

Research Report

KTC-15-25/OHS K9-15-04-1F

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Creating a Highway Information System for Safety Roadway Features

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KTC-15-25/OHS K9-15-04-1F

Creating a Highway Information System for Safety Roadway Features

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16. Abstract Roadway departures are the leading cause of roadside fatalities. The Kentucky Transportation Cabinet (KYTC) has undertaken a number of roadside safety measures to reduce roadway departures. Specifically, KYTC has installed several low-cost, systemic roadway safety treatments to Kentucky's roadways in recent years. These treatments include cable barriers, high friction surface treatments, rumble stripes, and Safety Edges. KYTC has installed approximately 44 cable barrier systems over 265 miles of roadway, 112 HFST applications over 20 miles of roadway, 750 rumble stripe installations over 2,500 miles of roadway, and 147 Safety Edge treatments on 580 miles of roadway. The project team developed a complete inventory for safety measure installations, including their locations and select characteristics. This information was collected through interviews, KYTC databases, KYTC contract proposals, KTC studies, and onsite assessments. These data served as inputs into KYTC's statewide highway model. ArcMap was used to reference locations of the inventoried safety treatments. All safety measure installations were compiled into a comprehensive Excel database. The database is a tool that will allow policy makers and transportation agencies to evaluate the effectiveness, cost, and benefits of roadway safety treatments.			
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Executive Summary

Roadway departures are the leading cause of roadside fatalities. The Kentucky Transportation Cabinet (KYTC) has implemented a number of roadway safety measures to reduce roadway departures. Specifically, KYTC has installed safety treatments such as cable barriers, high friction surface treatments, rumble stripes, and safety edges. For this project, Kentucky Transportation Center (KTC) researchers developed a complete inventory for each of these safety treatments by identifying their locations and documenting select characteristics.

Cable barriers are longitudinal safety barriers composed of high-tensioned, steel cables connected by a series of posts driven into the ground. They are primarily used to prevent errant vehicles from crossing over into opposing lanes of traffic. Research has proven they are effective in reducing crossover median crashes and associated fatalities. KYTC has installed 44 cable barrier systems along approximately 265 miles of Kentucky's highways since 2007. KTC researchers located cable barrier installations through coordination with KYTC's Office of Highway Design.

High friction surface treatments (HFSTs) are thin, high friction overlays that consist of small aggregates held together by a binding agent. A HFST increases surface friction for a vehicle's tires and prevents skidding. Research demonstrates that HFST installations reduce crashes. They are most commonly applied to horizontal curves, interstate ramps, and approaches to stop-condition intersections. Since 2009, KYTC has installed 112 HFST applications atop 20 miles of roadway. KTC collected HFST data with the aid of KYTC's Division of Traffic Operations. KTC also conducted onsite inspections for each application to verify its presence and to obtain select characteristics.

Rumble stripes consist of a series of indentations along the roadway surface overlain with a pavement marking to mark the lane boundary. When vehicle tires drive over rumble stripes, a distinct sound and vibratory sensation are produced. This alerts the errant driver to move back into the travel lane. Numerous research studies have shown rumble stripes and their closely related rumble strips (rumbles installed without pavement markings, typically on the shoulder) can effectively reduce lane departure crashes. KYTC has installed rumble stripes at over 750 locations along 2,500 miles of roadway since 2008. KTC researchers obtained inventory locations for rumble stripes through previous KTC studies, KYTC interviews, and KYTC contract proposals; they verified those locations throughout the state.

The Safety Edge treatment reduces the slope angle at the pavement's edge, allowing errant drivers who are leaving the pavement the chance to safely correct their course. This feature creates a 30 degree angle relative to the existing ground surface and eliminates vertical drop-offs often associated with roadway departures. A Safety Edge reduces incidents related to "tire scrubbing" whereby the driver tends to oversteer and crash. KYTC has installed 147 Safety Edge treatments along 580 miles within the state. KTC identified Safety Edge locations through a comprehensive search of KYTC project proposals.

Multiple research studies across the nation have demonstrated the benefits associated with these safety measures; the largest benefit is a reduction in fatalities. Data taken from interviews, KYTC databases, KYTC contract proposals, KTC studies, and onsite served as inputs into KYTC's statewide highway model. ArcMap was used to reference locations of the inventoried safety treatments before all safety measure installations were compiled into a comprehensive Excel database. Until now, KYTC lacked a spatially explicit statewide inventory of these safety measures. KYTC could not track their locations or monitor safety outcomes to quantify their benefits and/or costs to Kentucky. This project addressed those

concerns by developing a comprehensive, spatially-explicit inventory of selected safety measures. The database will allow policy makers and transportation agencies to evaluate the effectiveness, cost, and benefits of roadway safety treatments.

Chapter 1: Background

1.1 Introduction

Roadway departures are the leading cause of vehicle fatalities in the United States. In fact, the Federal Highway Administration (FHWA) concluded roadway departures were the cause of 18,257 fatalities in 2013 alone.¹ The FHWA defines a roadway departure as an instance when a vehicle crosses the edge line or center line, or otherwise leaves the traveled way. The traveled way represents the portion of the road intended for driving on between the centerline and edgeline. State departments of transportation (DOTs) and various transportation professionals have sought solutions to reduce roadway departure fatalities and have developed several roadway safety treatments to reduce errant departures. A number of safety treatments have demonstrated utility in reducing the number of roadway departures and associated fatalities along U.S. highways.

1.2 Problem Statement

The Kentucky Transportation Cabinet has installed several types of roadway safety measures to Kentucky's roads in recent years. These safety measures include median cable barriers, high friction surface treatments, centerline and edgeline rumble stripes, and safety edges. Various transportation studies have examined and touted the safety benefits derived from these measures. Unfortunately, KYTC lacks a comprehensive inventory listing the locations for these installed safety treatment measures across the state. KYTC needed a system to better track safety measure locations and assess their overall performance.

1.3 Objectives

This study developed a comprehensive inventory for the following safety measures:

- a. Cable Barriers
- b. High Friction Surface Treatments
- c. Rumble Stripes (Centerline and Edgeline)
- d. Safety Edges

Chapter 2: Cable Barrier

2.1 Introduction

Cable barriers are longitudinal safety barriers composed of high-tensioned, steel cables connected by a series of posts.² In their role as safety barriers, they may be placed parallel and alongside the outer edge of the roadway (i.e., just off the shoulder) or longitudinally inside the median. In the former, a cable barrier serves to redirect an errant vehicle back onto the road's travelled way if it moves off the outer edge of the road. For the latter, the median cable barrier provides for the same purpose but with the added benefit of preventing crossover lane crashes. According to the Federal Highway Administration (FHWA), "median crossover crashes tend to be severe" and many state departments of transportation that installed median cable barriers have reported a "decrease in cross-median crash fatalities of 90 percent or more".³

2.2 Composition and Function

Cable barriers typically employ either three or four steel cables—also known as strands—that stretch across attached posts. Each steel post is embedded within the ground to provide structural support through load transfer to the foundations. Recent crash tests performed by the National Crash Analysis Center have found that four strands provided greater containment for a larger swath of vehicle sizes.² A typical four strand cable median barrier is shown in the figure below.

Figure 1: Four Strand, Cable Median Barrier



Source: Federal Highway Administration⁴

Cable barriers function by absorbing much of the energy from a vehicular impact crash. The strands will deflect while nearby posts snap from their embedded foundational sleeves.⁵ These actions prevent the vehicle from stopping suddenly, which can increase potential harm to the driver.

2.3 Inventory

The Kentucky Transportation Cabinet (KYTC) has developed their own cable barrier program as a means to increase highway safety. Since 2007, the Cabinet has installed 44 separate cable barrier systems throughout the state. For the purpose of this inventory, an installation is defined as a single cable barrier system installed along a route in Kentucky with a unique beginning and ending milepoint. Some routes and/or project contracts may contain more than one installation. In total, KYTC has installed over 265 miles of cable barrier along its highways. This project captured the locations and various characteristics associated with each cable barrier installation and consolidated the data into a single, comprehensive database.

Kentucky Transportation Center (KTC) researchers coordinated efforts with the Kentucky Transportation Cabinet to collect cable barrier data. Specifically, KTC requested and obtained source data from KYTC's Division of Highway Design, Developmental Branch. This division is responsible for the delivery and letting of highway projects and in this role, maintains visibility on cable barrier installations. The primary point of contact for this data request was the Transportation Engineering Branch Manager for the Developmental Branch (phone: 502-564-3280).

KYTC provided KTC a spreadsheet dataset that displayed all installed cable barriers from 2007 to the present. This spreadsheet included the following categories:

- Item number/contract ID
- Date of letting
- Date of installation completion
- Route
- County
- Beginning and ending milepoints
- Total miles
- Vendor
- Contractor
- Cost

KTC collected and sorted cable barrier attributes into a separate spreadsheet database. The KTC database consisted of the following categories that were deemed necessary for a focus on safety:

- Identification number
- District number
- County
- Route
- Beginning and ending milepoints
- Length of cable barrier
- Direction of travel
- Date of installation (month, year)

Next, cable barrier installations were incorporated into the GIS-based ArcMap platform. KYTC uses ArcMap as their GIS-based platform to collect and display locations and attributes for their overall state

highway network. KYTC's ArcMap relies upon its Highway Information System (HIS) database to populate road locations, their characteristics, and other related transportation factors. Multiple divisions within KYTC collect this data and provide it to the Division of Planning for incorporation into their ArcMap statewide transportation network. Furthermore, KYTC maintains centerlines for all of its roadways which is used as a linear reference system for route-based data. Centerline data provides the basis for determining locations for all roads in Kentucky and the dataset is referred to as "All Roads Measured".⁶ Using ArcMap, the cable locations were geo-referenced using the starting and ending milepoints of the cable barrier installation.

The original cable barrier data received from KYTC often identified lengthy cable barriers across multiple county boundaries. In these instances, the KYTC data listed each cable barrier project as a single, distinct project with multiple beginning and ending milepoints. It did not differentiate a cable barrier installation by county. This became problematic when trying to geo-reference the data. To compensate, KTC researchers utilized the online KYTC Active Highway Plan GIS map as a tool to determine the beginning and ending milepoints for each cable barrier project in each county.⁷ Researchers identified the location for each cable barrier project and determined the associated milepoints for the cable barrier as it crossed from one county to the next. Subsequently, beginning and ending milepoints were assigned to cable barriers by county and incorporated into ArcMap. All of the cable barrier installations are shown in Appendix A, Figure 11.

Chapter 3: High Friction Surface Treatment

3.1 Introduction

High friction surface treatment (HFST) is a thin, high friction overlay consisting of small aggregates held together by a binding agent. This treatment increases the roughness or friction at the roadway surface and helps reduce vehicle skidding on wet-roads or on worn pavement. Although the technology has existed for many years, HFST applications have enjoyed a resurgence in popularity as state DOT's have attempted to reduce highway crashes, most notably, highway fatalities. According to the Federal Highway Administration (FHWA), intersections and horizontal curve locations account for nearly half of all vehicular fatalities.^{8,9} Recent cases studies, including the Kentucky Transportation Cabinet, lend support to HFST as an effective treatment to reduce highway fatalities at these locations.¹⁰ Consequently, KYTC has installed HFST at several high-risk locations within the state, including a U.S. 68 curve in Mercer County (Figure 2). In this figure, the HFST layer begins near the start of the curve and is shown as a darker shade of gray than the preceding roadway surface.

Figure 2: HFST at U.S. 68 Curve, Mercer County



Source: Kentucky Transportation Center¹¹

3.2 Composition and Function

HFST consists of high friction, abrasion-resistant aggregates bound together by a resin or polymer binder. This treatment measure is less prone to wear over time, thus contributing to its ability to maintain high friction surface. Higher surface friction between the vehicle and the roadway surface provides greater ability to overcome the elevated friction demands inherent at intersections and horizontal curves and thereby reduces the rates at which vehicles leave their intended path.

HFST is applied over the top of an existing roadway surface and forms a bond so that it remains in place. HFST may be applied either mechanically or manually. In the former, a mechanical spreader completes the thin overlay process. In the latter, small sections requiring HFST may only require roadway workers to use squeegees to evenly spread the coating while sweeping away the excess. HFST must be applied over a structurally sound, existing roadway surface and typically lasts up to 10 years.¹² In Figure 4, the HFST aggregate is shown in a close-up, detailed view.

Figure 3: HFST Aggregate



Source: Federal Highway Administration¹³

HFST applications help reduce crashes in both types of locations by providing higher friction capacity than on standard roadways.¹⁴

3.3 Inventory

The Kentucky Transportation Cabinet (KYTC) recently adopted the use of HFST applications as a tool in improving highway safety across the commonwealth. In this effort, the Cabinet has installed 112 high friction surface treatment applications along its highways since 2009. An individual installation is characterized as possessing a unique beginning and ending mile point along a given highway route. Each installation took into account HFST applications on lanes in both directions of travel and were not counted as separate installations (assuming they had the same beginning and end). HFST was most often applied to horizontal curves and interstate ramps. HFST installations were also identified for a few approaches to stop-condition intersections.

Early HFST results have proved promising. Several case studies demonstrated significant decreases in traffic crashes following the installation of HFST. In a 2009 example, KYTC installed HFST to an Oldham County horizontal curve that experienced a high number of crashes. Since that time, the curve's annual crash rate dropped from 18.7 to 1.6 crashes per year over a 6-year period (data collected at three year intervals prior to and following installation). In another case, KYTC applied HFST to a high-crash intersection in Knox County in 2011. Early results demonstrated a crash reduction of nearly 50 percent. Additional post-installation crash data is required for further validation.¹⁵

This project captured the locations and various characteristics associated with HFST installations and consolidated the data into a single, comprehensive database. KTC researchers coordinated efforts with

the KYTC to inventory HFST installations across Kentucky. In this effort, KTC identified high-risk crash areas across the commonwealth utilizing *Highway Safety Manual* (HSM) methodological procedures on Kentucky's crash data. Using the network screening techniques, a prioritized list was developed showing locations with the most potential for crash reduction. KYTC collected this list and used it to formulate a HFST treatment project list. This project list formed the basis for approval of future contract proposals at locations requiring HFST installation.

The Highway Safety Improvement Program (HSIP) within KYTC's Division of Traffic Operations funds and executes the HFST program. KTC coordinated with HSIP to collect the HFST data. The HSIP Manager may be reached by phone at (502) 564-3020 or (502) 782-5534.

KYTC provided KTC with a spreadsheet dataset. It contained a collection of high friction surface treatment applications, installed from 2009 to the present. This spreadsheet included the following categories:

- Identification Number (ID)
- District
- County
- Route
- Milepoint, Beginning
- Milepoint, End
- Site
- Length
- Width
- Area (Square Yards)
- Description (Direction)
- Product
- Install Date

KTC collected and sorted HFST attributes into a separate spreadsheet database. The KTC database consisted of the following categories that were deemed necessary for a focus on safety:

- Identification number
- District number
- County
- Route
- Milepoints (Beginning and End)
- Quantity (Length, Width, Surface Area)
- Direction of travel
- Install Date

HFST data were then uploaded into ArcMap. This platform allowed KYTC users to visualize the location of all HFST installations across Kentucky. In addition, the user could click on the HFST boundary line to see all of the attributes associated with that application such as county, route, and milepoints. All of the HFST installations are shown in Appendix A, Figure 12.

Chapter 4: Rumble Stripes

4.1 Introduction

Rumble stripes are a safety treatment that prevents roadway departures from the vehicular lane of travel. Errant vehicles depart a lane of travel by either leaving the outer edge of a roadway or crossing over the centerline into an opposing lane of traffic. Similar to rumble strips, rumble stripes consist of a series of indentations constructed along the roadway surface which react with vehicle tires to produce a distinct sound for the driver. However, rumble stripes go beyond conventional rumble strips because paint is applied on the top, for increased visual awareness. Rumble stripes act as roadway safety treatments by alerting errant drivers of lane departure through these visual and auditory cues.

Research studies demonstrate both rumble strips and rumble stripes reduce crash frequencies. In one study, a joint team of researchers from the Midwest Research Institute and the Pennsylvania Transportation Institute showed significant decreases in crash rates following the installation of center line and shoulder rumble stripes. The study's research findings indicated a 45 percent and 64 percent reduction in crashes on rural two-lane roads and urban two-lane roads, respectively, after installation of centerline rumble strips. Similarly, crash rates decreased by 36 percent and 17 percent for rural two-lane roads and rural freeways, respectively, after installation of shoulder rumble stripes.¹⁶ Consequently, state departments of transportation, including KYTC, have constructed these treatments to help reduce the number of lane departures and associated crashes.

4.2 Composition and Function

Rumble stripes begin as a series of indentations or depressions constructed into the pavement along the edge of the roadway or on top of the centerline. At this stage, this safety treatment is categorized as a *rumble strip*.¹⁷ Typical rumble stripe characteristics include:

- Widths ranging from 5 to 7 inches,
- Lengths ranging from 12 to 16 inches,
- Depth of 0.5 inch below the pavement surface, and
- Separated by an approximate 12-inch spacing.¹⁸

The series of indentations are located perpendicular to the direction of vehicle traffic and react upon impact with a vehicle's tires to produce a distinct sound and accompanying vibration. This alerts a fatigued or distracted driver that lane departure is imminent so he or she can make the necessary course corrections and safely reenter the lane of travel. *Rumble stripes* receive additional safety modifications in the form of a pavement marking painted directly over the top. Pavement markings are simply the painted lines indicating the travel lane, both for the centerline and the edgeline. Rumble stripes also provide increased delineation during rain events. Microbeads contained within the rumble stripes enhance the refractive properties of the markings during wet road conditions and assist in redirecting light back to its source. This results in increased night time pavement marking visibility for the driver.

Previously, rumble strips were placed parallel and offset to the roadway's pavement markings. Rumble strips would not notify the driver until the vehicle had already departed the lane of travel. In the modified rumble stripes, drivers are notified in real-time when they cross over the travel lane pavement markings. The convergence of the rumble stripes with lane pavement markings ensures drivers receive

instantaneous auditory and visual cues at the moment of lane departure. Illustrations for centerline and edgeline rumble stripes are shown in the figures below.

Figure 4: Centerline Rumble Stripes



Source: U.S. Hwy 60, Franklin County, KY

Figure 5: Edgeline Rumble Stripes



Source: KY Hwy 55, Henry County, KY

4.3 Inventory

KYTC has installed rumble strips for many years and only recently transitioned to the modified rumble stripe. Since 2008, KYTC has installed rumble stripes across 750 locations over 2,500 miles. Rumble stripes may be installed along the roadway centerline, edgeline, or both. In this inventory, an installation is defined as a static rumble stripe condition along a given segment of roadway. A segment of roadway starts at a beginning mile point (BMP) and ceases at the ending milepoint (EMP). For example, a centerline rumble stripe installed from BMP 0.0 to EMP 5.0 would constitute a single installation. The centerline rumble stripe continues along the highway but an additional edgeline rumble strip is also constructed from BMP 5.1 to EMP 10.0. This second segment of highway also counts as an individual rumble stripe installation. In this case, the addition of an edgeline rumble stripe parallel to the existing centerline rumble stripe represents a change in the static condition and therefore constitutes a new installation scenario. This installation nomenclature is used because this represents the best approach for inputting data into ArcMap. ArcMap must interpret data through assigned milepoints and roadway locations (i.e., centerline or edgeline) in order to accurately plot rumble stripe installations.

KTC utilized multiple data sources to compile the rumble stripe database used for the ArcMap inventory. Early on, KTC researchers determined that a comprehensive source of data for rumble stripe installations was lacking. KYTC has only constructed rumble stripe treatments in recent years and has not yet developed internal processes to capture and collect rumble stripe locations. KTC researchers needed to develop different data collection methods to overcome the initial data challenges. Consequently, KTC researchers identified multiple sources to construct the initial rumble stripe inventory such as: KYTC contract archives, interviews and discussions, previous KTC research studies, and visual inspections. The compilation of these data sources were divided into the following categories: (a) Pre-2009 Data, (b) 2009 KTC Study, (c) FY 2011-14 Resurfacing Projects, and (d) 2010 and 2012 Retrofit Projects. Each rumble stripe data category will be discussed in greater detail below.

Pre-2009 Data: In 2008, KTC conducted a research study on snowplow impacts on pavement markers. One research objective in the study required the examination of existing rumble stripes installations across the state. Although rumble strips have been used for many years, KYTC had only recently implemented the rumble stripe program and therefore had only installed four rumble stripe treatments. Each rumble stripe was placed along the centerline on four major highways within the state. The four locations and corresponding installation lengths include:

- Mountain Parkway (Magoffin, Morgan, and Wolfe counties), 32.5 miles
- Hal Rogers Parkway (Clay, Laurel, Leslie, and Perry counties), 54 miles
- AA Highway (Bracken, Greenup, Lewis, Mason, and Pendleton counties), 71.3 miles
- US 31W (Jefferson County), 5.2 miles

Additional details on these rumble stripes and the methods used to obtain them can be found in the original research study *Evaluation of the Use of Snowplowable Raised Pavement Markers* (KTC-09-09).¹⁹

2009 KTC Study: In 2009, KTC examined additional rumble stripe installations across the state. This research effort focused on those rumble stripes installed since the release of the initial KTC 09-09 research study. In total, rumble stripes had been installed at 10 locations along the edgeline on two-lane roads. This rumble stripe group included the following:

Table 1: Rumble Stripe Installs, KTC-10-01

Highway	County	Miles
U.S. 51	Ballard	5.5
KY 36	Bath	8.0
U.S. 42	Gallatin	5.6
KY 39	Garrard	5.3
U.S. 421	Henry	6.4
KY 699	Leslie	9.4
KY 7	Letcher	2.6
KY 59	Lewis	11.0
KY 7	Magoffin	3.7
U.S. 62	Nelson	7.6

Source: Kentucky Transportation Center (KTC-10-01/SPR330-07-41)²⁰

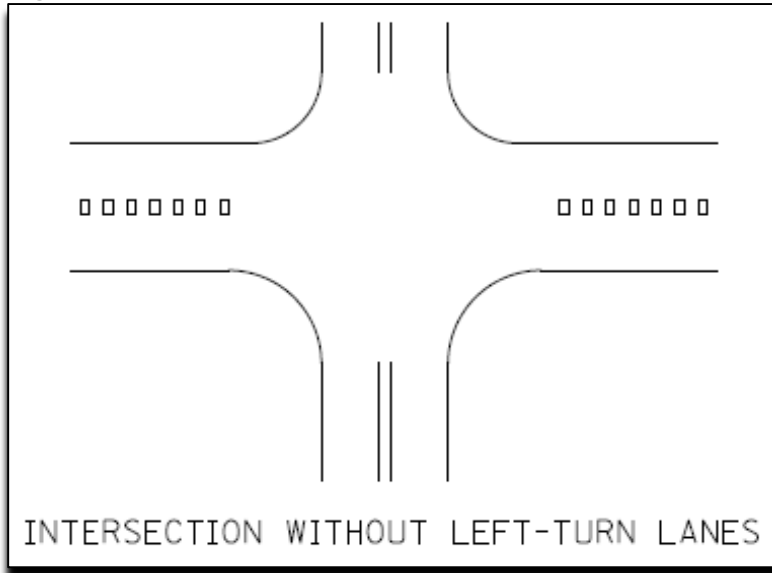
Additional details regarding these rumble stripes can be found in the original research study *Evaluation of Rumble Stripes* (KTC-10-01).

FY 2011-15 Resurfacing Projects: In 2011, KYTC broadened the rumble stripe program for wide-scale implementation across the state.²¹ The dataset for rumble stripe construction projects during these fiscal years was obtained from KYTC historical project archives. The KYTC Division of Construction Procurement collects and archives all authorized construction projects each fiscal year, including rumble striping projects. KTC obtained a copy of KYTC's project archive list and searched the entire list for all rumble stripe projects installed between fiscal years 2011 through 2015.²² These projects specifically involved installations on new pavement and did not include any existing pavements retrofitted with installed rumble stripes. The project archives list included the following categories:

- Contract Identification Number (ID)
- Project Number
- Project Location
- Work Description
- Project Description
- Project Road Name
- Project Cost
- Date of Letting

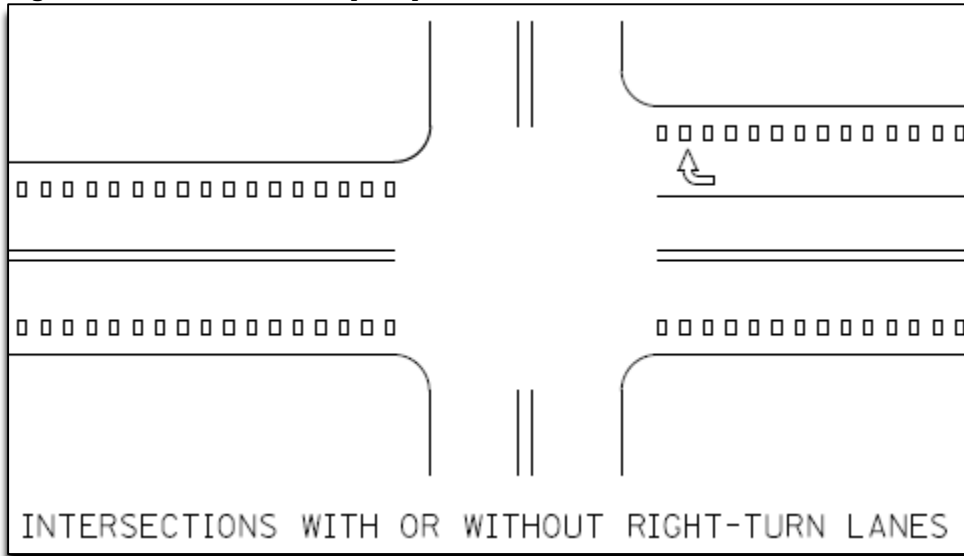
Rumble stripe installations for new resurfacing projects are required to follow Active Sepias 2012 drawing specifications for all installations. The Active Sepias list provides updates to the Standard Drawings which are not yet reflected in the Standard Drawings. KYTC has detailed sheets for both centerline and shoulder rumble strips. As described previously, rumble strips form the basis of rumble stripes and therefore, these detailed sheets are also used during rumble stripe installations. Select portions of both the centerline and shoulder rumble strip detail sheets are shown in the figures below.

Figure 6: Centerline Rumble Strip, Sepia Sheet 010



Source: Kentucky Transportation Cabinet²³

Figure 7: Shoulder Rumble Strips, Sepia Sheet 011



Source: Kentucky Transportation Cabinet²⁴

2010 and 2012 Retrofit Projects: In select cases, KYTC installed rumble striping on existing roadway pavements. These cases were let in fiscal years 2010 and 2012. KTC inspectors examined the sites for the presence of retrofitted rumble stripes. Data collected during these inspections included the date of inspection, route identification number (ID), county, and milepoints installed. Collectively, all rumble stripe data was displayed using ArcMap for the final inventory output. All of the rumble stripe installations in the state are shown in Appendix A, Figure 13.

Chapter 5: Safety Edge

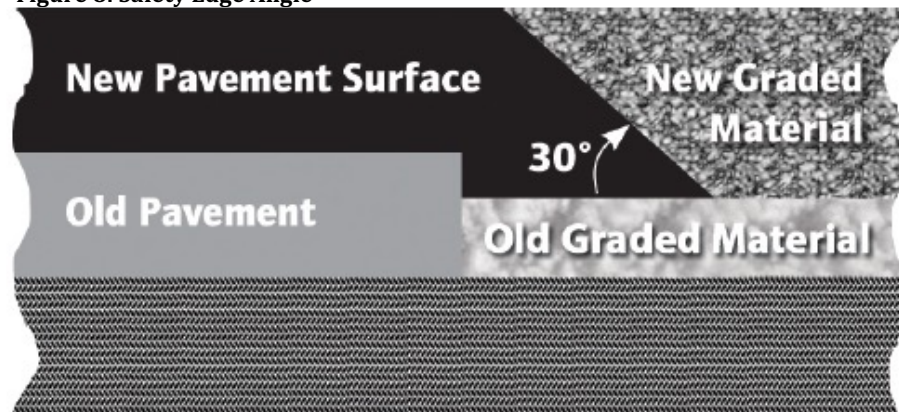
5.1 Introduction

The Safety Edge treatment reduces the slope angle at the pavement's edge. This allows errant drivers leaving the pavement to safely return. Many roadways experience a steep vertical drop-off in elevation between the paved surface of the travel course and the adjacent graded surface. This sharp elevation difference makes it difficult for drivers to safely navigate the vehicle back onto the road due to “tire scrubbing”. This condition frequently leads the driver to over-steer and increases the probability of a severe crash—collisions or overturning of the vehicle. Research studies have shown the Safety Edge is effective in allowing errant vehicles to smoothly reenter the roadway, even at higher speeds.

5.2 Composition and Function

The Safety Edge forms a smooth, mild-slope transition on the outer pavement edge directly bordering the newly graded material. This pavement slope lies at a 30 degree angle above the old graded material elevation. This reduces the excessive drop-off typically associated with conventional roadways. Following resurfacing, newly graded material is installed flush with the new pavement surface in accordance with standard construction practices. Any future degradation of this graded material at its boundary with the roadway exposes the Safety Edge and allows errant vehicles to safely transition back onto the roadway. An illustration of this concept is shown in the figure below.

Figure 8: Safety Edge Angle



Source: FHWA, Safety Edge²⁵

The Safety Edge can be installed using either asphalt concrete (AC) or Portland cement concrete (PCC) materials.²⁶ Special devices are attached to existing paving construction equipment to install the Safety Edge. Inspectors verify the angle of the Safety Edge upon installation to ensure quality control. Figures 7 and 8 below compare newly constructed pavement surfaces (using the safety edge transition) with a conventional roadway boundary (without the safety edge).

Figure 9: Pavement with Safety Edge



Source: FHWA, Safety Edge Presentation²⁷

Figure 10: Pavement without Safety Edge



Source: FHWA, Safety Edge Presentation²⁸

5.3 Inventory

KTC conducted a comprehensive search across all KYTC project proposals approved from January 1, 2011 to September 30, 2015 to generate the Safety Edge inventory. KYTC project proposals notify contractors and businesses on upcoming KYTC-sponsored projects and solicit bids for consideration. Bids are evaluated by KYTC using select criteria before a contractor is awarded the project. Each project proposal contains relevant information needed by contractors to evaluate the scope and costs for the project. Project proposal details may include, but are not limited to, the following: location (route, county), letting date, and the scope of work. In this case, KTC researchers only examined those proposals containing a Safety Edge construction requirement contained within the overall scope of work.

The start date of January 1, 2011 was selected since Safety Edge installations did not occur prior to 2011. The end date represented the completion date of this report. To download a project proposal, first, the researcher navigated to the KYTC website and selected "Construction Procurement" underneath the drop-down menu option "Business."²⁹ Construction Procurement represented the KYTC Division responsible for letting projects for construction. On this webpage, the researcher selected a specific letting date residing within the selected time period of interest (2011-2015). Letting dates were shown under the "Lettings" header and showed up as hyperlinks. Next, the "Letting Details" webpage provided "Proposal Information" for all project proposals contained within the letting date.

When all project proposals were analyzed to determine which projects involved installation of one or more Safety Edges, the complete number of KYTC projects totaled 3,826. This number included any type of project KYTC released for bid. Upon further examination, 52 projects were removed from this initial total after determining those contracts had been formally withdrawn (or removed from contract bidding). An Adobe multi-file search was used on the remaining 3,774 project proposals. This search identified any files containing the term "Safety Edge" and revealed 140 project proposals meeting this criteria. Each proposal was subsequently scanned to confirm the project's scope of work required the actual installation of a Safety Edge. Each of the 140 project proposals contained stipulations requiring installation of a Safety Edge/s within the scope of work. However, one project proposal was identified as a false positive in terms of inventory applicability. In this case, the project installed a safety edge at an airport and therefore, did not fit the scope of this inventory covering roadside safety. It was subsequently eliminated from the inventory database to arrive at a final safety edge proposal count of 139.

Several project proposals required the installation of more than one Safety Edge along a given route/s. In this context, a single Safety Edge installation entailed any single, continuous Safety Edge installation along a roadway segment (as defined by milepoints) without an interruption or break in installation. A single project proposal may have multiple Safety Edge installations spread across multiple routes or even along different sections within the same route. An analysis using this methodology was needed to determine the exact number of Safety Edge installations occurring within the 139 project proposals. A thorough analysis of the project proposals revealed 188 separate Safety Edge installations took place between 2011 and 2015.

KTC researchers developed an inventory from the Safety Edges identified within the applicable project proposals. The attributes were sorted into an Excel spreadsheet that also noted relevant contract information and identified location. This spreadsheet included the following categories:

- County
- Route Number
- Beginning Milepoint
- Ending Milepoint
- Prefix (US or KY route)
- Contract Identification Number (CID)
- Contract Call Number
- Date of Letting

In total, a list of 147 Safety Edge projects were installed during this time period, on approximately 580 miles of roadways. Each Safety Edge installation was plotted in ArcMap. All of the Safety Edge installations in the state are shown in Appendix A, Figure 14.

Conclusion

The Kentucky Transportation Cabinet continues to seek out innovative measures for improving highway safety. The installation of recently developed safety measures on existing roadways forms a key component in that strategy. Safety measures such as cable barriers, high friction surface treatments (HFST), rumble stripes, and Safety Edges have demonstrated tangible reductions in crashes and fatalities. Studies conducted across the nation have confirmed the reductions. To date, KYTC has constructed numerous installations over many miles:

<u>Type of Installation</u>	<u>Number of Installations</u>	<u>Miles of Installations</u>
Cable Barriers	44	265
High Friction Surface Treatments	112	20
Rumble Stripes	750	2,500
Safety Edges	147	580

All safety measure installations across the state have been compiled into a comprehensive database in the form of an Excel spreadsheet. After ArcMap was used to reference locations of the inventoried safety treatments, this data serves as input into KYTC’s statewide linear reference system. Furthermore, attributes were assigned to each safety treatment type; they are also accessible through ArcMap. Common attributes collected for the safety measure identification include: district number, county, route, beginning and ending milepoints, length, direction of travel, and date of installation.

Historically, KYTC has not possessed a single, comprehensive database showing the locations and attributes for the safety measures listed above. The compilation of this comprehensive database provides KYTC transportation officials with a single site that monitors and assesses the different safety measure types. This may prove beneficial in future years by allowing policy makers and KYTC officials to fully evaluate each of the safety measure types. An evaluation could yield insights into installation costs and safety outcomes on crashes, giving the ability to compare outcomes with initial predictions. This inventory should serve as a useful tool to evaluate costs and benefits of safety measures installed across Kentucky.

Appendix A

Figure 11: Cable Barriers

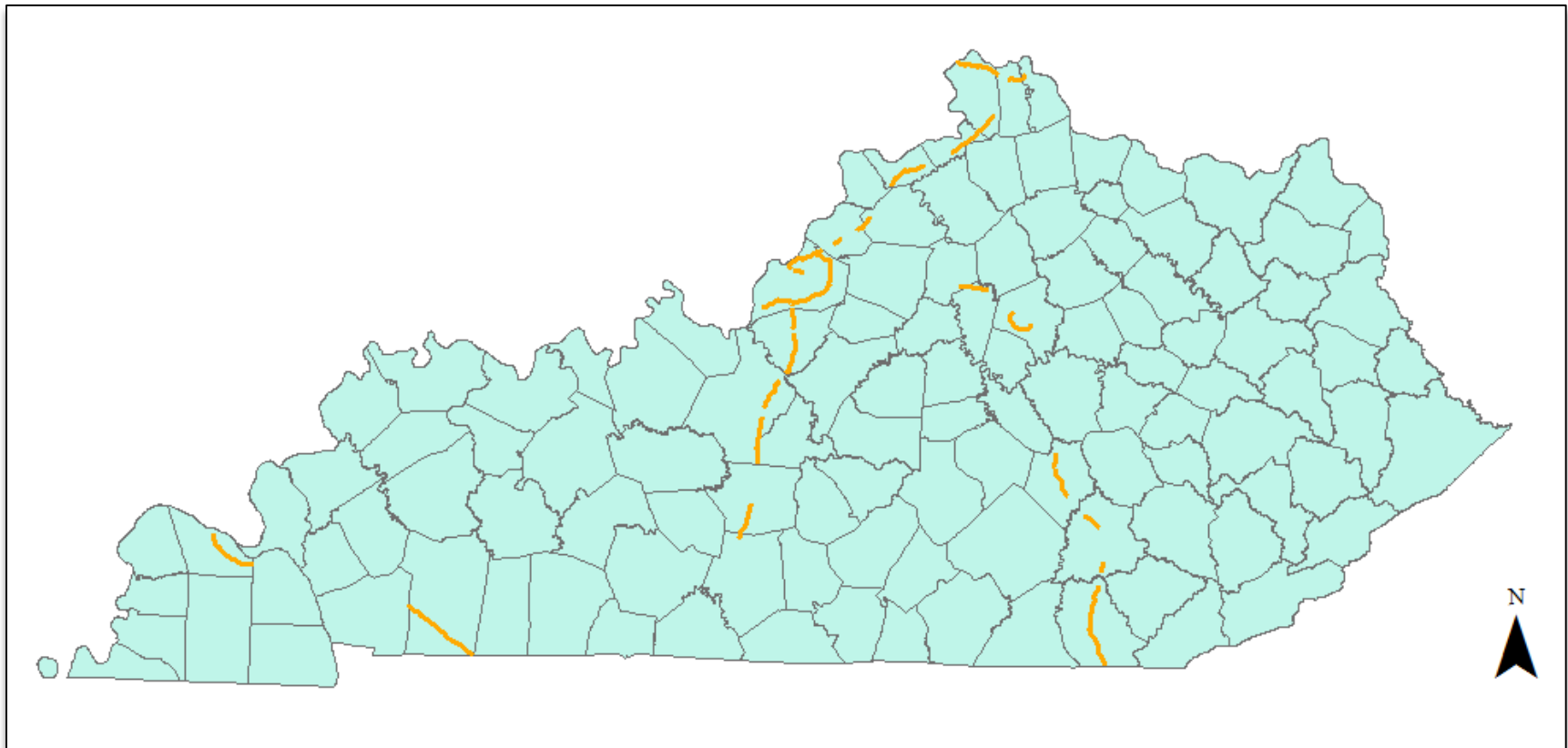


Figure 12: High Friction Surface Treatments

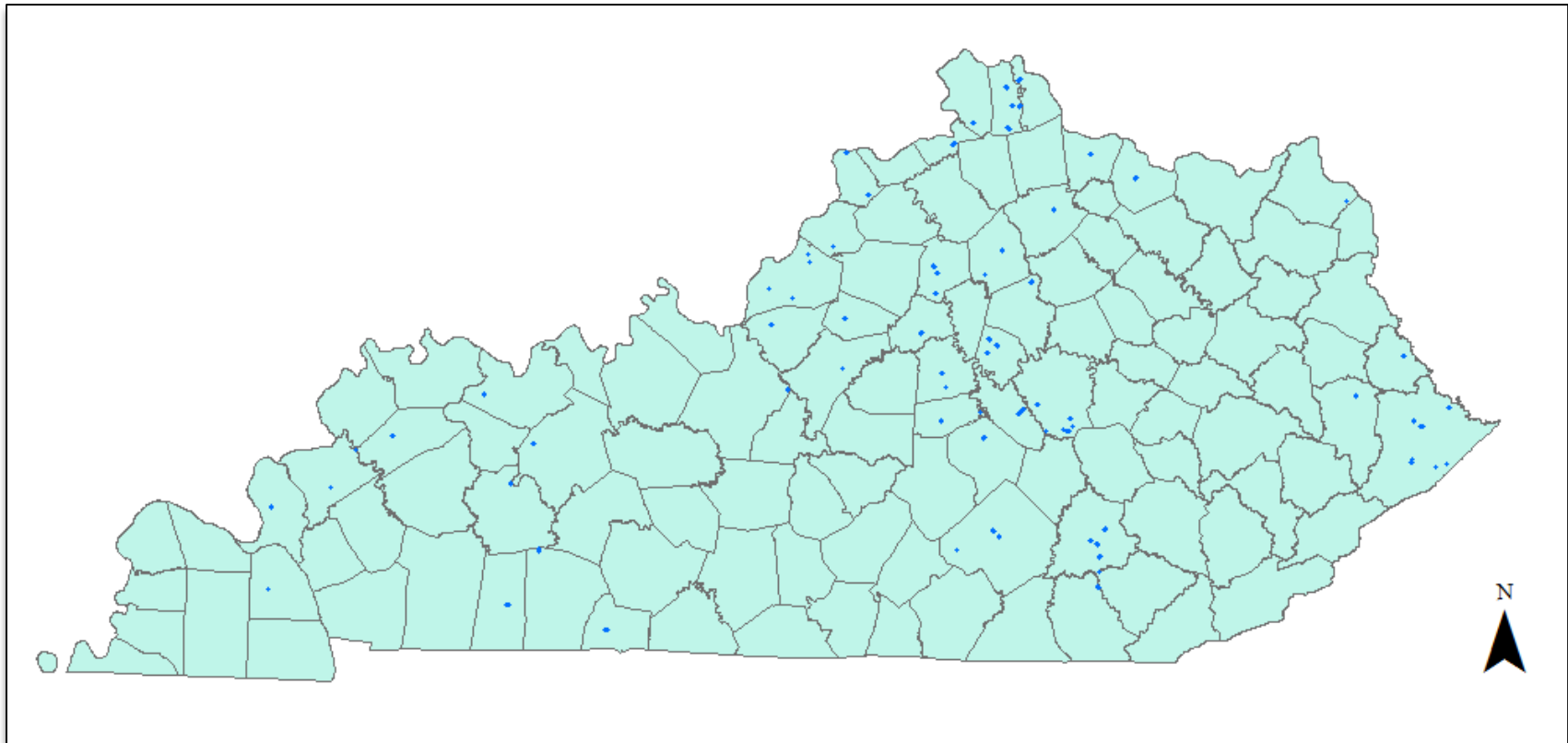


Figure 13: Rumble Stripes

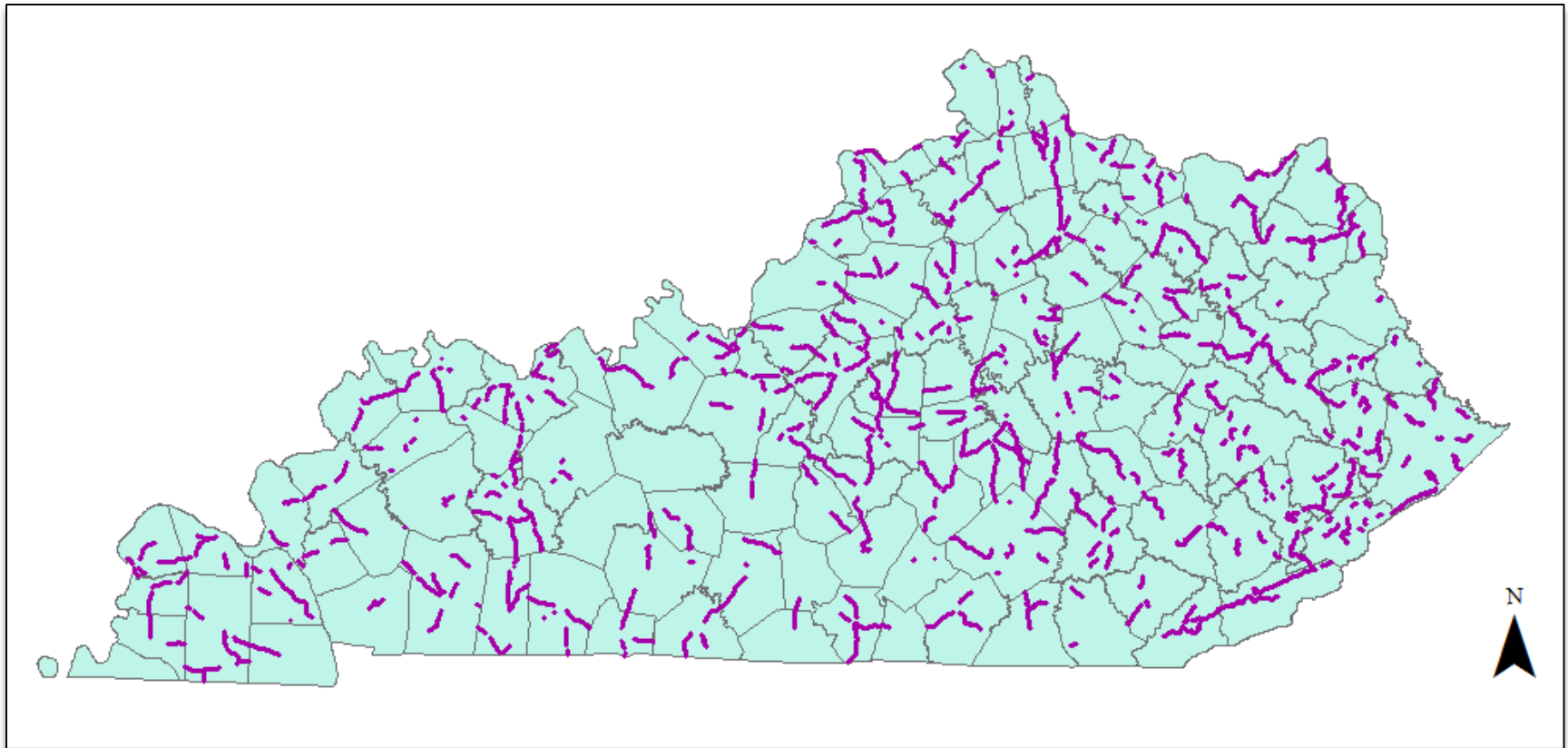
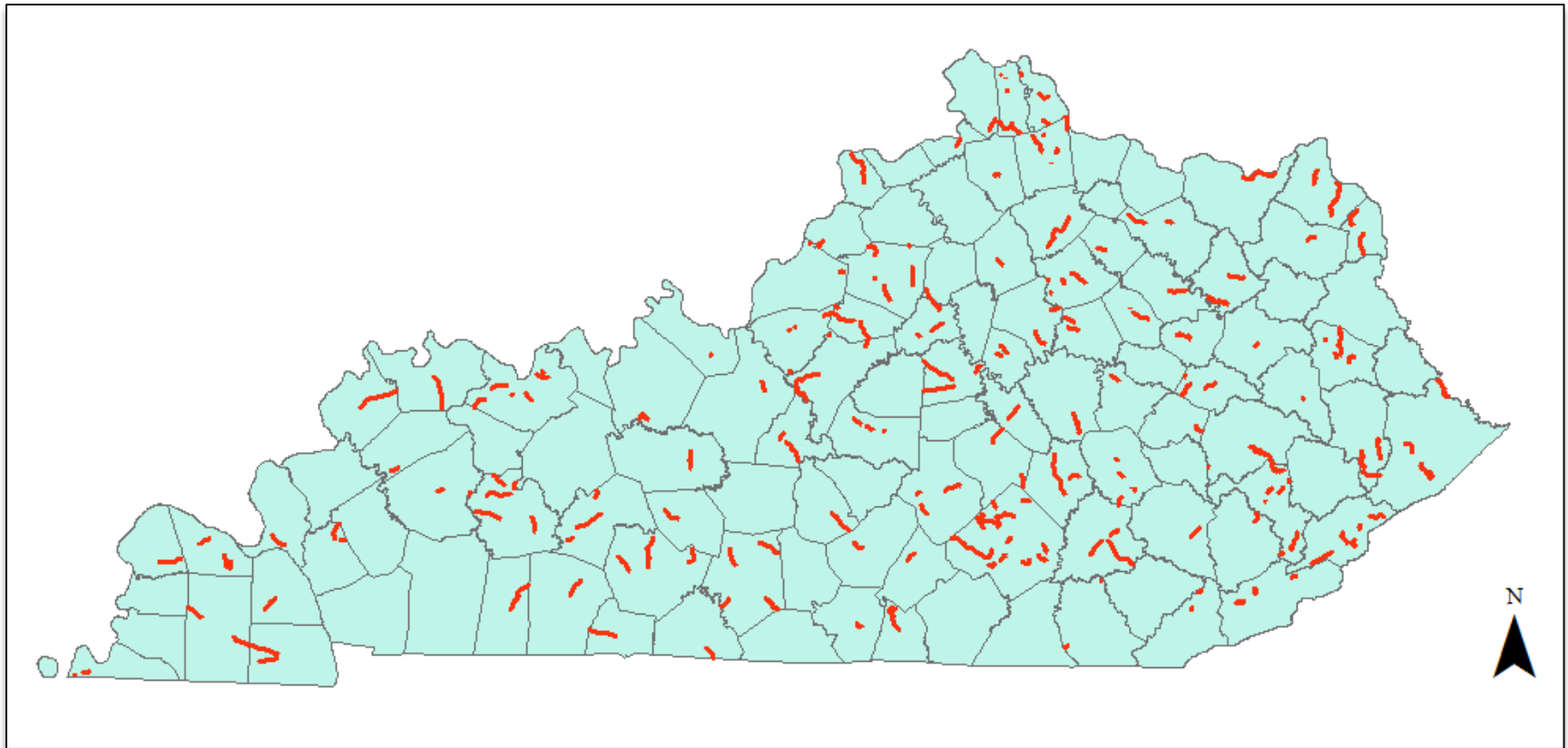


Figure 14: Safety Edges



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¹⁷ Rumble stripes can be either milled or raised. Milled rumble stripes are the most common and involve the process of creating depressions or grooves into the roadway surface. Raised rumble stripes elevate the markers above the existing pavement surface. Milled rumble stripes are used extensively in KYTC due to their ease of maintenance for snowplow removal and will be only discussed here. **Not sure this qualifies as a reference.**

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²¹ The state fiscal year (FY) begins on July 1 and ends on July 31. The first let contract for rumble stripes in this category group was on August 27, 2010. **Not sure this qualifies as a reference.**

²² KYTC Division of Construction Procurement project archives list. Retrieved from:
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