

WISCONSIN DEPARTMENT OF TRANSPORTATION

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# **BURLINGTON BYPASS: ROAD SAFETY AUDIT**





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# **BURLINGTON BYPASS: ROAD SAFETY AUDIT**

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## 1.0 INTRODUCTION

### 1.1 Background

The Burlington Bypass (FIGURE 1.1) was initially proposed in the 1960s, when the need for additional roadway capacity was identified. Existing roads direct both local and long-distance traffic into the center of Burlington (population 10,000), creating high levels of demand on city streets and increasing the potential for conflicts between long-distance traffic (including trucks associated with the west Racine County industrial area) and pedestrians, local traffic, and trains using at-grade crossings.

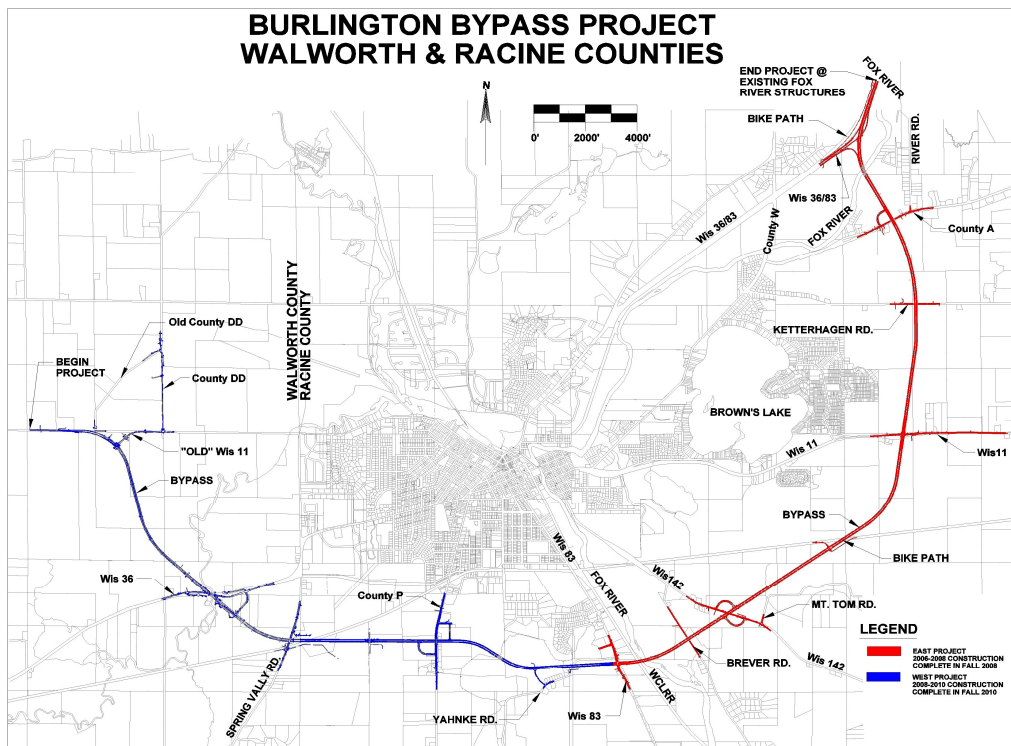


FIGURE 1.1 PROJECT LOCATION

The Bypass design is currently in its final stages. In previous planning stages, several alternative alignments were considered. The chosen alignment was adopted with regard for environmental and engineering constraints, as well as concerns expressed by the City of Burlington and the public during an extensive public consultation process. Construction has started on the chosen alignment, and was underway at the time of the audit workshop.

The Bypass is expected to accommodate an AADT of about 7,000 vehicles (west end) to 11,000 vehicles (middle). Trucks are expected to compose up to 12 percent of the traffic. Bicycles will be allowed on the Bypass, but will not be encouraged.

## **1.2 Road Safety Audits**

A road safety audit is a formal safety performance examination of an existing or future road or intersection by an independent audit team. Road safety audits help to promote road safety by identifying safety issues at the design and implementation stages, promoting awareness of safe design practices, integrating multimodal safety concerns, and considering human factors in the design.

## **1.3 Reminder**

The audit team has conducted this audit to the best of its professional abilities within the time available and by referring to available information. While every attempt has been made to identify significant safety issues, the design team and the project owner are reminded that responsibility for the design, construction, and performance of the project remains with the engineers of record.

## **1.4 Audit Project and Scope**

This staged project is currently at a various design stages. Construction started in the summer of 2006, and is expected to continue through 2010. The audit team reviewed design drawings of the Bypass between old County Road DD and the interchange with STH 36/83 (FIGURE 1.1). The construction of this segment include the following:



- Three bridges over the Fox and White Rivers;
- Five grade-separated interchanges (including four jug-handle configurations), two at-grade signalized intersections, two at-grade unsignalized intersections, and three viaducts over existing roads;
- Three private at-grade accesses;
- About nine-miles of roadway on the main Bypass alignment;
- Lighting at signalized intersections only;
- Improvements to local roads at connections to the Bypass;
- Some pedestrian and bicycle facilities at intersections and local roads.

The design speed of the Bypass mainline is 60 mph, and the posted speed is expected to be 55 mph. Jug-handle ramps have a design speed of 30 mph.

### **1.5 Audit Team and Process**

The audit team and the project material on which the audit was based are described in *Attachment 1*.

Site visits were conducted in August 2006 to gain an understanding of the existing conditions and surroundings. Notes on the site visits are contained in *Attachment 2*.

A road safety audit framework was applied in both the audit analysis and presentation of findings. The expected frequency and severity of crashes caused by each safety issue have been identified and rated according to the categories shown in TABLES 1.1 and 1.2. These two risk elements were then combined to obtain a risk assessment on the basis of the matrix shown in TABLE 1.3. Consequently, each safety issue is assessed on the basis of a ranking between F (highest risk and highest priority) and A (lowest risk and lowest priority).

For each safety issue identified, possible mitigation measures have been suggested. The suggestions have focused on measures that can be cost-effectively implemented at the current design stage, and consequently include few geometric changes.

**TABLE 1.1 FREQUENCY RATING**

ESTIMATED		EXPECTED CRASH FREQUENCY (per audit item)	FREQUENCY RATING
EXPOSURE	PROBABILITY		
high	high	10 or more crashes per year	<i>frequent</i>
medium	high		
high	medium	1 to 9 crashes per year	<i>occasional</i>
medium	medium		
low	high		
high	low	less than 1 crash per year, but more than 1 crash every 5 years	<i>infrequent</i>
low	medium		
medium	low	less than 1 crash every 5 years	<i>rare</i>
low	low		

**TABLE 1.2 SEVERITY RATING**

TYPICAL CRASHES EXPECTED (per audit item)	EXPECTED CRASH SEVERITY	SEVERITY RATING
crashes involving high speeds or heavy vehicles, pedestrians, or bicycles	probable fatality or incapacitating injury	<i>extreme</i>
crashes involving medium to high speed; head-on, crossing, or run-off-road crashes	moderate to severe injury	<i>high</i>
crashes involving medium to low speeds; left-turn and right-turn crashes	minor to moderate injury	<i>moderate</i>
crashes involving low to medium speeds; rear-end or sideswipe crashes	property damage only or minor injury	<i>low</i>

**TABLE 1.3 CRASH RISK ASSESSMENT**

FREQUENCY RATING	SEVERITY RATING			
	<i>Low</i>	<i>Moderate</i>	<i>High</i>	<i>Extreme</i>
<i>Frequent</i>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>
<i>Occasional</i>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
<i>Infrequent</i>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<i>Rare</i>	<b>A</b>	<b>A</b>	<b>B</b>	<b>C</b>

*Crash Risk Ratings:*

*A: lowest risk level*

*D: moderate-high risk level*

*B: low risk level*

*E: high risk level*

*C: moderate-low risk level*

*F: highest risk level*

## 2.0 AUDIT FINDINGS

### 2.1 Safety Benefits of the Proposed Improvements

The Burlington Bypass is motivated by the safety-related goal of reducing conflicts between long-distance/industrial traffic and local/pedestrian traffic in Downtown Burlington. In addition, the Bypass and many features of its design already incorporate many features that are expected to substantially improve traffic safety in the Burlington area:

- *Use of innovative interchange design:* The Bypass design includes four jug-handle interchanges, all of which were adopted after consideration of at-grade signalized intersections. Although some safety issues associated with single jug-handle configurations have been identified, the use of the innovative jug-handle configuration reduces the potential for high-speed conflicts associated with signalized at-grade intersections.
- *Improved truck access to industrial areas:* The Bypass will remove truck traffic associated with existing and planned industrial land uses from Downtown Burlington, where it conflicts with local, pedestrian, and bicycle traffic.
- *Generous geometry and a roadside clear zone on mainline road:* The Bypass mainline includes twelve-foot travel lanes, an eight-foot outside shoulder (paved), six-foot inside shoulder (paved and gravel), and concrete median barrier in some locations. These design elements can be expected to contribute to safety.
- *Improvements to existing roads:* Part of the Bypass construction include improvements to the existing local road infrastructure, such as improved alignment of curves and partial installation of a bicycle network.
- *Reduced emergency response times:* Emergency vehicles currently use City streets, where they may be delayed by congestion and at-grade railroad crossings. By providing an alternative high-speed route, the Bypass will reduce emergency response times.

## 2.2 RSA Issues and Suggestions

Safety issues and suggestions associated with the proposed improvements are discussed in ATTACHMENT 3, and summarized in TABLE 2.1.

**TABLE 2.1 SUMMARY OF RSA SAFETY ISSUES AND SUGGESTIONS**

SAFETY ISSUE (Number and Description)		Risk Rating	Suggestions
1. Risk of Off-Road Collisions on Curves		D	<ul style="list-style-type: none"> <li>▪ Enhanced delineation:                             <ul style="list-style-type: none"> <li>▪ Six-inch edgeline</li> <li>▪ Rumble strips</li> <li>▪ Chevron signs</li> </ul> </li> <li>▪ Lighting along the Bypass</li> <li>▪ Warning signs</li> <li>▪ Berm to obstruct drivers' view of abandoned highway alignment</li> </ul>
1a	The combination of high speeds and frequent horizontal curves may generate an increased risk of off-road collisions		
1b	At the north interchange of STH 36/83 and the Bypass, a tight ramp configuration may result in an increased risk of off-road crashes.		
1c	At the west end of the project, drivers may expect to follow the abandoned alignment of STH 11, resulting in an increased risk of off-road crashes.		
2. Limited Intersection Conspicuousness		D	<ul style="list-style-type: none"> <li>▪ Lighting at intersections</li> <li>▪ Multiple overhead signal displays on each approach</li> <li>▪ Signal backplates with reflective borders</li> <li>▪ Enhanced intersection warning signs</li> </ul>
2a	The absence of lighting at at-grade intersections limits visibility and conspicuousness.		
2b	Current design drawings indicate a single overhead signal display at signalized intersections.		
3. Intersection Operations		D	<ul style="list-style-type: none"> <li>• Signalization of intersection</li> <li>• Slotted left turn lane</li> <li>• Right-turn acceleration lane</li> <li>• Offset right-turn deceleration lane</li> </ul>
3a	A high left-turn volume onto the ramp at STH 36 from the Bypass may increase the risk of rear-end and left-turn collisions on the Bypass.		

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SAFETY ISSUE (Number and Description)		Risk Rating	Suggestions
3b	A high left-turn volume from the Bypass ramp onto STH 36 may increase the risk of rear-end and left-turn collisions from STH 36.		<ul style="list-style-type: none"> <li>▪ Signal or roundabout at ramp intersection</li> </ul>
3c	Substantial left-turn movements at the intersections of the CTH P ramp and Brookview Avenue may lead to turning conflicts and queuing on the ramp.		<ul style="list-style-type: none"> <li>• Roundabout at "T" intersection</li> </ul>
3d	Drivers turning right from the CTH P ramp may interfere with through traffic on the Bypass.		<ul style="list-style-type: none"> <li>▪ Right-turn acceleration lane</li> </ul>
4. Intersection Geometrics		D	<ul style="list-style-type: none"> <li>▪ Offset right turn lane</li> <li>▪ Parallel acceleration lane</li> <li>▪ Enhanced curve delineation and signing</li> <li>▪ Deceleration/acceleration lanes at Yahnke Road/Buck Archers Club intersection</li> </ul>
4a	Auxiliary lane lengths at five ramps appear to be short, and ramp entry turn radii appear to be abrupt.		
4b	Unsignalized left turns at at-grade intersections on the Bypass generate a risk of high-speed left-turn collisions, which may be potentially severe.		
5. High Driver Workload		D	<ul style="list-style-type: none"> <li>▪ Review Signing</li> <li>▪ Converging Chevron Pavement Markings</li> </ul>
A required merge on a horizontal curve contributes to a high driver workload on the north interchange.			
6. Accommodating Pedestrians and Cyclists		B	<ul style="list-style-type: none"> <li>▪ Relocation of crossing</li> <li>▪ Barrier break</li> </ul>
6a	An at-grade bicycle trail crossing over Hwy 36/83 exposes cyclists to several lanes of high-speed traffic.		
6b	A guardrail obstructs pedestrian access to a signalized intersection.		
7 Weather-Related Issues		D	<ul style="list-style-type: none"> <li>▪ Increased driver guidance and warning</li> <li>▪ Improved pavement friction</li> </ul>
Icy and foggy conditions may aggravate the risk of collisions.			

## **2.3 Conclusions**

Seven safety issues have been identified in this design-stage road safety audit. Suggestions for improvements have been identified and are described in this report. The owner and design team are invited to consider the suggested changes. To complete the audit process, the owner and design team may prepare a short written response to the issues and options outlined in this report.

**ATTACHMENT 1  
ROAD SAFETY AUDIT TEAM AND MATERIALS**

<b>Location</b>	south of Burlington, WI
<b>Audit Team</b>	Jeff Bagdade, P.E. (Opus International Consultants) Margaret Gibbs, P.Eng. (Opus International Consultants) Nicole Thompson, E.I.T. (Opus International Consultants) Ted Meagher (Wisconsin State Patrol) Will Anderson (WisDOT) Paul Ambrose (WisDOT) Chris Quesnell (WisDOT)
<b>Project Owner</b>	Wisconsin Department of Transportation
<b>Design Team</b>	Kapur & Associates
<b>Review Date</b>	August 15-17, 2006
<b>Audit Stages</b>	various
<b>Start Up Meeting</b>	August 15 2006
<b>Attended by</b>	Wisconsin Department of Transportation Wisconsin State Patrol Federal Highway Administration Kapur & Associates Opus International Consultants

**Project Documents Available for the Audit:**

- Large design drawings (no date):
  - STH 11 to STH 36/83
  - STH 11 to Spring Valley Road and Spring Valley Road to STH 36/83
- 11x17 drawings (various dates):
  - Burlington Bypass STH 83 (South) to STH 36/83 (North): Grading (dated December 05)
  - Burlington Bypass STH 11 Burlington Bypass to Crossway Road (dated December 05)
  - Burlington Bypass STH 83 (South) to STH 36/83 (North): Structures (dated August 06)
  - Burlington Bypass CTH DD to STH 83 (South): STH 11 Racine County (July 2006, labelled "RSA Plan Set")
- Burlington Bypass Supplemental Information from the Ventry Prepared Value Engineering Study of the Major Projects Program (no date)
- Burlington Bypass Value Engineering Report (WisDOT, May 2004)
- 2002 traffic volume projections for 2006, 2016, 2026
- Design Study Report: STH 11 Bypass, STH 11/36/83 (Kapur & Associates, 2004)

All documents were provided prior to or at the RSA workshop of August 15-17, 2006.



## ATTACHMENT 2

### NOTES OF SITE VISIT

**Project Name:** Burlington Bypass

**Site Visit Date:** August 15, 2006

**Land Uses:** The Bypass runs through undeveloped areas south of the City of Burlington, Wisconsin, including agricultural lands and wetlands. Adjacent land uses are primarily farming, industrial (quarry), and residential. Commercial land uses are present near intersecting roads. The Buck Trail Archers Club is located adjacent to the planned alignment.

**Road User Characteristics:** A high proportion of trucks was observed on roadways that will be connecting with the Bypass. Few pedestrians or cyclists were observed on connecting roads during site visits.

**Topography:** The Bypass will pass through rolling terrain. The alignment requires three river crossings, including a long crossing of the Fox River flood plain.



*intersection of Bypass ramp with existing roadway*



*Bypass roadway (foreground) with jug-handle ramp (background)*

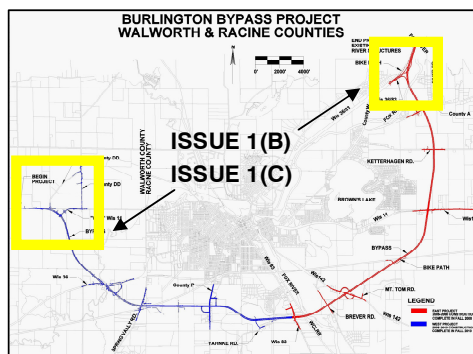
**ATTACHMENT 3  
RSA ISSUES AND SUGGESTIONS**

**Road Safety Audit**  
**Burlington Bypass**  
**Safety Issue 1: Risk of Off-Road Collisions on Curves**

**Safety Issue 1(a):** The combination of high speeds and frequent horizontal curves may generate an increased risk of off-road (lane departure) collisions.

**Safety Issue 1(a) Description:** The Bypass follows a semi-circular alignment that incorporates many horizontal curves (*right*). The presence of frequent horizontal curves, even if compliant with AASHTO criteria, can be expected to result in an increased risk of run-off-road collisions when drivers fail to follow a changing alignment. Aggravating factors include:

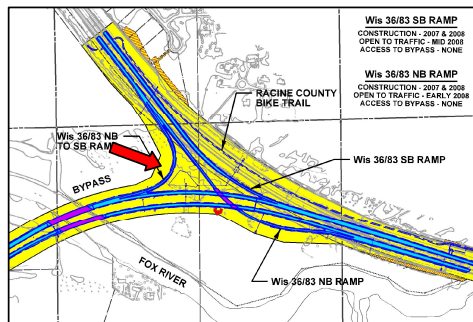
- the high speed environment (mainline design speed of 60 mph and posted speed of 55 mph),
- the limited use of lighting,
- the possibility of fog associated with the surrounding wetlands and streams,
- the potential presence of wildlife on the road in this rural area.



**Safety Issue 1(b):** At the north interchange (*right*) of STH 36/83 and the Bypass, a tight ramp configuration may result in an increased risk of run-off-road (lane departure) crashes.

**Safety Issue 1(b) Description:** Severe constraints at the eastern end of the Bypass have resulted in a ramp design based on a design speed of 30 mph and posted speed of 25 mph. The ramp connects two roads (STH 36/83 and the Bypass) having posted speed limits of 55 mph. Drivers who fail to slow sufficiently on the ramp have an increased risk of off-road crashes and, in the case of trucks, rollovers. Aggravating factors contributing to an increased risk of collision include:

- possible icy pavement on this section of road, which is on structure;
- a high driver workload on the ramp, where entering drivers must merge with higher-speed traffic on the through route while navigating a reverse curve.

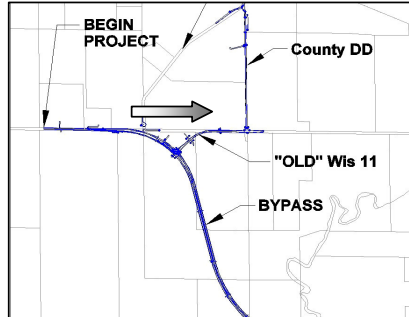


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**Safety Issue 1(c):** At the west end of the project, drivers may expect to follow the abandoned alignment of STH 11, resulting in an increased risk of off-road (lane departure) crashes.

**Safety Issue 1(c) Description:** The design team has diverted the existing STH 11 alignment to intersect the new Bypass alignment at a right angle (*right*). Vestiges of the old alignment such as pavement, landscaping, or a roadside utility corridor may confuse inattentive eastbound drivers. Drivers who follow the old alignment may enter the opposing lanes of traffic or the roadside.



**Expected Crash Types:** run-off-road collisions

**Expected Frequency:** occasional



**Expected Severity:** high

**Risk Rating:** D (moderate-high risk level)

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Safety Issue			Suggestions
1a	1b	1c	
			1. <i>Enhance delineation using low-cost measures:</i>
√	√	√	<ul style="list-style-type: none"> <li><i>Six-inch edgeline:</i> To assist drivers, particularly at night or in fog, a wide retroreflective edgeline may be used along the entire Bypass alignment. A typical edgeline is four to six inches wide; the design team may consider using a width of six inches (i.e., the upper end of this range). Discussions during the preliminary findings meeting (August 17, 2006) indicate that test application of six-inch edgelines is currently scheduled for 2008 on I-94 in Waukesha County. It is noted that the use of six-inch edgelines may be inconsistent with state policy, and may therefore require justification (see Issue 7 below).</li> </ul>
√		√	<ul style="list-style-type: none"> <li><i>Rumble strips:</i> To alert drivers who have left the travel lane and entered the shoulder, shoulder rumble strips may be considered. NCHRP Report 500 (<i>Volume 6: A Guide for Addressing Run-Off-Road Collisions</i>) cites several before/after studies of the effectiveness of shoulder rumble strips, and concludes that a “best guess” estimate is a 20- to 30-percent reduction in single-vehicle run-off-road collisions on rural freeways with the use of</li> </ul>

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Safety Issue			Suggestions
1a	1b	1c	
			<p>shoulder rumble strips. A design that includes shoulder rumble strips will need to consider the following factors:</p> <ul style="list-style-type: none"> <li>○ the presence of cyclists,</li> <li>○ adequate drainage to ensure that water does not accumulate in the rumble strips.</li> </ul> <p>An additional discussion of rumble strips is provided in Issue 7 below.</p>
	√	√	<p><i>W1-8 (Chevron Alignment) signs:</i> Chevron signs may be posted to provide additional emphasis and guidance to drivers. Chevron signs may be used as an alternate or supplement to standard delineators on curves. </p>
√	√	√	<p><i>2. Implement lighting along the Bypass.</i> Lighting is generally considered beneficial at intersections (to improve night-time visibility) and horizontal curves (to provide improved sight distance and curve delineation). Along the Bypass, horizontal curves and intersections (including at-grade intersections associated with interchanges) occur at such a frequency that lighting along the entire Bypass could be considered.</p> <p>Lighting is further discussed under Safety Issue 2.</p> <p>It is noted that the capital and ongoing costs of this measure are substantial.</p>
	√		<p><i>3. Provide warning signs.</i> In addition to the chevron signs discussed in Suggestion (1) above, other warning signs (some of which may already be proposed by the design team) may be considered to assist drivers on the north interchange ramp, where the driver workload is high and the risk of truck rollovers may be high:</p> <ul style="list-style-type: none"> <li>○ An advance W1-1 (Horizontal Alignment) warning sign and W1-13 (Truck Rollover) sign (<i>right</i>), with advisory W13-1 speed plaques, may be posted in advance of the curve to warn drivers that they will need to slow for the curve ahead. </li> <li>○ A W13-3 (Advisory Ramp Speed) sign may be used on the ramp to advise drivers of the slower speed limit.</li> <li>○ W4-1 (Merge) signs may be used on the ramp and mainline to advise drivers that ramp traffic must merge at the ramp terminus.</li> </ul> <p>Posting a large number of warning signs on the ramp and its approach may contribute to a high driver workload as drivers attempt to understand the signs, adjust their speed appropriately, and accomplish a safe merge. Prioritization of the hazards on the tight curve, and the resulting signing requirements, may be beneficial.</p>
		√	<p><i>4. Use a berm to obstruct drivers' view of the abandoned highway alignment.</i> During the preliminary findings meeting (August 17, 2006), the design team discussed the possibility of providing a berm at the intersection of STH 11 and the Bypass. The berm could be positioned to obstruct eastbound drivers' view of the old STH 11 alignment. The berm should be outside the roadside clear zone (or designed with recoverable slopes), and should not obstruct sightlines at the new intersection.</p>

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**Road Safety Audit  
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Safety Issue 2: Limited Intersection Conspicuousness**

**Safety Issue 2(a): The absence of lighting at at-grade intersections limits visibility and conspicuousness.**

**Safety Issue 2(a) Description:** Current design drawings do not show luminaires at any location along the Bypass, including signalized and unsignalized intersections. The absence of lighting limits approaching drivers' awareness of intersections, and limits sight distance at intersections, where conflicts with vehicles (slowing and turning) and pedestrians (crossing) are most likely to occur. The varying intersection types along the Bypass (four-leg intersections, three-leg intersections, and jug-handle intersections) limit drivers' ability to anticipate intersection configurations, and therefore the possible conflicts at intersections, increasing the need for intersection lighting.

**Safety Issue 2(b): Current design drawings indicate a single overhead signal display at signalized intersections.**

**Safety Issue 2(b) Description:** The use of a single overhead signal head limits signal (and intersection) conspicuity for drivers approaching the intersection, and may limit signal visibility for drivers whose view of the single overhead display is compromised by a tall vehicle (such as a truck) ahead, or affected by a bright rising or setting sun. The risks associated with limited signal and intersection conspicuousness is greatest at the intersection with STH 83, where westbound drivers' view of the intersection ahead is limited by vertical and horizontal curves on the approach. Drivers who fail to observe the signal display increase the risk of angle and rear-end collisions. The risk and severity of collisions is increased by high approach speeds.

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**Expected Crash Types:** intersection collisions (all types)

**Expected Frequency:** occasional

**Expected Severity:** high

**Risk Rating:** D (moderate-high risk level)

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**Suggestions:**

1. *Provide lighting at intersections.* The NCHRP Report 500 (*Volume 5: A Guide for Addressing Unsignalized Intersection Collisions*) states that provision of lighting at unsignalized intersection

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should be targeted at intersections with a substantial pattern of night-time crashes. The Burlington Bypass has no crash history; however, the crash experience on similar facilities (the Whitewater and Oconomowoc Bypasses) suggests that lighting may be beneficial and should be considered. Although installation of lighting at isolated rural intersections may conflict with statewide practices concerning rural lighting, the following design elements that are present at all or some intersections increase the potential benefits that could be derived from intersection lighting:

ELEMENT	INTERSECTIONS (from west end to east end of Bypass)							
	STH 11 (west end)	STH 36	CTH P	Yahnke Rd	STH 83	STH 142	STH 11 (east end)	CTH A
channelization or auxiliary lanes on main line	√	√	√	√	√	√	√	√
limited sight distance on mainline					√			
horizontal curve on mainline approach(es)	√		√	√	√		√	√
unusual configuration (angle, offset, or jughandle)		√	√		√	√		√
downhill approach on mainline	√				√			√
high volume on cross street	√	√			√		√	
pedestrians anticipated					√		√	
high operating speed on cross street	√				√		√	

Experience on the Whitewater and Oconomowoc Bypasses suggests that lighting may be considered in association with the local road authority (the City of Burlington) to share the ongoing costs associated with lighting.

2. *Provide a redundant signal display on each approach.* The use of multiple overhead signal displays on a single approach enhances signal conspicuousness, provides redundancy in the event of signal failure or damage, and may improve signal visibility. Redundancy may be achieved by providing multiple signal overhead heads (such as one signal head over each approach lane).



Source: Iowa DOT



3. *Provide signal backplates with reflective borders.* The effectiveness of a yellow reflective border is shown below. The reflective border renders the signal more conspicuous under both daytime and night-time conditions. By outlining the perimeter of the backplate, the reflective tape also enables drivers to more easily distinguish the relative position of the lighted lens, assisting elderly and color-blind drivers who have poor color perception. Reflective borders on signal backplates have received interim approval from the FHWA<sup>1</sup>.



signals with (left) and without (right)  
reflective border at night\*



signals with reflective border  
in daytime

\* Source: Miska, deLeur, and Sayed,  
"Road Safety Performance Associated with Improved Traffic Signal Design and Increased Signal Conspicuity"

4. *Enhance intersection warning signs.* Signing plans show standard-size "Intersection Ahead" warning signs. The MUTCD advises that the minimum size is appropriate on low-speed roadways, but that oversized signs and larger sizes may be used for those applications where speed, volume, or other factors result in conditions where increased emphasis and improved recognition would be desirable. The use of larger size signs may be considered on the approaches to the intersections with Yahnke Road (where drivers' view of the intersection is limited by a horizontal curve) and CTH A (for drivers entering the Bypass, who may not expect an at-grade intersection).

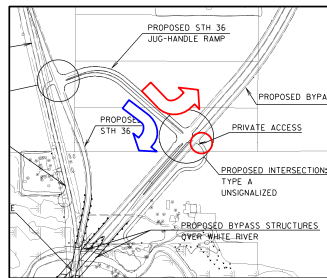
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<sup>1</sup> The interim approval was granted in February 2004 ([http://mutcd.fhwa.dot.gov/res-interim\\_approvals.htm](http://mutcd.fhwa.dot.gov/res-interim_approvals.htm)). The interim approval memorandum states (in part): "The use of retroreflective backplate borders appears to provide positive safety benefits at relatively low cost. Therefore, the FHWA intends to propose amending the MUTCD to specifically allow such borders in a future MUTCD rulemaking. The FHWA is issuing Interim Approval for this use so that this application may be used by jurisdictions who wish to do so pending the rulemaking."

**Road Safety Audit**  
**Burlington Bypass**  
**Safety Issue 3: Intersection Operations**

**Safety Issue 3(a): A high left-turn volume onto the Bypass ramp at STH 36 may increase the risk of rear-end and left-turn collisions on the Bypass.**

**Safety Issue 3(a) Description:** Traffic forecasts show a high left-turn volume from the SE STH 36 ramp on to the Bypass (*red arrow, right*). The high turning volume at this unsignalized intersection can be expected to increase the collision risk due simply to volume-related exposure. The risk and potential severity of collisions is increased by high approach speeds (posted speed 55 mph) on the Bypass.



The intersection complexity is increased by the presence of a private access that forms a fourth intersection leg (*red circle, right*). In the present design, vehicles turning into or out of the private access are accommodated only by a short taper for left-in movements. Accelerating or decelerating vehicles associated with this private access may interfere with through traffic on the Bypass, increasing the risk of collision. Currently, the risk is limited by low volumes on the private access, but future development may result in higher volumes and a higher risk.

Interference between right-turn movements from the ramp (*blue arrow, above*) and through traffic on the Bypass can also be anticipated, since a limited deceleration and acceleration taper is provided on the Bypass.

**Suggestions:** The audit team identified five suggestions that can be considered to enhance safety at this intersection:

- A signalized intersection may be considered to provide assured gaps for right- and left-turning drivers. A signal warrant may be applied for guidance. Signalization would require consideration of signal visibility at this intersection, where drivers' view of the signal may be obstructed by a horizontal curve (westbound traffic) and overpass structure (eastbound drivers). The use of a roundabout instead of a signal was discussed at the preliminary findings meeting, but a high-speed roundabout would likely require more land than is available, given right-of-way and environmental constraints.
- A slotted left-turn lane (using a corrugated median) may be considered for turns into the private access. A left turn lane would provide additional deceleration distance for left-turning drivers, who otherwise will need to slow in the left through lane, and provide additional storage space for queued vehicles in the event of future development.
- A parallel acceleration lane on the Bypass for right-turning traffic may be considered to allow right-turning drivers to accelerate for a longer distance before merging into the right Bypass lane.

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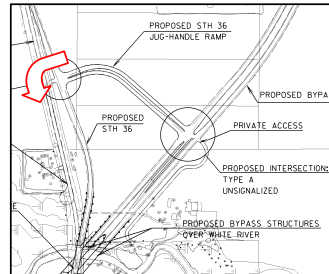
- An offset right turn lane (example at right) on the Bypass may be considered. The offset lane would provide a longer deceleration distance for drivers turning right onto the ramp, and would position these decelerating vehicles further right to reduce interference with sightlines between through traffic on the Bypass and drivers entering the Bypass (turning either left or right).



Source: Kentucky DOT

**Safety Issue 3(b): A high left-turn volume from the Bypass ramp onto STH 36 may increase the risk of rear-end and left-turn collisions on STH 36.**

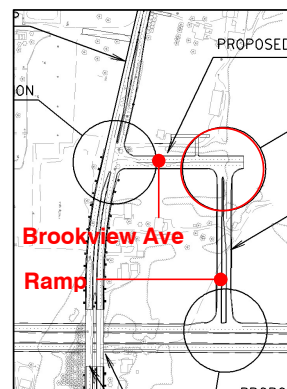
**Safety Issue 3(b) Description:** Traffic forecasts show a high left-turn volume from the Bypass ramp onto southbound STH 36 (right). The high turning volume at this unsignalized intersection may cause queuing on the ramp (where sight distance is limited by a horizontal curve for drivers exiting the Bypass), and an increased risk of left-turn collisions on STH 36. The risk and potential severity of collisions is increased by high approach speeds (posted speed 55 mph) on STH 36.



**Suggestion:** Install a signal or roundabout at the ramp intersection. The introduction of a signal at the intersection of STH 36 and the ramp may be considered if WMUTCD traffic signal warrants are satisfied. Alternatively, the design team may consider providing a roundabout at this intersection to accommodate the substantial through and left-turn volumes. A preliminary review suggests that sufficient right of way is available to accommodate a roundabout.

**Safety Issue 3(c): Substantial turning movements at the intersection of the CTH P ramp and Brookview Avenue may lead to turning conflicts and queuing on the ramp.**

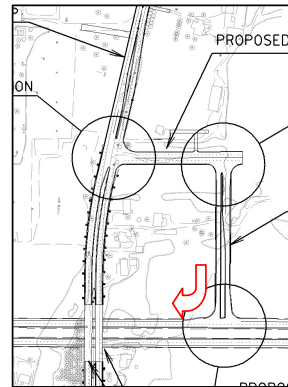
**Safety Issue 3(c) Description:** The CTH P ramp intersects Brookview Avenue at a "T" intersection (red circle, right). Traffic forecasts show a substantial volume on the ramp and Brookview Avenue, reflecting existing demand as well as future development of an industrial park on the site adjacent to the intersection. All-way STOP control at the intersection may lead to substantial delays, resulting in undesirable queuing on the ramp. Two-way STOP control, which would likely require drivers exiting the industrial park and drivers on Brookview Avenue to stop, may result in driver confusion when stopped drivers fail to anticipate that the ramp approach is uncontrolled.



**Suggestion:** *Install a roundabout at the “T” intersection.* The design team may consider providing a roundabout at this intersection to accommodate the substantial through and turning volumes on the ramp and Brookview Avenue. A preliminary review suggests that sufficient right of way is available to accommodate a roundabout. Although the industrial park is not expected to be developed until after completion of the Bypass, construction of a roundabout at the time of Bypass construction may be less costly than future re-configuration of the “T” intersection.

**Safety Issue 3(d): Drivers turning right from the CTH P ramp may interfere with through traffic on the Bypass.**

**Safety Issue 3(d) Description:** Interference between right-turn movements from the ramp (*red arrow, right*) and through traffic on the Bypass can be anticipated, since a limited deceleration and acceleration taper is provided on the Bypass. Interference between right-turning and through traffic is likely at this intersection, since the ramp provides access to trucks (which typically have slow acceleration characteristics) associated with the JW Peters Quarry and the future industrial park.



**Suggestions:** A parallel acceleration lane on the Bypass for right-turning traffic may be considered to allow right-turning drivers to accelerate for a longer distance before merging into the right Bypass lane. At this location, a longer acceleration lane may require widening of the adjacent overpass structure.

An offset right turn lane (*example shown above under Safety Issue 3(a)*) on the Bypass may be considered. The offset lane would provide a longer deceleration distance for drivers turning right onto the ramp, and would position these decelerating vehicles further right to reduce interference with sightlines between through traffic on the Bypass and drivers entering the Bypass (turning either left or right).

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<b>Expected Crash Types:</b>	intersection crashes
<b>Expected Frequency:</b>	occasional
<b>Expected Severity:</b>	high
<b>Risk Rating:</b>	D (moderate-high risk level)

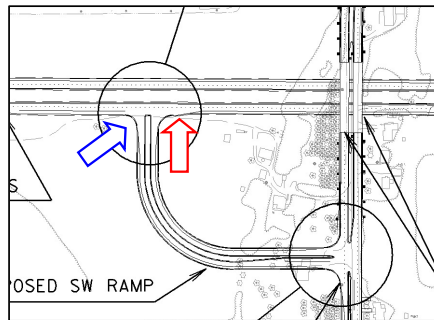
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**Suggestions:** Suggestions for each intersection are discussed separately above. The design team may consider the advisability of widespread adoption of some improvement measures (at most or all Bypass intersections) to maintain consistency for drivers on the Bypass.

**Road Safety Audit  
Burlington Bypass  
Safety Issue 4: Intersection Geometrics**

**Safety Issue 4(a): Auxiliary lane lengths at five ramps appear to be short, and ramp entry turn radii appear to be abrupt.**

**Safety Issue 4(a) Description:** Five interchange ramps or intersections include short right-turn acceleration lanes (usually of a tapered design), often limited by adjacent structures or upstream features. The short tapered acceleration lanes limit right-turning drivers' ability to accelerate to highway speed before merging into the right through lane. Slower vehicles, especially slowly-accelerating trucks, may interfere with through traffic on the Bypass, increasing the risk of rear-end and sideswipe collisions. Drivers who fail to merge may leave the travel lane, resulting in off-road and fixed-object collisions.



**Example (ramp at CTH P and the Bypass):**  
A short acceleration lane is provided (red arrow, likely due to the overpass structure), and the right-turn radius onto the ramp (blue arrow) appears to be abrupt.

For drivers exiting the Bypass, all deceleration lanes appear to have been designed to the minimum length advised in the AASHTO Green Book. Six ramps or intersections have been designed with an entry curve having a design speed of 30 mph, which is at the lower limit of the AASHTO ramp design speed for a highway design speed of 60 mph (Bypass design speed). If drivers approaching a ramp from highway speeds fail to slow sufficiently (as they might where deceleration lanes are minimum length), they may strike the ramp median or enter the opposing lane of traffic on the ramp.

Ramps and intersections (going west to east) to which these observations apply are:

- STH 36: short tapered acceleration lanes, tight right-turn radius
- CTH P (two ramps): short tapered acceleration lanes, tight right-turn radius
- Buck Trail Archers Club: no deceleration and acceleration lanes, right right-turn radius
- Yahnke Road: short tapered deceleration and acceleration lanes, tight right-turn radius
- STH 142 (two ramps): tight right-turn radius
- CTH A: short tapered acceleration lane, tight right-turn radius

**Suggestions:**

1. *Provide an offset right turn lane:* An offset right turn lane (example shown above under Safety Issue 3(a)) on the Bypass may be considered. The offset lane would provide a longer deceleration distance for drivers turning right onto the ramp, and would position these decelerating vehicles further right to reduce interference with sightlines between through traffic on the Bypass and drivers entering the Bypass (turning either left or right).

2. *Provide a parallel acceleration lane:* A parallel acceleration lane on the Bypass for right-turning traffic may be considered to allow right-turning drivers to accelerate for a longer distance before merging into the right Bypass lane. Longer acceleration lanes may particularly assist older drivers, whose ability to view mainline traffic may be compromised. At most interchange locations, a longer acceleration lane may require widening of the adjacent overpass structure.

3. *Provide enhanced curve delineation and signing.* To assist drivers on tight right-turn ramp and intersection curves, the use of post-mounted delineators and wide (6 inches or wider) edgelines may be considered. A W13-2 (Advisory Ramp Speed) sign (*right*) may be posted on the ramp to advise drivers of the substantially slower ramp speed.

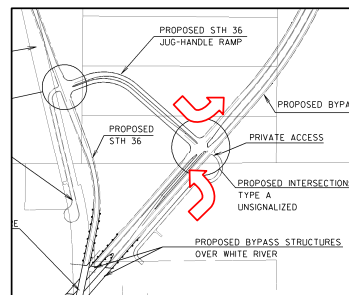


4. *At Yahnke Road/Buck Trail Archers Club, provide facilities for decelerating and accelerating vehicles.* Bypass drivers may fail to anticipate accelerating, decelerating, and turning traffic at this relatively minor intersection. Although limited traffic is expected to access Yahnke Road and the Archers Club, transient peaks may be experienced following Club events, and future development may increase regular traffic. To better accommodate traffic turning right into Yahnke Road or the Club driveway, a full width paved shoulder may be provided. To better accommodate traffic turning left, offset left turn lanes may be considered in the median.

**Safety Issue 4(b): Unsignalized left turns at at-grade intersections on the Bypass generate a risk of high-speed left-turn collisions, which may be potentially severe.**

**Safety Issue 4(b) Description:** Three ramp or road intersections involve an unprotected left turn across two lanes of opposing or crossing Bypass traffic. The risk and potential severity of left-turn crashes is aggravated by:

- high speeds on the Bypass
- forecast high left-turn volumes at CTH A and STH 36 ramps, which increases exposure
- absence of night-time lighting
- a high proportion of trucks (with slower acceleration and braking capabilities) in forecast Bypass and ramp traffic
- winter road conditions (contributing to poor acceleration and braking capabilities) and the potential for fog (contributing to limited sight distance) in low-lying areas around rivers.



**Example (ramp at STH 36 and the Bypass):** Left turns from and onto the ramp must cross two lanes of Bypass traffic.

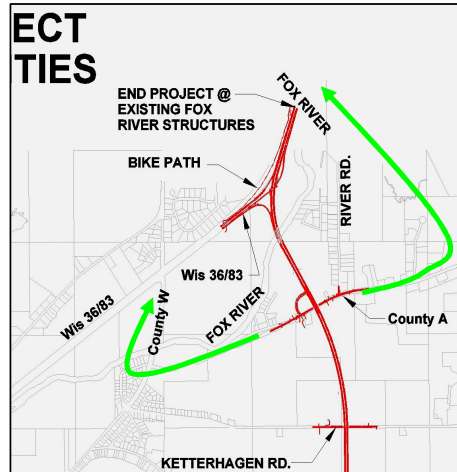
Ramps and intersections (going west to east) to which these observations apply are:

- STH 36
- Buck Trail Archers Club/Yahnke Road
- CTH A

**Suggestions:**

Signalization of ramps may be considered, but the addition of two signals to the Bypass may be operationally undesirable. Although signalization remains an option, three alternative suggestions can be considered by the design team:

1. *Restrict left turns from the CTH A ramp onto the Bypass.* To reduce the risks associated with left turns from the CTH A ramp onto the Bypass, the ramp configuration may be revised to eliminate this movement. A review of the road network in the area of the CTH A interchange indicates that convenient alternative routes, which would involve less apparent risk, are readily available for users of CTH A to access STH 36/83 (which is the destination of drivers turning left from the CTH A ramp onto the Bypass) (*right*).



2. *Reserve right-of-way to construct a double jughandle.* Left turns onto and from the Bypass are required at the single jughandle interchanges (at CTH A and STH 36), but are not required at the double jughandle interchanges (CTH P and STH 142 interchanges) that utilize only right-in-right-out movements on the Bypass. If frequent or severe left-turn collisions occur at the single jughandle interchanges following the opening of the Bypass, conversion of the single jughandle to a double jughandle may be desirable. As there is currently little or no development in the vicinity of the interchanges, the Owner may consider early acquisition of right-of-way in the diagonal quadrants of the CTH A and STH 36 interchanges, so that the option to introduce a second jughandle can be more easily implemented.

3. *Provide a guiding line to facilitate left turns onto ramps.* To facilitate left turns from the Bypass onto jughandle ramps, and direct left-turning drivers to the correct lane on the jughandle ramp (where adjacent entry and exit lanes may be difficult to distinguish from each other), dotted lane line extensions may be painted along the path that left-turning drivers should take to enter the correct lane on the ramp.

**Expected Crash Types:** sideswipe, rear-end, and fixed-object collisions

**Expected Frequency:** occasional

**Expected Severity:** high

**Risk Rating:** D (moderate-high risk level)

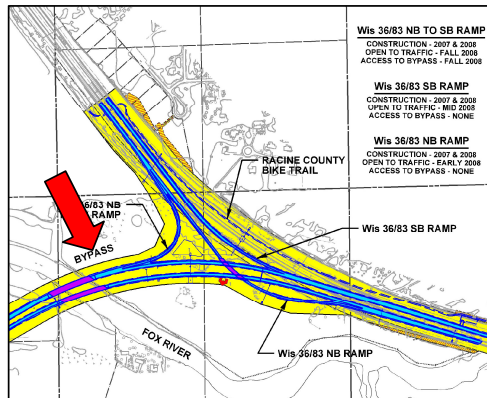
**Suggestions:** Suggestions for each intersection are discussed separately above. The design team may consider the advisability of widespread adoption of some improvement measures (at most or all Bypass intersections) to maintain consistency for drivers on the Bypass.



**Road Safety Audit  
Burlington Bypass  
Safety Issue 5: High Driver Workload**

**Safety Issue:** A required merge on a horizontal curve contributes to a high driver workload at the north interchange.

**Safety Issue Description:** Drivers entering the Bypass from Hwy 36/83 enter a reverse curve (*right*) before encountering a required merge movement on segment of roadway having horizontal and vertical curves. The merge will take place on a bridge over the Fox River, where icy pavement and foggy conditions may prevail. The challenging geometric features are in part the result of severe constraints reflecting limited right-of-way and environmental limitations.



Acceleration and merging on a curved roadway contribute to a high driver workload, which may be aggravated by poor visibility or pavement conditions due to fog or ice. In addition to the challenging geometry of the ramp, proposed guide signing provides a large amount of information that drivers must process as they navigate the curve and merge.

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<b>Expected Crash Types:</b>	off-road, rear-end, and sideswipe collisions
<b>Expected Frequency:</b>	occasional
<b>Expected Severity:</b>	high
<b>Risk Rating:</b>	D (moderate-high risk level)

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**Suggestions:** It is suggested that upgrades to the signing and pavement markings be considered for the horizontal curve. These include:

- *Flourescent Yellow Warning Signs:* Due to the high driver workload for this curve, it is suggested that all speed waring signs and advisory panels on guide signs use brighter flourescent yellow sheeting as a means to encourage drivers to slow down.

- *Converging Chevron Pavement Markings:* Another way to get the driver's attention that they should slow down through this curve is through the use of the converging chevron pavement marking scheme. This measure has been shown to reduce speeds in advance of high speed ramp curves with high driver workload. Converging chevrons are currently used on the ramp from I-94 West to I-43 South on the Mitchell Interchange.

**Road Safety Audit  
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Safety Issue 6: Accommodating Pedestrians and Cyclists**

**Safety Issue 6(a): An at-grade bicycle trail crossing over Hwy 36/83 exposes cyclists to several lanes of high-speed traffic.**

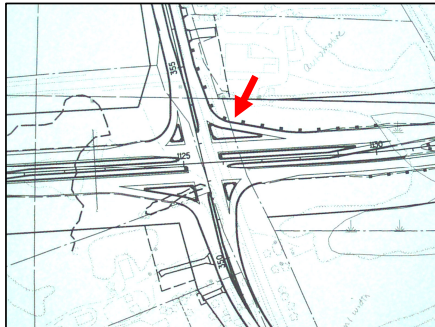
**Safety Issue Description:** The new north interchange will require relocation of an existing County bicycle trail from the south side of STH 36/83 to the north side of the highway. Bicyclists will be directed to an at-grade mid-block crossing over STH 36/83 (*right*), where they will cross a divided four-lane highway having a posted speed of 55 mph.

The risk of collision is increased by the high speeds, the need to cross multiple lanes (*right*), absence of lighting, potentially high proportion of trucks (which have reduced braking ability), and the possible presence of young and/or inexperienced cyclists on the County bike trail.



**Safety Issue 6(b): A guardrail obstructs pedestrian access to a signalized intersection.**

Design drawings show a continuous guardrail in the northeast corner at the intersection of the Bypass with STH 83. The guardrail obstructs pedestrian access to the intersection, which has pedestrian crossing facilities.



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**Expected Crash Types:** bicycle collisions and secondary rear-end collisions

**Expected Frequency:** rare

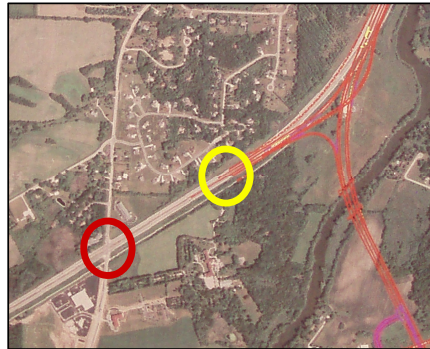
**Expected Severity:** high

**Risk Rating:** B (low risk level)

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**Suggestions:**

1. *Relocate bicycle crossing:* The design team may consider relocating the planned bicycle trail crossing from its proposed location to the signalized intersection at CTH W (red circle at right). Relocation of the crossing would allow cyclists to cross with the signal at a lighted intersection, where drivers may more readily expect and see them.



Discussions at the preliminary findings suggest that relocating the crossing would place a segment of new trail on a steep slope, where a retaining wall may be required. The retaining wall may increase costs and impact nearby residents. Alternatively, the bicycle trail may be redirected away from the highway along local residential roads (using bike route signs and/or pavement markings), reconnecting with the existing trail where topographic constraints are not so severe.

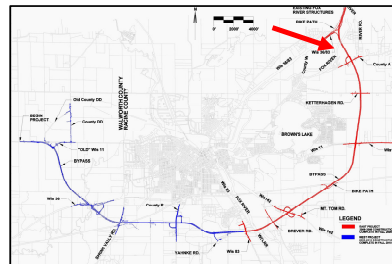
2. *Provide barrier break to allow pedestrian access.* Design drawings may be amended to provide a crashworthy break in the barrier at the STH 83 intersection to allow pedestrian access to the intersection without compromising the performance of the barrier in a crash. Pedestrian visibility should be considered in the redesign of the barrier.

**Road Safety Audit  
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Safety Issue 7: Weather-Related Issues**

**Safety Issue: Icy and foggy conditions may aggravate the risk of collisions.**

**Safety Issue Description:** The Bypass is located in a wetlands area where the alignment will require three river/lowland crossings. These environmental elements increase the risks associated with:

- *Icy Pavement:* Since bridges typically freeze before adjacent road segments on grade, drivers may fail to anticipate icy conditions on bridges. The risks associated with a slippery road surface are substantial at the north interchange bridge (*red arrow, right*), as described under Issue 5 above.
- *Foggy Conditions:* Foggy conditions can be frequently encountered in wetland and river areas. Visibility may be unexpectedly and intermittently reduced in foggy areas.



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<b>Expected Crash Types:</b>	off-road collisions
<b>Expected Frequency:</b>	occasional
<b>Expected Severity:</b>	high
<b>Risk Rating:</b>	D (moderate-high risk level)

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**Suggestions:**

*Introduce measures to increase driver guidance and warning.* Improved driver guidance and warning may be achieved using the following methods:

- roadway and/or intersection lighting (discussed in Issue 2),
- wide 6-inch edgelines (discussed in Issue 1),
- shoulder and centerline rumble strips (discussed in Issue 1).

The latter two measures may be combined by introducing edgeline rumble strips, formed by painting edgelines over rolled or milled rumble strips. The presence of paint on the vertical rumble

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strip faces provides enhanced delineation, particularly during wet weather. Similarly, centerline rumble strips may be considered. Discussions during the preliminary findings meeting indicate that edgeline and centerline rumble strips have been implemented already on STH 51 south of Madison (centerline) and I-39 near Wisconsin Rapids (edgeline).

*Improve pavement friction.* Improved pavement friction may be achieved using automatic de-icing on bridges. An automatic de-icing system was piloted in Wisconsin at a site on STH 50 east of US 45.

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- Road Safety Engineering
- Traffic Operations
- Transportation Planning
- Transit and Sustainability
- Community & School Safety
- Asset Management