensive options explored). Additional research is needed to determine actual costs for INDOT.
6	Update noise barrier specs - noise barriers should be placed at edge of DOT land to prevent the need for maintenance behind barriers. Where this is not feasible, access doors in noise barriers should be large enough to allow equipment access and drop-offs should be remediated.	2 years	Follow-up project to current project due to the budget and timeline.	Vegetation behind noise barriers is difficult to access.	<p>Improved vegetation management around noise barriers.</p> <p>Increased lifespan of noise barriers.</p>	<p>We are assuming that better access will mean better maintenance around noise barriers (independent of the equipment recommendation above).</p> <p>We are assuming that improved vegetation maintenance around noise barrier structures will help preserve their structural integrity.</p>	<ul style="list-style-type: none"> Illinois - Usually the noise barriers are at the end of the ROW. They usually use fencing to prevent entrance onto the ROW. Design specs call for minimum 3 ft (0.9 m) wide by 7 ft (2.1 m) high minimum clear access openings. Iowa - have gates in noise barrier for access. Some of the gates are double doors which allow access by tractors or pickups. 	Unknown	Unknown	Unknown	Unknown	
7	Test GeoWeb® or similar alternative slope stabilization techniques.	3-6 months 2-5 years	DRG will review options for slope stabilization strategies and identify locations for possible testing. DRG can monitor sites where slope stabilization methods being tested. The testing will be outside of the current project's timeline and budget.	Slope failures occur frequently, causing maintenance difficulties and inhibiting vegetation establishment.	Reduced slope failures and improved vegetation establishment.	Given that INDOT's current slope stabilization methods are causing difficulties for maintaining vegetation, we suggest some alternative/innovative technologies could provide improvement in slope stabilization effectiveness. We do not have any data to predict the degree of improvement and thus cannot calculate an ROI at this time.	Unknown, this was not a DOT survey question.	Unknown	Unknown	Unknown	Unknown	Costs will depend on acreage of slopes greater than a certain angle of repose throughout the state.
8	Update culvert/ditch specifications so that they are a set distance from the roadway and/or are marked with physical markers in the field.	2 years	Follow-up project to current project due to the budget and timeline.	Culverts and ditches are not visible for inspection or maintenance staff.	Inspections and maintenance around culverts and ditches will be completed more efficiently and reduce follow-up visits.	Having ditches and culverts marked and in a consistent location will reduce the time it takes staff to find them. This will reduce costs associated with follow-up visits by inspectors who could not gain access due to overgrown vegetation.	Unknown, this was not a DOT survey question.	Unknown	Unknown	Unknown	Unknown	

Table C.4 Other.

Action #	Action	Timeline	When/How to Complete	Problems Addressed	Benefits	Benefit Validation/Cost Savings & Assumptions	Other State DOTs Completing This	Anticipated Cost (\$)	Total Annual Savings (\$)	First year Return on Investment (%)	Time to ROI	Explanation of Anticipated Costs
9	Roadside maintenance coordination with the public affairs office or similar group at INDOT to send out informative press releases and/or social media blurbs when changes to vegetation management practices occur, or to generally educate the public on INDOT's vegetation management program as it relates to driver safety, landscape aesthetics, pollinator benefits, etc.	3 -6 months	This task can be done internally within INDOT.	Customer service complaints are a large portion of the annual workload.	Less customer service complaints, crews have more time to spend on other tasks such as proactive vegetation maintenance.	We cannot estimate a ROI for this action item at this time. It is unknown what percentage of INDOT's time is spent on activities or calls that could be resolved/avoided by just having a more informed public. To our knowledge, there is no data on this within INDOT, and was not explored by DRG on other DOT projects.	<ul style="list-style-type: none"> Illinois - Mowing information is sent out at the beginning of the mowing season. IDOT has a YouTube video detailing the reasons for the reduced mowing. A new law that will be coming on the books soon: when they are spraying, they need to notify landowners when herbicide is being applied through multiple sources, e.g., door hangers or signs along the road. Kentucky - send out press releases and social media posts. They release info about the new mowing cycles every year. Wisconsin - public affairs office has put videos together in the past about VM. Public affairs is trying to promote the DOT's goals and the reasons vegetation management is completed. WisDOT is doing this through social media, press releases, and a website page about pollinators and mowing. 	INDOT Cost: Unknown	Unknown	Unknown	Unknown	
10	Develop inventory/mapping system for vegetation management, and integrate into INDOT deficiency app	1-3 years	Follow-up project to current project due to the budget and timeline.	Staff need access to improved tracking and inventory of vegetation management work needed and accomplished.	<p>Improved integration of vegetation management into work plans.</p> <p>Overall improvement to the quality of roadside vegetation management in the state since INDOT will be more aware of where and when vegetation management is needed.</p> <p>More detailed quality control for vegetation management activities.</p>	<p>INDOT's current method of tracking vegetation management work (which for some staff involves a lot of hand drawing on maps) could be greatly improved with tracking/mapping technology to increase efficiency. To our knowledge there is no data comparing efficiencies/cost effectiveness of roadside crews before and after a mapping system is initiated, therefore we cannot estimate savings or an ROI for this action item at this time.</p> <p>More accurate tracking of vegetation maintenance locations, acreages sprayed, trees trimmed, etc. will allow for better quality control of vegetation maintenance for both contractors and in-house staff.</p>	<ul style="list-style-type: none"> California - tracks some landscape assets in a GIS asset management system, but is also working on redesigning their Transportation Asset Management System (TAMS) to integrate more detailed information about vegetation management work. Ohio - can integrate vegetation management work details using their bi-weekly collector app and Transportation Information Mapping System (TIMS). Tennessee - contracts with a mapping software company to map trees along the roadside. Wisconsin - maintains an interactive geoportal for internal staff that contains shapefiles of remnant prairie areas, endangered species distributions, mowing areas, and expectations (frequency, completion dates, etc.). Washington - has begun utilizing unmanned aerial vehicles (UAVs) via private contractors to plan and carry out herbicide application and monitor vegetation cover. 	Unknown	Unknown	Unknown	Unknown	Costs for developing a mapping system for roadside vegetation assets can be highly variable and are not known at this time for INDOT. Recommend conducting a research project to determine costs and recommended course of action for INDOT.
11	Update contracting processes and pre-qualification process.	2-4 months 1-2 years	<ul style="list-style-type: none"> DRG will review current contracting process and provide recommendations INDOT will work with contracting office to initiate use of updated protocols. 	Additional qualified bidders needed for vegetation management projects.	<p>Increased competition between bidders for vegetation management contracts.</p> <p>Reduced conflicts caused by vendors taking on more contracts (acreage) than they can work at one time.</p> <p>Increased contract compliance.</p>	<p>We assume that additional competition will decrease bid prices. It is not known how much savings this would result in for INDOT.</p> <p>INDOT benefiting from this is based on the assumption that a contractor's quality of work will increase if they have not taken on more than they can handle.</p> <p>This is based on the assumption that competition will enhance the quality of contractor work and adherence to contracted quantities/goals to accomplish.</p>	Iowa increased contractors by updating qualifications requirements.	DRG Cost: \$25,000 INDOT Cost: Unknown	Unknown	Unknown	Unknown	

Action #	Action	Timeline	When/How to Complete	Problems Addressed	Benefits	Benefit Validation/Cost Savings & Assumptions	Other State DOTs Completing This	Anticipated Cost (\$)	Total Annual Savings (\$)	First year Return on Investment (%)	Time to ROI	Explanation of Anticipated Costs
12	Develop performance-based quality assurance metrics for vegetation management.	6-12 months	Follow-up project to current project due to the timeline. DRG will develop performance metrics for vegetation management and develop training materials detailing the purpose of the performance and detailing how management can work to ensure the performance metrics are being used correctly across the state.	The quality of contractor vegetation management work is not adequately tracked.	Improved quality of contracted vegetation management work. Reduced need for in-house follow-up vegetation management work.	We are assuming that if contractors are aware that their efforts are being more closely monitored, quantified, and evaluated, and will have an impact on future contracting, then they will increase the quality of their work. If contractors are more closely meeting performance standards, following proper protocols, etc., we can assume that this would lead to a reduction in the need for follow-up efforts.	Unknown, this was not a DOT survey question.	DRG - \$40,000	Unknown	Unknown	Unknown	Currently costs listed are just for DRG to develop the metrics, but other costs may be involved.

Appendix D. Technical Memorandums

Following site visits and meetings with each district, DRG interviewed other regional DOTs to determine if INDOT's challenges were experienced by the other DOTs and if they had been overcome. Technical memorandums were created that included:

- Completion of vegetation management around difficult-to-access roadside assets, cable rails, and guardrails
- Completion of vegetation management around culverts and ditches
- Contract language
- Maintenance operations input during the design stages of roadside projects
- Prequalified vendor process
- Access behind noise barriers
- Vegetation management work standards

Roadside Safety Appurtenances Preliminary Recommendations

Technical Memorandum

Executive Summary

The gap analysis research explored new and innovative approaches to long-term vegetation management under guardrails to address vegetation maintenance issues. These strategies vary in their effectiveness, longevity, construction costs, maintenance needs, and aesthetics. The research revealed that some newer approaches to managing vegetation beneath currently installed guardrail and cable rail systems may be cost-prohibitive for Department of Transportation (DOT) implementation. Despite these initial findings, the lack of consideration for vegetation maintenance in Indiana DOT's (INDOT's) current guardrail and cable rail designs meant further research into improvements was necessary. As such, Davey Resource Group (DRG) recommended continued exploration of design improvement options for guardrails and cable rails for the implementation phase of this project.

Background

Unchecked vegetation growth around difficult-to-access roadside assets, cable rails, and guardrails can impede motorist vision and reduce roadside aesthetics. Given their proximity to the roadside, guardrails and similar safety appurtenances increase exposure risk for staff and contractors conducting string trimming and other vegetation maintenance. DOT staff and contractors use cab-equipped motorized equipment to reduce worker exposure to traffic, but typical mowing equipment cannot adequately clear vegetation from around posts or behind cable rails and guardrails.

Furthermore, specialty equipment on the market that can be used to maintain these areas and reduce worker exposure does not always perform as well as needed in adverse terrain, leaving the expense difficult to justify for specialty single-purpose equipment. New and innovative approaches to long-term vegetation management under guardrails were explored to address these maintenance issues. The research revealed that some newer approaches to vegetation management beneath currently installed guardrail/cable rail systems may be cost-prohibitive for implementation. As such, DRG recommends continued exploration of design improvement options for guardrails/cable rails for the implementation phase of this project to determine the best long-term vegetation management options under guardrails for DOTs. Preliminary findings and cost information from this additional research are provided below.

Findings and Cost Savings

Mow Strips

While more innovative approaches to guardrail vegetation management (e.g., interlocking plastic panels, flexible concrete canvas) remain rare amongst DOTs, further discussion with DOT representatives revealed that concrete mow strips are a common yet effective method of preventing vegetation growth around guardrail and cable rail systems.

Concrete mow strips can prevent vegetation growth several feet around guardrail installations. They are utilized to some degree by Florida, California, Ohio, Kentucky, Illinois, and Texas state DOTs; however, INDOT currently does not have a design standard for these. Posts for guardrail and cable rails in Indiana are installed directly into the soil.

Based on a 2024 INDOT contract to install concrete mow strips beneath cable barriers (the first INDOT contract to do so), mow strips cost INDOT \$23.20/lineal foot for material and installation. This cost is comparable to states that install mow strips as a standard practice (e.g., Caltrans - average \$20.31/lineal foot between 2020-22; WisDOT - average \$41.21/lineal foot between 2022-24). A cost of \$23.20/lineal foot concrete mow strip equates to \$122,496/mile.

An INDOT contractor estimated that string trimming guardrail/cable rails along the roadside costs approximately \$190/mile per occurrence. With an exposure cost of \$28.80 (to account for safety risk during roadside maintenance activities; Nemati et al., 2024), and three trimming cycles per year, this would result in a cost of \$656.40/mile to string trim guardrail. Assuming an annual inflation rate of 2% for string trimming, the savings from not having to pay contractors to string trim INDOT's guardrail/cable rails would provide a return on investment (ROI) for the mow strip concrete material and installation cost in approximately 79 years.

Concrete Barriers

Organic matter can build up on concrete pads, creating suitable growing conditions for vegetation. A better and more cost-effective option over the lifespan of the barrier is the avoidance of future guardrail installation altogether, at least in areas where vegetation management would be of concern. The most common alternative to metal guardrail to prevent run-off-road incidents are concrete barriers. Although the decision to install guardrail or concrete barriers will vary based on road geometry, traffic conditions, and other factors, in general concrete barriers appear to be the preferred treatment (Nemati et al., 2024). Concrete barriers can prevent vegetation growth since they are often poured up to the pavement edge, thus restricting the growth of unwanted vegetation in front of and underneath the structures. Concrete barriers can reduce the need for vegetation

management while providing a quicker return on investment than guardrail with concrete mow strips.

In a cost analysis study of Caltrans concrete barriers and W-beam guardrails (Figures D.1 and D.2), costs to be incurred by these structures over their lifetime include construction, maintenance, exposure, and public costs (Nemati et al., 2024). Construction costs for guardrails include additional costs for mow strips in areas where vegetation management is necessary. Maintenance costs are mainly related to repairs from traffic incidents. Exposure accounts for risks for staff during all maintenance activities, and public costs account for costs imposed on the traveling public from crash outcomes.

The estimated cost of an example road from this Caltrans study (65 mph speed limit, 100,000 Annual Average Daily Traffic (AADT), lane width of 12 ft, shared median) for one mile of concrete barrier construction is \$567,362.40, and one mile of guardrail with a no mow strip (INDOT's current cable rail and guardrail situation) is \$478,737.60. For INDOT, concrete barrier installation projects may also involve the removal and disposal of an existing guardrail, which would be an additional cost of \$75,240/mile (based on 2019 contract cost data from Los Angeles County). To hypothetically install a guardrail that does not have a mow strip and then remove and replace it with a concrete barrier, the total project costs would be \$1,121,340.00/mile.

The average annual cost/mile for maintenance, exposure, and public costs was estimated to be \$215,922 and \$275,404.27 for a concrete barrier and metal guardrail, respectively. Additionally, string trimming costs INDOT \$656.40/mile annually. So, for a one mile stretch of roadside, an annual savings of \$60,138.24/mile is estimated from using concrete barriers as an alternative to guardrails and not having to pay contractors to string trim, resulting in an ROI of approximately 18.4 years to make up for the initial project costs (\$1,121,340.00).

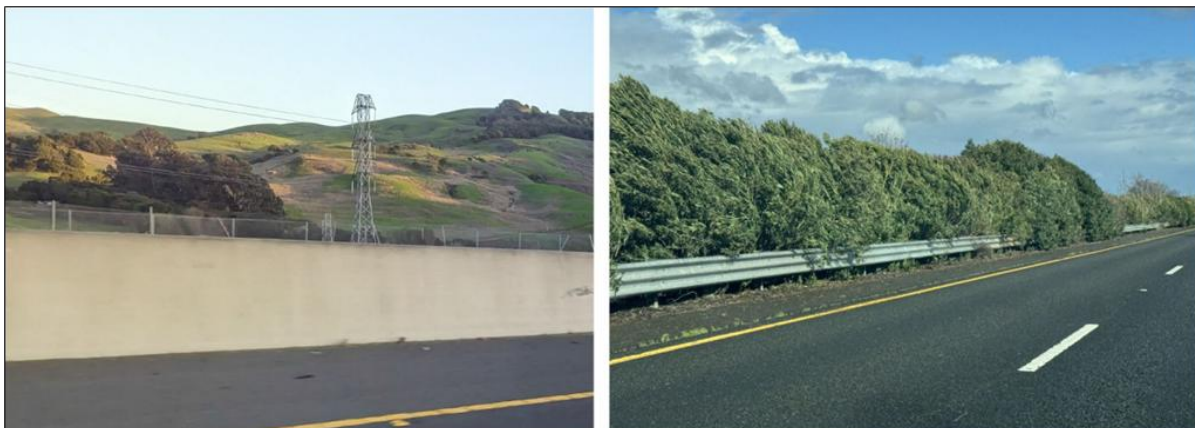


Figure D.1 & Figure D.2 Samples of typical concrete barriers and three-beam guardrail installed on highways I-80 near Sacramento, California, USA (Nemati et al., 2014; [CC BY 4.0](#)).

Recommendations

Concrete barriers should be strongly considered by INDOT engineers as an alternative to steel guardrails when calling for additional or replacement roadside safety appurtenances. Recent research suggests that higher initial construction costs will be offset by reduced maintenance, exposure, and public costs over their lifetime. Not only will concrete barriers reduce vegetation maintenance needs, but they will also improve crash outcomes when installed as an alternative to guardrails where appropriate, thus enhancing the safety of the traveling public (Nemati et al., 2024). Future research should analyze current and future guardrail installation locations along INDOT roadsides and evaluate the costs and benefits of utilizing concrete barriers in these areas in greater detail.

Culvert and Ditch Maintenance Recommendations Technical Memorandum

Executive Summary

To further explore culvert and ditch maintenance beyond the Department of Transportation (DOT) interviews, Davey Resource Group, Inc. (DRG) examined culvert and ditch marking, maintenance, and design requirements from various state design standards documents. DRG recommended that Indiana DOT (INDOT) begin using culvert field markers in conjunction with standard drawings, providing maps of culverts and ditches via Global Positioning System (GPS) to all staff, reducing the variation in distance from pavement within individual ditches, and reducing ditch bank slopes to ensure maintenance can be completed along culverts and ditches.

Background

Culvert and ditch vegetation management practices varied across the states that were interviewed, but several viable maintenance practices were presented that INDOT could adopt to move towards a more proactive vegetation management approach. To further explore culvert and ditch maintenance beyond the DOT surveys, as well as to substantiate survey responses, DRG examined culvert marking in the field and culvert and ditch maintenance and design requirements from various state design standards documents. Findings from the surveys and background research were used to generate recommendations for INDOT's vegetation management program.

Findings

Of the six other state DOTs surveyed, three mentioned that their state as a whole or some districts within the state use some kind of marking to help inspectors and maintenance personnel identify culvert locations in the field. The Illinois Department of Transportation (IDOT) marks most culverts with posts. Standard drawings for these posts are given in IDOT design standard 667007-01. Some Missouri Department of Transportation (MoDOT) districts utilize reflective markers to prevent culverts from being hit by mowers and other equipment along the ROW

(Figure D.3). MoDOT was the only state DOT to have a standard drawing describing both the placement and design of culvert markers. MoDOT staff also use GIS coordinates to locate culverts and ditches. Iowa DOT (Iowa DOT) uses markers protected by "sleeves" to indicate culvert locations.

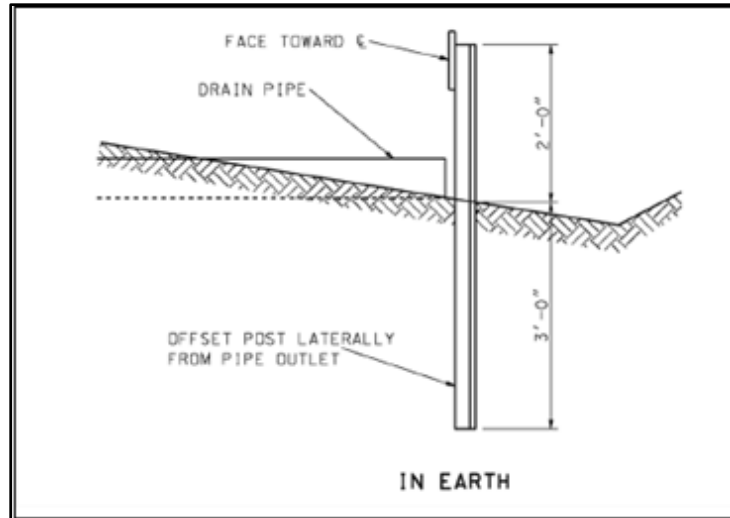


Figure D.3 MoDOT standard drawing for drain markers (602.00D).

Each state DOT interviewed indicated that the vegetation around culverts and ditches is maintained during routine mowing operations. Any additional vegetation maintenance work around culverts and ditches is conducted as needed in response to routine inventories and inspections. The frequency of these inspections appears to differ between states with some state DOTs, indicating that culverts are inspected annually, while others are inspected biannually. In Indiana, small culvert inventory and inspections are completed by technical services staff annually, while large culverts are inspected at least every two years.

Culvert maintenance is a part of the Minnesota Department of Transportation (MnDOT) asset management system. As a result, MnDOT has performance measures in place to create accountability for culvert maintenance and creates targets for culvert inspection frequencies.

Most of the state DOTs surveyed have standard roadside ditch drawings. These standard drawings give recommended depths and slopes for roadside ditches but do not provide suggested distances from the road. INDOT staff stated that the distance of ditches from pavement varies along the ROW. The only exception is INDOT's standard drawing (No. E 617-CDIN-01) for ditch sections near inlet pipes that detail the location and center of the ditch at 26 ft from the edge of pavement (13 ft width from pavement edge to the top of the ditch foreslope, and 13 ft from the top of the ditch foreslope to the center of the ditch).



Figure D.4 & Figure D.5 Examples of culverts choked with vegetation along the Indiana ROW. These images were captured during culvert inspections. The culvert on the right is located approximately 100 feet from the road edge behind a noise barrier. Photos taken by INDOT staff, used with permission.

If ditches other than sections near inlet pipes had similar guidance for the distances from the pavement edge, it would be beneficial in helping maintenance staff locate ditches that have become overgrown (Figures D.4 and D.5). Even though in practice, the distance of a ditch from the roadside may need to vary based on site conditions and hydraulic requirements of the ditch.

The recommended ditch side slopes across various DOT state design documents range from 3H:1V to 6H:1V. INDOT’s Design Manual lists 3H:1V as the maximum slope for backslopes, and 4H:1V for foreslopes. INDOT staff indicated that in practice they aim for 6H:1V but will design steeper if needed.

Large drainage tiles or pipes outside of the pavement area can be used to reduce the depth of ditches by allowing water flow to occur below the surface of the ground. This is currently implemented by Iowa DOT and MnDOT. These systems can pipe stormwater away from the roadway, allowing INDOT to reduce the slope of existing ditches. The water can be collected in above-surface ditches or through perforated pipes below the surface and routed to these underground pipes.

Recommendations

To reduce maintenance challenges around culverts and roadside ditches, INDOT should consider adopting some of the maintenance practices implemented by other state DOTs. Firstly, DRG recommends that INDOT physically demarcate culverts, and similarly to IDOT and MoDOT, develop standard drawings for the markers. These markers can be marking posts, flagging, or a reflective marker to be placed offset from the end of

inlets/outlets. These markers will assist inspectors and maintenance staff locate culverts and ditches and will reduce instances of machines, such as mowers, damaging culverts. As a supplement to markers, it would be helpful to make the locations of culverts and ditches easily accessible in a GIS system to field and supervisory staff. It is recommended that individual ditches maintain a consistent distance from the road, where possible due to topography and ROW limits. This consistent distance does not require all ditches to be equally distant from the pavement. However, establishing consistent distances will be particularly helpful for inspectors and vegetation management staff in instances where vegetation has become severely overgrown, and markers have become difficult to see.

DRG recommends that INDOT update Ch 203 of the Design Manual that states “channel side slopes should not exceed the soil or lining’s angle of repose and should be 3H:1V or flatter” to a slope maximum of 6H:1V. INDOT staff indicated that they aim for 6H:1V slopes in practice. Conversations with California Department of Transportation (Caltrans) staff revealed they were successful in updating the maximum slope from 3H:1V to 4H:1V by maintenance staff expressing to design staff that they could not maintain steeper slopes and that steeper slopes would lead to slope failure. As done in California, INDOT designers may be convinced to update the slope maximum if INDOT maintenance staff present a consistent slope limit and reasoning. Convincing designers to update this standard will reduce instances of mowing contractors avoiding ditches because side slopes appear too steep, thus reducing the prevalence of overgrown ditches along Indiana roadways.

To increase accountability for culvert and ditch maintenance, INDOT should include culverts and ditches in an asset management system like MnDOT, and make this system available to staff while in the field. Having technical services complete annual inspections on small culverts does not address the need for better maintenance of these areas throughout the year before inspections occur. As such, small culverts should be a tracked asset of the maintenance division, and appropriate goals should be set for their maintenance annually.

Cost Savings and ROI

The combined cost of INDOT in-house vegetation maintenance work around culverts and roadside ditches during 2023 was \$294,936.68.

Although no cost or savings information from other DOTs that are currently implementing the recommended practices above is available to the research team, we expect the above recommendations will improve the quality of vegetation maintenance around culverts and ditches and will reduce future costs.

For example, the installation of markers is a relatively inexpensive means of identifying culvert locations. The benefits of markers are two-fold. Not only will maintenance staff be able to find these locations when clean-outs or any follow-up maintenance is needed, reducing the time staff search for culverts for inspections and maintenance, but damage from machinery, like mowers, will also be reduced because of increased visibility, reducing the need for replacement or repair. By positioning culverts a set distance from the pavement more regularly, they will fall into the areas where vegetation management occurs more frequently. The increased maintenance may reduce flooding issues along the roadway as small culverts will not be clogged as frequently by vegetation.

Updating the maximum slope requirements should also create cost savings. Creating gentler slopes may require the purchase of an additional ROW, but the savings that result from having ditches better designed for maintenance needs may outweigh these ROW purchase costs. Less severe roadside slopes will avoid costs incurred from failing slopes that compromise the roadway. It will also avoid situations in which special provisions are implemented for slope stabilization that can introduce additional safety hazards to the ROW that bring additional costs.

Pre-Qualification Recommendations Technical Memorandum

Executive Summary

To gain a better understanding of why the Indiana Department of Transportation (INDOT) is having issues expanding the qualified contractor pool, Davey Resource Group (DRG) reviewed INDOT's pre-qualification requirements and compared them to the requirements of other state DOTs. Comparisons were made between state requirements to identify where INDOT's requirements vary from other state DOTs and to identify where changes can be made to INDOT requirements to increase the number of INDOT pre-qualified contractors. The research team recommends that INDOT begin using two periods of pre-qualification. Those contractors who submit an audited statement or a reviewed statement should have the period between the pre-qualification review increased to 16 months from 12 months. Contractors completing a compiled statement should continue to receive a pre-qualification that lasts twelve months to align with the validity period of the compiled statement. Furthermore, the pre-qualification period should begin at the time of approval, not the time of application, in the event pre-qualification takes a couple of months.

To help increase the number of possible contractors, INDOT should conduct vendor outreach with informational sessions two times per year to discuss upcoming jobs and the prequalification process in general. An updated frequently asked questions document should also be created with information on the types of financial statements accepted by INDOT, information on contractors' bidding capacity, and a statement indicating when a performance bond is required of contractors. In addition to outreach, it is recommended that well-established companies with no issues in fulfilling contract(s) or newly formed companies with key staff that have ten years or more of experience in the field for which they are applying for INDOT pre-qualification be given the opportunity to apply for a reduction in pre-qualification requirements where they would only need to provide financial statements for prequalification. This reduction would last so long as the key personnel remain with the contractor (e.g., field supervisor remains with the company) and so long as the contractor shows the capability to rectify work that is underperformed or shows the ability to pay for any financial or legal liabilities.

Background

Sometimes, due to the low number of bidders for contracts, a contractor will be awarded more contracts than they have the capacity to handle within the designated timeframes. This results in work being delayed, which means seasonally sensitive contracts for items such as herbicide applications will have diminished effectiveness. After discussion with INDOT, it was revealed that this lack of contractors extends beyond vegetation management into additional sectors of INDOT, such as construction.

Table D.1: State Department of Transportation Pre-Qualification Requirements.

State DOT	Prequalification Work Types & # of Contractors	%Contracted	Pre-Qualification Length (Months)	Provisions to Reduce Bidder Qualification Restrictions	Policy Document Length (Pages)
INDOT	<ul style="list-style-type: none"> • Permanent seeding, sodding & topsoil (80) • Roadside mowing (12) • Tree planting (3) • Tree trimming & removal (20) • Vegetation control (9) 	100% for planned work, follow-up and as needed work is performed in-house	12 (can be as little as 1 month based on the date of financial statement used and amount of time needed for prequalification to be approved)	No	32
Iowa DOT	N/A*	80% spraying 90% plantings 10% brush cutting 10% tree removal	18	Yes	45
MDOT	<ul style="list-style-type: none"> • Clearing & grubbing (155) • Sodding & seeding/turf establishment (176) 	90% tree removal/maintenance 51-60% other tasks	16 (pre-qual rating < \$10 million) 28 (pre-qual rating > \$10 million)	No	12
ODOT	<ul style="list-style-type: none"> • Clearing & grubbing (413) • Soil stabilization (177) • Temporary soil erosion & sediment control (343) • Landscaping (268) • Mowing (90) • Herbicidal spraying (29) 	10% mowing 90% spraying 100% planting 75% seeding	12	No	18
PennDOT	Not Available	85% spraying 90% tree removal/maintenance	24	No	22

*Only landscaping contractors require pre-qualification, clearing, and grubbing contractors do not require pre-qualification.

Findings

Each state DRG researched (Iowa Department of Transportation (Iowa DOT), Michigan Department of Transportation (MDOT), Ohio Department of Transportation (ODOT), and Pennsylvania Department of Transportation (PennDOT)) requires vegetation management contractors to be pre-qualified. However, some states have incentives, such as small business initiative contracts (Iowa DOT), that remove these pre-qualification requirements, and each state has a different frequency with which the pre-qualification process must occur. DRG conducted interviews with regional DOTs, and asked each DOT if they had issues obtaining bids from qualified contractors. Of the six states interviewed, only Iowa DOT stated they had difficulty obtaining bidders in the past; they have since updated their specifications to increase the number of contractors. The frequency of pre-

qualification review and the number of contractors who have obtained pre-qualification status are the main items that vary between the state DOTs (Table D.1). Iowa DOT is the only state with special provisions to reduce bidder qualification restrictions.

Vendor Feedback

The research team solicited pre-qualified INDOT vegetation management contractors who had not placed bids on vegetation management contracts between 2020-2024 to determine the cause for the lack of bids. The most common reason shared by pre-qualified contractors for not bidding was a lack of staff and capacity.

One contractor who has bid and been awarded INDOT contracts indicated that the most significant barrier to bidding on INDOT projects is that city, county, and state letting all come out around the same time, which makes it difficult to pursue all opportunities. Additionally, one DBE contractor expressed that the paperwork is often difficult to complete due to the size of their business and requested INDOT aid in the completion of the pre-qualification documentation. Contractors stated that the document contains information on pre-qualification and contains a lot of information and is difficult to digest.

Pre-Qualification Frequency

The frequency of the pre-qualification review was the item within the prequalification requirements that varied the most between the five DOTs. MDOT had multiple expiration dates for the pre-qualification package, depending on the pre-qualification rating sought (Table D.1). The shortest expiration among the requirements reviewed was with INDOT's at a maximum of twelve months. INDOT requirements state "No certificate of qualification will be valid for more than twelve (12) months, nor will its expiration date under any circumstance be subsequent to sixteen (16) months after the date of the statement upon which it is based" under Rule 2 Section 1 (i) of Article 11 Prequalification of Contractors and Bidding document. According to INDOT's Prequalification Frequently Asked Questions document, if a fifteen-month-old financial statement is used to obtain pre-qualification status, the company will be pre-qualified for one month. In contrast, ODOT's contractor pre-qualifications are valid for 12 months from the date approved unless rescinded for cause as determined by the director.

The other states researched have pre-qualification terms extending between 16 and 28 months. Three of the five states researched have at least one pre-qualification option that lasts twenty-four months or more.

MDOT has both 16- and 28-month pre-qualification periods, depending on pre-qualification rating requirements met, and 229 vegetation management related contractors.

Reducing Bidder Qualifications

Initially after increasing the amount of contracted vegetation management work, Iowa DOT had difficulty obtaining enough bids from qualified contractors. As a result, Iowa DOT began conducting outreach to local vendors to increase the number of vendors available to Iowa DOT for vegetation management. Iowa DOT is not the only DOT that conducts vendor outreach - MDOT conducts vendor outreach multiple times per year, including information sessions with presentations and time for questions and answers with representatives from their Office of Business Development. In addition to the vendor outreach mentioned above, Iowa DOT section 1102.02: Reduction in Bidder Qualification Restrictions was introduced into the Iowa DOT Proposal Requirements and Conditions document to increase the number of qualified contractors. Iowa DOT was the only state researched or interviewed with standards to reduce bidder qualifications to support increasing the number of eligible contractors. According to Iowa DOT staff, these changes were effective in increasing the number of contractors. The two means of qualification restrictions for the Iowa DOT are reduced as follows:

1. Contractors with well-established performance records or adequate financial responsibility and experienced supervisory personnel available for the work under consideration.
2. Newly formed or reorganized contractors that are mainly composed of veterans of the construction industry with proven records of satisfactory performance in the selected field they are bidding in, with adequate financial responsibility, equipment, and experienced supervisory personnel.

A newly formed contractor with no experience in the field they are attempting to perform work would not qualify for either qualification restriction. Adequate financial responsibility means that the contractor can afford to pay for any damages that are incurred during the duration of the contract and there has not been any evidence of a material change in financial responsibility by judgment of the contract engineer. A proposal guaranty must be included in each proposal to show that the contractor has adequate finances for the contract for which they are applying. This guaranty can be provided through a “certified check or credit union certified share draft, cashier's check, money order, or bank draft drawn on a solvent bank or credit union.” A contractor can choose to complete an Annual Bid Bond in lieu of a proposal guaranty if desired. Iowa DOT prescribes the proposal guaranty amount in each request for bid that the DOT puts out. If a contractor does not include this in their bid, it is automatically rejected by the DOT. After the introduction of the reduction in the bidder qualification restrictions, Iowa DOT has had less difficulty in obtaining enough contractors to complete work throughout the state.

Recommendations

After reviewing regional DOTs requirements for pre-qualifications and locating the areas where INDOT requirements vary from the other state DOTs, DRG compiled recommendations for updates to contractor pre-qualification requirements to help INDOT increase the number of qualified contractors bidding on contracts throughout the state.

Recommendations Per Vendor Feedback

It is recommended that INDOT mowing and herbicide letting occur a month or two earlier than similar city and county contracts to assist contractors in identifying their capacities for the work type. It is also recommended that INDOT meet with potential contractors twice per year, once in spring and once in fall, to assist with filling out prequalification paperwork.

It is recommended that INDOT update the INDOT Prequalification Frequently Asked Questions document to include information on the three types of financial statements accepted by INDOT, information on how contractors bidding capacity is determined, and a statement indicating when a performance bond is required of contractors.

Pre-Qualification Frequency

The research team recommends that INDOT begin using two periods of pre-qualification. Those contractors who submit an audited statement or a reviewed statement should have the period between the pre-qualification review increased from 12 to 16 months. Contractors completing a compiled statement should continue to receive a pre-qualification that lasts twelve months. The additional pre-qualified months obtained by using the audited/reviewed statement will encourage contractors to complete the more advanced statement. The financial statements should be submitted annually to ensure contractors continue to meet financial obligations for contracts annually.

A decrease in the frequency of pre-qualifications, outside of financial documents, would likely further increase the number of contractors who would apply for pre-qualification; however, this would require INDOT to re-evaluate the validity period of financial statements. DRG believes that the number of contractors who apply for pre-qualification will improve with the increased time between pre-qualification expiration dates.

It is recommended that when a contractor gains pre-qualification, the age of the financial statement does not factor in the length of the initial pre-qualification period. No change is recommended to the age of the statement at the time of submission.

Furthermore, the pre-qualification period should begin at the time of approval, not the time of application.

For example, a contractor who applies for pre-qualification on April 18, 2025, with an audited statement, and is approved for bidding July 5, 2025, should have a pre-qualification expiration date of November 4, 2026, not August 17, 2026, to allow for 16 months.

Bidder Qualifications

To help increase potential contractors, INDOT should conduct vendor outreach with informational sessions two times per year to discuss upcoming jobs and the prequalification process in general. INDOT can direct this outreach to local vendors within Indiana and adjacent states who have not applied for pre-qualification with INDOT. INDOT could reach out to other Indiana agencies for lists of pre-qualified vendors, post on social media, and advertise on radio or television to let local vendors know of the bidding opportunities. The sessions should occur in the winter and summer. During these sessions, INDOT staff can answer questions pertaining to the pre-qualification process and assist potential contractors as needed with their applications. Responsible parties within INDOT who are leading the contract letting should reach out to prequalified contractors who have not placed bids on available contracts in over a year to inform those vendors of the available contracts up for bid. When a contractor becomes prequalified with INDOT, they should be required to provide local contact information and be automatically placed on a list-serve to be contacted with bid-letting opportunities that match the pre-qualification for which their company has been approved.

For companies that are well established for ten years or more with no issues in fulfilling contract(s) in the field for which they are applying for INDOT pre-qualification, it is recommended that they be given the opportunity to apply for a reduction in pre-qualification requirements.

This reduction should last so long as the key personnel who had ensured success in the field in which they had been successful remains with the contractor, e.g., field supervisor remains with the company, and so long as the contractor shows the capability to rectify work that is underperformed or shows the ability to pay for any financial or legal liabilities as a result of their staff. This reduction in pre-qualification requirements will only require these vendors to provide financial statements for pre-qualification.

Simplifying the pre-qualifications for vegetation management work would also be helpful to attract and retain additional qualified bidders. Although vegetation maintenance is often associated with constructed projects, it is not a construction activity and should be

treated as a separate activity. This would reduce the instances of qualified vendors from being barred from bidding on this work due to restrictions that are only relevant to construction projects (e.g., training requirements of journeymen).

Cost Savings and Benefits

Due to the complexity of contracting and the pre-qualification process, DRG cannot provide a detailed estimate of the cost savings that would be provided by the updates to the pre-qualification requirements. However, following the law of supply and demand through economic principles, the more contractors who bid, the lower the pricing of the contracts may be (Syverson, 2007).

In addition to the contract pricing, by increasing the number of contractors bidding, there may be an improvement in the contractors' ability to perform the work according to contract timelines. This can be accomplished in two ways: by decreasing the amount of work a singular contractor receives across the state any given year, and by allowing INDOT a greater ability to hold contractors accountable. With additional contractors bidding, INDOT will be able to refuse contracts to contractors who fail to meet INDOT requirements in contracts the prior year.

Noise Barrier Recommendations Technical Memorandum

Executive Summary

Vegetation that is not properly maintained near noise barriers can result in tree failures that can compromise the integrity of structures, cause damage from root growth that can crack the wall's foundation or introduce pooling water at the base of the barrier, and cause moisture build-up from shading. Davey Resource Group (DRG) recommends that new access doors that are installed be large enough to allow maintenance equipment to pass through while continuing to function as designed as noise barriers. Maintenance should be provided on existing access doors to maintain usability for INDOT staff. If access doors are not feasible due to topography or other factors, then access openings wide enough for equipment are recommended to be placed along the noise barriers to allow maintenance staff access. As an alternative to access doors and access openings, the noise barrier can be placed along the edge of the right-of-way (ROW) to minimize maintenance needs. The noise barriers should be placed along the edge of the ROW to minimize vegetation maintenance, or if utility access is required, 15 feet (4.57 meters) from the edge of the ROW.

Background

Staff indicated that the inability to access areas behind noise barriers has contributed to numerous areas of overgrown vegetation behind noise barriers that have gone unmaintained for years (Figures D.6–8). Access difficulties are caused by long distances between access openings, access doors that have become rusted shut and are too small for equipment to pass through, and the steep drop-offs on the backside of the access doors are significant safety concerns.

Vegetation not properly maintained near noise barriers can compromise the integrity of structures through the damage caused by tree failures falling onto noise barriers, root growth cracking the wall's foundation, and moisture build-up from shading that occurs due to vegetation, and water pooling at the base of the noise barrier from roots deteriorating the wall's structural integrity.

To supplement the regional DOT interviews that followed the INDOT staff meetings, DRG conducted a further investigation of other DOTs' noise barrier specifications. These included Texas Department of Transportation (TxDOT), Ohio Department of Transportation (ODOT), Virginia Department of Transportation (VDOT), and industry guidelines (American Association of State Highway and Transportation Officials - AASHTO and Federal Highway Administration - FHWA Design Manuals) to determine potential design changes to improve access for INDOT maintenance staff in the future.



Figure D.6 Fire access door in noise barrier along I-465, West of Indianapolis, IN. Inset: Close-up of rusted door bolted shut.



Figure D.7 Elevated roadside behind barrier wall with woody vegetation growing over noise barrier along I-465 Indianapolis, IN.



Figure D.8 Vegetation built up behind a noise barrier along I-65, Lebanon, IN.

Findings

The AASHTO Design Manual highlights the importance of maintenance and proper access around noise barriers. Specifically, the Design Manual states, “special consideration should be given to maintaining the adjoining land behind the noise barrier and adjacent to the right-of-way line.” While the manual suggests that “if access is not available via local streets, access gates or openings are essential at intervals along the noise barrier.” No further details are given regarding vegetation maintenance.

Of the seven states surveyed (including Indiana), four install access doors in the noise barriers. Most of these are small, man-sized doors that are unable to fit any large machinery and are primarily meant for fire hydrant access. As experienced by INDOT, these can become rusted over time, or blocked by adjoining property owners, reducing the ability of DOT maintenance staff to use them. The only detail INDOT’s current Standard Specifications give for emergency access door design is that the doors should be built with “additional reinforcement or bracing and protective coating around the opening as necessary to maintain structural integrity.

The construction of these doors is to ensure fire hydrant access, and emergency access off the ROW while maintaining the sound reflection requirements of the noise barrier. However, both INDOT and Illinois Department of Transportation (IDOT) staff stated that fire departments do not use these small doorways. IDOT noise barrier specifications provide standards for door dimensions, structural material requirements, considerations like drainage holes to avoid an accumulation of trapped moisture, door pulls on both sides of the door, and other additional features. These specific access door design requirements likely improve the long-term structural integrity and utility of the access doors. Iowa Department of Transportation (Iowa DOT) was the only DOT surveyed that had double-door gates in their noise barriers that are wide enough for large equipment such as tractors or pickup trucks to pass through. Though not surveyed, TxDOT uses man-sized doors, and 10 foot (3.05 meters) wide double-door gates or removable panels for equipment to access behind noise barriers, using a concrete mow strip under and behind the noise barrier to minimize the need for vegetation management (Harbin, et al., 2022). States that do not utilize access doors for maintenance behind noise barriers indicated that staff utilize the access openings at the ends of noise barriers to gain access. However, of the states included in the survey, the states’ standards and specifications did not include a limitation on the length of noise barriers before access openings are necessary. Excessive distances between gaps in noise barriers may reduce maintenance staff efficiency if machinery needs to travel far to get around a noise barrier. Standards for ODOT specify that overlapped ground-mounted noise barriers should have a 3:1 ratio of length of overlap to width of gap. INDOT standards state that noise barriers must have a 4:1 ratio of overlap to

width of gap. There is no minimum gap width given to account for maintenance access for either state.

The placement of noise barriers relative to the ROW boundary line varies between states. Kentucky Transportation Cabinet (KYTC) generally places noise barriers at the ROW boundary; staff indicated that this practice reduced maintenance needs.

This is also the preferred placement of noise barriers for ODOT and IDOT. Conversely, according to research conducted by the Texas A&M Transportation Institute (Harbin et al., 2022), placing noise barriers on the edge of the ROW is not recommended due to conflicts with utilities since the edge of the ROW is the most common place for utilities. The report suggests a minimum of five feet between the back of the noise barrier and the edge of the ROW for future construction and maintenance work behind noise barriers. Mow strips and other hardscapes, such as rip rap that is used in one TxDOT district, around the base of noise walls are used in several TxDOT districts to reduce trimming needs. The Missouri Department of Transportation (MoDOT) also places noise barriers five feet inside public land, to allow for DOT maintenance. Caltrans has been making agreements with adjacent property owners allowing property owners to maintain and use the land between the property line and the noise barrier at their own risk as long as the property owners do not plant trees or allow trees to grow on the ROW and they do not install permanent structures on the ROW. As the adjacent property owners have easier access and an interest in the area's appearance, these agreements have been successful thus far and Caltrans has found these agreements can reduce illegal camping and the associated fires.

Recommendations

INDOT's current noise barrier configurations cause significant challenges for vegetation maintenance. Given the difficulties experienced by INDOT staff with the current access doors, it is recommended that the design of these doors be updated.

Where possible, new access doors should be large enough to accommodate large trucks or other machinery necessary for maintenance and should be made with materials that maintain door function and require minimal maintenance (e.g., fiberglass, acrylic). Existing access doors should be maintained annually and inspected to ensure functionality in case they are needed for access.

If functional access doors are not feasible or less desirable in certain circumstances, such as in areas with steep slopes, access openings between overlapping walls should be provided. The access openings should be designed to be wide enough for typical maintenance equipment to obtain access while still ensuring noise attenuation. A

ratio between 2.5:1 (AASHTO standard) and 3:1 of overlap length to gap width is suggested. As noted in TxDOT specifications for retaining walls, at least 15 feet (4.57 meters) of space should be left for access behind sound walls in areas where utility access will be needed. As done in several TxDOT districts, noise walls should be installed with mow strips at their base to reduce the need for trimming. Elsewhere, walls can be placed against the ROW boundary to reduce maintenance needs as long as excessive vegetation growth that could affect structural integrity is not anticipated behind the wall. INDOT could notify adjacent property owners and make agreements similar to Caltrans that land management would fall to them due to the location of the noise barrier.

Cost Savings

In 2023, costs for INDOT in-house vegetation maintenance work around noise barriers totaled \$45,944.82. Given the struggles expressed by INDOT staff about noise barrier access, DRG expects that increases in future maintenance costs for new or repaired noise barriers will be buffered by improving access behind the new and/or repaired noise barriers.

By implementing the recommendations above, it is expected that INDOT will save on future repair costs due to increased longevity and structural integrity of better-maintained noise barriers. Wisconsin Department of Transportation (WisDOT) spent \$952,000 to repair 14 noise barriers in 2024. The noise barriers that were repaired were experiencing "various minor deficiencies, including rusting of posts, concrete spalling and cracked or shifted panels." There was no specific mention of vegetation growth causing these issues, but when interviewed, WisDOT staff indicated that areas behind noise barriers are typically not maintained for vegetation, leading to the assumption that vegetation was likely a contributing factor to the structural deficiencies. It can be inferred that INDOT could likely incur similar costs if vegetation management is not completed around noise barriers.

The adoption of noise barrier designs that integrate improved access will likely increase construction costs. TxDOT bid prices for noise barrier work appear to be higher than states that do not use alternative noise barrier materials and designs that consider maintenance access. Between 2019-2024, the average cost/sq foot to construct a noise barrier in Texas was \$103.65, whereas in other states the average cost/sq foot was \$54.83. However, given the potential costs that could be incurred without proper maintenance, we expect that these savings will compensate for higher initial construction costs in the long term.

Contract Language Recommendations Technical Memorandum

Executive Summary

To gain insight into what may be reducing the effectiveness of contractor vegetation management efforts, Davey Resource Group (DRG) reviewed in detail three recent contracts for mowing (2025) and herbicide (2024 contracts for both broadcast and spot herbicide applications). DRG recommends updating contract language, including adding document references as needed, clarifying specifications, and specific requirements for tracking contractor work.

Background

Contractors complete the majority of the Indiana Department of Transportation's (INDOT's) vegetation maintenance. Several items were identified regarding the quality of contractor work by both INDOT staff, as well as by DRG staff while traveling on Indiana roadways. To gain insight into what may be reducing the effectiveness of contractor vegetation management efforts, DRG reviewed in detail three recent contracts for mowing (2025) and herbicide (2024 contracts for both broadcast and spot herbicide applications). Observed issues with these contracts and DRG's recommendations for updates are provided below.

Findings and Recommendations

DRG recommends that copies of the Road Plans should be provided in Spanish to accommodate workers that do not speak English. DRG recommends that the Contract Information Books (CIBs) state INDOT staff that are responsible for performing inspections of contractor work (e.g., HT-2 contract inspectors or similar) and provide a standardized description of what inspections of work will entail (e.g., frequency of inspections, any measurements to be made, etc.). Providing plans in both English and Spanish and detailing what inspections will entail will enhance contractor compliance and improve the consistency of quality control and assurance of contracted mowing and herbicide application work across districts.

All contractor work should match the in-house standards with both aligning with the Standard Specifications and Recurring Special Provisions.

Mowing Contracts

In the CIB for mowing contract M-44989, the research team noticed several items in need of clarification that are potentially influencing the quality of INDOT contracted vegetation management. Within the CIB on page 11, the E-Ticketing Incentive section,

which refers to material delivery, should be removed as it does not pertain to mowing along the right-of-way (ROW).

In the Reporting and Acceptance section on page 21, the CIB states “The Daily Work Plan shall indicate routes planned to be mowed for the day, a list of equipment and workers being deployed for the day, and the anticipated beginning and ending point of the work to be performed to the nearest reference post or other identifiable roadside feature.” No further details regarding work tracking are given in the CIB. In future mowing contracts, it would be beneficial to add more specific requirements to track work accomplished.

Georeferencing requirements for the area mowed can be added, such as GPS records of the starting and end points, total acreages mowed, and tracking of areas where the required mowing width (15 ft) was reduced for any reason. With more stringent tracking requirements for mowing, this will increase the quality of contractor work and better inform INDOT staff on what areas may need follow-up.

Although the CIB describes the specifications that mowing contractors are to meet and provides the above monetary penalties for "non-compliance," there are no additional specifics given about how their performance is to be measured by INDOT. Deficiencies are noted as being identified by “observations by the Department.” Each contract includes three cycles with “approximate” start dates, each with 25 days for completion.

The mowing area is defined within the Road Plans as:

- “Mow and trim a minimum of 15 ft beyond the edge of the pavement, unless otherwise indicated.
- Trim 5 ft around fixed objects within the right-of-way, regardless of the mowing limits
- Do not mow or trim beyond the apparent right-of-way limits.”

The road plans do not address potential issues contractors may experience with identifying ROW boundaries, and what they should do if ROW boundaries are unclear. This can be addressed through the contact information of the project engineer listed in the contract, in the event this occurs in the field, as well as some additional details on what features to look for to help identify the ROW. This can be added to the CIB, as well as directly on the Road Plans. These additions to future mowing contracts will reduce instances of contractors mowing an incorrect width in places where the ROW boundary is not clear. This could reduce the need for follow-up mowing by INDOT staff and reduce ROW boundary conflicts with residents. Additionally, any known restricted mowing areas should be explicitly listed in the Road Plans or CIB with route name and mile marker.

The road plans show how intersections are to be mown. Future road plans should make the details for tapered mowing beginning at a distance 500 feet (152.4 meters) from the intersection more visible to ensure contractors connect the stop bar with the additional 15 feet (4.57 meters) to be mowed, particularly if INDOT staff continue to express issues with insufficient mowing at intersections and include some explanatory text.

Herbicide Contracts

The research team also examined the CIB for Broadcast Spraying Contract M- 44183 and the CIB for Spot Spraying Contract M- 44186 and their associated Road Plans. In the “Materials” section of the Broadcast CIB, it is stated that “The herbicide shall be mixed with water that has been tested for pH and hardness by the Contractor such that it falls within label recommended levels for the herbicide mixture being used.” A certain number of water tests from each contractor each year should be required to ensure that contractors are testing the water, results can be provided via test strips or lab result documentation prior to payment of the contractor. Language could be added that the number of tests will be determined by the contract supervisor. Improved water testing can increase the effectiveness of herbicide application. The Broadcast Spraying Road Plans call for odd numbered roads to be sprayed during odd years, and even numbered roads to be sprayed during even years. We highly recommend that all roads are targeted each year. This will significantly reduce the need for in-house vegetation management for site distance during the growing season.

In the “Equipment” sections of both the broadcast and spot spraying CIBs, the CIBs refer to a demonstration of the spraying equipment and state that “this demonstration may be required at any time during the contract period.” Additional clarification regarding the frequency of demonstrations should be added to this statement. Specifically, the contracts should state that the contract project supervisor is responsible for determining the frequency of these inspections/demonstrations. This will create accountability for these supervisors to consistently perform these inspections and, as a result, could increase the effectiveness of contractor herbicide spraying. As an example, MDOT spraying contracts specify that inspection of equipment will occur during the “Pre-Award” meeting with the project Contract Compliance Inspector or designee.

The INDOT spraying contracts include monetary penalties for non-compliance with contract terms– “a penalty of \$1,000.00 per calendar day that the work is not completed will commence until corrections are completed to the satisfaction of the Department.” This fee is not listed on page three with the other potential fees contractors will be subject to for failure to comply with the contract; this fine should be included on this page. Future INDOT herbicide contract language should be updated from “penalty” to “liquidated damage” for “damages sustained.”

DRG recommends that INDOT include more specifics about evaluating the performance of contractor spraying. Currently, INDOT broadcast and spot spraying application contracts state inspections will occur “approximately 15 calendar days following the completion of the application” to determine areas that did not receive “adequate treatment” to achieve desired results. More detailed specifications for “adequate treatment” should be provided internally for contract inspectors for enhanced quality assurance. For example, MDOT herbicide contracts require “a minimum of 90% of weeds in the 15-foot swath adjacent to the turf edge of both the outside and the median shoulders be controlled within 28 days after herbicide application.” INDOT inspectors can be trained to adopt a similar percentage approach to establish internal guidelines and ensure consistency for what is being deemed “adequate coverage” during contract work inspections.

The Road Plans for INDOT broadcast and herbicide spraying contain labels for the “apparent” ROW with no further clarification. Direction as to who should be contacted or what resources or tools should be utilized if ROW boundaries are unclear should be provided in the CIB, with reference to these details noted on the Road Plans. Another issue identified with the Road Plans is the mention of both spot spraying and broadcast spraying on the standard drawings. If a contract is exclusively for spot spraying, it should be noted that broadcast spraying will be completed by another contract. The same is true of the broadcast spraying contracts with references to spot spraying. This will reduce any confusion regarding contractor responsibilities. The organization of spray dates should be updated to ensure that odd-year and even-year spray locations are listed together, respectively, to ensure contractors do not apply herbicide to the wrong location during the contract.

Cost Savings

Due to the lack of existing data on how the above language improvements could influence the costs of DOT vegetation maintenance, DRG cannot provide a full picture of the cost savings that would be provided to INDOT by implementing the above updates. However, 2023 cost data is available on some activities that are targeted by these language updates. For example, in 2023 in-house spot mowing activities near intersections cost INDOT at least \$38,646.55 based on available work orders that were noted as taking place near intersections. Note this is likely significantly lower than the actual cost due to inconsistencies in data reporting (i.e. INDOT staff estimate that only about 50% of customer requests get assigned a work order). Some of these costs may be offset by the above contract language improvements.

Table D.2 Recommendations Vegetation Management Contract Language.

Document	Issue	Pg #	Recommended Update/Clarification Needed	Savings, ROI and/or Other Benefits
Mowing Contract 44989 Contract Information Book (CIB)	The relevant pages of the INDOT Work Performance Standards or Operations Memorandum (OM) 14-05 are not included in the list of documents included in the contract.	3 of pdf	<ul style="list-style-type: none"> These standards documents should be included or at least referenced with all vegetation management contracts. If particular contracts require changes to any of INDOT’s in-house standards, the contracts should note these changes. 	<ul style="list-style-type: none"> Increased quality of contractor work and consistent standards between contractors and in-house staff, where appropriate.
	E-ticketing incentives are included, but these are not relevant to mowing operations.	5 (11 of pdf)	<ul style="list-style-type: none"> Remove section on e-ticketing. 	<ul style="list-style-type: none"> Reduced contractor confusion about e-ticketing processes since it does not relate to mowing.
	Restricted mowing areas are described in general, but no specific location is given.	13 (19 of pdf)	<ul style="list-style-type: none"> Provide a table of known restricted mowing areas with route name and mile markers either in the CIB or in the Road Plans. 	<ul style="list-style-type: none"> Increased compliance with avoidance of restricted mowing areas.
	The CIB states “The Daily Work Plan shall indicate routes planned to be mowed for the day, a list of equipment and workers being deployed for the day, and the anticipated beginning and ending point of the work to be performed to the nearest reference post or other identifiable roadside feature.” No further details regarding work tracking are given.	15 (21 of pdf)	<ul style="list-style-type: none"> This would be a good section to add more specific requirements about tracking work accomplished, such as GPS points, total acreages mowed, and tracking of areas where the required mowing width (15 ft) was reduced for any reason. 	<ul style="list-style-type: none"> Increased quality of contractor work. INDOT staff will have a better understanding of areas that will require follow-up.
	The CIB does not address ROW boundary identification issues.	N/A	<ul style="list-style-type: none"> Need to add language about what contractors should do if ROW boundaries are unclear. 	<ul style="list-style-type: none"> Reduce instances of contractors mowing too narrow or too wide of an area in places where the ROW boundary is not clear. This will reduce the need for follow up and reduce ROW boundary conflicts with residents.
	The CIB no longer includes a description of the tapered mowing at intersections.	N/A	<ul style="list-style-type: none"> Add language regarding the tapered mowing at intersections. 	<ul style="list-style-type: none"> At least \$38,646.55 total cost for spot mowing near intersections in 2023. Language clarification could reduce these intersection issues and the in-house maintenance costs for mowing these intersections.
	The CIB states "Upon the Contractor notifying the Engineer that a mowing cycle has been completed, the Department will inspect and either accept the completed work or notify the Contractor that additional work is required to fulfill the contract obligations." There are no additional specifics given about how these inspections are to be done.	15 (21 of pdf)	<ul style="list-style-type: none"> More specific performance metrics and how they will be monitored/enforced by inspectors should be included. These do not have to be paid items with date milestones, but just additional language for items that contractors should keep in mind when mowing (adequate mow height, mow length consistent with what was reported, fixed objects cleared adequately, etc.). 	<ul style="list-style-type: none"> Increased contract compliance/quality of contractor work.

Document	Issue	Pg #	Recommended Update/Clarification Needed	Savings, ROI and/or Other Benefits
Mowing Contract 44989 Road Plans	The plans state "Mow 15'-0" or to R/W limit (whichever is less)." Given that INDOT staff have their own issues identifying ROW boundaries, contractors probably have the same issues identifying ROW boundaries.	11	<ul style="list-style-type: none"> Need to add a statement about identifying ROW boundaries to the plans or CIB - e.g., "If the ROW boundary is not clearly defined, contact the Roadside Maintenance Specialist to identify the proper boundary or provide other guidance." 	<ul style="list-style-type: none"> Reduce instances of contractors mowing too narrow or too wide of an area in places where the ROW boundary is not clear. This will reduce the need for follow up and reduce ROW boundary conflicts with residents.
	There were complaints from INDOT staff about contractors not mowing 500 ft from intersections using the tapered width as seen in the plan set.	15	<ul style="list-style-type: none"> An explanation of this intersection mowing practice needs to be made clearer on the Road Plans. Specifically, note 2 is confusing. 	<ul style="list-style-type: none"> At least \$38,646.55 total cost for spot mowing near intersections in 2023. Language clarification could reduce these intersection issues and the in-house maintenance costs for mowing these intersections.
	Mowing details pages only give the notes in English.	Multiple	<ul style="list-style-type: none"> Provide copies of road plan details pages with notes in Spanish for foreman to distribute to staff if needed. 	<ul style="list-style-type: none"> Increased quality of contractor work if some staff do not speak English.
Broadcast Herbicide Contract 44183 Contract Information Book (CIB)	The relevant pages of the INDOT Work Performance Standards or OM 14-05 are not included in the list of documents included in the contract.	3 of pdf	<ul style="list-style-type: none"> These standards documents should be included or at least referenced with all vegetation management contracts. If particular contracts require changes to any of INDOT's in-house standards, the documents should be modified accordingly and provided to contractors. 	<ul style="list-style-type: none"> Increased quality of contractor work.
	The CIB states "The herbicide shall be mixed with water that has been tested for pH and hardness by the Contractor such that it falls within label recommended levels for the herbicide mixture being used. If the water source is unsuitable, the Contractor shall amend the water such that it falls within recommended levels or shall utilize a different water source that meets the requirements of the product label for each component of the mixture."	11 (17 of pdf)	<ul style="list-style-type: none"> INDOT should require a certain number of water tests from each contractor each year, to ensure that they are testing the water, including the date completed and the results. Language could be added that the number of tests is to be determined by the project contract supervisor. 	<ul style="list-style-type: none"> Increased effectiveness of contractor herbicide spraying.
	The CIB states "This demonstration may be required at any time during the contract period."	12 (18 of pdf)	<ul style="list-style-type: none"> Additional clarification should be added that states that the contract project supervisor is responsible for determining the frequency of these inspections/demonstrations. 	<ul style="list-style-type: none"> Increased effectiveness of contractor herbicide spraying.
	The CIB states "A penalty of \$1,000.00 per calendar day that the work is not completed will commence until corrections are completed to the satisfaction of the Department."	18 (24 of pdf)	<ul style="list-style-type: none"> This fee is not listed on page three of the PDF with the other fees for failure to comply with the contract; this fine should be included on this page. Ensure all future contracts use the term "liquidated damage" for "damages sustained" as an alternative to "penalty". 	<ul style="list-style-type: none"> Increased contract compliance/quality of contractor work.

Document	Issue	Pg #	Recommended Update/Clarification Needed	Savings, ROI and/or Other Benefits
Broadcast Herbicide Contract 44183 <i>Contract Information Book (CIB), (Cont'd.)</i>	The CIB states "Approximately 15 calendar days following the completion of the application, an inspection of the work will be made to determine areas that did not receive adequate treatment to achieve results comparable with the rate of kill obtained in the overall spraying operation." This is the only mention of inspection of the quality of contractor work.	17 (23 of pdf)	<ul style="list-style-type: none"> Additional specifications that elaborate on "adequate treatment" should be provided internally to contract inspectors. 	<ul style="list-style-type: none"> Consistent quality assurance for contracted herbicide work.
Broadcast Herbicide Contract 44183 <i>Road Plans</i>	Not all roads are targeted each year.	4-5 of pdf	<ul style="list-style-type: none"> Both even and odd roads should be sprayed annually. 	<ul style="list-style-type: none"> Improved invasive vegetation control and reduced site distance issues.
	Even and Odd year broadcast application routes are on different pages for different target areas.	4-5 of pdf	<ul style="list-style-type: none"> If the odd year/even year regime is continued, it may be helpful to contractors if even year applications and odd year applications are listed together on the same page or spring applications and fall applications are listed on the same page. The current organization is confusing. 	<ul style="list-style-type: none"> Reduce confusing language in contracts.
	There are labels for "apparent edge of ROW" with no further clarification.	16	<ul style="list-style-type: none"> How to determine the apparent edge of the ROW should be better defined for contractors. 	<ul style="list-style-type: none"> Reduce instances of contractors spraying outside ROW limits, or not far enough within the ROW.
	The standard drawings include mention of both spot spraying and broadcast spraying applications.	Multiple	<ul style="list-style-type: none"> If a contract is only for broadcast, then mentions of spot spraying should be removed from the plans, or at least specified to be completed by another contract so broadcast contractor knows they are not responsible for these areas. 	<ul style="list-style-type: none"> Reduce confusing language regarding contractor responsibilities.
	Notes in the standard drawings are only provided in English.	Multiple	<ul style="list-style-type: none"> Provide copies of standard drawings with notes in Spanish for foreman to distribute to staff if needed. 	<ul style="list-style-type: none"> Increased quality of contractor work if some staff do not speak English.
Spot Herbicide Contract 44186 <i>Contract Information Book (CIB)</i>	The relevant pages of the INDOT Work Performance Standards or OM 14-05 are not included in the list of documents included in the contract.	4 of pdf	<ul style="list-style-type: none"> These standards documents should be included or at least referenced with all vegetation management contracts. If particular contracts require changes to any of INDOT's in-house standards, the documents should be modified accordingly and provided to contractors. 	<ul style="list-style-type: none"> Increased quality of contractor work and consistent standards between contractors and in-house staff, where appropriate.
	The CIB states "This demonstration may be required at any time during the contract period."	10 (18 of pdf)	<ul style="list-style-type: none"> Additional clarification should be added that states that the contract project supervisor is responsible for determining the frequency of these inspections/demonstrations. 	<ul style="list-style-type: none"> Increased effectiveness of contractor herbicide spraying.

Document	Issue	Pg #	Recommended Update/Clarification Needed	Savings, ROI and/or Other Benefits
Spot Herbicide Contract 44186 <i>Contract Information Book (CIB), (Cont'd.)</i>	The CIB states "A penalty of \$1,000.00 per calendar day that the work is not completed will commence until corrections are completed to the satisfaction of the Department."	16-18 (23-25 of pdf)	<ul style="list-style-type: none"> This fee is not listed on page three of the PDF with the other fees for failure to comply with the contract; this fine should be included on this page. Ensure all future contracts use the term "liquidated damage" for "damages sustained" as an alternative to "penalty". 	<ul style="list-style-type: none"> Increased contract compliance/quality of contractor work.
	Notes in the standard drawings are only provided in English.	Multiple	<ul style="list-style-type: none"> Provide copies of standard drawings with notes in Spanish for foreman to distribute to staff if needed. 	<ul style="list-style-type: none"> Increased quality of contractor work if some staff do not speak English.
Spot Herbicide Contract 44186 <i>Road Plans</i>	The standard drawings include mention of both spot spraying and broadcast spraying applications.	Multiple	<ul style="list-style-type: none"> If a contract is only for spot spraying, then mentions of broadcast spraying should be removed from the plans, or at least specified to be completed by another contract so spot herbicide contractors know they are not responsible for these areas. 	<ul style="list-style-type: none"> Reduce confusing language regarding contractor responsibilities.

Improving Maintenance Operations' Involvement in Design and Construction Recommendations Technical Memorandum

Executive Summary

Communication with design and construction staff, particularly during the scoping and early design stages of a project, is vital to be able to voice concerns over future maintenance challenges. A variety of maintenance challenges that incur long-term costs, reduce efficiency, or present safety concerns could be addressed and potentially resolved by improved communication with design staff. For example, design input from maintenance staff could reduce slope failures, improve access around structures, and reduce safety risks such as drop-offs behind sound walls. Davey Resource Group, Inc. (DRG) recommends that Indiana Department of Transportation (INDOT), at a minimum, use Greenfield District's three-page *Transportation Project Meeting Descriptions and Attendees* document that details the purpose and length of each meeting and lists the staff from each department that are required to lead, required to attend, or are desired to attend various meetings throughout the design and construction process. INDOT can also utilize a similar model to Caltrans by breaking down their design review personnel into various teams or committees with varying responsibilities during design administration or developing a more flexible structure to accommodate district and project-specific needs.

Background

Staff from one of the northern district offices indicated that they receive invitations to pre-construction meetings on occasion, but this stage is too late to make any changes to construction plans in the event of an observed conflict with maintenance, perpetuating vegetation maintenance issues. Additionally, for staff that attend these meetings, it is difficult to give informed feedback because they are not always familiar with reading engineering plans and cannot identify potential issues.

Following the INDOT meetings, DRG sent surveys to other state DOTs to compare vegetation management practices, and some of these questions covered items relating to the maintenance division's role in the design and construction of roadside projects. DRG also examined the design, construction, and procedural manuals of other state DOTs (California-Caltrans, Nebraska-NDOT, Ohio-ODOT, Texas-TxDOT, and Virginia-VDOT) to determine the processes and standards they have implemented for maintenance staff to provide input in the roadside design and construction process.

An additional discussion with staff from INDOT's Greenfield District revealed that their district has a three-page *Transportation Project Meeting Descriptions and Attendees*

document that lists the staff from each department that are required to lead, required to attend, or are desired to attend various meetings throughout the design and construction process. This document also details what each meeting entails and the estimated duration. The Maintenance Engineer, Unit Supervisor, and Sub-District Manager are required to attend the Virtual Van Trip and the Scoping Field Check meetings. The Unit Supervisor is also required to attend the Preliminary Field Check and Final Field Check. Additionally, maintenance staff are invited to the Design Kickoff, Bridge Inspection, Preliminary Field Check, Final Field Check, Pre-Construction, Pre-Final Construction, and Lessons Learned meetings during the design process. Meetings, where maintenance staff attendance is desired or required, tend to be either field checks or meetings where INDOT staff will look at the site either in person or through online map platforms.

Findings

In practice, most of the surveyed DOTs' maintenance staff have minimal involvement in the roadside design and construction process and as a result experience access issues similar to INDOT.

In most states with communication between maintenance and design divisions, it is inconsistent. When maintenance staff are involved, it is usually late in the process, when design decisions are nearly finalized. For example, the Illinois Department of Transportation (IDOT) sends construction plans to multiple departments, including the maintenance department. The Iowa Department of Transportation (Iowa DOT) has maintenance staff work with construction staff during construction to locate issues in lieu of construction plan review prior to bid letting. In the past, the Wisconsin Department of Transportation (WisDOT)'s maintenance engineering staff attended project scoping meetings, but as most vegetation maintenance is completed by county government staff, the WisDOT staff were generally not experienced with needs and issues related to maintenance access and vegetation selection and establishment. Therefore, they could only provide limited input at the meetings, with no practical knowledge of how areas could safely be accessed for maintenance and designed for vegetation establishment. The inclusion of WisDOT maintenance engineering staff in plan set reviews has been inconsistent over the years.

Caltrans was the only DOT with detailed requirements in the state standards that provide guidance for maintenance involvement in the design and construction processes in their Project Development Procedural Manual (PDPM). The PDPM helps determine which project stakeholders to involve in the design and construction process. The PDPM emphasizes that it is essential that the maintenance unit be involved in the project development process from project conception through construction. For all projects, a

maintenance staff representative (typically landscape specialists or district maintenance engineers) should be invited to be a part of the project Safety Review Committee (SRC) and Project Development Team (PDT). Maintenance personnel are to be forwarded to the Design Intent Statement at the start of a project, and maintenance needs are to be considered when developing the Project Initiation Document (PID).

The Caltrans maintenance division may also be a part of the Constructability Review Team. When it was discovered that maintenance operations staff were not trained to read construction plan sets, designers started to meet maintenance operations staff at future construction sites to describe the proposed changes to the sites with the plans in hand. After this change was made, maintenance operations staff were able to provide more active input. A more recent advancement by Caltrans is the utilization of “360 Tours” which can provide three-dimensional models of future roadside projects, which vastly improves visualization of what the roadside may look like in comparison to standard plan set drawings. Other DOTs, including the Michigan Department of Transportation, are piloting similar software and offering training to staff and construction vendors. As part of the construction process, Caltrans maintenance operations staff are brought in before construction starts, and then conduct required “Maintenance Reviews” at the start of work, 50% completion, and 90% construction completion. Manuals from other state DOTs mention email communication for pre-construction meetings and general statements about considering maintenance needs with no specific requirements.

Recommendations

The Greenfield District meeting document provides a path to include maintenance staff at meetings within INDOT. DRG recommends that INDOT incorporate the Greenfield project meeting document throughout the state to ensure that maintenance staff provide input on construction projects at the appropriate times. Maintenance reviews should ideally begin no later than the 30% design stage, with additional reviews throughout the design process. It is also recommended that the Roadside Maintenance Specialist be included in the emails to ensure the proper staff are notified within each district.

INDOT can also follow a similar model to Caltrans by breaking down their design review personnel into various teams or committees with varying responsibilities during design administration or developing a more flexible structure to accommodate district and project-specific needs.

Cost Savings

We expect that the increased involvement of INDOT maintenance staff in the design and construction process will ultimately lead to reduced costs for INDOT. Maintenance

staff input during the development stages of roadside projects will reduce and possibly prevent instances of designs creating access issues, safety concerns, or other challenges. For example, in a situation where plan sets call for a guardrail or cable rail to be installed without a concrete mow strip in an area with a narrow shoulder or a sharp turn with low visibility, maintenance staff would be able to identify issues and suggest an alternative to improve the safety and feasibility of maintaining the vegetation or possibly reducing the need for vegetation maintenance.

The costs of implementing these changes should be relatively minimal and consist of staff labor hours for participating in design and construction meetings, and labor hours for staff to update procedural documents to create these standards.

Work Performance Standards Recommendations Technical Memorandum

Executive Summary

Davey Resource Group, Inc. (DRG) reviewed Indiana Department of Transportation's (INDOT's) in-house vegetation management practices and challenges through a gap and SWOT (strengths, weaknesses, opportunities, and threats) analysis. It was found that INDOT's documents that guide vegetation management work for in-house staff can be improved to potentially reduce these gaps. DRG recommends updates to various sections of the Operations Memorandum 14-05 (OM 14-05) and the Indiana Department of Transportation Division of Maintenance Work Performance Standard (WPS), including the Purpose section, the Operational Zone mowing requirements, Brush Control requirements, among others within the OM 14-05. Recommendations were provided to the vegetation category of the WPS, including adding information on herbicide application to the WPS for Mechanical Brush cutting tasks (Code 2221) and updating production guidelines for INDOT staff for Manual Brush Cutting (2220), Spot Seeding & Fertilization (2241), and Tree Removal (2251) to better match INDOT staff capabilities.

Background

Following district meetings with INDOT staff, DRG reviewed INDOT's in-house vegetation management practices and challenges through a gap and SWOT analysis. It was found that the documents that guide vegetation management work for in-house staff—OM 14-05 and WPS—can be improved to potentially reduce these gaps. DRG examined these documents in further detail to identify language that could be made clearer to improve the quality of in-house vegetation management staff performance and reduce costs.

Findings and Recommendations

Operations Memorandum 14-05

The INDOT OM 14-05 is currently being revised. The research team has noted a few items that require updating within the current draft and items to keep in mind throughout the revision process. Firstly, as the naming conventions for maintenance zones have been updated, there are a few images that will require updated labeling to reflect the new zone names. Several language updates have already been proposed to the "Purpose" section of OM 14-05, including reference to "targeted maintenance efforts" that should be driving vegetation management throughout the state rather than "reactionary and/or cyclical" work. This section should include some additional details or guidance as to what these targeted efforts would entail to clarify the responsibilities of internal staff and contractors. This may include the system percentages that are currently located throughout the

document (i.e., “Monitoring and necessary treatments shall occur on thirty percent (30%) of the system annually”). Introducing specific goals, such as these percentages, in the beginning section of OM 14-05 would be beneficial. A means of verifying how these goals are met should also be described in the appropriate zonal maintenance section. For example, this verification can occur via analysis of GPS data of the length of areas sprayed and mowed and compared to the total length of INDOT roadsides on an annual basis.

Operational Zone mowing requirements state that “all vegetation less than three (3) inches in diameter growing around INDOT infrastructure within the zone shall be trimmed.” It would be helpful to list examples of INDOT infrastructure in this section. This may help to remind staff to clear around infrastructure such as culverts regularly. This would be particularly helpful for items that are not standalone maintenance items such as small (less than 48in diameter) culverts that do not support driving surfaces.

Additionally, a specific note should be added to the Operational Zone maintenance section stating if small culverts or open roadside ditches are encountered, they need to be maintained accordingly (e.g., mowed where necessary, while adhering to INDOT mowing regulations such as maximum slope angle for machines).

In the “Brush Control” requirements for the Operational Zone, all woody vegetation impacting sight distances that are cut are required to be “promptly treated with a cut surface herbicide treatment.” Timelines and recommended dates are provided in the WPS documents, inserting a reference to the relevant standard documents would be helpful to ensure that herbicide is applied when needed. For “Tree Removal” procedures, the trees targeted for removal are those that are deemed to pose an “unacceptable level of risk.” Training or additional information on what constitutes an unacceptable level of risk would help to ensure appropriate trees are removed from the ROW. OM 14-05 should specify the party responsible for making these decisions. This can improve tree removal decision processes and ultimately improve safety.

Another item marked for updating OM 14-05 is the maximum slope angle that INDOT staff are permitted to operate mechanized equipment. In the published OM 14-05 and in past contract documents, the maximum slope that any mechanized equipment could be operated on was 3H:1V, but this is being updated to 2.5H:1V. In the Operational Zone section of the revised draft, the slope requirement for machinery is still set at 3H:1V in the “Other/Special Considerations” on page 9 and should be updated to 2.5H:1V to be consistent. Note that these updates to 2.5H:1V do not include the mention of the 3H:1V slope as it relates to hydro-seeding operations in the Revegetation section.

In the definition of the Selective Zone, OM 14-05 states “existing specimens of native species greater than three (3) inches DBH are excluded from this removal

requirement.” Caveats to this rule should be specified here (e.g., if the native tree is a threat to infrastructure) as this relates to the definition of "unacceptable level of risk." Providing clear guidelines here will improve the management of native trees in the Selective Zone while also considering safety.

The research team also noticed an area of potential confusion between the Bridge and Large Culvert Zones and the Vertical Infrastructure Zone. The Vertical Infrastructure Zone width (15 ft) is less than that specified for the Bridge and Large Culvert Zone (30 ft). It is not clear in OM 14-05 why the maintenance widths for these types of structures differ. To reduce confusion for staff, a brief explanation as to why these zone widths differ would be helpful to allow staff to better understand the reasoning and maintain these areas accordingly. Also, the current photo of a sound wall representing the Vertical Infrastructure Zone is not an adequate example of a structure outside the Operational Zone since it is located directly on the roadway edge. A picture of a sound wall, tower, or other structure that is more clearly located outside the Operational Zone would be a better example.

Work Performance Standards

The research team does not have many recommendations for the methodologies outlined in the WPS, nor any specific recommendations for the dates, and other guidelines outlined in the WPS for most vegetation management related tasks.

Within the WPS for Mechanical Brush cutting tasks (Code 2221), it is recommended that the statement “Schedule follow-up herbicide application within the WMS according to Herbicide Broadcast Treatment (Code 2231). Only licensed applicators may apply herbicides” be added into the “Scheduling and Coordination” section. In the Work Method section, item number 7, add “Broadcast application must be applied while leaves remain green”.

Analysis conducted during the Gap Analysis stage of this project revealed discrepancies between the production guidelines for some vegetation management activities and what was accomplished in the field. INDOT in-house vegetation management data indicates that Manual Brush Cutting (2220), Spot Seeding & Fertilization (2241), and Tree Removal (2251) production guidelines should be updated. All districts were below the minimum production guidelines for Manual Brush Cutting and Spot Seeding & Fertilization, and most districts were above the guidelines for Tree Removal. Based on average work accomplished by INDOT staff during 2023, DRG recommends that the Manual Brush Cutting production guideline be reduced from 10,000-15,000 square feet per day to 5,000-10,000 square feet per day and the Spot Seeding & Fertilization guideline be reduced from 7,500 square feet per day to 4,000 square feet per day. Since not all districts exceeded the Tree Removal guideline, this can either remain at four trees per day or be increased to eight

trees per day to more closely match the districts that were more efficient at tree removal. These updates to production guidelines will allow for more accurate labor hours calculations in the Work Management System.

Cost Savings

Due to the lack of existing data on how the above language improvements and other updates to WPS could influence the costs of DOT vegetation maintenance, DRG cannot provide a full picture of the cost savings that would be provided to INDOT by implementing the above updates. However, 2023 cost data is available on some activities that are targeted by these language updates. For example, the total cost of vegetation management work around culverts for 2023 was \$113,895.44. This expense could potentially be reduced if smaller culverts (i.e., those less than 48 inches in diameter that do not also function as a bridge) are explicitly called out as infrastructure to maintain in OM 14-05 and included in annual planned maintenance activities, and if large culverts (those greater than 48 inches diameter) have vegetation maintenance completed more regularly.

Table D.3 Recommendations for Vegetation Management Work Standards.

Document	Issue	Pg #	Recommended update/Clarification needed	Savings, ROI, and/or other benefits
Operations Memorandum (OM) 14-05 (draft currently under revision)	Spelling correction of "miscellaneous".	1	Correct spelling to "miscellaneous".	Readability.
	Zones 1, 2, 3 and Vegetation Free, Operational Zone, and Selective Zone.	Multiple	Naming conventions within the images need to be updated to reflect updated naming convention for the zones.	Language consistency within the standards.
	OM 14-05 states that vegetation management should occur "through targeted maintenance efforts."	3	<ul style="list-style-type: none"> It would be beneficial to include some additional details/guidance as to what these targeted efforts would entail to clarify responsibilities of internal staff vs contractors. This would include the percentages that are currently located throughout the document (i.e., "Monitoring and necessary treatments shall occur on thirty percent (30%) of the system annually"). Introducing these percentages upfront would be beneficial. Add relative dates for mowing, herbicide application, tree pruning, brush cutting, etc. These should match those noted in the Work Standards, or explain instances where recommended dates would differ. 	<ul style="list-style-type: none"> Increase proactive vegetation management efforts. Overall improved vegetation management along roadsides.
	OM 14-05 states "All vegetation less than three (3) inches in diameter growing around INDOT infrastructure within the zone shall be trimmed."	8	It would be helpful to list examples of INDOT infrastructure, this may help to remind staff off infrastructure such as culverts.	Clearer instructions will increase the quality of vegetation maintenance work.
	Woody vegetation impacting line of sight shall be cut flush with the surrounding ground surface and promptly treated with a cut surface herbicide treatment.	8	Including a timeline may help to ensure that herbicide is applied when needed.	Increased effectiveness of herbicide spraying.
	Trees within the zone that are identified as posing an unacceptable level of risk shall be removed. Removals should be scheduled for 1 October through 1 April, unless it is deemed as an immediate threat to life or property.	8	Training or additional information on what constitutes an unacceptable level of risk would be helpful to ensure only appropriate trees are removed from the ROW. OM 14-05 should also specify who is responsible for making these kinds of decisions in the field.	<ul style="list-style-type: none"> Improved hazard tree removal decision processes. Enhanced safety of roadsides.
	OM 14-05 states "slopes steeper than 3:1 (Horizontal to Vertical) shall have no mechanized equipment operated on the slope."	9	Should be updated to 2.5H:1V.	Ensure consistency between contract documents and standards.
	OM 14-05 states "existing specimens of native species greater than three (3) inches DBH are excluded from this removal requirement."	10	Caveats to this rule should be specified here (e.g., if the native tree was a threat to infrastructure). This relates to the definition of "unacceptable level of risk" mentioned above.	Improved management of trees in the Selective Zone (ROW Zone 3).

Document	Issue	Pg #	Recommended update/Clarification needed	Savings, ROI, and/or other benefits
Operations Memorandum (OM) 14-05 (draft currently under revision), (Cont'd)	Maintenance for smaller culverts that do not support a driving service (<48" opening) are not discussed.	14	A specific note should be added to the Operational Zone maintenance section that states that if small culverts or open ditches are encountered, they need to be maintained accordingly (e.g., mowed where necessary, but adhering to rules about mowing on certain slope angles).	<ul style="list-style-type: none"> • Improved vegetation maintenance around culverts. • Total cost of vegetation maintenance work around culverts for 2023 was \$113,895.44. This could potentially be reduced if smaller culverts are included in planned maintenance activities.
	Vertical Infrastructure Zone - zone width differs from other structures (e.g., bridges and large culverts).	16	Should the space without vegetation be over 6 inches in height be increased to 30 feet to match the space around the culverts and bridges? If not, reasoning for this difference in space should be added.	Consistency between zone widths for ease of maintenance; if widths are supposed to differ, staff will understand the reasoning and maintain these areas accordingly.
	OM 14-05 states "Thirty (30) percent of the assets shall be scheduled for treatment annually."	Multiple	A means of verifying that this treatment goal is met should be described.	Annual herbicide treatment goals will be met more frequently.
	Sight distance to signage.	17	The "specified distances" for the different speed limits should be mentioned in this section.	Improved vegetation management for sight distance issues.
	OM 14-05 states "Areas beyond fifteen (15) feet from the edge of pavement are not required to be mown. Further, these areas shall only be mown as part of achieving a vegetation management objective other than for aesthetic reasons. If mowing is to occur outside of the Operational Zone, this work is to be completed from 1 December through 1 April- or with approval from Statewide Roadside Maintenance Specialist."	21	Have regularly scheduled reviews of these areas to ensure no trees/shrubs are growing outside of allowed areas.	Regularly scheduled reviews will help to prevent major issues in the future, then staff can have these areas scheduled during winter as needed.

Document	Issue	Pg #	Recommended update/Clarification needed	Savings, ROI, and/or other benefits
Vegetation Management Work Performance Standards	Mechanical Brush cutting does not mention herbicide application as part of the process.	Multiple	Emphasize that ALL brush cut areas should be treated with herbicide, whether manual or mechanical techniques are used.	Improved herbicide effectiveness, less follow-up required in subsequent years.
	INDOT in-house vegetation maintenance data indicate that Manual Brush Cutting (2220) production guidelines need updating - all districts were below the minimum.	Last page of the standard	Reduce from 10-15,000 sq ft/day to 5-10,000 sq ft/day.	More accurate labor hours calculations in the Work Management System.
	INDOT in-house vegetation maintenance data indicate that Spot Seeding & Fertilization (2241) production guidelines need updating - all districts were below the minimum.	Last page of the standard	Reduce from 7,500 sq ft/day to 4,000 sq ft/day.	More accurate labor hours calculations in the Work Management System.
	INDOT in-house vegetation maintenance data indicate that Tree Removal (2251) production guidelines need updating - most districts were above the goal.	Last page of the standard	Keep at 4 or increase to 8 trees/day.	More accurate labor hours calculations in the Work Management System.

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About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1 — evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at <https://docs.lib.purdue.edu/jtrp/>.

Further information about JTRP and its current research program is available at <https://engineering.purdue.edu/JTRP>.

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