WisDOT Work Zone Traffic Analysis Tool Update

December 7th, 2023

PROVIDING TRAFFIC ENGINEERING SOLUTIONS

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Subject: Work Zone Traffic Analysis Tool Update
Work Zone Traffic Analysis Tool Development
I.D. 0656-17-20

PART A – INTRODUCTION

The *Statewide Work Zone Capacity Analysis (I.D. 0656-43-01)* project was completed in August 2020 with the release of Version 4.2 of the Work Zone Traffic Analysis Tool (WZTAT). As part of this first study (herein referred to as the "original study"), Wisconsin-specific work zone capacity and queueing models were developed that serve as the cornerstone of the analysis performed in the WZTAT. To validate the work zone capacity and queueing models presented in the original project, the Wisconsin Department of Transportation (WisDOT) hired TADI to collect and analyze additional work zone data in the summer and fall of 2022 (herein referred to as the "validation study").

In addition to capacity/queue model validation, WisDOT requested expanded diversion analysis capabilities within the WZTAT. WZTAT version 4.2 has a user input for diversion. The input is available for each direction and is applied to all analysis hours. However, the diversion input is not automated and must be manually entered by the user. It is a percentage input, where the user of the tool estimates the percent diversion expected based on past experiences (*a priori*) and engineering judgement. WisDOT requested an update to the WZTAT tool which would provide an automated diversion estimate.

Also, after multiple years of use, WisDOT provided comments and feedback on WZTAT Version 4.2 from the regional work zone engineers regarding changes and/or updates they wanted to be included in the next build version of the tool.

Therefore, the goals of the *Work Zone Traffic Analysis Tool Development (I.D. 0656-17-20)* revision project were threefold:

1. Validate the existing work zone capacity and queueing models using empirical data.
2. Enhance the diversion analysis capabilities in the WZTAT.
3. Implement additional revisions to the WZTAT based on user feedback.

This technical memorandum summarizes the data collection efforts, documents the model validation process, and outlines recommendations for the capacity and queue models based on the newly collected data. This memo also presents the development of a diversion model and how it is implemented into the tool. Lastly, this memo describes other updates made to the WZTAT based on feedback from the regional work zone engineers.

PART B – WORK ZONE CAPACITY AND QUEUE MODEL VALIDATION

B.1 – Data Collection

Data were collected and processed using the same methodology as the original study. Nine total lane closures were analyzed from locations within the North Central, Northeast, Northwest, and Southwest regions during the summer and fall of 2022, as shown in Figure 1. Video footage was obtained by on-site cameras and, if available, closed-circuit television (CCTV) footage was retrieved from the statewide Traffic Management Center (TMC) monitoring cameras.

In total, 25 different days/times were processed for analysis. Sixteen observations included queueing and nine did not, as shown in Table 1. Sites with queueing were compared to the existing work zone capacity model (Version 4.2) to validate the model. Sites without queueing were used as an additional check on the work zone capacity model since when queueing is not observed, the observed flow rate should not routinely exceed the model's capacity estimate.

Figure 1. Collection Sites

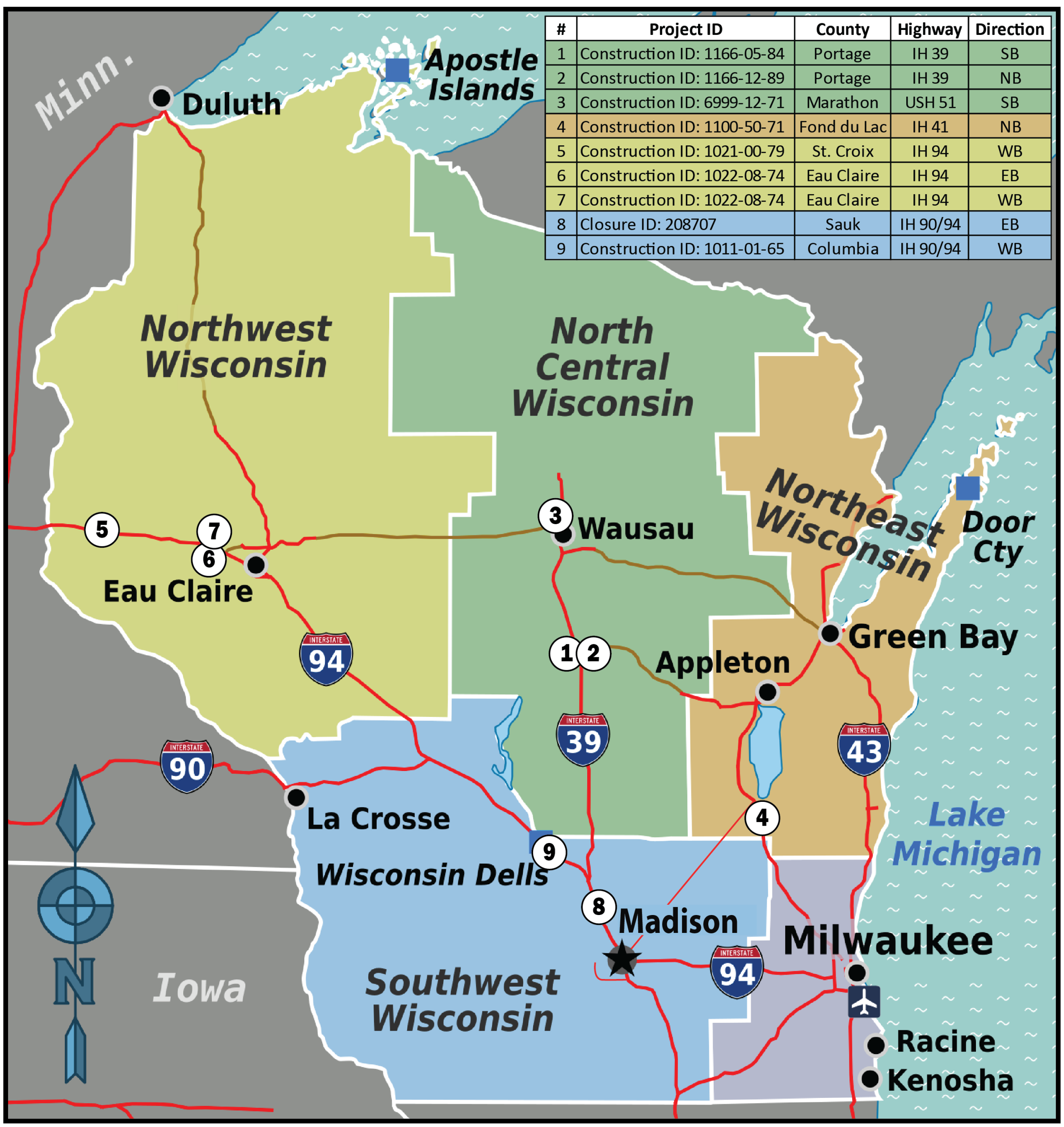


Table 1. Processed Observations

	#	Project ID	Region	County	Highway	Direction	Date	Closure Type	Barrier	T.O.D.	Area Type	Cons. Intensity
Observed Queueing	1	Construction ID: 1166-05-84	North Central	Portage	IH 39	SB	9/18/2022	2 to 1	Soft	Day	Rural	Low
	4	Construction ID: 1100-50-71	Northeast	Fond du Lac	IH 41	NB	9/29/2022	2 to 1	Soft	Day	Urban	High
	4	Construction ID: 1100-50-71	Northeast	Fond du Lac	IH 41	NB	9/29/2022	2 to 1	Soft	Day	Urban	High
	4	Construction ID: 1100-50-71	Northeast	Fond du Lac	IH 41	NB	9/30/2022	2 to 1	Soft	Day	Urban	High
	4	Construction ID: 1100-50-71	Northeast	Fond du Lac	IH 41	NB	10/7/2022	2 to 1	Soft	Day	Urban	High
	6	Construction ID: 1022-08-74	Northwest	Eau Claire	IH 94	EB	8/17/2022	2 to 1	Soft	Day	Rural	High
	6	Construction ID: 1022-08-74	Northwest	Eau Claire	IH 94	EB	8/23/2022	2 to 1	Soft	Day	Rural	High
	6	Construction ID: 1022-08-74	Northwest	Eau Claire	IH 94	EB	8/24/2022	2 to 1	Soft	Day	Rural	High
	7	Construction ID: 1022-08-74	Northwest	Eau Claire	IH 94	WB	8/18/2022	2 to 1	Soft	Day	Rural	Low
	7	Construction ID: 1022-08-74	Northwest	Eau Claire	IH 94	WB	9/1/2022	2 to 1	Soft	Day	Rural	Low
	7	Construction ID: 1022-08-74	Northwest	Eau Claire	IH 94	WB	9/1/2022	2 to 1	Soft	Day	Rural	Low
	8	Closure ID: 208707	Southwest	Sauk	IH 90/94	EB	10/31/2022	2 to 1	Soft	Day	Urban	High
	8	Closure ID: 208707	Southwest	Sauk	IH 90/94	EB	11/1/2022	2 to 1	Soft	Day	Urban	High
	8	Closure ID: 208707	Southwest	Sauk	IH 90/94	EB	11/2/2022	2 to 1	Soft	Day	Urban	High
	9	Construction ID: 1011-01-65	Southwest	Columbia	IH 90/94	WB	11/2/2022	3 to 1	Soft	Night	Rural	High
	9	Construction ID: 1011-01-65	Southwest	Columbia	IH 90/94	WB	11/3/2022	3 to 1	Soft	Night	Rural	High
No Observed Queueing	1	Construction ID: 1166-05-84	North Central	Portage	IH 39	SB	9/11/2022	2 to 1	Soft	Day	Rural	Low
	2	Construction ID: 1166-12-89	North Central	Portage	IH 39	NB	9/15/2022	2 to 1	Soft	Day	Rural	High
	2	Construction ID: 1166-12-89	North Central	Portage	IH 39	NB	9/16/2022	2 to 1	Soft	Day	Rural	High
	2	Construction ID: 1166-12-89	North Central	Portage	IH 39	NB	9/17/2022	2 to 1	Soft	Day	Rural	High
	3	Construction ID: 6999-12-71	North Central	Marathon	USH 51	SB	9/13/2022	2 to 1	Soft	Day	Rural	High
	3	Construction ID: 6999-12-71	North Central	Marathon	USH 51	SB	9/14/2022	2 to 1	Soft	Day	Rural	High
	3	Construction ID: 6999-12-71	North Central	Marathon	USH 51	SB	9/15/2022	2 to 1	Soft	Day	Rural	High
	5	Construction ID: 1021-00-79	Northwest	St. Croix	IH 94	WB	10/5/2022	2 to 1	Soft	Day	Rural	High
	9	Construction ID: 1011-01-65	Southwest	Columbia	IH 90/94	WB	11/1/2022	3 to 1	Soft	Night	Rural	High

B.2 – Existing Work Zone Capacity Model Comparison

Using information from the traffic management plans (TMP) and field observations for the nine construction projects used in analysis, a WisDOT existing work zone model (Figure 2) estimated queue discharge rate (QDR) was estimated for each of the 25 days/times analyzed:

Figure 2. WisDOT Existing Work Zone Capacity Model

$$\boxed{Average\ QDR_{PCE} = 1{,}866 - 40f_{LCSI} - 132f_{barrier} - 101f_{TOD} - 205f_{area} - 207f_{CI} - 47f_{regional}}$$

where,

$Average\ QDR_{PCE}$ = average queue discharge flow rate (pc/hr/ln),

f_{LCSI} = lane closure severity index; $\frac{1}{\#\ of\ open\ lanes * open\ ratio}$, where open ratio is the ratio of open lanes during construction to the total number of lanes,

$f_{barrier}$ = barrier type; concrete = 0, cone/barricade/drum = 1,

f_{TOD} = time of day; day = 0, night = 1,

f_{area} = area type; urban =0, rural = 1,

f_{CI} = construction intensity; low = 0, high = 1, and

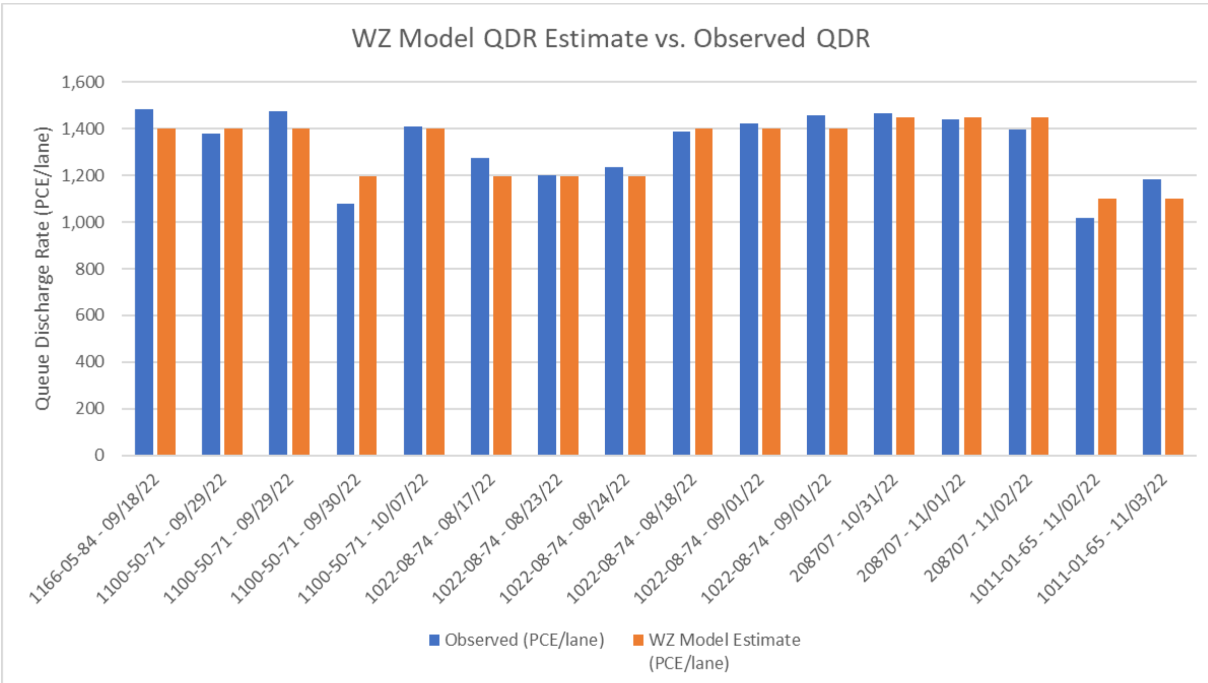
$f_{regional}$ = regional area; south = 0, north = 1.

The queue discharge spreadsheets for all 25 observations are included in Appendices A & B.

B.2.1 – Comparisons for Sites with Observed Queueing

The estimated QDR for the sites with observed queueing were compared to the observed QDR for each location. Observed QDRs were derived from the count data during the length of time of the queueing period, which ranged from 15 minutes to multiple hours in length. The model's estimates were similar to what was observed in the field. While there were some differences, the overall observed QDR was approximately one percent higher than the model's estimates. Differences in individual observations are attributable to natural variations in QDR. The comparisons are shown in Figure 3.

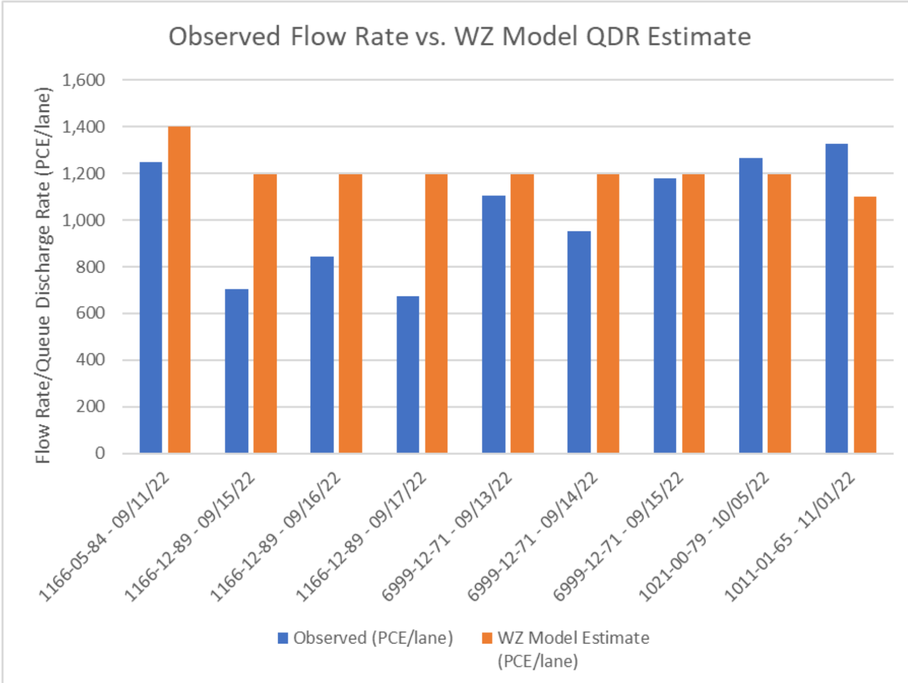
Figure 3. WisDOT Existing Model Comparison to Observed



B.2.2 – Comparisons for Sites without Observed Queueing

As previously stated, nine of the 25 locations did not experience any queueing during the observed period. A WisDOT existing work zone model estimated QDR was calculated for each of these sites to compare to the observed flow rate. When no queue is observed, the observed flow rate should be near or below WisDOT's existing work zone model estimated QDR values. The highest 15-to-30-minute flow rates were used in the comparison to ensure the highest observed flow rates were compared to the estimated QDR. In seven of the nine locations, the observed volumes did not exceed the estimated QDR, as shown in Figure 4. In the other two locations (1021-00-79 and 1011-01-65), observed volumes exceeded the estimated QDR. Additional analysis regarding these observations are provided in the subsequent text.

Figure 4. WisDOT Existing Model Comparison to Non-Queueing Observations



The 1021-00-79 – 10/05/22 location on I-94 WB in St. Croix County in the Northwest Region observed a flow rate approximately 5.7% higher than the estimated QDR. Per the Highway Capacity Manual 6th Edition (HCM6), the pre-breakdown capacity of a freeway work zone is approximately 13.4% higher than the QDR, so the 1021-00-79 – 10/05/22 observation falls within that range and therefore avoided breakdown conditions.

The 1011-01-65 – 11/01/22 observation from I-90/94 WB in Columbia County in the Southwest Region observed a flow rate approximately 20.5% higher than the estimated QDR. This overage was likely due to the timing of the lane closures. This site was a 3-lane to 1-lane closure at night and the difference in observed volumes and the model's estimated capacity is larger than would be expected, as noted above. It is unclear why the additional volume was able to travel through the work zone without queueing, but it is possible that only a single lane may have been closed during the observation period rather than the expected double lane closure, which may have actually occurred later in the night.

B.2.3 - Work Zone Capacity Model Recommendation

Based on the newly collected data, which came from four different regions within the state, including the North Central Region which was without a work zone project included in the original study, no changes are recommended to be made to the WisDOT work zone capacity model shown in Figure 2. As shown in Section B.2.1, the observed QDRs are comparable to the model estimated QDR, with the overall total observed QDR being only one percent higher than the overall total estimated QDR. In addition, most of the sites without queueing experienced flow rates below the estimated QDR. Only one observation was substantially higher than the estimated QDR and that was likely the result of the timing of the double lane closure.

B.3 – Existing Work Zone Queue Model Comparison

To recap the original study, work zone queues are generally characterized by moving queues rather than stand-still queues. Using a stand-still queue spacing estimate of 25 feet per vehicle would underestimate work zone queues. Moving queues typically have more space between vehicles than stand-still queues, and the faster the average speed of a moving queue, the larger the spacing becomes. The original study utilized the HCM6 speed/density relationship and a work zone average speed estimate equation from *A Primer on Work Zone Safety and Mobility Performance Measurement* by the Federal Highway Administration (FHWA) to provide the recommended work zone queue spacing model shown in Figure 5.

Figure 5. WisDOT Existing Queue Spacing Model

$$Average\ PCE\ Headway = (3.1495)\left(\frac{FFS}{2}\right)\left(1-\left(1-\frac{WZ\ QDR * \#\ of\ open\ lanes}{FFC * \#\ of\ normal\ lanes}\right)^{\frac{1}{2}}\right) + 27.789$$

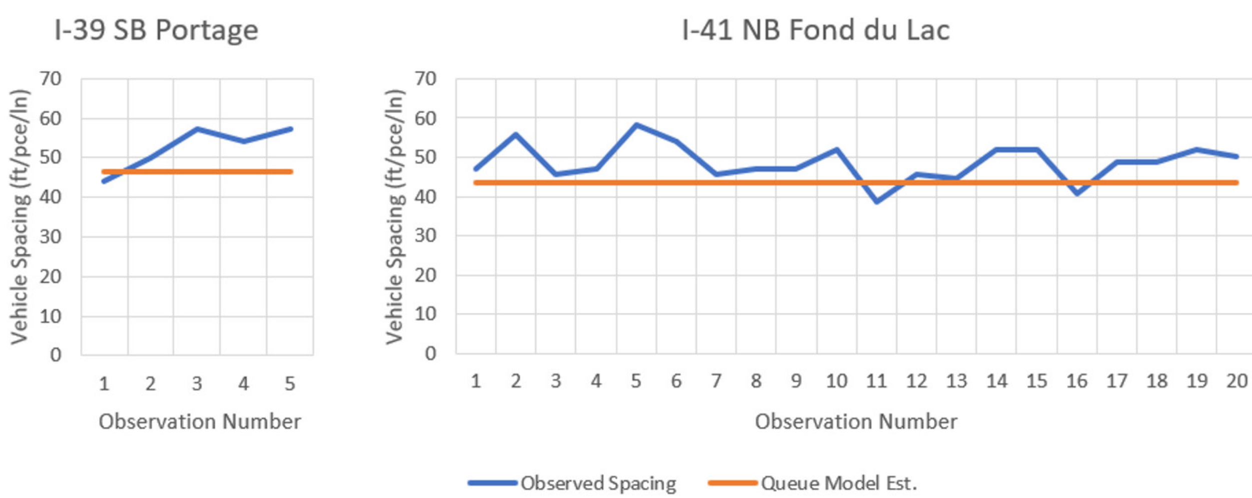
where,

FFS = free flow speed (mi/hr),
WZ QDR = work zone queue discharge rate (pc/hr/ln), and
FFC = free-flow capacity (pc/hr/ln).

B.3.1 – New Field Data

In the validation study, new data was collected in 2022 to test and validate the WZTAT queue model. Collecting such data is challenging since long queues are needed on segments of freeway without upstream on- or off-ramps. The project team was able to obtain queueing observations from two of the nine work zone sites that data was collected at during summer/fall 2022 and had a total of 25 observations. In Figure 6, the 25 queueing observation samples are compared to the queue spacing estimated by the WZTAT.

Figure 6. Queue Spacing Samples vs. WisDOT Queue Model Estimate



The 1166-05-84 observation from I-39 SB in Portage County in the North Central Region observed queue spacing utilizing a taper camera and an upstream camera. Five queue spacing samples were obtained on September 18, 2022. When queue speeds were observed at both the taper camera and the upstream camera, a queue space sample was able to be obtained. The average observed spacing was 52.5 feet, while the WisDOT queue model estimate based on the characteristics of the work zone site was 46.5 feet. The observed queue spacing was approximately 13% higher than the model-estimated spacing.

The 1100-50-71 observation from I-41 NB in Fond du Lac County in the Northeast Region collected queue spacing utilizing CCTV camera that observed multiple miles of freeway. When queue speeds were observed the entire distance of freeway, a queue space sample was able to be obtained. Twenty queue spacing samples were obtained from September 29, September 30, and October 7, 2022. The average observed spacing was 48.7 feet, while the WisDOT queue model estimate based on the characteristics of the work zone site was 43.5 feet. The observed queue spacing was approximately 12% higher than the model-estimated spacing.

B.3.2 – Early Merging Notice

As noted in the original study, the queue model assumes full utilization of the available lanes for queueing. There are some circumstances where motorists may merge much earlier than at the beginning of the designated taper. When this happens, the resulting queue may be longer than the model's prediction because vehicles stack in fewer lanes than are available. The current WZTAT tool does not account for early merging.

B.3.3 – Work Zone Queue Model Recommendation

The queue spacing observed was slightly higher than the estimated queue spacing at both new data sites. However, they both observed larger queue spacing than the static value of 30 or 40 feet previously used in WisDOT tools before the original study. The newly collected queueing data yielded results consistent with the findings of the 2020 study. Therefore, no modifications to the WisDOT work zone queue model shown in Figure 5 are recommended at this time.

PART C – TRIP SHIFT/DIVERSION MODEL AND DISTRIBUTION MODEL DEVELOPMENT

C.1 – Background

Reduction in travel demand through a work zone is primarily the result of two factors: *diversion* and *trip shift*. Both are defined below:

Diversion is when a driver is traveling on the highway with a work zone and diverts to an alternate route to bypass the work zone. Typically, the driver exits the highway once they see a queue or become aware one is occurring, and later returns to the highway, downstream of the lane closure.

Trip shift is when drivers modify their travel plans due to the presence of a work zone. This can include changing the time or day of their trip, taking a substantially different route, stopping for an extended period to eat or shop until the delay has decreased, or cancelling their trip altogether.

Both diversion and trip shifts decrease the volume of vehicles passing through the work zone. With states adding or enhancing lane closure systems and with drivers having access to live traffic route mapping services such as Google Maps or Waze, the number of drivers that trip shift or divert is likely greater than in the past.

C.2 – Data Obtention/Collection

Queue and volume data were obtained from four work zones that had substantial queuing for use in the trip shift/diversion model development. The maximum observed queues were provided for each work zone and were used to calibrate the model. WisDOT work zone engineers provided data for three sites listed below:

- USH 51 NB in Marathon County *(I.D. 1176-22-73)*
  - maximum queue observed was about 7.0 miles on Memorial Day weekend 2022
- IH 39 SB in Portage County *(I.D. 1166-12-89)*
  - maximum queue observed was about 2.0 miles on Labor Day weekend 2022
- IH 90/94 EB in Juneau County *(unknown project I.D.)*
  - maximum queue observed was about 7.0 miles on Independence Day weekend 2022

In addition, data were collected at a fourth site on IH 43 in Green Bay, Wisconsin specifically for use in this validation study. The approximate maximum queue length was observed from CCTV video provided by the TMC.

- IH 43 NB in Brown County *(I.D. 1220-21-60)*
    - maximum queue observed was about 2.5 miles in May 2023

C.3 – Trip Shift/Diversion Model Development

Drivers, when presented with a delay inducing work zone, have varying approaches to their travel decisions. Based on surveys conducted in a study titled "*Development of a Traffic Diversion Estimation Model for Freeway Construction Work Zones"* [1], there are three types of drivers regarding work zones.

1. *Resigned Drivers:* These drivers will always go through the work zone irrespective of the traffic conditions.
2. *Aware Drivers:* These drivers might or might not choose to travel through the work zone. They possess sufficient information about the work zone and prevailing traffic conditions to make an informed decision before beginning their journey.
3. *Avoiders:* These drivers will always circumvent the work zone, opting to completely change their route due to the unpredictability of travel times through the work zone.

These distinctions are crucial for understanding work zone capacity and queue estimates. Due to behaviors of *aware drivers* and *avoiders*, the theoretical number of vehicles passing through a work zone is expected to consistently be lower than the overall demand. Based on the information derived from the four work zone sites identified above, there is evidence that that the higher the demand is over the work zone QDR, the greater number of *aware drivers* will shift their trip or divert to another route, and some (i.e., *avoiders*) appear to always adjust their trip.

This led to the development of a power function model for trip shift/diversion estimates, shown in Figure 7. A power function with an exponent greater than one is appropriate for the trip ship/diversion model because as the demand increases compared to the QDR, the rate of the trip shift/diversion percentage also increases. In other words, as a work zone becomes busier due to increasing demand, more drivers will choose to avoid the work zone.

Microsoft Excel's Solver function was utilized to estimate the adjustment factors to best fit the maximum queue data from the four work zone sites listed in Section C.2. Figure 7 uses a demand-to-QDR ratio to estimate the trip shift/diversion percentage for each hour of analysis. The trip shift/diversion percentage multiplied by the hourly demand provides the number of vehicles that are estimated to divert or shift their trip each hour.

Figure 7. Trip Shift/Diversion Model

$$Trip\ Shift\ \&\ Diversion = \left(\frac{Demand}{QDR}\right)^{1.352} * 16.6\%$$

The equation in Figure 7 modeled maximum queues similar to queues that were observed in the field for all four work zone sites, as shown in Figure 8.

[1] Liu Y. and Horowitz A.: 'Development of a traffic diversion estimation model for freeway construction work zones' (University of Wisconsin-Milwaukee Press, 2011)

Figure 8. Trip Shift/Diversion Model Maximum Queue Comparisons

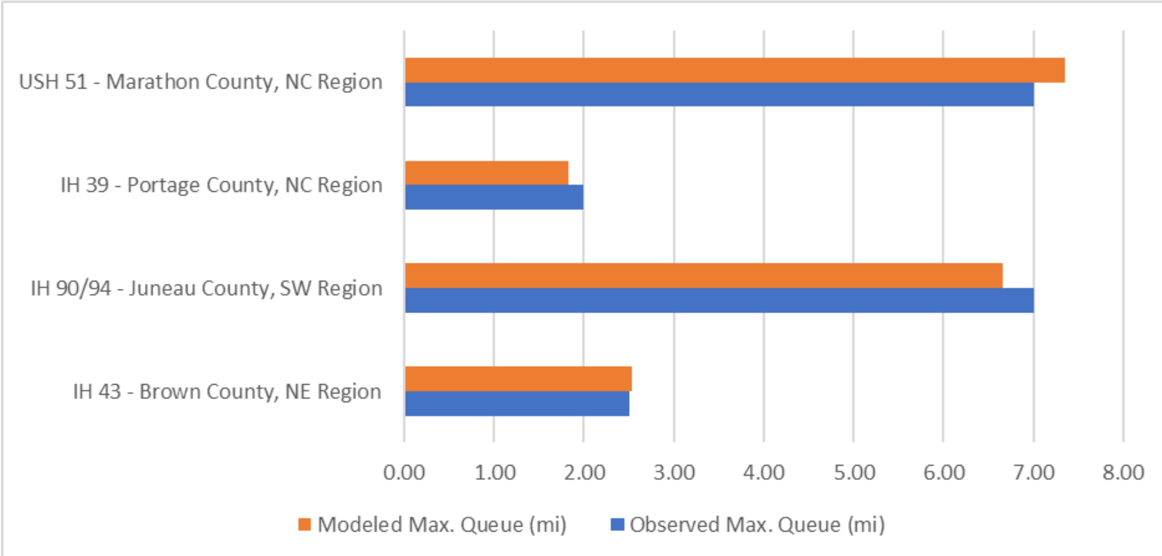


Figure 7 illustrates estimated maximum queues similar to the queues observed at the four studied sites, but other power function models were investigated using different ratios than the demand-to-QDR ratio. Other models tested included various combinations of the demand, the QDR, and the free flow capacity for the ratio. However, none of the other models tested estimated queues similar to all four of the observed work zone sites. In most cases, three of the sites had similar estimates, but the fourth estimate was substantially different than the observations. Therefore, the equation in Figure 7 is recommended for the trip shift/diversion model.

C.4 – Distribution Model Development

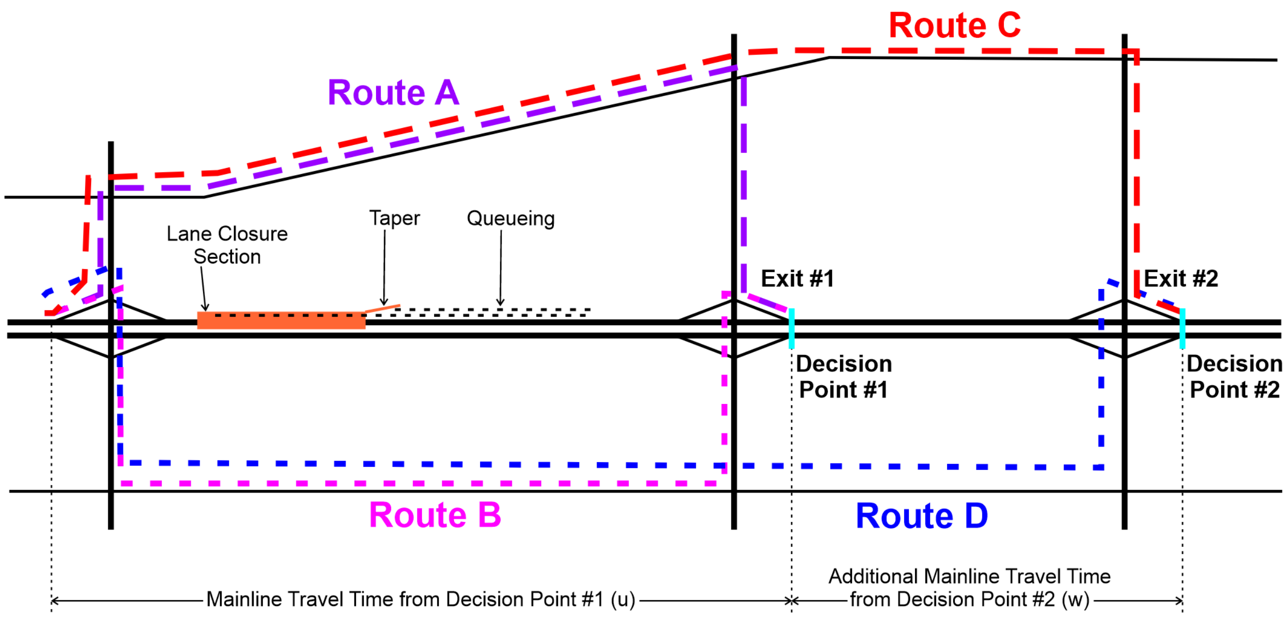
The trip shift/diversion model developed in Section C.3 estimates the total number of vehicles that divert or shift their trip. The model does not estimate any diversion routes individually. Estimating the number of vehicles that will divert to the local roadway network is helpful for the development of traffic management plans (TMP). As part of this study, a distribution method was developed to estimate the number of vehicles diverting to available alternate routes.

C.4.1 – Distribution Model Theory

Travel time equilibrium is the guiding principle behind the distribution model developed in this study. The general premise is that drivers are assumed to take the route that has the lowest travel time. Travel times for each route, including the mainline, increase as more vehicles are added to each route. The model balances the distribution of vehicles to reach a point of equilibrium in travel time for diversion routes and the mainline.

Based on discussions with the WisDOT regional work zone engineers, it was decided that two interchanges would be adequate to model viable diversion routes in a majority of circumstances. The model also assumes that each interchange will have two diversion routes, one using a right-turn and one using a left-turn from the off-ramp, thus, the WZTAT assumes a total of four diversion routes, as shown in Figure 9.

Figure 9. Graphical Representation of Four Possible Diversion Routes



C.4.2 – Adjustments for Mainline Delay Tolerance

An adjustment added to the travel time equilibrium model developed in this study was a delay tolerance to account for drivers' preference to stay on the mainline even if the travel time is longer. Previous research has established that drivers generally favor staying on the mainline, opting for a diversion route only if it provides a significant time saving. Research in Houston, TX found that delay tolerance in their area was approximately 5-6 minutes[2]. Discussing the delay tolerance concept and that study with the WisDOT regional work zone engineers led to a delay tolerance selection of five minutes for urban areas and 10 minutes for rural areas. A longer time was selected for rural areas because there are generally fewer detour routes available. For future updates of the tool, additional research could be done to further understand delay tolerance in Wisconsin.

In the travel time equilibrium model developed in this study to estimate diversion from work zones, the delay tolerances of five minutes (urban) and 10 minutes (rural) are subtracted from the mainline travel times. This way, the results of the model take delay tolerance into consideration when distributing traffic to the diversion routes based on travel time.

C.4.3 – Diversion Route Travel Time Base Equations

In the model's assumed diversion route scenario shown in Figure 9, Routes A & B capacities are interdependent on Routes C & D, respectively, because it is assumed that the driver will ultimately follow the same path once Routes C & D reach Exit #1 crossroad. Therefore, the travel times along the diversion routes are calculated by the following equations, shown in Figure 10.

[2] Huchingson, R.D., Whaley, J.R., & Huddleston, N.D. (1984). Delay Messages and Delay Tolerance at Houston Work Zones (Abridgment). Transportation Research Record.

Figure 10. Diversion Routes Travel Time Equations

$$Travel\ Time_A = Base\ Travel\ Time_A + (Diverted\ Volume_A + Diverted\ Volume_C) * i$$

$$Travel\ Time_B = Base\ Travel\ Time_B + (Diverted\ Volume_B + Diverted\ Volume_D) * i$$

$$Travel\ Time_C = Base\ Travel\ Time_C + Diverted\ Volume_C * i$$

$$Travel\ Time_D = Base\ Travel\ Time_D + Diverted\ Volume_D * i$$

The factor *"i"* is the incremental travel time added per vehicle added to the diversion route. Note that the travel times for Routes A & B also have the volume of diverted traffic to Routes C & D, respectively, included in the calculation. The next section discusses how a formula for the *"V*i"* added travel time factor was developed.

C.4.4 – Incremental Added Travel Time Formula Development

As you add traffic to a diversion route, travel delay along that diversion route will increase. As the travel delay increases, it impacts the decisions of drivers, which impacts the amount of traffic on the mainline versus diversion routes. Understanding this incremental delay became an important component of this study because better estimates of the incremental delay would lead to better diversion estimates. Limited research was available regarding incremental delays on diversion routes, so the project team conducted an additional study to better understand incremental delay. A model was developed to estimate the incremental delay factor using the approach described below.

It was hypothesized that there would be a non-linear relationship between added volumes and incremental delay. To test this hypothesis, five diversion routes were randomly selected. Each diversion route was modeled in the capacity analysis software, Synchro 11, to estimate travel time. Lastly, each of the five models was incrementally loaded with traffic volumes to better understand the relationships between increased volumes and incremental delay. As suspected, a non-linear relationship was found and the approach and results are discussed below.

C.4.5 – Site Selection

Five interchanges were randomly selected from the WisDOT Traffic Engineering, Operations & Safety (TEOpS) Manual exit numbers list in Chapter 2 Section 6 (TEOpS 02-06). Since many interchanges have both NB/SB or EB/WB exit ramps having the same exit number, a travel direction for each of the five interchanges was randomly selected. Finally, whether the route would take a right-turn or left-turn from the exit ramp was also randomly selected.

After the initial random selection of five interchanges, three were deemed applicable for analysis and two were removed. The two were removed because one was outside of an urbanized area and the other was near a system interchange and didn't have a realistic detour route. Six more randomization iterations were run to get two more applicable exit ramps. Reasons for the removal of selections during those additional iterations include an exit ramp being within a system interchange, an exit ramp being in the same county as a previous selection, and an exit ramp being outside an urbanized area. Table 2 below shows information about the five randomly selected highway exit ramps that were used in analysis.

Table 2. Exit Ramps Randomly Selected for Incremental Added Travel Time Synchro Analysis

Iteration	County	Highway	Interchange with	Exit No.	Direction	Left or Right?
1	Ozaukee	IH 43	CTH H West and STH 32 South	100	SB	Left
1	Waukesha	IH 94	CTH T	293	WB	Right
1	Calumet/ Outagamie	STH 441	CTH KK – Calumet Street	7	NB	Right
2	Kenosha	IH 94	CTH C	345	EB	Left
7	Winnebago	IH 41	9th Avenue	117	SB	Left

Appendix C shows mapped routes assumed for each detour route analyzed in the Synchro model for each route.

C.4.6 – Synchro 11 Analysis

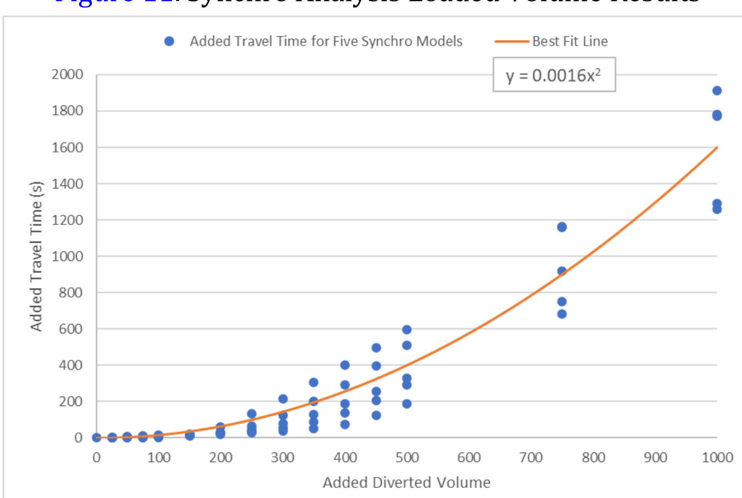
The Synchro 11 traffic models were developed following the latest WisDOT guidelines. Attempts were made to obtain the most recent traffic counts and signal timings for each intersection involved in the analysis. For intersections with no counts, turning movements were estimated based on the roadway counts available from WisDOT and the WisTransPortal. For intersections with no signal timings available, they were input based on the latest WisDOT TIA guidelines.

Each of the five routes were first analyzed with base volumes and the delay for the applicable movement along the designated route at each intersection was summed for a base travel time. Next, volumes were added along the designated route starting with 25 added vehicles up to 1,000 added vehicles, with 25 vehicle steps from 25 to 100, then 50 steps from 100 to 500, and then 250 vehicle steps from 500 to 1,000. At each volume, the delay was summed up and the difference between the base travel time was plotted.

C.4.7 – Incremental Delay Model

Multiple types of best-fit trendlines were investigated, but the one that fit the data the best was an order two polynomial. The intercept was set to (0,0) because adding no traffic to the exit ramp would add no delay. Figure 11 below shows the plotted data points with the best fit line and the best-fit equation.

Figure 11. Synchro Analysis Loaded Volume Results



$$\boxed{Added\ Travel\ Time = 0.0016 * (Diverted\ Volume)^2}$$

C.4.8 – Distribution Model System of Equations

With mainline travel times *"u"* and *"w"* shown in Figure 9, the diversion route travel time equations shown in Figure 10, and the added travel time formula shown in Figure 11, a system of equations was developed that can statically estimate diversion volumes for each diversion route. The base equations were developed under two scenarios based on whether or not the work zone queue reaches Exit #2's buffer distance or not. A buffer distance was used rather than the exit ramp location itself because it is assumed that drivers can see a queue ahead and make a decision before the queue actually reaches the exit ramp.

If the queue does not reach Exit #2's buffer distance, then it is assumed that no vehicles divert to that exit and only divert to Exit #1. The base equations for Routes A & B are shown in Figure 12.

Figure 12. Diversion Routes A & B Base Equations – Exit #1 Only

$$u - f = a + 0.0016 * A^2$$

$$u - f = b + 0.0016 * B^2$$

where,

u = mainline travel time from decision point #1,
f = delay tolerance,
a = Route A base travel time,
A = Route A diversion volume,
b = Route B base travel time, and
B = Route B diversion volume.

The base equations take the mainline travel time minus the delay tolerance (five minutes in urban areas and 10 minutes in rural areas) and equates that to the base travel time of the diversion route plus the added travel time based on the number of vehicles that divert to that route. Therefore, shown in Figure 13, solving each equation for the diversion volume variable provides estimates for the number of vehicles that divert to Routes A & B if the queue does not reach Exit #2's buffer distance.

Figure 13. Diversion Volume Estimates for Routes A & B – Interchange #1 Only

$$A = 25 * \sqrt{u - f - a}$$

$$B = 25 * \sqrt{u - f - b}$$

If the queue reaches Exit #2's buffer distance, then it is assumed that diversion could occur at both interchanges, so the base equations, shown in Figure 14, are as follows:

Figure 14. All Diversion Route Base Equation – Exits #1 and #2

$$u - f = a + 0.0016 * (A + C)^2$$

$$u - f = b + 0.0016 * (B + D)^2$$

$$w - f = u + c + 0.0016 * C^2$$

$$w - f = u + d + 0.0016 * D^2$$

where,

- w = mainline travel time from decision point #2 to decision point #1,
- c = Route C base travel time,
- C = Route C diversion volume,
- d = Route D base travel time, and
- D = Route D diversion volume.

Therefore, shown in Figure 15, solving each equation for the diversion volume variable provides estimates for the number of vehicles that divert to all four diversion routes.

Figure 15. All Diversion Volume Estimates for All Routes – Exits #1 and #2

$$A = \left(25 * \sqrt{u - f - a}\right) - C$$

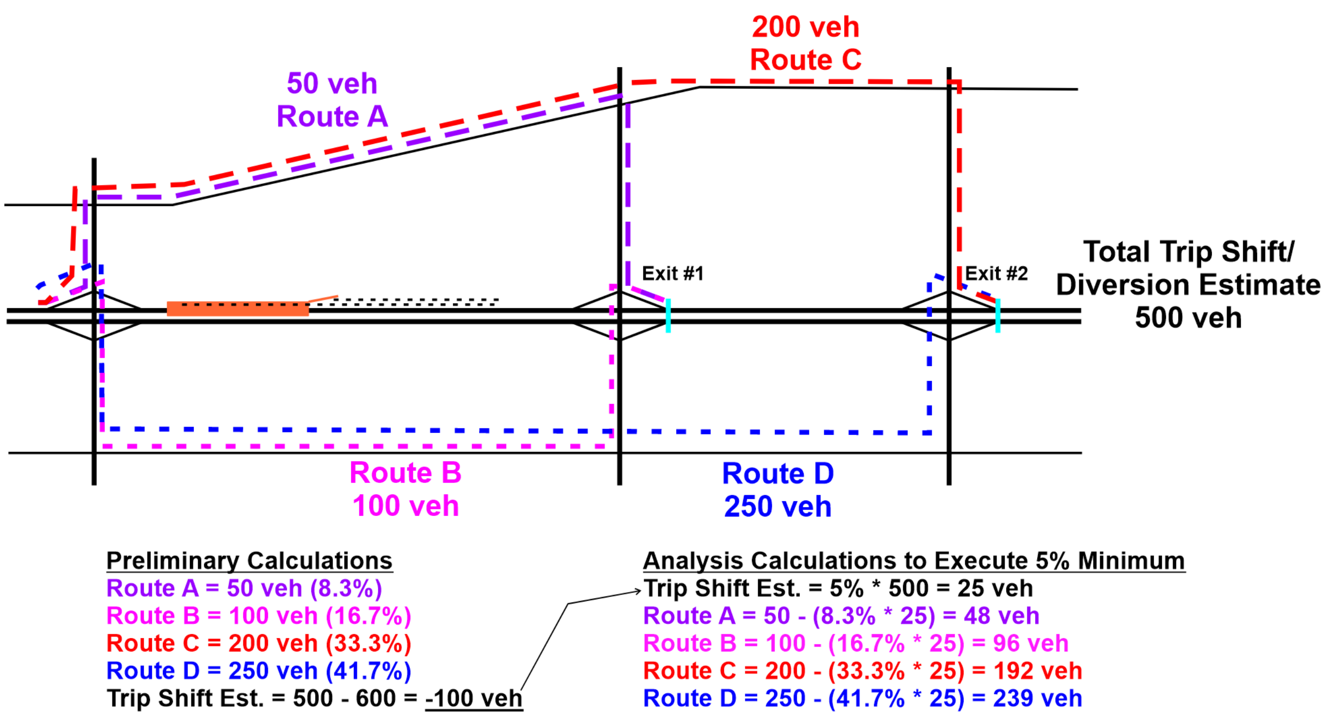
$$B = \left(25 * \sqrt{u - f - b}\right) - D$$

$$C = \left(25 * \sqrt{w - u - f - c}\right)$$

$$D = \left(25 * \sqrt{w - u - f - d}\right)$$

The trip shift volume estimate is calculated by the total trip shift/diversion volume estimated in Figure 7 minus the sum of the volumes estimated in Figure 13 or 15, depending on the work zone queue length. Because these are independently calculated, the trip shift could end up with a negative estimate. Therefore, a trip shift minimum was input into the WZTAT calculations, so the trip shift volume can be no less than 5% of the total trip shift/diversion volumes estimated. If that minimum is executed, then the that 5% is proportionally subtracted from the diversion volumes estimated, so the sum of trip shift and diversion volume estimates will still equal the total estimated from Figure 7. An example of this 5% minimum calculation is shown in Figure 16.

Figure 16. Analysis Steps for 5% Minimum Calculation



PART D – NEW WZTAT FEATURES

In addition to the expanded diversion analysis capabilities discussed in Part C, many other new features were added to the WZTAT as part of this project. Most were added based on feedback provided by the WisDOT regional work zone engineers after using the tool since its initial release in August 2020. The diversion feature and brand-new summary tabs will be highlighted in detail, while a list of other new features will be provided at the end of this section.

D.1 – New Diversion Feature

As previously mentioned, WZTAT version 4.2 has a manual input for diversion for each direction and is applied to all analysis hours. It is a percentage input, where the user of the tool estimates the percent diversion expected based on past experiences and engineering judgement. Part C discussed the development of a new, automatic trip shift/diversion model that estimates the number of vehicles that divert to local roads or shift their trip entirely, and a distribution model to estimate the number of vehicles on four possible detour routes.

The calculations are built into the "Calculations" tab in the WZTAT, but a new "Diversion Inputs" tab was added where the user must input information about the detour routes. Because the tool takes into account two upstream interchanges, the user must input the distance (miles) each interchange is upstream of the work zone taper. Since each interchange has two routes, the user must then input the diversion route free flow travel time (minutes) for each of the four routes. It is recommended that the user use Google Maps, Waze, or another route mapping service to get the base travel time for each route. Finally, the user must enter the distance (miles) from the end of the lane closure to the downstream interchange where the mainline and detours meet up.

With the normal posted speed limit (mph), the work zone speed limit (mph), and the closure length (miles) inputs already present on the "Pos Inputs" and "Neg Inputs" tabs and the delay tolerance (minutes) programmed in the "Calculations" tab, all of the variables for the diversion volume equations shown in Figures 13 & 15 are known, allowing for the diversion volumes to be estimated for each route.

D.2 – New Summary Tabs

Based on user feedback from the WisDOT regional work zone engineers, additional summary tabs were added to provide more readily available information for TMPs and Work Zone Impact Assessments (WZIA). These are the "Overall Summary" tab, the "Queue Summary" tab, and the "TW Summary" tab for the time windows.

D.2.1 – Overall Summary Tab

The "Overall Summary" tab provides averages and maximums for various work zone measures that would be useful for TMPs and WZIAs. Figure 17 shows a screenshot of the "Overall Summary" tab's values for the overall analysis period and for Closure #1. There are similar tables for Closures #2, #3, and #4 within the WZTAT, but are not shown in this memo.

The "Base Information" table at the top provides basic information about the work zone's location, construction ID, speed limits, and closure length. Below that table are a list of the months that were included in analysis, the annual heavy vehicles percentage for that direction, information about the tool's version, the user's name, and the date of analysis.

The "Overall" table shows the Monday to Thursday, Friday, Saturday, and Sunday averages for expected maximum delay, expected maximum queues, road user costs, and maximum hourly diversion to local roads. The expected maximum delay, expected maximum queues, and maximum hourly diversion to local roads values are calculated by taking the maximum value from each day of the year, then averaging the days for each day category row. The road user costs are summed up for each day of the year and averaged for each day category row. Note that months and days excluded from analysis are not included in the calculations.

The "Daily Avg." row shows those same metrics calculated in the same manner but shows the average for all days included in analysis. This row also shows the daytime and nighttime work zone capacities in units of vehicles per hour per lane (vphpl) since TMPs ask for work zone capacity with those units.

The "Daily Max." row shows the metrics for the single day that is calculated to have the longest estimated queue. This is to give the user a gauge on the worst-case scenario.

The "Total" row shows the total sum of the road user costs for the work zone for all analysis days.

The "Description" cell in the "Overall" table provides information about the location and length of the work zone. This is automatically filled in by information on the input tabs. The tool automatically converts the formula to text so the user can copy/paste it to TMP or WZIA and can add/remove text as needed.

Figure 17. WZTAT Overall Summary Tab Screenshot

WZTAT OVERALL SUMMARY - EB

Base Information			
Region	Southeast	Area Type	Urban
County	Waukesha	Normal Posted Speed Limit	70 mph
Construction ID	0000-00-00	Work Zone Speed Limit	55 mph
Highway	I-94 EB	Closure Length	1.7 mi

Months included in analysis: January, February, March, April, May, June, July, August, September, October, November, December	Annual HV% 8%	*Beta Version 5.1 Released: 12/08/2023*	*User: DRAFT Date: 12/08/23*

Delay Legend	<15 min	15-30 min	30-60 min	60-120 min	>120 min

		Daytime WZ Capacity	Nighttime WZ Capacity	Expected Max. Delay	Expected Max. Queue	Road User Costs	Max Hourly Diversion to Local Roads (vph)
Overall	**Mon-Thu Avg.**			7 min	1.6 mi	$10,381 per day	11
	Friday Avg.			8 min	1.7 mi	$10,957 per day	51
	Saturday Avg.			---	---	---	---
	Sunday Avg.			---	---	---	---
	Daily Avg.	3,110 vphpl	3,062 vphpl	7 min	1.6 mi	$10,496 per day	19
	Daily Max.	<--------Fri 08/05/22-------->		15 min	3.3 mi	$23,918 max day	212
	Total					**$2,728,932 total**	
	Description: The lane closure takes place on an urban 1.7 mile segment of I-94 EB in Waukesha County in the Southeast Region.						
Closure #1	**Mon-Thu Avg.**			7 min	1.6 mi	$9,796 per day	11
	Friday Avg.			8 min	1.7 mi	$10,439 per day	51
	Saturday Avg.			---	---	---	---
	Sunday Avg.			---	---	---	---
	Daily Avg.	3,110 vphpl	2,983 vphpl	7 min	1.6 mi	$9,924 per day	19
	Daily Max.	<--------Fri 08/05/22-------->		15 min	3.3 mi	$23,118 max day	212
	Total					**$2,580,341 total**	
	Description: Closure #1 is a 3 lane to 2 lane closure with a soft barrier and high construction activity. Mon: 6 AM to 10 PM ---- Tue: 6 AM to 10 PM ---- Wed: 6 AM to 10 PM ---- Thu: 6 AM to 10 PM Fri: 6 AM to 10 PM ---- Sat: no closure ---- Sun: no closure						

The "Closure #" tables calculate all the rows and metrics in the same manner as the "Overall" table, but only uses the days/hours that are under that closure condition. For example, the "Closure #1" table in Figure 17 only uses hours from 6:00 AM to 10:00 PM on Monday through Friday in the calculations because those are the only hours that the work zone is under closure #1 conditions.

The "Description" cell for the "Closure #" tables displays the lane closure type, barrier type, and construction intensity and also the times that each closure # is active. This is automatically filled in by information on the inputs tab. The tool automatically converts the formula to text so the user can copy/paste it to TMP or WZIA and can add/remove text as needed.

Cells in the average and maximum rows are highlighted based on the delay value using the colors in the legend to give the user a quick glance at how things are expected to operate.

D.2.2 – Queue Summary Tab

The "Queue Summary" tab shows queue, delay, and road user cost information for each day of the year, organized by months. A screenshot of the tab showing the August table is shown in Figure 18.

At the top of this tab is a table that shows the same basic information about the work zone as the "Overall Summary" tab. Below this table are three legends providing information about some of the different aspects of the table, as well as information about the tool's version, the user's name, and the date.

The monthly tables show metrics for each day of the month and then an averages, maximum, and total table for the month as a whole. The "Queue" column shows a line graph of the queue length throughout each day. As the legend shows, the maximum for each cell is five miles. If the queue extends longer than five miles, the cell will not show the line for those hours and a note will show in the cell alerting the user that the queue is greater than five miles. The "Max. Queue" column shows the maximum queue length expected for each day. The "Approx. Time of Max. Queue" column estimates the time of day (15-minute periods) that the maximum queue is expected to occur. The "# of Queueing Hours" column shows the number of queueing hours expected for each day. If a queue was expected from 9:00 AM to 3:00 PM, then this column would show six hours. The "Max. Delay" column shows the maximum delay expected for each day. Finally, the "Total Road User Cost" column shows the total road users costs expected to accrue each day due to the work zone.

Below the daily rows is an averages, maximum, and total table. Monday through Thursday, Friday, Saturday, and Sunday averages are calculated for the month based on the daily rows above. The "Max. Queue" row highlights the day of the month that is expected to have the longest queue length observed. The "Total Monthly Road User Costs" sums the road user costs expected in the month.

Similar to the "Overall Summary" tab, rows are highlighted based on the delay observed and are colored based on the "Delay Legend".

D.2.3 – Time Window Summary Tab

The "TW Summary" tab shows delay for each day of the year, organized by months. A screenshot of the tab showing the August table is shown in Figure 19.

At the top of this tab is a table that shows the same basic information about the work zone as the "Overall Summary" and "Queue Summary" tabs. Below this table is a legend showing the color coding for the cells in each monthly table, as well as information about the tool's version, the user's name, and the date.

Each row in the monthly tables shows the delay for each hour of each day, color coded according to the legend. The delay values themselves are not shown. This table is to give the user a quick visualization of work delays expected throughout the day and visually shows the time windows that queues are expected to occur. An averages table is shown at the end of each month showing the Monday through Thursday, Friday, Saturday, and Sunday averages expected for that particular month.

Figure 18. WZTAT Queue Summary Tab Screenshot

WZTAT QUEUE SUMMARY - EB

Base Information			
Region	Southeast	Area Type	Urban
County	Waukesha	Normal Posted Speed Limit	70 mph
Construction ID	0000-00-00	Work Zone Speed Limit	55 mph
Highway	I-94 EB	Closure Length	1.7 mi

blank = no queue
--- = no data

Queue Legend: 5.0 mi, 2.5 mi, 0.0 mi; 12 am, 6 am, noon, 6 pm, 12 am

Beta Version 5.1 *User: DRAFT*
Released: 12/08/2023 *Date: 12/8/2023*

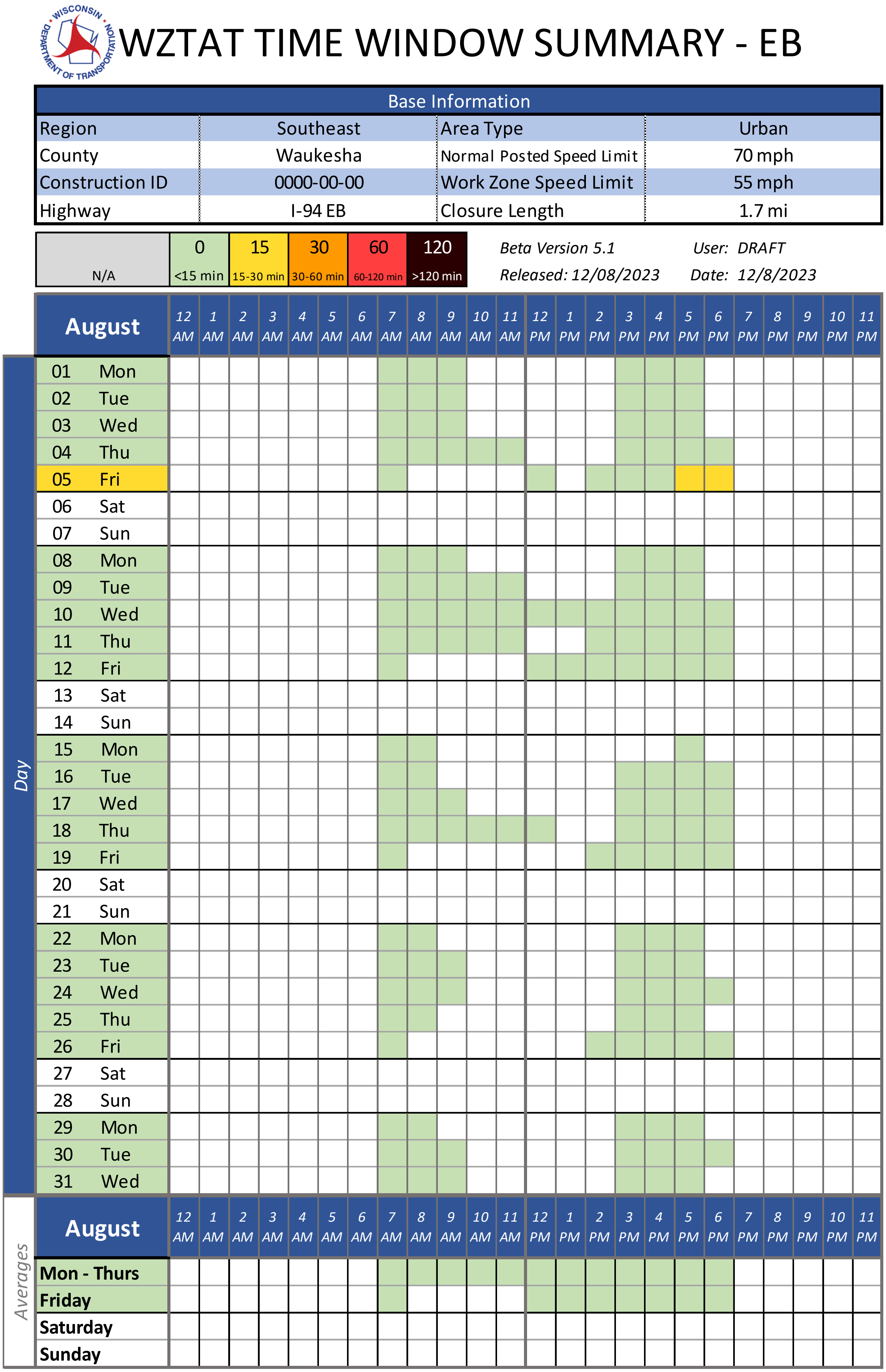
Delay Legend	<15 min	15-30 min	30-60 min	60-120 min	>120 min

	August		Queue	Max Queue	Approx. Time of Max Queue	# of Queueing Hours	Max Delay	Total Road User Cost*
Day	01	Mon		1.5 mi	7:45 AM	6 hours	6.8 min	$ 8,671
	02	Tue		2.2 mi	8:00 AM	6 hours	10.2 min	$ 12,569
	03	Wed		1.8 mi	8:00 AM	6 hours	8.2 min	$ 10,169
	04	Thu		2.0 mi	8:30 AM	9 hours	9.4 min	$ 15,576
	05	Fri		3.3 mi	5:15 PM	7 hours	15.3 min	$ 22,457
	06	Sat						$ -
	07	Sun						$ -
	08	Mon		1.1 mi	7:30 AM	6 hours	5.3 min	$ 8,509
	09	Tue		2.3 mi	8:15 AM	8 hours	10.7 min	$ 13,536
	10	Wed		2.4 mi	10:45 AM	12 hours	11.0 min	$ 23,918
	11	Thu		2.5 mi	4:45 PM	10 hours	11.5 min	$ 16,456
	12	Fri		3.1 mi	4:30 PM	8 hours	14.2 min	$ 18,597
	13	Sat						$ -
	14	Sun						$ -
	15	Mon		1.1 mi	7:30 AM	3 hours	5.2 min	$ 7,817
	16	Tue		1.5 mi	4:45 PM	6 hours	6.8 min	$ 10,138
	17	Wed		2.8 mi	4:45 PM	7 hours	13.1 min	$ 16,267
	18	Thu		2.4 mi	4:45 PM	10 hours	11.1 min	$ 16,288
	19	Fri		2.5 mi	4:30 PM	6 hours	11.8 min	$ 14,545
	20	Sat						$ -
	21	Sun						$ -
	22	Mon		1.2 mi	7:30 AM	5 hours	5.6 min	$ 8,634
	23	Tue		1.9 mi	4:30 PM	6 hours	8.7 min	$ 13,254
	24	Wed		1.8 mi	4:30 PM	7 hours	8.6 min	$ 12,769
	25	Thu		1.9 mi	4:30 PM	5 hours	8.7 min	$ 10,879
	26	Fri		2.6 mi	5:15 PM	6 hours	12.5 min	$ 15,996
	27	Sat						$ -
	28	Sun						$ -
	29	Mon		1.4 mi	7:15 AM	5 hours	6.5 min	$ 9,417
	30	Tue		2.2 mi	4:45 PM	7 hours	10.4 min	$ 14,333
	31	Wed		2.0 mi	7:45 AM	6 hours	9.4 min	$ 10,996

	August	Queue	Max Queue	Approx. Time of Max Queue	# of Queueing Hours	Max Delay	Total Road User Cost*
Averages	**Mon - Thurs**		1.6 mi	7:45 AM	7 hours	7.5 min	$ 12,642
	Friday		2.9 mi	4:45 PM	7 hours	13.3 min	$ 17,899
	Saturday						$ -
	Sunday						$ -
	Max. Queue	<--------Fri 08/05/22-------->	3.3 mi	5:15 PM	7 hours	15.3 min	$ 22,457
	Total Monthly Road User Costs						**$ 311,790**

*If a queue is not observed, decreased speeds through the work zone can still result in delay costs.

Figure 19. WZTAT Time Window Summary Tab Screenshot



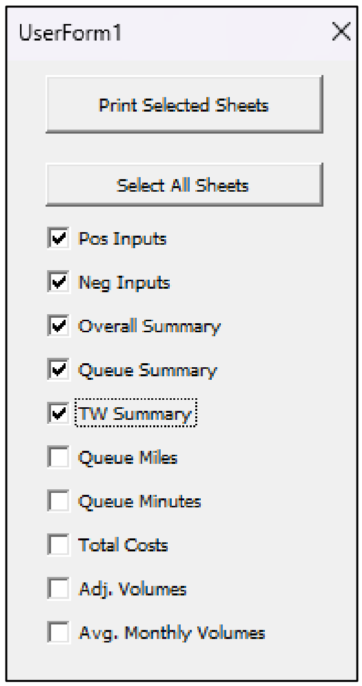
D.3 – Other New Feature in WZTAT Update

Many other new features were added with this release of the WZTAT. This section outlines those features.

D.3.1 – Print Macro Update

In the previous WZTAT, the print macro printed all tabs by default, which led to PDFs that were over 100 pages long. The regional work zone engineers said that many of these pages were unnecessary as attachments to TMPs, so they wanted a way to select which tabs to print. With the new print macro in this release, a window pops up allowing the user to manually select which tabs they want to print, shown in Figure 20. This substantially decreases the number of pages printed, allowing the user to only print the necessary pages for attachments to other documents.

Figure 20. WZTAT Print Macro UserForm



D.3.2 – Inputs Tab Update

The previous WZTAT had a single tab for work zone inputs and would apply the work zone conditions to both freeway directions. However, there are many work zones that have different requirements for each direction. Therefore, the "Inputs" tab was separated into "Pos Inputs" and "Neg Inputs" tabs so the user can have different work zone conditions for each direction.

The "Pos Inputs" tab is the main tab that should be filled in first. In case the user wants to have both directions use the same work zone conditions, rather than having the user fill in all the same information on the "Neg Inputs" tab again, a copy button was added that automatically copies the inputs from the "Pos Inputs".

One more minor update to the inputs tabs involves the highway selection in cell C9. The selection list updates based on the region selected, however, in the previous tool, if a desired highway was not in that list, the user could not manually enter it into the cell. With this update, the error message was removed so the user can manually type in a highway that is not on the existing list.

D.3.3 – Remove Dates from Analysis

In the previous tool, it was assumed that the work zone would be present for all dates for the year. There was no way to remove specific dates from analysis. The regional work zone engineers commented that it would be useful to be able to remove dates, such as holidays and the days around them, since in some cases no lane closures would occur those days.

This new version of the tool has three ways to remove dates from analysis. The "View/Print List" checkboxes on the "Pos Inputs" tab previously only hid rows and excluded months from printing for any months that were unchecked. The WZTAT update now removes the entire month from analysis if it is unchecked.

A "Date Range to Exclude" table was added to the "Pos Inputs" tab that removes dates in the range entered. For example, if the user enters 07/01/2022 for start date and 07/07/2022 for end date, all days between, and including, the start and end dates, are excluded from the analysis.

An individual date removal table was also added to the "Pos Inputs" tab. The user can add up to 20 individual dates to remove from the analysis. This table also provides information on what day of the week each date is and whether it is a holiday (New Year's Day, MLK Jr. Day, President's Day, Memorial Day, Independence Day, Labor Day, Columbus Day, Veteran's Day, Thanksgiving Day, Christmas Day). The holiday flag is valid for all years between 2019 and 2050.

The dates entered into the date range or individual date tables must be present in the year of the volumes imported. For example, if the volumes imported were from 2022, the user must enter 07/01/2022 to remove that date from analysis. If the user enters a date from outside the data collection year, a red flag will appear to alert the user to verify the date entered.

D.3.4 – Volume Import Macro Update

The traffic counters at WisDOT's continuous count sites can malfunction and they stop counting vehicles. These periods of no data can range from a few hours to a few days or even longer. In the previous tool, the hours without data were automatically excluded from analysis. However, if a malfunction occurred during a time of year that a work zone was expected to occur, some of the work zone metrics calculated in the WZTAT are thrown off. For example, total road user costs would be lower in the tool than because hours that would have actual queueing would show zero since there was no volume available to be entered for those hours.

During the volume import process in the updated tool, any hours with zero data are replaced with a monthly average of that hour. For example, if 10:00 AM on Monday, May 7th was missing volume data, the calculations for that hour will use the average volume observed at 10:00 AM on all other Mondays in May. This method allows for all 8,760 hours of the year to be included in analysis.

The "Volume Stats" tab tables still show statistics based on the raw volume in that they show which days had missing data. Only the analysis calculations are updated with the averaged volumes for missing data. Below the statistics tables is a list of the exact dates that had missing data in case the user wants to view or note them.

D.3.5 – Road User Cost Calculations

The previous version of the WZTAT summed queue/delay costs and diversion costs to get the total road user cost value for each hour of the year. However, this did not account for the reduced speed through the work zone that occurs through the lane closure section of the work zone. This closure cost value was added as a column for each direction in the calculations tab to account for that reduced speed.

To calculate the closure cost, the tool must be told how long the lane closure section is and what the work zone speed limit will be for the work zone. Therefore, both of these inputs were added to the "Pos Inputs" and "Neg Inputs" tabs for the user to manually enter along with all other input data.

Note that these two values are also used in the trip shift/diversion model and distribution model, so they are required inputs for the tool to calculate properly.

PART E – CONCLUSION

The goals of this *Work Zone Traffic Analysis Tool Development (I.D. 0656-17-20)* project were threefold:

1. Validate the existing work zone capacity and queueing models.
2. Expand the diversion analysis capabilities in the Work Zone Traffic Analysis Tool (WZTAT).
3. Implement additional updates to the WZTAT based on user feedback.

The technical memorandum summarized how the data collection/analysis efforts and WZTAT updates met the goals and re-issued a tool that will continue to accurately model work zones in Wisconsin and provide easy access to information that will make filling out TMPs and WZIAs simpler.

E.1 – Capacity and Queue Model Validation Conclusion

Additional work zone data was collected in the summer/fall of 2022 for use in validating the work zone capacity and queueing models developed in the *Statewide Work Zone Capacity Analysis (I.D. 0656-43-01 – August 24th, 2020)*. In total, 25 different days/times were processed for analysis from nine different construction projects in the North Central, Northeast, Northwest, and Southwest regions. Sixteen observations had active queueing, while nine observations did not see queueing.

Based on the results of the work zone capacity model validation analysis, it is recommended that no changes be made to the existing WisDOT work zone capacity model. The sites that had active queueing observed QDRs that are comparable to the model estimated QDR, with the overall total observed QDR being only one percent higher than the overall total estimated QDR. In addition, a majority of the sites without queueing observed flow rates below the estimated QDR, which is what was expected. Therefore, no changes are recommended to the WisDOT work zone capacity model shown in Figure 2 on page 3.

Based on the results of the work zone queueing model, it is recommended that no charges be made to the existing WisDOT work zone queue model. Twenty-five observed queue spacing samples at the two work zone sites were only slightly higher than the model estimate and both observed larger queue spacing than the 30 feet or 40 feet static values previously used in WisDOT tools before the *Statewide Work Zone Capacity Analysis (I.D. 0656-43-01 – August 24th, 2020)*. The newly collected data was consistent with the queue data collected in the 2020 study. Therefore, no changes are recommended to the WisDOT work zone queue model shown in Figure 5 on page 6.

E.2 – Trip Shift/Diversion Model and Distribution Model Development Conclusion

The previous WZTAT version had a user input for diversion. There was a separate input for each direction, and they were applied to all analysis hours. However, the diversion input was not automated and was manually input by the user based on past experiences and engineering judgement. WisDOT requested an update to the WZTAT tool to provide an automated diversion estimate.

This technical memorandum describes the development of a trip shift/diversion model to estimate the total number of vehicles that will divert or shift their trip. Furthermore, the development of a travel time equilibrium-based distribution model is explained which estimates the number of vehicles that will divert to a maximum of four different diversion routes.

E.2.1 – Trip Shift/Diversion Model Conclusion

To estimate accurate queue lengths and delays, it is important to accurately estimate the number of vehicles that will pass through the work zone. Both diversion and trip shift will decrease the volume of vehicles that pass through the work zone. A trip shift/diversion model was developed to do just that. Data was obtained/collected from four sites where the maximum queue length was known to be used in developing the model.

A power function with an exponent greater than one was deemed appropriate for the trip ship/diversion model because as the demand increases compared to the QDR, the rate of the trip shift/diversion percentage also increases. As a work zone becomes busier due to large demand, more drivers will want to avoid the work zone.

Microsoft Excel's Solver function was utilized to estimate the adjustment factors to best fit the maximum queue data from the four work zone sites listed in Section C.2. The modeled maximum queues are similar to what was observed in the field for all four work zone sites. Therefore, it is recommended that the model presented in Figure 7 on page 8 be implemented in the WZTAT to estimate the total trip shift/diversion that occurs for each hour at the work zone.

E.2.2 – Distribution Model Conclusion

The trip shift/diversion model estimates the total number of vehicles that divert or shifts their trip. The model does not estimate any diversion routes individually. Therefore, a distribution method was developed to estimate the number of vehicles that divert to multiple diversion routes. The theory behind the model is that drivers will take the route that has the shortest travel time. Once a queue develops, if a diversion route is faster, drivers will want to take that route. However, as more drivers divert, the travel time on the alternate route will increase, so there is a limit to how many vehicles the diversion route can handle. Also, from previous research it is known that drivers generally want to stay on the mainline, so they will only take a diversion route if it is a certain amount of time faster. After discussing with the WisDOT regional work zone engineers, it was decided that a delay tolerance of five minutes will be used in urban areas and 10 minutes will be used in rural areas.

Through discussions with the regional work zone engineers, it was decided that the updated WZTAT will model two routes and two interchanges, so four total diversion routes. It is assumed that the further upstream interchange route will follow a similar path to the second interchange route, so routes on each side of the highway are calculated together.

A crucial part of this method involves the added travel time to the diversion route based on added vehicles to the route. This is the factor that limits how many vehicles can be added to the route before the travel times are equal. To do so, five exit ramps were randomly selected from the TEOpS Manual freeway exit list. The freeway direction and right or left off the exit ramp were also randomly selected. The five diversion routes were modeled in Synchro 11 under base conditions and then under added volume conditions, from 25 added vehicles up to 1,000. Added travel time for each added vehicle condition were plotted for each route and a best fit line was found. Figure 11 on page 12 shows the graph with the best fit equation for added travel time based on number of vehicles added. It is recommended that this equation is used in the distribution model.

If a queue only reaches the first upstream interchange and does not reach the second upstream interchange (minus some buffer distance for driver seeing up ahead), it is assumed that vehicles will only divert to the first upstream interchange. Therefore, two sets of base equations for diversion route scenarios were developed. One set assuming diversion only to the first interchange and another set assuming diversion to both interchanges. These base equations are static equations able to be solved for the diversion volume because the travel times required can be calculated by the distance and speed inputs the user enters into the tool. The diversion volume estimate equations for the first interchange scenario are shown in Figure 13 on page 13 and the diversion volume estimate equations for the two interchange scenario are shown in Figure 15 on page 14. It is recommended that these equations are used in the updated WZTAT to estimate diversion route volumes.

E.3 – New WZTAT Features Conclusion

After multiple years of use, WisDOT provided comments and feedback on WZTAT version 4.2 from the regional work zone engineers regarding any changes and/or updates they would like for the next iteration of the tool. This feedback was used as the basis of this WZTAT update and the updates/additions are listed below.

- More automated trip shift/diversion estimation implemented in queue/delay calculations.
- Additional summary tabs to provide easy access to information that is required for TMPs and WZIAs.
- Updated print macro to allow for user to selected what tabs to print to allow user to only print the necessary tabs.
- Separate directional input tabs to allow different work zone conditions for the positive and negative directions.
- Dates can be removed from analysis by months, a date range, or individual dates to allow the user more flexibility in choosing the analysis periods.
- Volume import macro update to estimate data for days the continuous count site malfunctioned. Uses the monthly average in calculations for each hour that has missing data.
- Added work zone speed limit and closure length inputs to calculate road user costs based on decreased speed traveling through the work zone to more accurately estimate total road user costs.

APPENDIX A

Queue Discharge Spreadsheets for Sites <u>with</u> Observed Queueing

Work Zone Capacity
Queue Discharge Flow Rates

IH 39 SB Portage County North Central (1166-05-84)

PCE Conversion Factor: **2.00**

Pre-Breakdown Capacity Drop Factor (PBCDF): **0.134**

0.142 <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 39
Direction	SB
Construction ID:	1166-05-84
Region:	North Central
County:	Portage
Date:	9/18/2022
Day of Week:	Sunday
Area Type:	Rural
Time of Day:	10:50 AM to 3:15 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

Paint steel components of bridge B-49-21, CTH HH over IH 39.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	10:50 AM	End Time:	11:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
128	128	per 5 minutes	152	152
377	377	per 15 minutes	432	432
1,508	1,508	per hour	1,728	1,728
1,508	1,508	Max Flow Rate$_s$*	1,728	1,728

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
125	125	per 5 minutes	141	141
376	376	per 15 minutes	424	424
1,515	1,515	per hour	1,712	1,712
1,504	1,504	Max Flow Rate$_s$*	1,698	1,698

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	11:05 AM	End Time:	3:15 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
108 per 5 minutes	12.9%	76%	24%	122 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
87	87	per 5 minutes	100	100
291	291	per 15 minutes	319	319
1,226	1,226	per hour	1,367	1,367

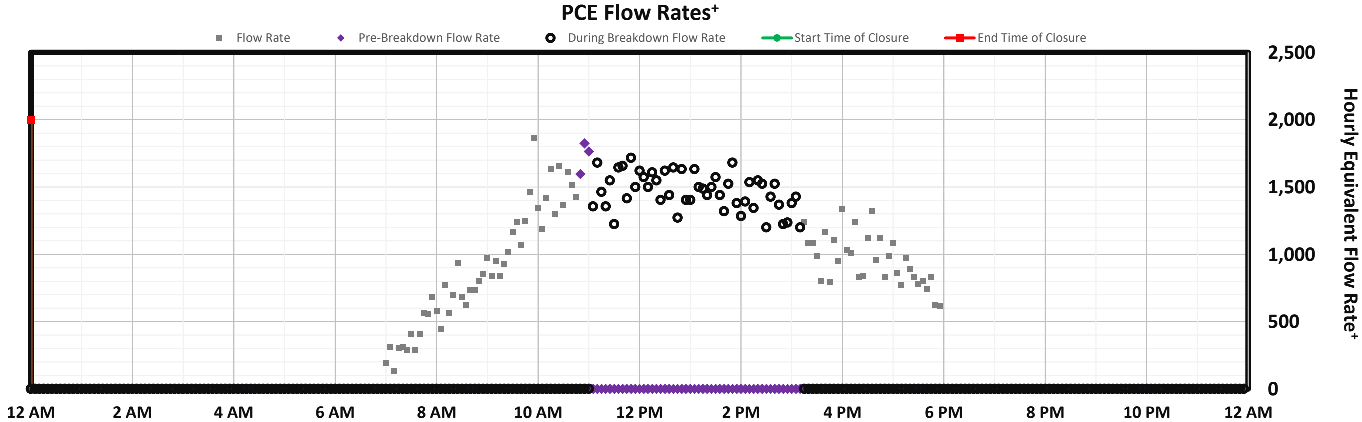
---------------- Average Observed Queue Discharge Rate ----------------

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
108	108	per 5 minutes	122	122
326	326	per 15 minutes	368	368
1,312	1,312	per hour	1,482	1,482
1,242	1,242	WZ Model Est.	1,402	1,402

-------------------------- Maximum Observed Queue Discharge Rate --------------------------

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
130	130	per 5 minutes	143	143
354	354	per 15 minutes	403	403
1,357	1,357	per hour	1,567	1,567

PCE Flow Rates⁺



⁺ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 41 NB Fond du Lac County Northeast (1100-50-71)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.156

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 41
Direction	NB
Construction ID:	1100-50-71
Region:	Northeast
County:	Fond du Lac
Date:	9/29/2022
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	9:00 AM to 11:05 AM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	0
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

This project proposes milling and paving 2 inches of SMA on IH 41 and 2 inches of HMA on the CTH B interchange ramps, replacing the median cable guard system and adjusting the median to a maximum slope of 6:1, replacing beam guard, grading side slopes steeper than 3:1 to meet the interstate conversion requirements, and re-tying culvert pipe joints exhibiting separation and secondary structure work.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	9:00 AM	End Time:	9:20 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
113	113	per 5 minutes	142	142
320	320	per 15 minutes	408	408
1,239	1,239	per hour	1,596	1,596
1,280	1,280	Max Flow Rate$_s$*	1,632	1,632

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
104	104	per 5 minutes	132	132
313	313	per 15 minutes	396	396
1,250	1,250	per hour	1,590	1,590
1,251	1,251	Max Flow Rate$_s$*	1,582	1,582

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	9:20 AM	End Time:	11:05 AM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
90 per 5 minutes	26.5%	32%	68%	114 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
72	72	per 5 minutes	87	87
252	252	per 15 minutes	313	313
1,065	1,065	per hour	1,355	1,355

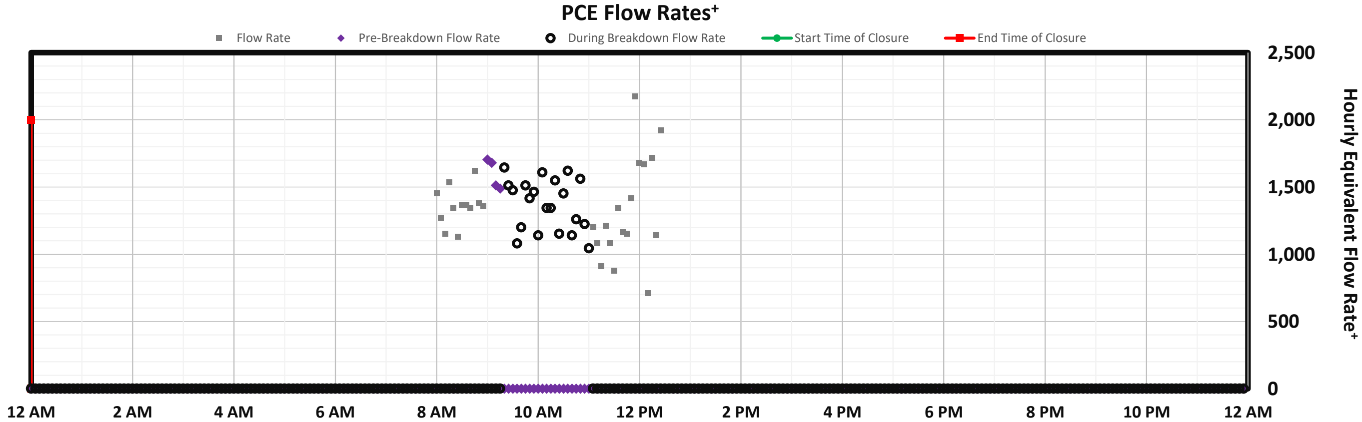
---------------- Average Observed Queue Discharge Rate ----------------

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
90	90	per 5 minutes	114	114
271	271	per 15 minutes	343	343
1,083	1,083	per hour	1,377	1,377
1,107	1,107	WZ Model Est.	1,400	1,400

-------------------------- Maximum Observed Queue Discharge Rate --------------------------

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
108	108	per 5 minutes	137	137
306	306	per 15 minutes	386	386
1,101	1,101	per hour	1,400	1,400

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 41 NB Fond du Lac County Northeast (1100-50-71)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.068

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 41
Direction	NB
Construction ID:	1100-50-71
Region:	Northeast
County:	Fond du Lac
Date:	9/29/2022
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	11:45 AM to 12:30 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	0
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

This project proposes milling and paving 2 inches of SMA on IH 41 and 2 inches of HMA on the CTH B interchange ramps, replacing the median cable guard system and adjusting the median to a maximum slope of 6:1, replacing beam guard, grading side slopes steeper than 3:1 to meet the interstate conversion requirements, and re-tying culvert pipe joints exhibiting separation and secondary structure work.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	11:45 AM	End Time:	12:00 PM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
140	140	per 5 minutes	181	181
313	313	per 15 minutes	395	395
1,252	1,252	per hour	1,580	1,580
1,252	1,252	Max Flow Rate$_s$*	1,580	1,580

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
110	110	per 5 minutes	142	142
307	307	per 15 minutes	397	397
1,316	1,316	per hour	1,700	1,700
1,226	1,226	Max Flow Rate$_s$*	1,587	1,587

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	12:00 PM	End Time:	12:30 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
95 per 5 minutes	29.1%	28%	72%	123 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
40	40	per 5 minutes	59	59
231	231	per 15 minutes	297	297
1,140	1,140	per hour	1,472	1,472

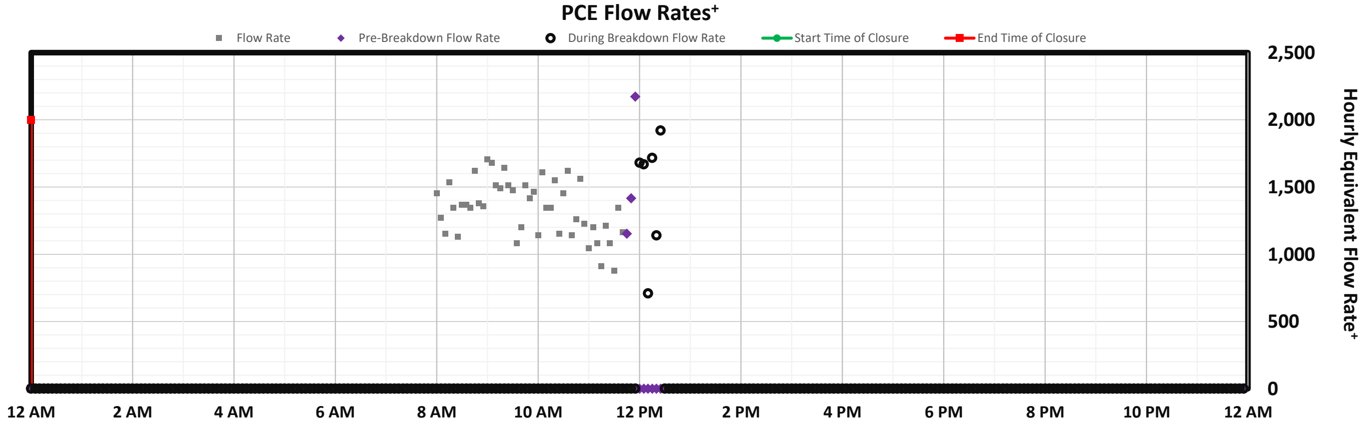
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
95	95	per 5 minutes	123	123
266	266	per 15 minutes	344	344
1,140	1,140	per hour	1,472	1,472
1,084	1,084	WZ Model Est.	1,400	1,400

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
121	121	per 5 minutes	160	160
312	312	per 15 minutes	398	398
1,140	1,140	per hour	1,472	1,472

PCE Flow Rates⁺



⁺ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 41 NB Fond du Lac County Northeast (1100-50-71)

PCE Conversion Factor: 2.00

Pre-Breakdown Capacity Drop Factor (PBCDF): 0.134

0.222 <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 41
Direction	NB
Construction ID:	1100-50-71
Region:	Northeast
County:	Fond du Lac
Date:	9/30/2022
Day of Week:	Friday
Area Type:	Urban
Time of Day:	8:45 AM to 10:45 AM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	0
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

This project proposes milling and paving 2 inches of SMA on IH 41 and 2 inches of HMA on the CTH B interchange ramps, replacing the median cable guard system and adjusting the median to a maximum slope of 6:1, replacing beam guard, grading side slopes steeper than 3:1 to meet the interstate conversion requirements, and re-tying culvert pipe joints exhibiting separation and secondary structure work.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	8:45 AM	End Time:	9:10 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
123	123	per 5 minutes	159	159
336	336	per 15 minutes	428	428
1,303	1,303	per hour	1,642	1,642
1,344	1,344	Max Flow Rate$_s$*	1,712	1,712

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
104	104	per 5 minutes	130	130
310	310	per 15 minutes	386	386
1,234	1,234	per hour	1,538	1,538
1,242	1,242	Max Flow Rate$_s$*	1,545	1,545

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	9:10 AM	End Time:	10:45 AM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
90 per 5 minutes	24.4%	34%	66%	112 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
68	68	per 5 minutes	91	91
232	232	per 15 minutes	293	293
1,041	1,041	per hour	1,301	1,301

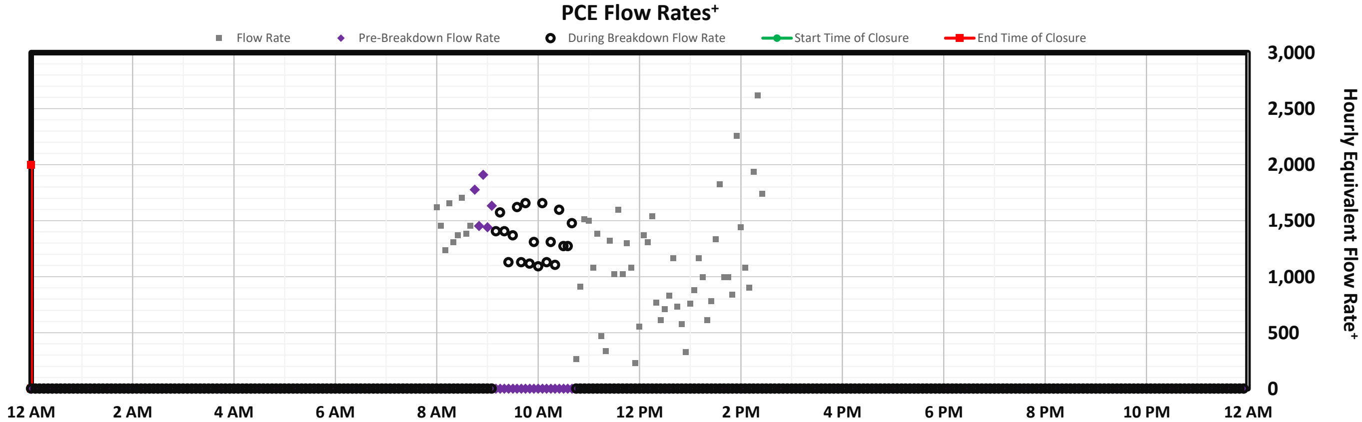
---------------- Average Observed Queue Discharge Rate ----------------

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
90	90	per 5 minutes	112	112
269	269	per 15 minutes	334	334
1,069	1,069	per hour	1,332	1,332
1,126	1,126	WZ Model Est.	1,400	1,400

-------------------------- Maximum Observed Queue Discharge Rate --------------------------

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
113	113	per 5 minutes	138	138
298	298	per 15 minutes	367	367
1,099	1,099	per hour	1,371	1,371

PCE Flow Rates⁺



⁺ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 41 NB Fond du Lac County Northeast (1100-50-71)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.189

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 41
Direction	NB
Construction ID:	1100-50-71
Region:	Northeast
County:	Fond du Lac
Date:	10/7/2022
Day of Week:	Friday
Area Type:	Urban
Time of Day:	8:45 AM to 10:30 AM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	0
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

This project proposes milling and paving 2 inches of SMA on IH 41 and 2 inches of HMA on the CTH B interchange ramps, replacing the median cable guard system and adjusting the median to a maximum slope of 6:1, replacing beam guard, grading side slopes steeper than 3:1 to meet the interstate conversion requirements, and re-tying culvert pipe joints exhibiting separation and secondary structure work.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	8:45 AM	End Time:	9:10 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
120	120	per 5 minutes	152	152
344	344	per 15 minutes	435	435
1,265	1,265	per hour	1,582	1,582
1,376	1,376	Max Flow Rate$_s$*	1,740	1,740

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Pre-Breakdown Capacity (Estimated)				
110	110	per 5 minutes	135	135
333	333	per 15 minutes	408	408
1,329	1,329	per hour	1,629	1,629
1,332	1,332	Max Flow Rate$_s$*	1,631	1,631

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

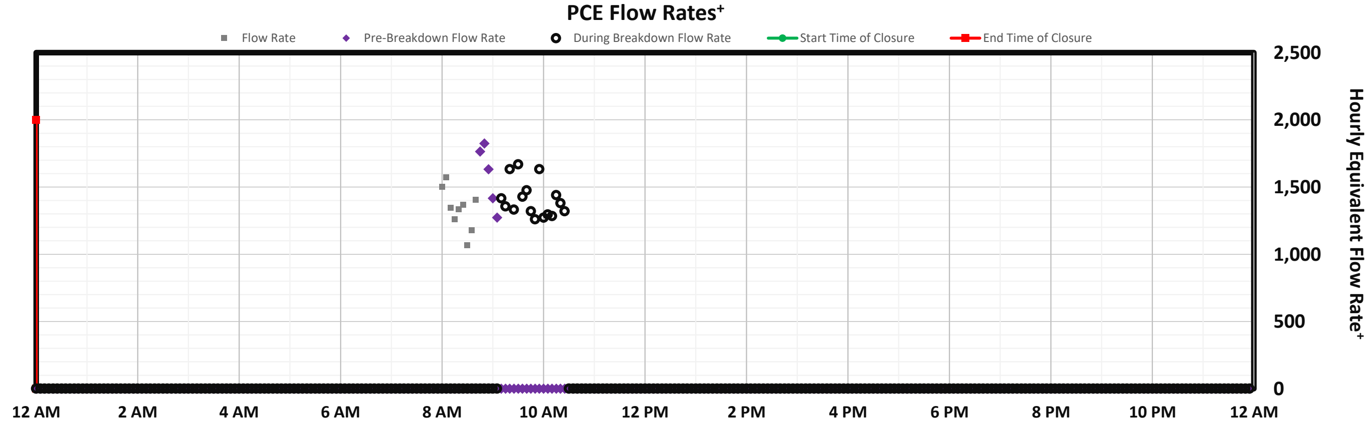
Select Times - >	Start Time:	9:10 AM	End Time:	10:30 AM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
96 per 5 minutes	22.8%	32%	68%	117 per 5 minutes

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Minimum Observed Queue Discharge Rate				
83	83	per 5 minutes	105	105
272	272	per 15 minutes	321	321
1,144	1,144	per hour	1,398	1,398

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Average Observed Queue Discharge Rate				
96	96	per 5 minutes	117	117
288	288	per 15 minutes	353	353
1,151	1,151	per hour	1,411	1,411
1,140	1,140	WZ Model Est.	1,400	1,400

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Maximum Observed Queue Discharge Rate				
109	109	per 5 minutes	139	139
307	307	per 15 minutes	386	386
1,157	1,157	per hour	1,424	1,424

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 94 EB Eau Claire County Northwest (1022-08-74)

PCE Conversion Factor: 2.00

Pre-Breakdown Capacity Drop Factor (PBCDF): 0.134

0.124 <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	EB
Construction ID:	1022-08-74
Region:	Northwest
County:	Eau Claire
Date:	8/17/2022
Day of Week:	Wednesday
Area Type:	Rural
Time of Day:	9:20 AM to 5:40 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	0
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

Proposed improvements include pavement replacement (new concrete) for 2.8 miles of IH 94 from STH 312 to CTH E. Approximately two miles east of the proposed concrete replacement, a 0.8-mile segment of IH 94 from CTH C to the Chippewa River will be milled and resurfaced with new HMA pavement. The project also includes pavement replacement for three of the four ramps at the STH 312 Interchange. No work is proposed for the existing Northeast Ramp (westbound entrance to IH 94).

A concrete deck overlay along with minor concrete surface repairs to the substructure is also proposed for the existing STH 312 overpass structure (B-18-15). Pavement replacement and concrete curb and gutter replacement is also proposed for STH 312 between the ramp terminal intersections.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	9:20 AM	End Time:	10:15 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
102	102	per 5 minutes	125	125
292	292	per 15 minutes	364	364
1,099	1,099	per hour	1,404	1,404
1,168	1,168	Max Flow Rate$_s$*	1,456	1,456

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
93	93	per 5 minutes	123	123
280	280	per 15 minutes	368	368
1,113	1,113	per hour	1,474	1,474
1,118	1,118	Max Flow Rate$_s$*	1,473	1,473

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	10:15 AM	End Time:	5:40 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
81 per 5 minutes	31.7%	16%	84%	106 per 5 minutes

Minimum Observed Queue Discharge Rate

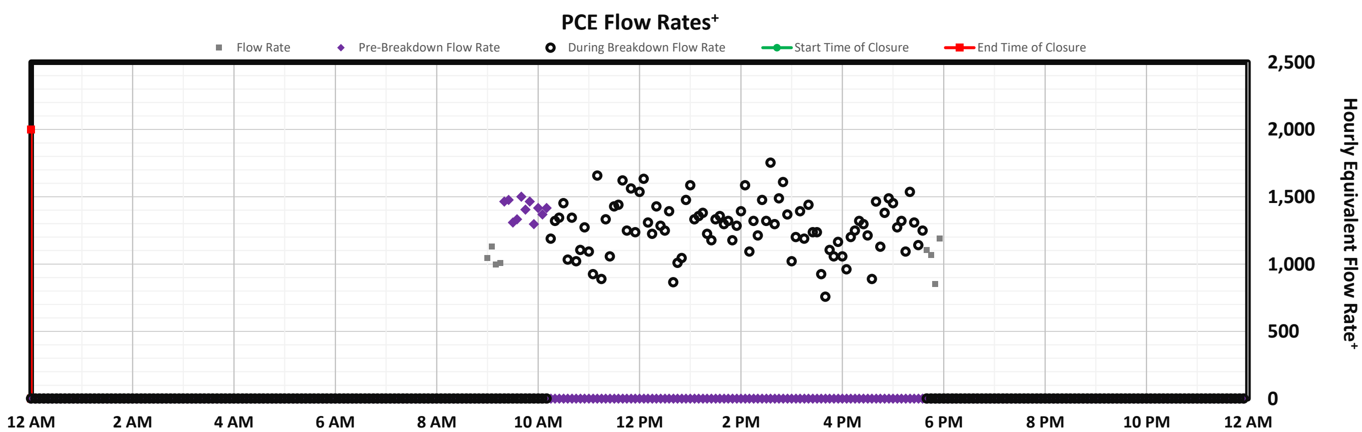
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
44	44	per 5 minutes	63	63
175	175	per 15 minutes	232	232
845	845	per hour	1,105	1,105

Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
81	81	per 5 minutes	106	106
242	242	per 15 minutes	319	319
964	964	per hour	1,276	1,276
908	908	WZ Model Est.	1,195	1,195

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
115	115	per 5 minutes	146	146
289	289	per 15 minutes	379	379
1,051	1,051	per hour	1,412	1,412



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates
IH 94 EB Eau Claire County Northwest (1022-08-74)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.209

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	EB
Construction ID:	1022-08-74
Region:	Northwest
County:	Eau Claire
Date:	8/23/2022
Day of Week:	Tuesday
Area Type:	Rural
Time of Day:	11:00 AM to 5:45 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	0
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

Proposed improvements include pavement replacement (new concrete) for 2.8 miles of IH 94 from STH 312 to CTH E. Approximately two miles east of the proposed concrete replacement, a 0.8-mile segment of IH 94 from CTH C to the Chippewa River will be milled and resurfaced with new HMA pavement. The project also includes pavement replacement for three of the four ramps at the STH 312 Interchange. No work is proposed for the existing Northeast Ramp (westbound entrance to IH 94).

A concrete deck overlay along with minor concrete surface repairs to the substructure is also proposed for the existing STH 312 overpass structure (B-18-15). Pavement replacement and concrete curb and gutter replacement is also proposed for STH 312 between the ramp terminal intersections.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	11:00 AM	End Time:	11:50 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
109	109	per 5 minutes	144	144
296	296	per 15 minutes	380	380
1,092	1,092	per hour	1,417	1,417
1,184	1,184	Max Flow Rate$_s$*	1,520	1,520

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
87	87	per 5 minutes	117	117
260	260	per 15 minutes	349	349
1,032	1,032	per hour	1,388	1,388
1,041	1,041	Max Flow Rate$_s$*	1,396	1,396

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	11:50 AM	End Time:	5:45 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
75 per 5 minutes	34.0%	12%	88%	101 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
52	52	per 5 minutes	67	67
170	170	per 15 minutes	217	217
816	816	per hour	1,096	1,096

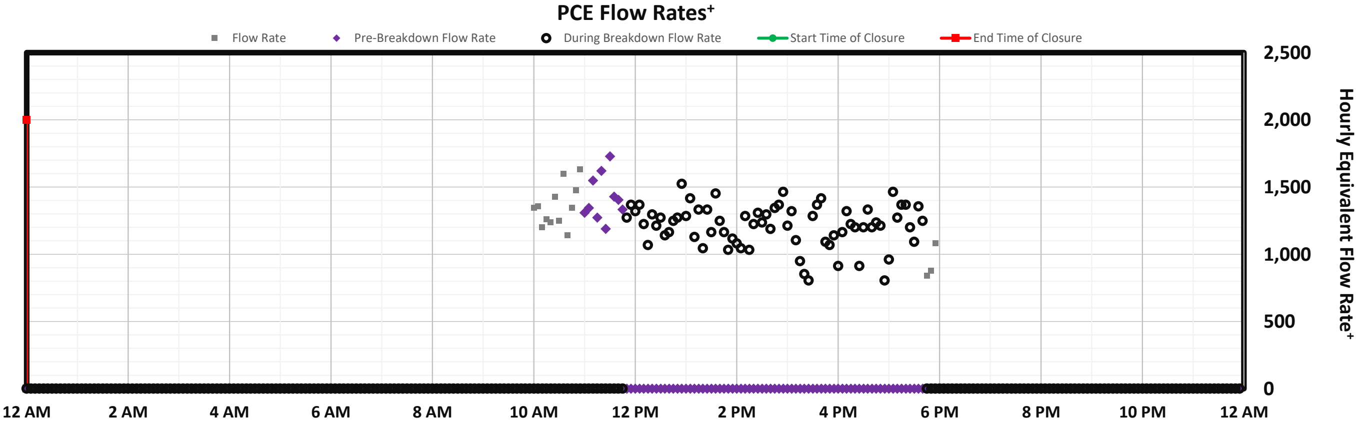
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
75	75	per 5 minutes	101	101
225	225	per 15 minutes	302	302
894	894	per hour	1,202	1,202
892	892	WZ Model Est.	1,195	1,195

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
95	95	per 5 minutes	127	127
266	266	per 15 minutes	352	352
957	957	per hour	1,287	1,287

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 94 EB Eau Claire County Northwest (1022-08-74)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.173

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	EB
Construction ID:	1022-08-74
Region:	Northwest
County:	Eau Claire
Date:	8/24/2022
Day of Week:	Wednesday
Area Type:	Rural
Time of Day:	10:00 AM to 3:20 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	0
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

Proposed improvements include pavement replacement (new concrete) for 2.8 miles of IH 94 from STH 312 to CTH E. Approximately two miles east of the proposed concrete replacement, a 0.8-mile segment of IH 94 from CTH C to the Chippewa River will be milled and resurfaced with new HMA pavement. The project also includes pavement replacement for three of the four ramps at the STH 312 Interchange. No work is proposed for the existing Northeast Ramp (westbound entrance to IH 94).

A concrete deck overlay along with minor concrete surface repairs to the substructure is also proposed for the existing STH 312 overpass structure (B-18-15). Pavement replacement and concrete curb and gutter replacement is also proposed for STH 312 between the ramp terminal intersections.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	10:00 AM	End Time:	10:40 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
109	109	per 5 minutes	141	141
280	280	per 15 minutes	373	373
1,025	1,025	per hour	1,343	1,343
1,120	1,120	Max Flow Rate$_s$*	1,492	1,492

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
88	88	per 5 minutes	118	118
263	263	per 15 minutes	354	354
1,055	1,055	per hour	1,424	1,424
1,054	1,054	Max Flow Rate$_s$*	1,417	1,417

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

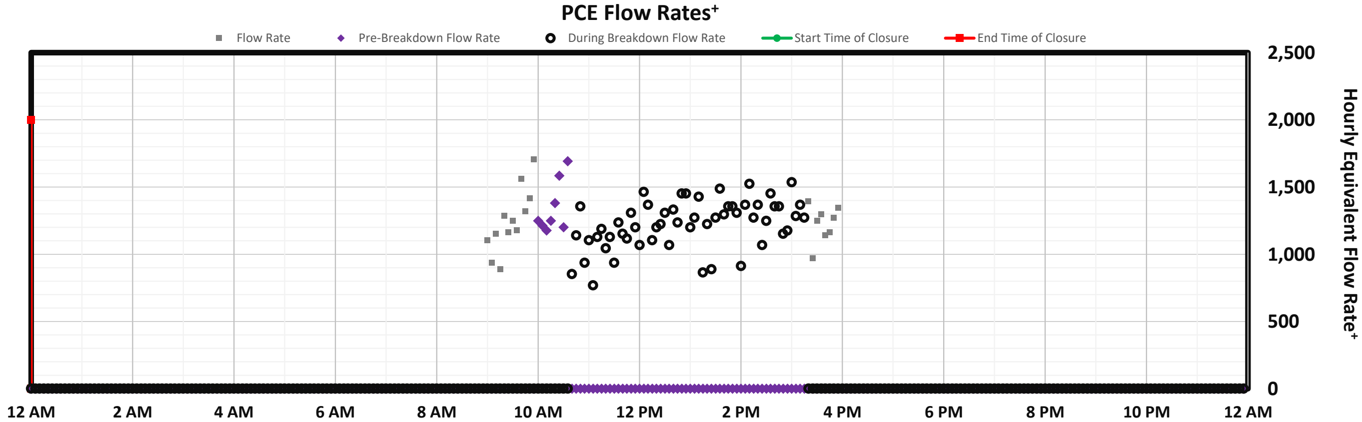
Select Times - >	Start Time:	10:40 AM	End Time:	3:20 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
76 per 5 minutes	34.2%	15%	85%	102 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
50	50	per 5 minutes	64	64
178	178	per 15 minutes	234	234
818	818	per hour	1,068	1,068

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
76	76	per 5 minutes	102	102
228	228	per 15 minutes	307	307
913	913	per hour	1,233	1,233
890	890	WZ Model Est.	1,195	1,195

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
99	99	per 5 minutes	128	128
268	268	per 15 minutes	349	349
975	975	per hour	1,323	1,323

PCE Flow Rates⁺



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates
IH 94 WB Eau Claire County Northwest (1022-08-74)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.154

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1022-08-74
Region:	Northwest
County:	Eau Claire
Date:	8/18/2022
Day of Week:	Thursday
Area Type:	Rural
Time of Day:	2:20 PM to 3:15 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	0
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

Proposed improvements include pavement replacement (new concrete) for 2.8 miles of IH 94 from STH 312 to CTH E. Approximately two miles east of the proposed concrete replacement, a 0.8-mile segment of IH 94 from CTH C to the Chippewa River will be milled and resurfaced with new HMA pavement. The project also includes pavement replacement for three of the four ramps at the STH 312 Interchange. No work is proposed for the existing Northeast Ramp (westbound entrance to IH 94).

A concrete deck overlay along with minor concrete surface repairs to the substructure is also proposed for the existing STH 312 overpass structure (B-18-15). Pavement replacement and concrete curb and gutter replacement is also proposed for STH 312 between the ramp terminal intersections.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	2:20 PM	End Time:	2:50 PM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
116	116	per 5 minutes	153	153
326	326	per 15 minutes	410	410
1,270	1,270	per hour	1,584	1,584
1,304	1,304	Max Flow Rate$_s$*	1,640	1,640

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
110	110	per 5 minutes	133	133
332	332	per 15 minutes	401	401
1,322	1,322	per hour	1,602	1,602
1,329	1,329	Max Flow Rate$_s$*	1,606	1,606

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	2:50 PM	End Time:	3:15 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
95 per 5 minutes	21.2%	31%	69%	116 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
45	45	per 5 minutes	55	55
255	255	per 15 minutes	310	310
1,145	1,145	per hour	1,387	1,387

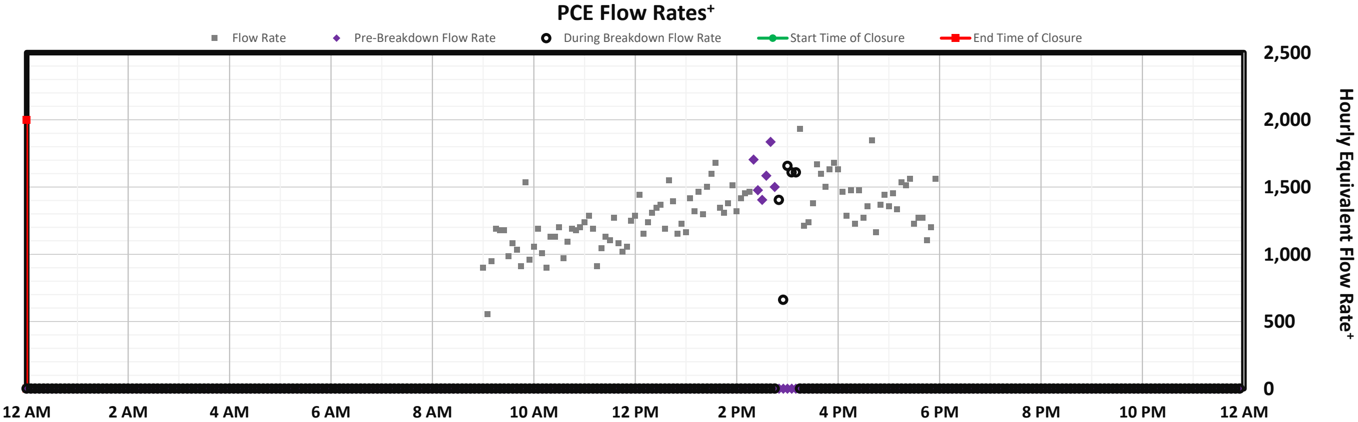
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
95	95	per 5 minutes	116	116
288	288	per 15 minutes	348	348
1,145	1,145	per hour	1,387	1,387
1,157	1,157	WZ Model Est.	1,402	1,402

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
117	117	per 5 minutes	138	138
339	339	per 15 minutes	406	406
1,145	1,145	per hour	1,387	1,387

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates
IH 94 WB Eau Claire County Northwest (1022-08-74)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.023

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1022-08-74
Region:	Northwest
County:	Eau Claire
Date:	9/1/2022
Day of Week:	Thursday
Area Type:	Rural
Time of Day:	12:40 PM to 1:25 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	60 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	0
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:40 PM	End Time:	1:15 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
106	106	per 5 minutes	134	134
286	286	per 15 minutes	364	364
1,106	1,106	per hour	1,406	1,406
1,144	1,144	Max Flow Rate$_s$*	1,456	1,456

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
107	107	per 5 minutes	137	137
#DIV/0!	#DIV/0!	per 15 minutes	#DIV/0!	#DIV/0!
1,289	1,289	per hour	1,642	1,642
#DIV/0!	#DIV/0!	Max Flow Rate$_s$*	#DIV/0!	#DIV/0!

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

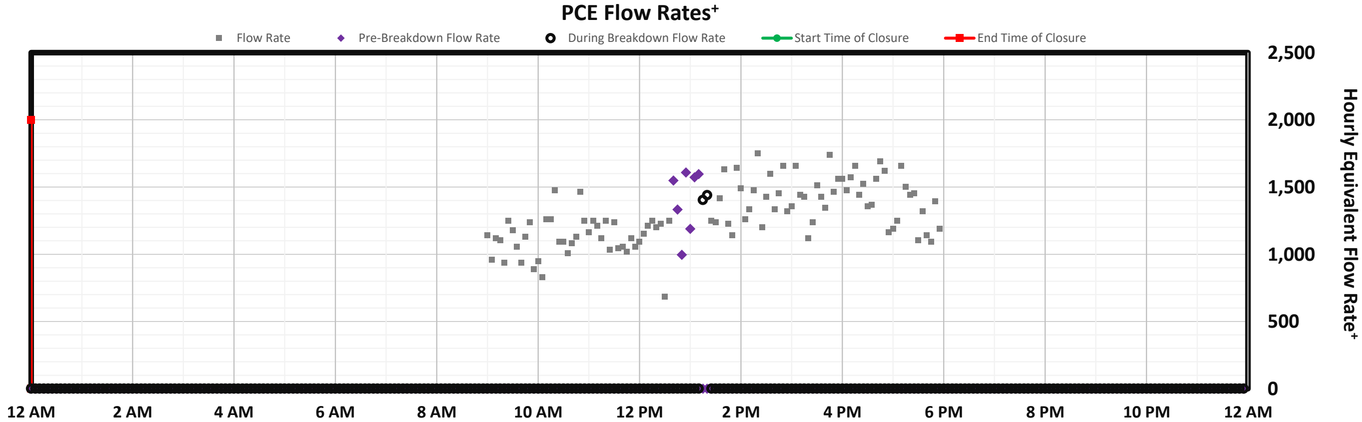
Select Times - >	Start Time:	1:15 PM	End Time:	1:25 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
93 per 5 minutes	27.4%	27%	73%	119 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
88	88	per 5 minutes	117	117
0	0	per 15 minutes	0	0
1,116	1,116	per hour	1,422	1,422

Average Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
93	93	per 5 minutes	119	119
#DIV/0!	#DIV/0!	per 15 minutes	#DIV/0!	#DIV/0!
1,116	1,116	per hour	1,422	1,422
1,100	1,100	WZ Model Est.	1,402	1,402

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
98	98	per 5 minutes	120	120
0	0	per 15 minutes	0	0
1,116	1,116	per hour	1,422	1,422

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 WB Eau Claire County Northwest (1022-08-74)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.035

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1022-08-74
Region:	Northwest
County:	Eau Claire
Date:	9/1/2022
Day of Week:	Thursday
Area Type:	Rural
Time of Day:	2:50 PM to 4:15 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	60 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	0
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	2:50 PM	End Time:	3:20 PM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
113	113	per 5 minutes	138	138
306	306	per 15 minutes	377	377
1,206	1,206	per hour	1,476	1,476
1,224	1,224	Max Flow Rate$_s$*	1,508	1,508

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
115	115	per 5 minutes	140	140
349	349	per 15 minutes	427	427
1,377	1,377	per hour	1,680	1,680
1,397	1,397	Max Flow Rate$_s$*	1,708	1,708

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	3:20 PM	End Time:	4:15 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
99 per 5 minutes	22.0%	17%	83%	121 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
76	76	per 5 minutes	93	93
261	261	per 15 minutes	322	322
1,192	1,192	per hour	1,455	1,455

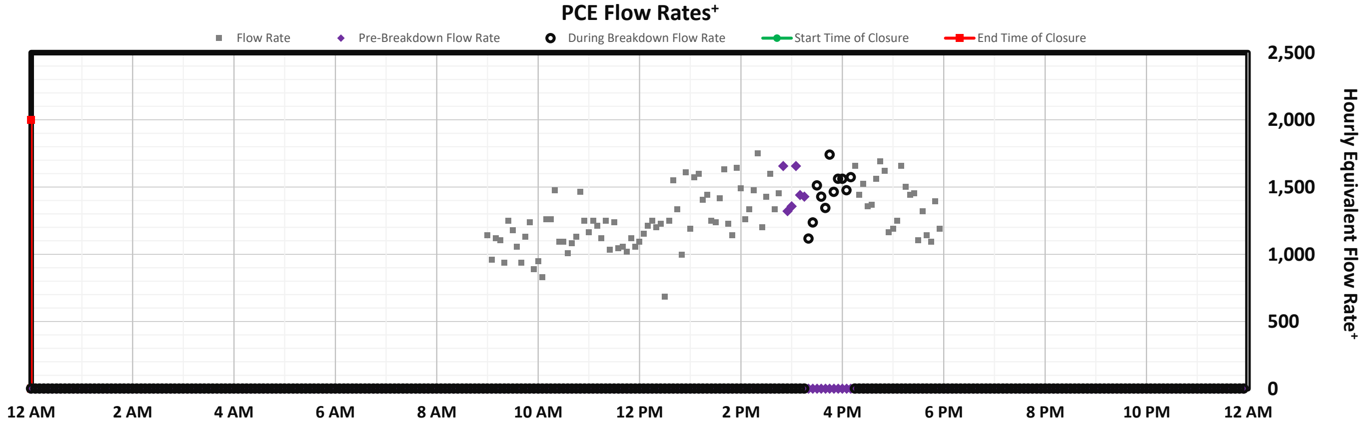
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
99	99	per 5 minutes	121	121
302	302	per 15 minutes	370	370
1,192	1,192	per hour	1,455	1,455
1,149	1,149	WZ Model Est.	1,402	1,402

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
122	122	per 5 minutes	145	145
327	327	per 15 minutes	397	397
1,192	1,192	per hour	1,455	1,455

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates
IH 90/94 EB Sauk County Southwest (208707)

PCE Conversion Factor: **2.00**

Pre-Breakdown Capacity Drop Factor (PBCDF): **0.134**

#DIV/0! <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 90/94
Direction	EB
Closure ID:	208707
Region:	Southwest
County:	Sauk
Date:	10/31/2022
Day of Week:	Monday
Area Type:	Urban
Time of Day:	2:25 PM to 4:00 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	2:25 PM	End Time:	2:35 PM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
94	94	per 5 minutes	145	145
0	0	per 15 minutes	0	0
1,044	1,044	per hour	1,524	1,524
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
96	96	per 5 minutes	141	141
291	291	per 15 minutes	425	425
1,164	1,164	per hour	1,694	1,694
1,163	1,163	Max Flow Rate$_s$*	1,699	1,699

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	2:35 PM	End Time:	4:00 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
84 per 5 minutes	46.5%	11%	89%	122 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
71	71	per 5 minutes	108	108
234	234	per 15 minutes	336	336
985	985	per hour	1,433	1,433

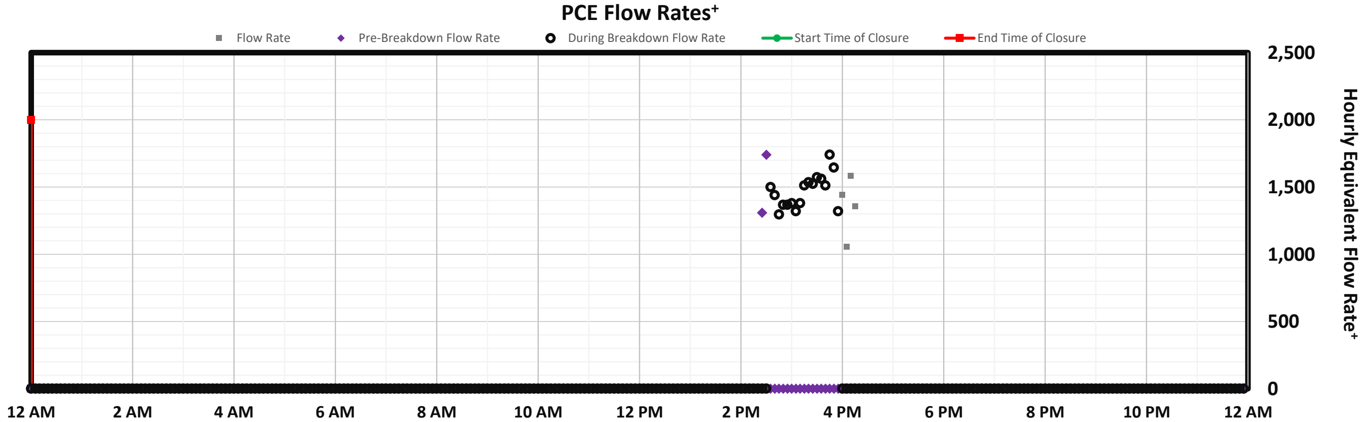
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
84	84	per 5 minutes	122	122
252	252	per 15 minutes	368	368
1,008	1,008	per hour	1,467	1,467
987	987	WZ Model Est.	1,447	1,447

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
95	95	per 5 minutes	145	145
275	275	per 15 minutes	408	408
1,033	1,033	per hour	1,504	1,504

PCE Flow Rates⁺



⁺ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 90/94 EB Sauk County Southwest (208707)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	-0.071

<-- Observed PBCDF
[1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 90/94
Direction	EB
Construction ID:	208707
Region:	Southwest
County:	Sauk
Date:	11/1/2022
Day of Week:	Tuesday
Area Type:	Urban
Time of Day:	2:05 PM to 2:45 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	2:05 PM	End Time:	2:30 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
95	95	per 5 minutes	132	132
237	237	per 15 minutes	336	336
953	953	per hour	1,380	1,380
948	948	Max Flow Rate$_s$*	1,344	1,344

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
93	93	per 5 minutes	139	139
278	278	per 15 minutes	416	416
1,113	1,113	per hour	1,663	1,663
1,113	1,113	Max Flow Rate$_s$*	1,663	1,663

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

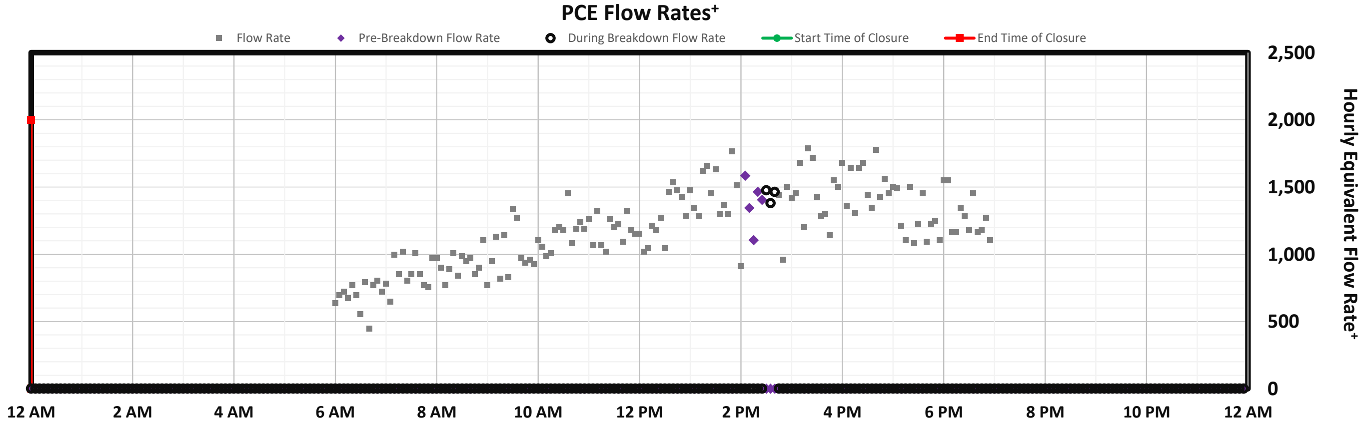
Select Times - >	Start Time:	2:30 PM	End Time:	2:45 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
80	49.4%	18%	82%	120
per 5 minutes				*per 5 minutes*

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
73	73	per 5 minutes	115	115
241	241	per 15 minutes	360	360
964	964	per hour	1,440	1,440

---------------- Average Observed Queue Discharge Rate ----------------				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
80	80	per 5 minutes	120	120
241	241	per 15 minutes	360	360
964	964	per hour	1,440	1,440
969	969	WZ Model Est.	1,447	1,447

-------------------------- Maximum Observed Queue Discharge Rate --------------------------				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
85	85	per 5 minutes	123	123
241	241	per 15 minutes	360	360
964	964	per hour	1,440	1,440

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 90/94 EB Sauk County Southwest (208707)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.086

<-- Observed PBCDF
[1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 90/94
Direction	EB
Construction ID:	208707
Region:	Southwest
County:	Sauk
Date:	11/2/2022
Day of Week:	Wednesday
Area Type:	Urban
Time of Day:	4:25 PM to 5:15 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

Notes:

---------------------------- PRE-BREAKDOWN CAPACITY ----------------------------

Select Times - >	Start Time:	4:25 PM	End Time:	4:50 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
92	92	per 5 minutes	136	136
258	258	per 15 minutes	382	382
1,034	1,034	per hour	1,534	1,534
1,032	1,032	Max Flow Rate$_s$*	1,528	1,528

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
90	90	per 5 minutes	134	134
278	278	per 15 minutes	411	411
1,084	1,084	per hour	1,613	1,613
1,110	1,110	Max Flow Rate$_s$*	1,643	1,643

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

------------- DURING BREAKDOWN QUEUE DISCHARGE RATE -------------

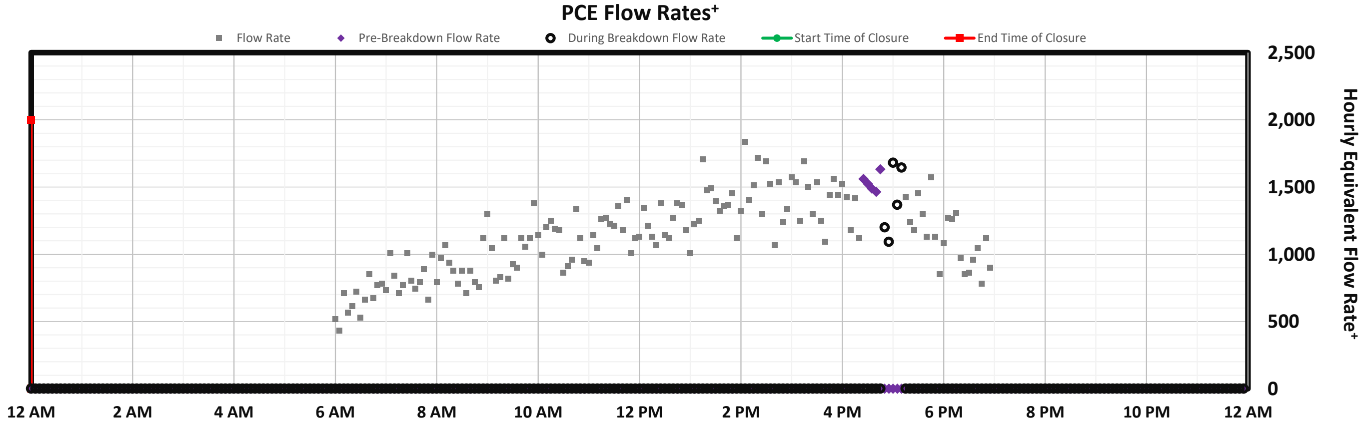
Select Times - >	Start Time:	4:50 PM	End Time:	5:15 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
78	48.8%	12%	88%	116
per 5 minutes				per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
61	61	per 5 minutes	91	91
222	222	per 15 minutes	331	331
938	938	per hour	1,397	1,397

---------------- Average Observed Queue Discharge Rate ----------------				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
78	78	per 5 minutes	116	116
240	240	per 15 minutes	356	356
938	938	per hour	1,397	1,397
972	972	WZ Model Est.	1,447	1,447

-------------------------- Maximum Observed Queue Discharge Rate --------------------------				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
94	94	per 5 minutes	140	140
263	263	per 15 minutes	391	391
938	938	per hour	1,397	1,397

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 90/94 WB Columbia County Southwest (1011-01-65)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.271

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 90/94
Direction	WB
Construction ID:	1011-01-65
Region:	Southwest
County:	Columbia
Date:	11/2/2022
Day of Week:	Wednesday
Area Type:	Rural
Time of Day:	7:00 PM to 8:55 PM
Barrier Type:	Soft
Day or Night	Night
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	0
Downstream Ramps (within 3mi)	0
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Other
# of permanent lanes	3
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

The proposed action consists of patching the existing pavement in spot locations. The patching would occur from the Columbia County line to the STH 60 interchange and take place in both the southbound and northbound travel lanes. The STH 60 interchange ramps will not be included. The proposed action will also include pavement markings on I-39/90/94.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	7:00 PM	End Time:	8:25 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
98	98	per 5 minutes	126	126
259	259	per 15 minutes	349	349
898	898	per hour	1,253	1,253
1,036	1,036	Max Flow Rate$_s$*	1,396	1,396

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
69	69	per 5 minutes	98	98
213	213	per 15 minutes	309	309
822	822	per hour	1,176	1,176
852	852	Max Flow Rate$_s$*	1,234	1,234

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

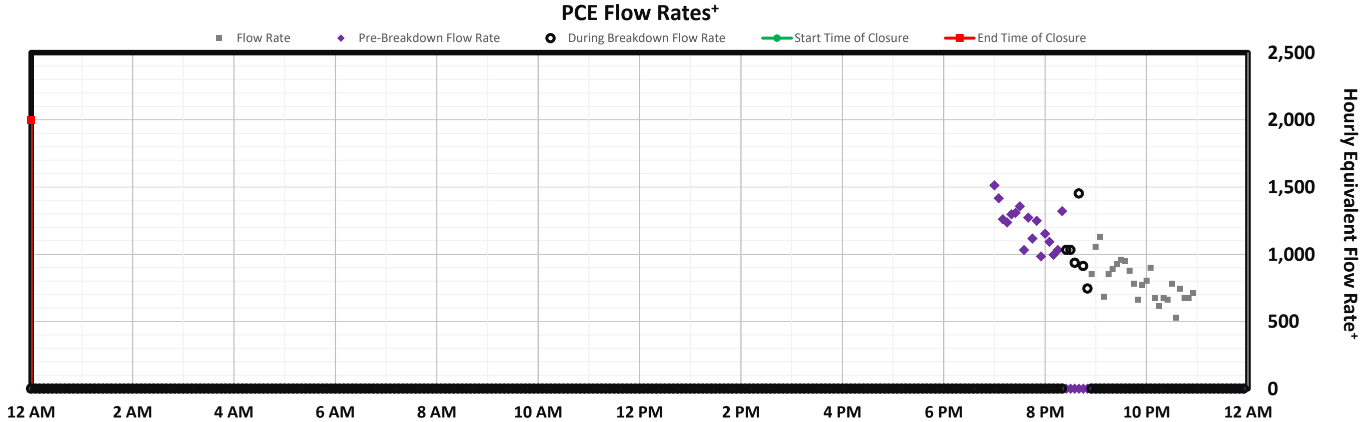
Select Times - >	Start Time:	8:25 PM	End Time:	8:55 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
59 per 5 minutes	43.0%	13%	87%	85 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
44	44	per 5 minutes	62	62
177	177	per 15 minutes	250	250
712	712	per hour	1,018	1,018

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
59	59	per 5 minutes	85	85
185	185	per 15 minutes	267	267
712	712	per hour	1,018	1,018
770	770	WZ Model Est.	1,101	1,101

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
81	81	per 5 minutes	121	121
194	194	per 15 minutes	285	285
712	712	per hour	1,018	1,018

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 90/94 WB Columbia County Southwest (1011-01-65)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.123 <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 90/94
Direction	WB
Construction ID:	1011-01-65
Region:	Southwest
County:	Columbia
Date:	11/3/2022
Day of Week:	Thursday
Area Type:	Rural
Time of Day:	7:30 PM to 8:05 PM
Barrier Type:	Soft
Day or Night	Night
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	0
Downstream Ramps (within 3mi)	0
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Other
# of permanent lanes	3
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

The proposed action consists of patching the existing pavement in spot locations. The patching would occur from the Columbia County line to the STH 60 interchange and take place in both the southbound and northbound travel lanes. The STH 60 interchange ramps will not be included. The proposed action will also include pavement markings on I-39/90/94.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	7:30 PM	End Time:	7:55 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
99	99	per 5 minutes	137	137
247	247	per 15 minutes	337	337
1,008	1,008	per hour	1,354	1,354
988	988	Max Flow Rate$_s$*	1,348	1,348

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
85	85	per 5 minutes	114	114
#DIV/0!	#DIV/0!	per 15 minutes	#DIV/0!	#DIV/0!
1,018	1,018	per hour	1,365	1,365
#DIV/0!	#DIV/0!	Max Flow Rate$_s$*	#DIV/0!	#DIV/0!

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

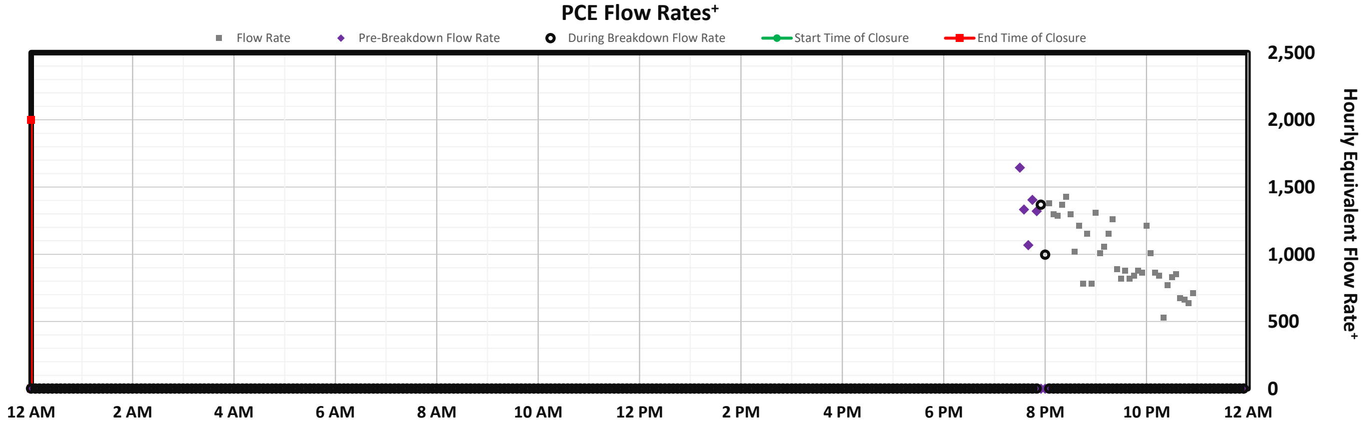
Select Times ->	Start Time:	7:55 PM	End Time:	8:05 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
74 per 5 minutes	34.0%	18%	82%	99 per 5 minutes

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
63	63	per 5 minutes	83	83
0	0	per 15 minutes	0	0
882	882	per hour	1,182	1,182

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
74	74	per 5 minutes	99	99
#DIV/0!	#DIV/0!	per 15 minutes	#DIV/0!	#DIV/0!
882	882	per hour	1,182	1,182
822	822	WZ Model Est.	1,101	1,101

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
84	84	per 5 minutes	114	114
0	0	per 15 minutes	0	0
882	882	per hour	1,182	1,182

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

APPENDIX B

Queue Discharge Spreadsheets for Sites without Observed Queueing

Work Zone Capacity

Queue Discharge Flow Rates

IH 39 SB Portage County North Central (1166-05-84)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	#DIV/0!

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 39
Direction	SB
Construction ID:	1166-05-84
Region:	North Central
County:	Portage
Date:	9/11/2022
Day of Week:	Sunday
Area Type:	Rural
Time of Day:	12:00 AM to 2:45 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

Paint steel components of bridge B-49-21, CTH HH over IH 39.

Notes:

---------------------------- PRE-BREAKDOWN CAPACITY ----------------------------

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	**0**	**Max Flow Rate$_s$***	**0**	**0**

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
109	109	per 5 minutes	120	120
327	327	per 15 minutes	359	359
1,310	**1,310**	**per hour**	**1,440**	**1,440**
1,307	**1,307**	**Max Flow Rate$_s$***	**1,435**	**1,435**

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

------------- DURING BREAKDOWN QUEUE DISCHARGE RATE -------------

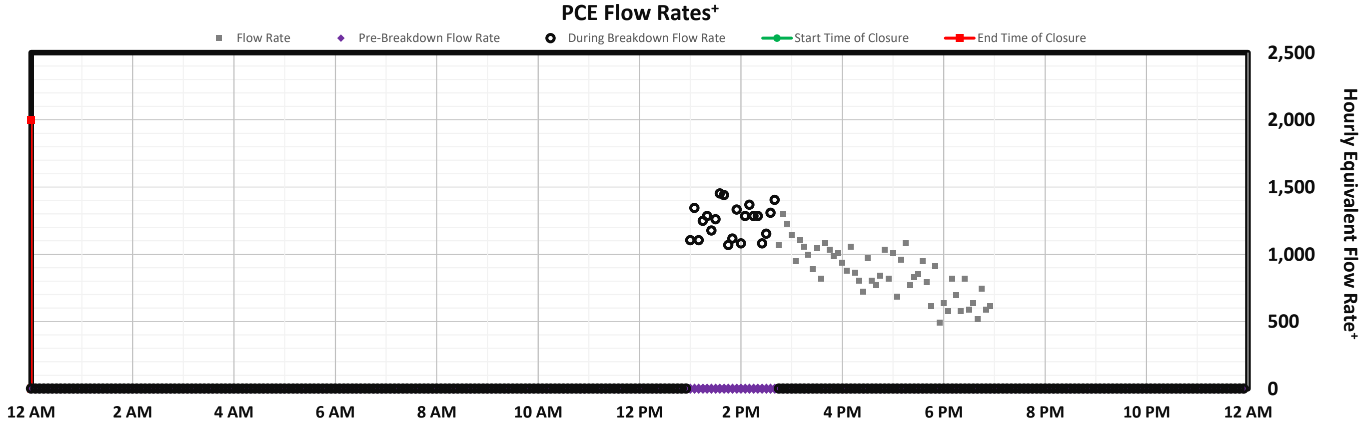
Select Times - >	Start Time:	1:00 PM	End Time:	2:45 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
95 per 5 minutes	9.9%	83%	17%	104 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
81	81	per 5 minutes	89	89
267	267	per 15 minutes	293	293
1,121	1,121	per hour	1,230	1,230

---------------- Average Observed Queue Discharge Rate ----------------				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
95	95	per 5 minutes	104	104
283	283	per 15 minutes	311	311
1,134	**1,134**	**per hour**	**1,247**	**1,247**
1,276	**1,276**	**WZ Model Est.**	**1,402**	**1,402**

-------------------------- Maximum Observed Queue Discharge Rate --------------------------				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
110	110	per 5 minutes	121	121
312	312	per 15 minutes	346	346
1,146	1,146	per hour	1,262	1,262

PCE Flow Rates+



\+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 39 NB Portage County North Central (1166-12-89)

PCE Conversion Factor: **2.00**

Pre-Breakdown Capacity Drop Factor (PBCDF): **0.134**

#DIV/0! <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 39
Direction	NB
Construction ID:	1166-12-89
Region:	North Central
County:	Portage
Date:	9/15/2022
Day of Week:	Thursday
Area Type:	Rural
Time of Day:	12:00 AM to 6:00 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

The work under this contract shall consist of resurface existing bridge structures, guardrail replacement, concrete joint replacement, vehicle detection loops, repair existing culverts, lengthen merge lane, and enhancing existing bridge protection.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - > Start Time: 12:00 AM End Time: 12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
57	57	per 5 minutes	67	67
170	170	per 15 minutes	203	203
680	680	per hour	814	814
679	679	Max Flow Rate$_s$*	811	811

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - > Start Time: 12:00 PM End Time: 6:00 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
49 per 5 minutes	19.3%	55%	45%	58 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
28	28	per 5 minutes	31	31
118	118	per 15 minutes	133	133
539	539	per hour	628	628

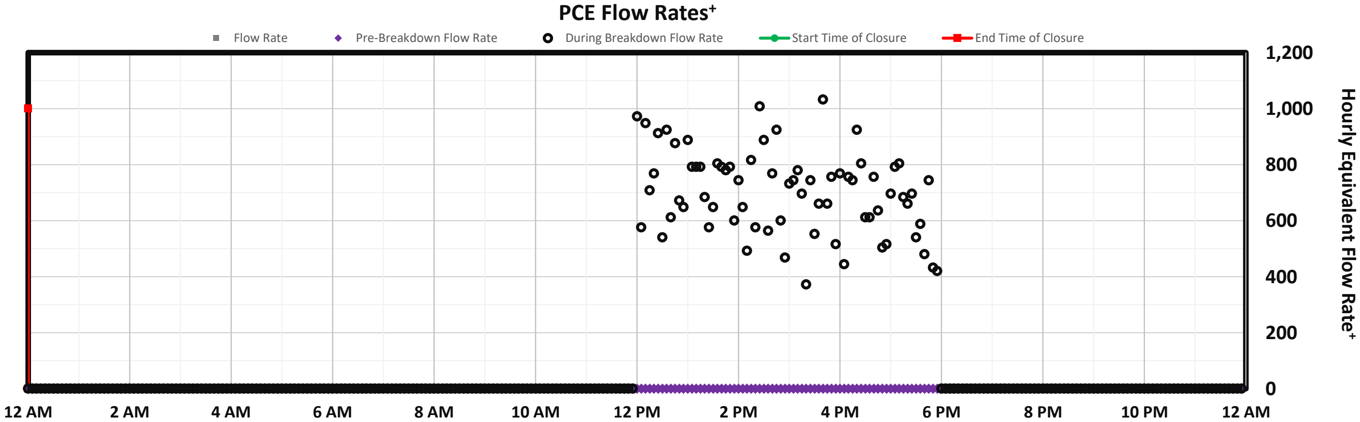
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
49	49	per 5 minutes	58	58
147	147	per 15 minutes	176	176
589	589	per hour	705	705
1,001	1,001	WZ Model Est.	1,195	1,195

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
73	73	per 5 minutes	86	86
179	179	per 15 minutes	208	208
635	635	per hour	774	774

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 39 NB Portage County North Central (1166-12-89)

PCE Conversion Factor: 2.00

Pre-Breakdown Capacity Drop Factor (PBCDF): 0.134

#DIV/0! <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 39
Direction	NB
Construction ID:	1166-12-89
Region:	North Central
County:	Portage
Date:	9/16/2022
Day of Week:	Friday
Area Type:	Rural
Time of Day:	12:00 AM to 6:00 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

The work under this contract shall consist of resurface existing bridge structures, guardrail replacement, concrete joint replacement, vehicle detection loops, repair existing culverts, lengthen merge lane, and enhancing existing bridge protection.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	**Vehicles**	**Time Period**	**PCEs/Lane**	**PCEs**
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	**Vehicles**	**Time Period**	**PCEs/Lane**	**PCEs**
70	70	per 5 minutes	81	81
209	209	per 15 minutes	244	244
837	837	per hour	976	976
836	836	Max Flow Rate$_s$*	974	974

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

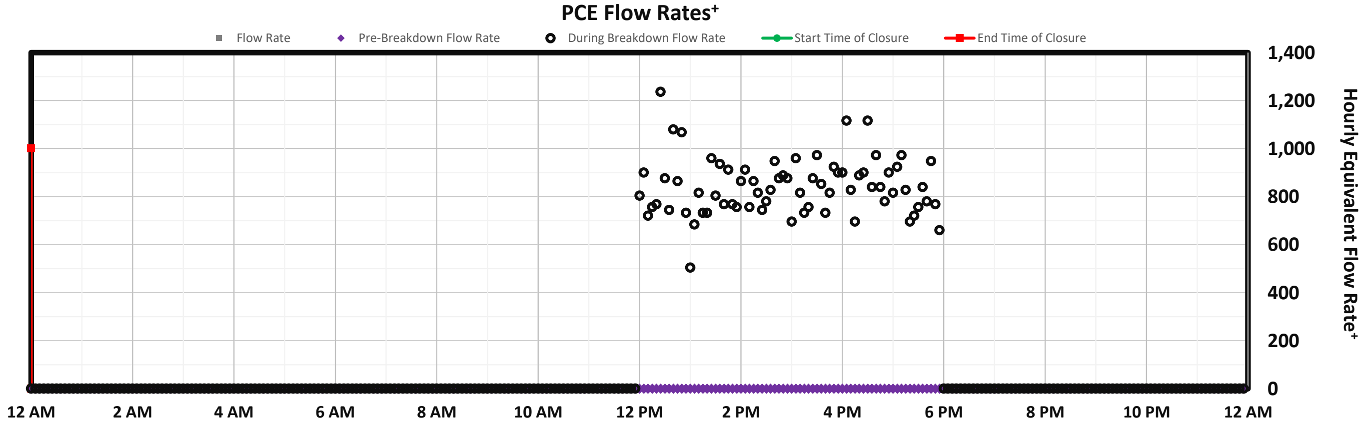
Select Times - >	Start Time:	12:00 PM	End Time:	6:00 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
60 per 5 minutes	16.4%	65%	35%	70 per 5 minutes

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	**Vehicles**	**Time Period**	**PCEs/Lane**	**PCEs**
37	37	per 5 minutes	42	42
137	137	per 15 minutes	160	160
666	666	per hour	779	779

Average Observed Queue Discharge Rate				
Vehicles/Lane	**Vehicles**	**Time Period**	**PCEs/Lane**	**PCEs**
60	60	per 5 minutes	70	70
181	181	per 15 minutes	211	211
725	725	per hour	845	845
1,026	1,026	WZ Model Est.	1,195	1,195

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	**Vehicles**	**Time Period**	**PCEs/Lane**	**PCEs**
84	84	per 5 minutes	103	103
212	212	per 15 minutes	251	251
789	789	per hour	910	910

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 39 NB Portage County North Central (1166-12-89)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	#DIV/0!

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 39
Direction	NB
Construction ID:	1166-12-89
Region:	North Central
County:	Portage
Date:	9/17/2022
Day of Week:	Saturday
Area Type:	Rural
Time of Day:	12:00 AM to 1:20 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

The work under this contract shall consist of resurface existing bridge structures, guardrail replacement, concrete joint replacement, vehicle detection loops, repair existing culverts, lengthen merge lane, and enhancing existing bridge protection.

Notes:

---------------------------- PRE-BREAKDOWN CAPACITY ----------------------------

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	**0**	**Max Flow Rate$_s$***	**0**	**0**

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
57	57	per 5 minutes	64	64
170	170	per 15 minutes	192	192
687	**687**	**per hour**	**776**	**776**
679	**679**	**Max Flow Rate$_s$***	**766**	**766**

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

------------- DURING BREAKDOWN QUEUE DISCHARGE RATE -------------

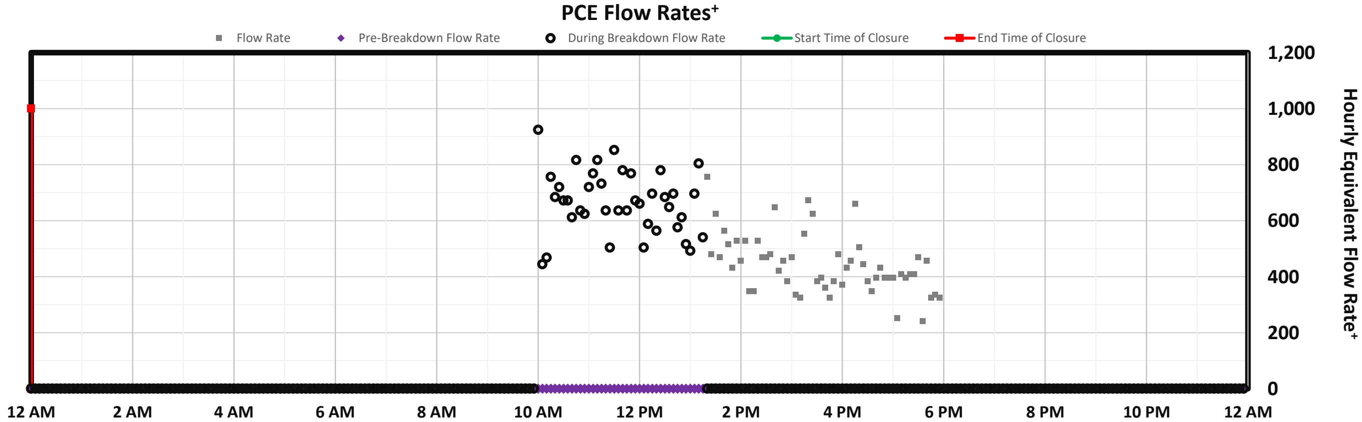
Select Times - >	Start Time:	10:00 AM	End Time:	1:20 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
49 per 5 minutes	12.9%	73%	27%	55 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
33	33	per 5 minutes	37	37
121	121	per 15 minutes	135	135
539	539	per hour	613	613

---------------- Average Observed Queue Discharge Rate ----------------				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
49	49	per 5 minutes	55	55
147	147	per 15 minutes	166	166
595	**595**	**per hour**	**672**	**672**
1,059	**1,059**	**WZ Model Est.**	**1,195**	**1,195**

-------------------------- Maximum Observed Queue Discharge Rate --------------------------				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
67	67	per 5 minutes	77	77
174	174	per 15 minutes	193	193
634	634	per hour	710	710

PCE Flow Rates⁺



[+] Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

USH 51 SB Marathon County North Central (6999-12-71)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
#DIV/0!	<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

TADI TRAFFIC ANALYSIS & DESIGN, INC.

WISCONSIN DEPARTMENT OF TRANSPORTATION

Version 1.8

Site Data	
Highway:	USH 51
Direction	SB
Construction ID:	6999-12-71
Region:	North Central
County:	Marathon
Date:	9/13/2022
Day of Week:	Tuesday
Area Type:	Rural
Time of Day:	12:00 AM to 7:55 AM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	65 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	4
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

The purpose of this project is to repair the CTH U bridge over USH 51 by removing the existing bridge deck underneath the eastbound lanes of CTH U, as well as the west approach slab and sidewalk, and replacing the damaged bridge girders. The project holds an emergency status, as the unexpected damage to the bridge must be repaired as soon as possible.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Pre-Breakdown Capacity (Estimated)				
98	98	per 5 minutes	106	106
294	294	per 15 minutes	318	318
1,175	1,175	per hour	1,273	1,273
1,175	1,175	Max Flow Rate$_s$*	1,273	1,273

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

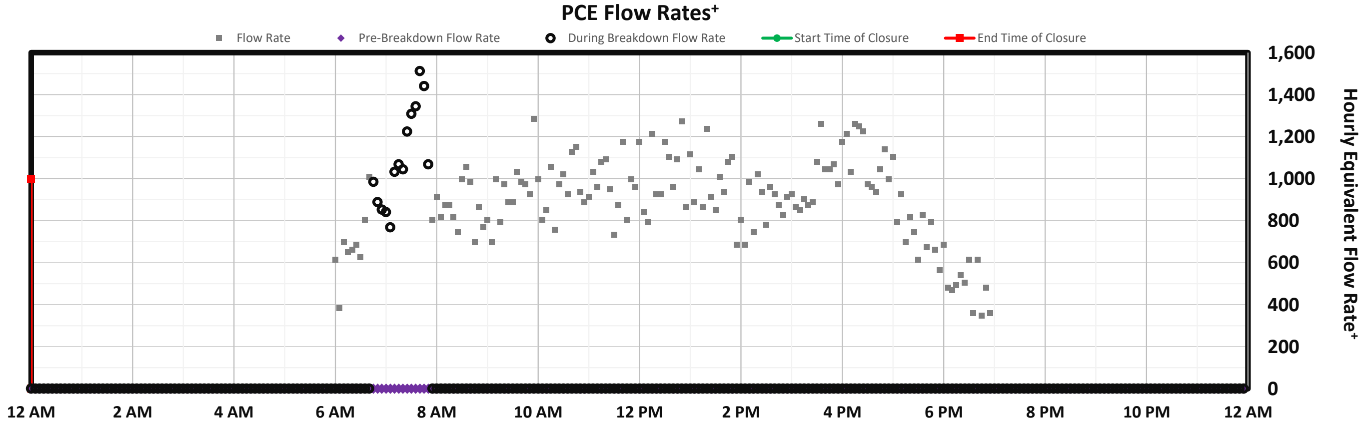
Select Times - >	Start Time:	6:45 AM	End Time:	7:55 AM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
85 per 5 minutes	8.0%	52%	48%	92 per 5 minutes

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Minimum Observed Queue Discharge Rate				
61	61	per 5 minutes	64	64
189	189	per 15 minutes	205	205
988	988	per hour	1,072	1,072

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Average Observed Queue Discharge Rate				
85	85	per 5 minutes	92	92
254	254	per 15 minutes	276	276
1,017	1,017	per hour	1,102	1,102
1,106	1,106	WZ Model Est.	1,195	1,195

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Maximum Observed Queue Discharge Rate				
118	118	per 5 minutes	126	126
339	339	per 15 minutes	358	358
1,039	1,039	per hour	1,125	1,125

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

USH 51 SB Marathon County North Central (6999-12-71)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	#DIV/0!

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	USH 51
Direction	SB
Construction ID:	6999-12-71
Region:	North Central
County:	Marathon
Date:	9/14/2022
Day of Week:	Wednesday
Area Type:	Rural
Time of Day:	12:00 AM to 9:50 AM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	65 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	4
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

The purpose of this project is to repair the CTH U bridge over USH 51 by removing the existing bridge deck underneath the eastbound lanes of CTH U, as well as the west approach slab and sidewalk, and replacing the damaged bridge girders. The project holds an emergency status, as the unexpected damage to the bridge must be repaired as soon as possible.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
84	84	per 5 minutes	95	95
248	248	per 15 minutes	282	282
970	970	per hour	1,100	1,100
993	993	Max Flow Rate$_s$*	1,127	1,127

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	7:15 AM	End Time:	9:50 AM

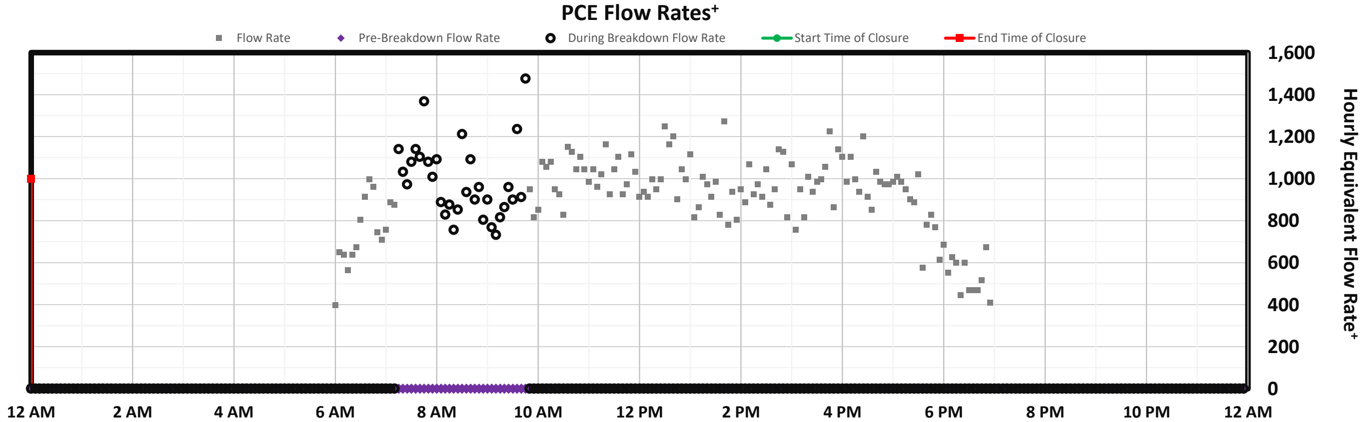
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
73 per 5 minutes	13.4%	51%	49%	82 per 5 minutes

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
47	47	per 5 minutes	61	61
161	161	per 15 minutes	193	193
766	766	per hour	886	886

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
73	73	per 5 minutes	82	82
215	215	per 15 minutes	244	244
840	840	per hour	953	953
1,054	1,054	WZ Model Est.	1,195	1,195

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
106	106	per 5 minutes	123	123
277	277	per 15 minutes	302	302
961	961	per hour	1,061	1,061

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

USH 51 SB Marathon County North Central (6999-12-71)

PCE Conversion Factor: 2.00

Pre-Breakdown Capacity Drop Factor (PBCDF): 0.134

#DIV/0! <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	USH 51
Direction	SB
Construction ID:	6999-12-71
Region:	North Central
County:	Marathon
Date:	9/15/2022
Day of Week:	Thursday
Area Type:	Rural
Time of Day:	12:00 AM to 4:55 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	65 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	4
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

The purpose of this project is to repair the CTH U bridge over USH 51 by removing the existing bridge deck underneath the eastbound lanes of CTH U, as well as the west approach slab and sidewalk, and replacing the damaged bridge girders. The project holds an emergency status, as the unexpected damage to the bridge must be repaired as soon as possible.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
101	101	per 5 minutes	114	114
303	303	per 15 minutes	343	343
1,207	1,207	per hour	1,362	1,362
1,213	1,213	Max Flow Rate$_s$*	1,371	1,371

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

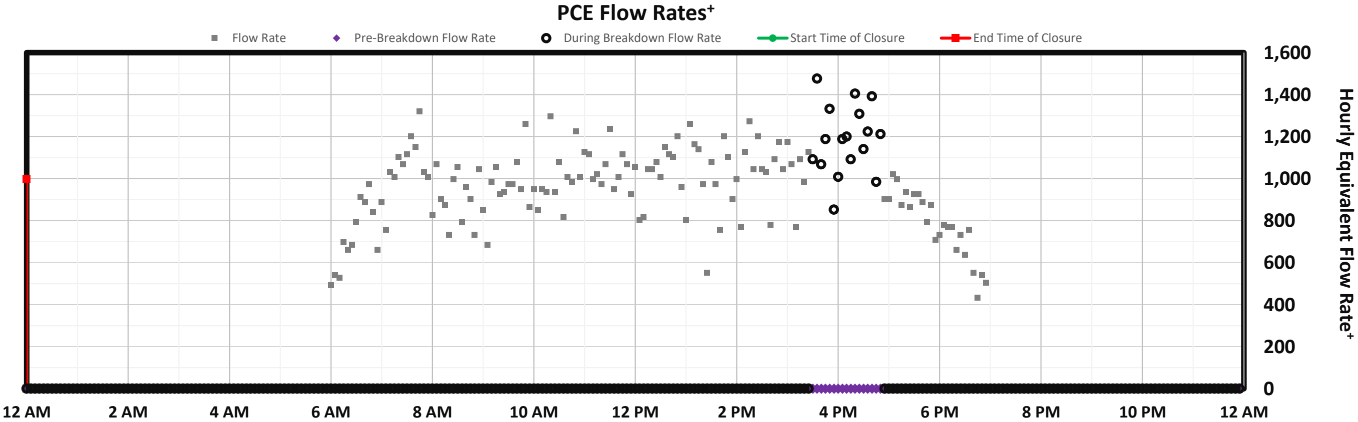
Select Times ->	Start Time:	3:30 PM	End Time:	4:55 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
88 per 5 minutes	12.8%	62%	38%	99 per 5 minutes

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
61	61	per 5 minutes	71	71
229	229	per 15 minutes	254	254
1,036	1,036	per hour	1,167	1,167

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
88	88	per 5 minutes	99	99
263	263	per 15 minutes	297	297
1,046	1,046	per hour	1,180	1,180
1,060	1,060	WZ Model Est.	1,195	1,195

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
104	104	per 5 minutes	123	123
285	285	per 15 minutes	321	321
1,058	1,058	per hour	1,194	1,194

PCE Flow Rates⁺



⁺ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 WB St. Croix County Northwest (1021-00-79)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	#DIV/0!

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1021-00-79
Region:	Northwest
County:	St. Croix
Date:	10/5/2022
Day of Week:	Wednesday
Area Type:	Rural
Time of Day:	12:00 AM to 11:55 PM
Barrier Type:	Soft
Day or Night	Day
Work Zone Speed Limit	60 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	0
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Middle
# of permanent lanes	2
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

Project proposal includes: replacing IH 94 EB and WB mainline bridge over CTH NN with proposed 3-lane single span bridge with future roadway expansion to the median side. IH 94 profiles will be adjusted to provide vertical clearance without lowering CTH NN profile. Construct box culvert C-55-19 extension. Traffic control will include single lane closures, cross overs, temporary widening on IH 94 westbound lanes to maintain 4 lanes of traffic during peak hours. Stage construction will be utilize.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
85	85	per 5 minutes	122	122
254	254	per 15 minutes	365	365
1,012	1,012	per hour	1,459	1,459
1,017	1,017	Max Flow Rate$_s$*	1,461	1,461

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	12:00 AM	End Time:	11:55 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
73 per 5 minutes	43.6%	15%	85%	105 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
44	44	per 5 minutes	59	59
169	169	per 15 minutes	247	247
797	797	per hour	1,143	1,143

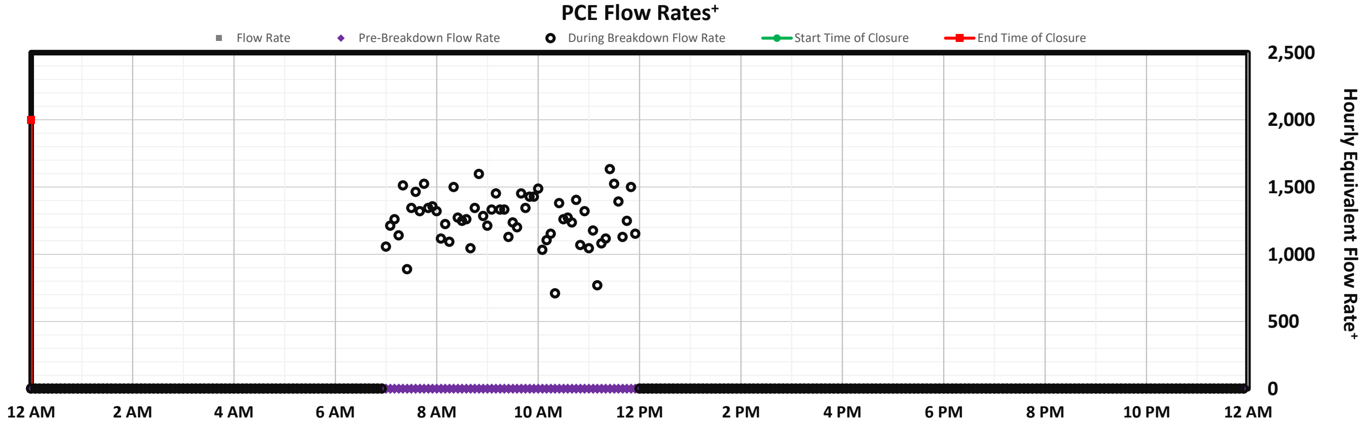
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
73	73	per 5 minutes	105	105
220	220	per 15 minutes	316	316
876	876	per hour	1,263	1,263
832	832	WZ Model Est.	1,195	1,195

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
94	94	per 5 minutes	136	136
267	267	per 15 minutes	379	379
934	934	per hour	1,346	1,346

PCE Flow Rates⁺



⁺ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 90/94 WB Columbia County Southwest (1011-01-65)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	#DIV/0!

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 90/94
Direction	WB
Construction ID:	1011-01-65
Region:	Southwest
County:	Columbia
Date:	11/1/2022
Day of Week:	Tuesday
Area Type:	Rural
Time of Day:	12:00 AM to 7:35 PM
Barrier Type:	Soft
Day or Night	Night
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Upstream Ramps (within 3mi)	0
Downstream Ramps (within 3mi)	0
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	3
# of lanes open during construction	1
Time Closure Began •	
Time Closure Ended •	

The proposed action consists of patching the existing pavement in spot locations. The patching would occur from the Columbia County line to the STH 60 interchange and take place in both the southbound and northbound travel lanes. The STH 60 interchange ramps will not be included. The proposed action will also include pavement markings on I-39/90/94.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	**Vehicles**	**Time Period**	**PCEs/Lane**	**PCEs**
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	**Vehicles**	**Time Period**	**PCEs/Lane**	**PCEs**
86	86	per 5 minutes	128	128
258	258	per 15 minutes	382	382
1,035	1,035	per hour	1,532	1,532
1,030	1,030	Max Flow Rate$_s$*	1,529	1,529

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	7:00 PM	End Time:	7:35 PM

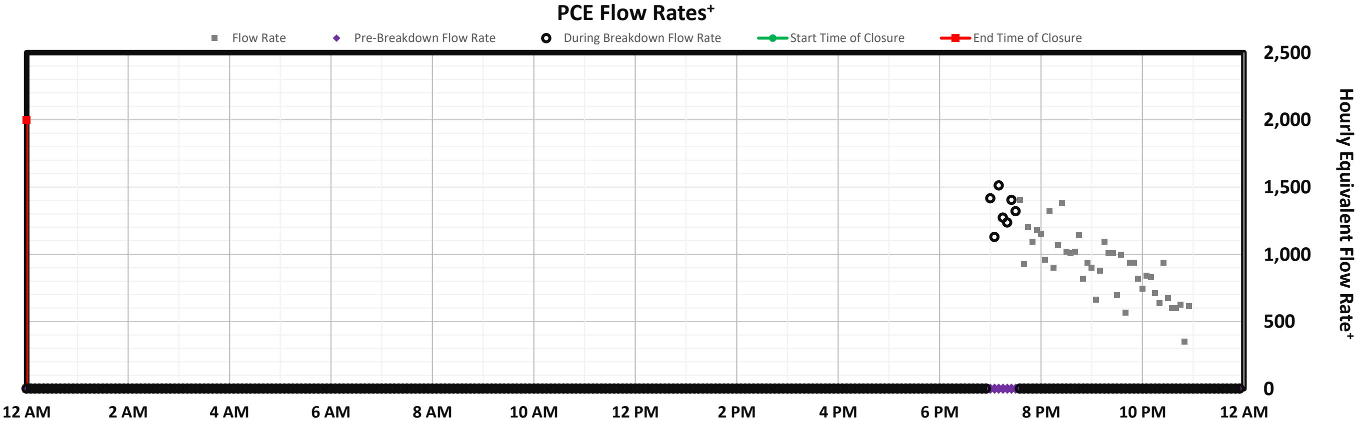
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
75 per 5 minutes	48.0%	10%	90%	111 per 5 minutes

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	**Vehicles**	**Time Period**	**PCEs/Lane**	**PCEs**
66	66	per 5 minutes	94	94
220	220	per 15 minutes	326	326
897	897	per hour	1,327	1,327

Average Observed Queue Discharge Rate				
Vehicles/Lane	**Vehicles**	**Time Period**	**PCEs/Lane**	**PCEs**
75	75	per 5 minutes	111	111
223	223	per 15 minutes	331	331
897	897	per hour	1,327	1,327
744	744	WZ Model Est.	1,101	1,101

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	**Vehicles**	**Time Period**	**PCEs/Lane**	**PCEs**
81	81	per 5 minutes	126	126
228	228	per 15 minutes	338	338
897	897	per hour	1,327	1,327

PCE Flow Rates+

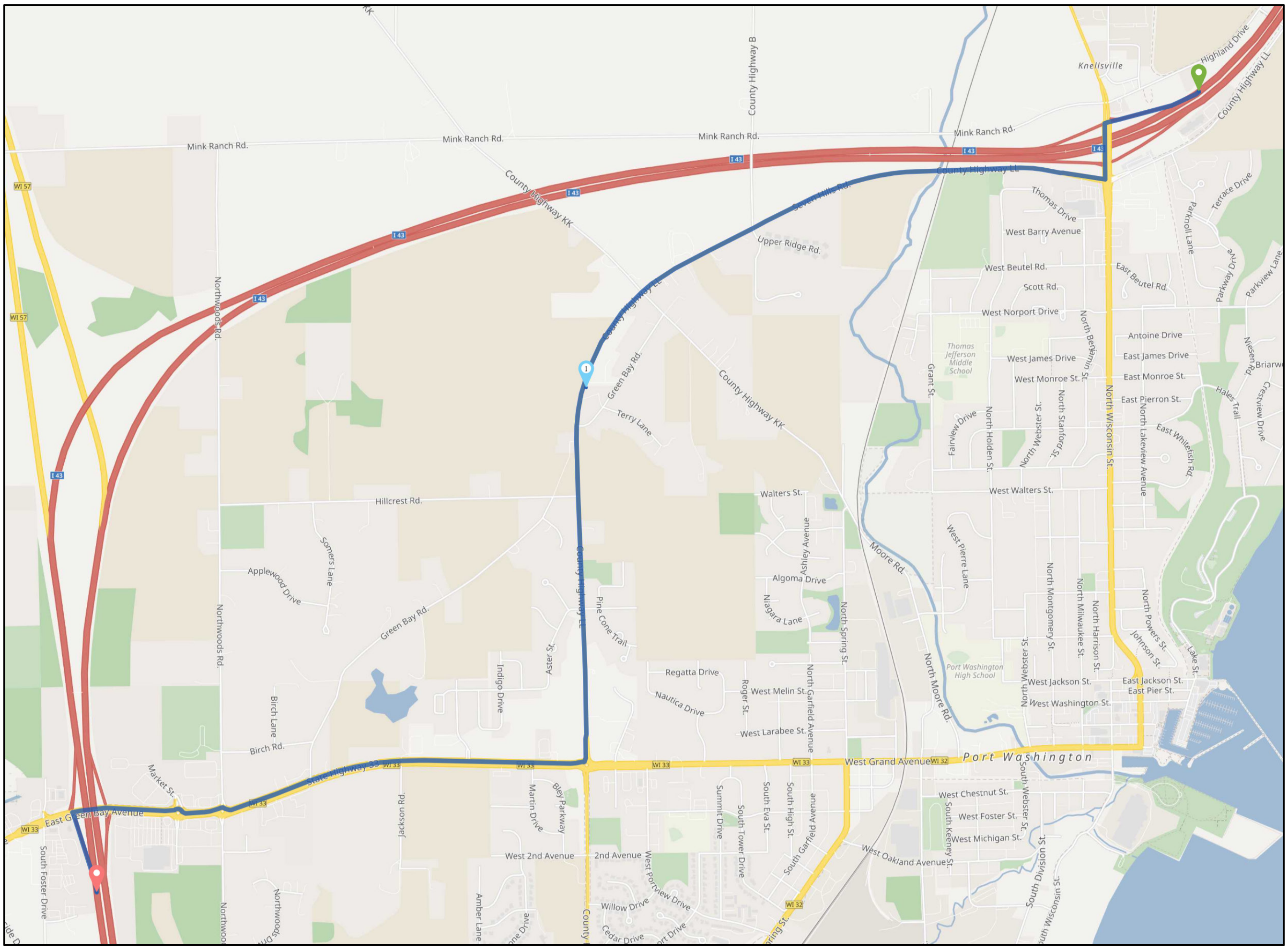


+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

APPENDIX C

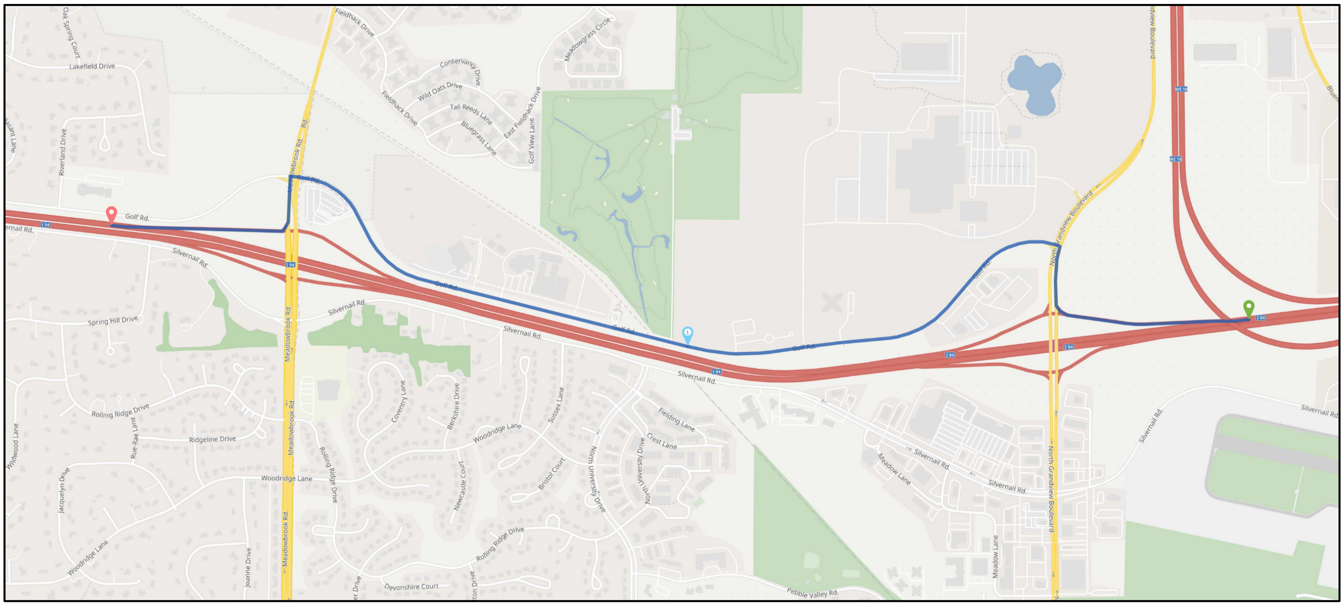
Maps for Randomly Selected Diversion Routes Used In The Incremental Added Travel Time Formula Development

Iteration	County	Highway	Interchange with	Exit No.	Direction	Left or Right?
1	Ozaukee	IH 43	CTH H West and STH 32 South	100	SB	Left



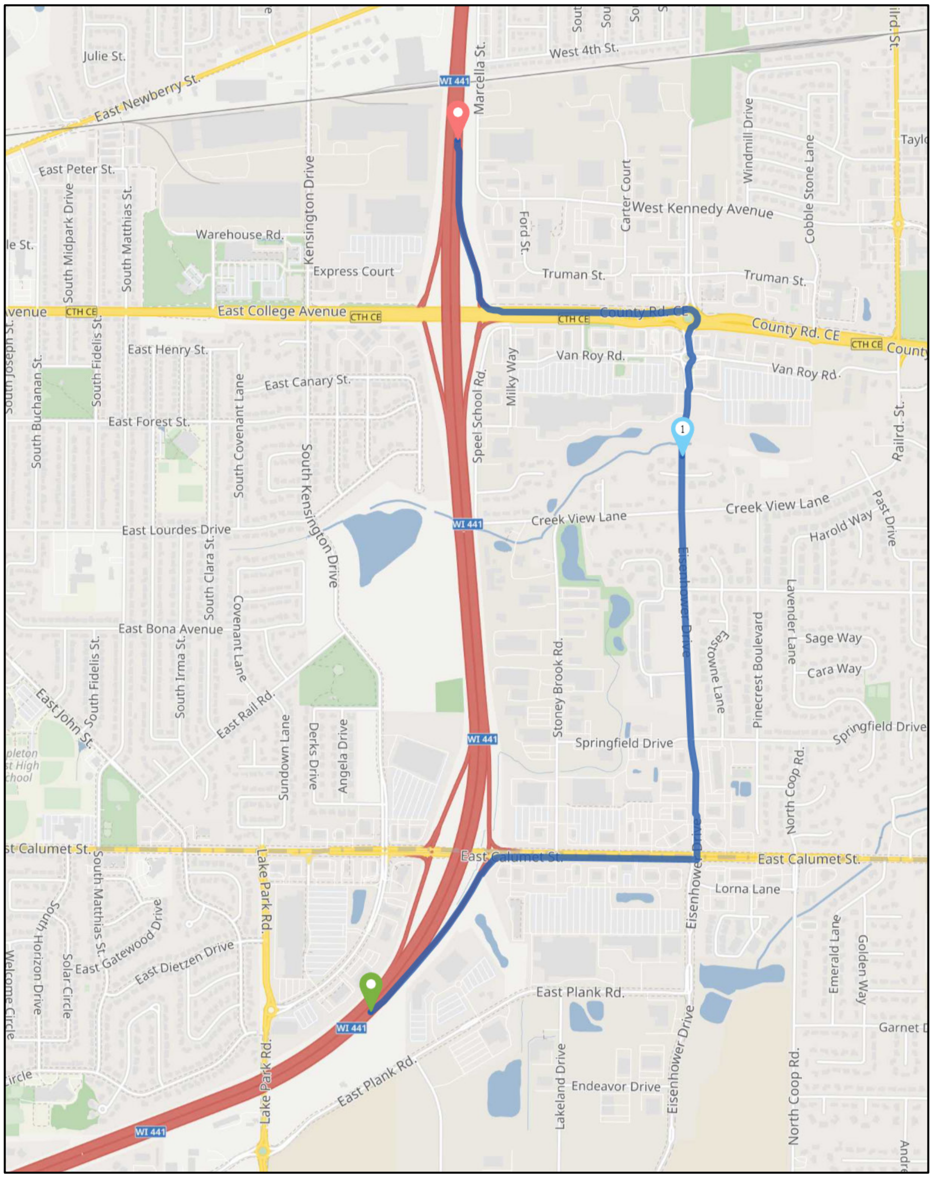
Route map obtained from GraphHopper

Iteration	County	Highway	Interchange with	Exit No.	Direction	Left or Right?
1	Waukesha	IH 94	CTH T	293	WB	Right



Route map obtained from GraphHopper

Iteration	County	Highway	Interchange with	Exit No.	Direction	Left or Right?
1	Calumet/ Outagamie	STH 441	CTH KK – Calumet Street	7	NB	Right

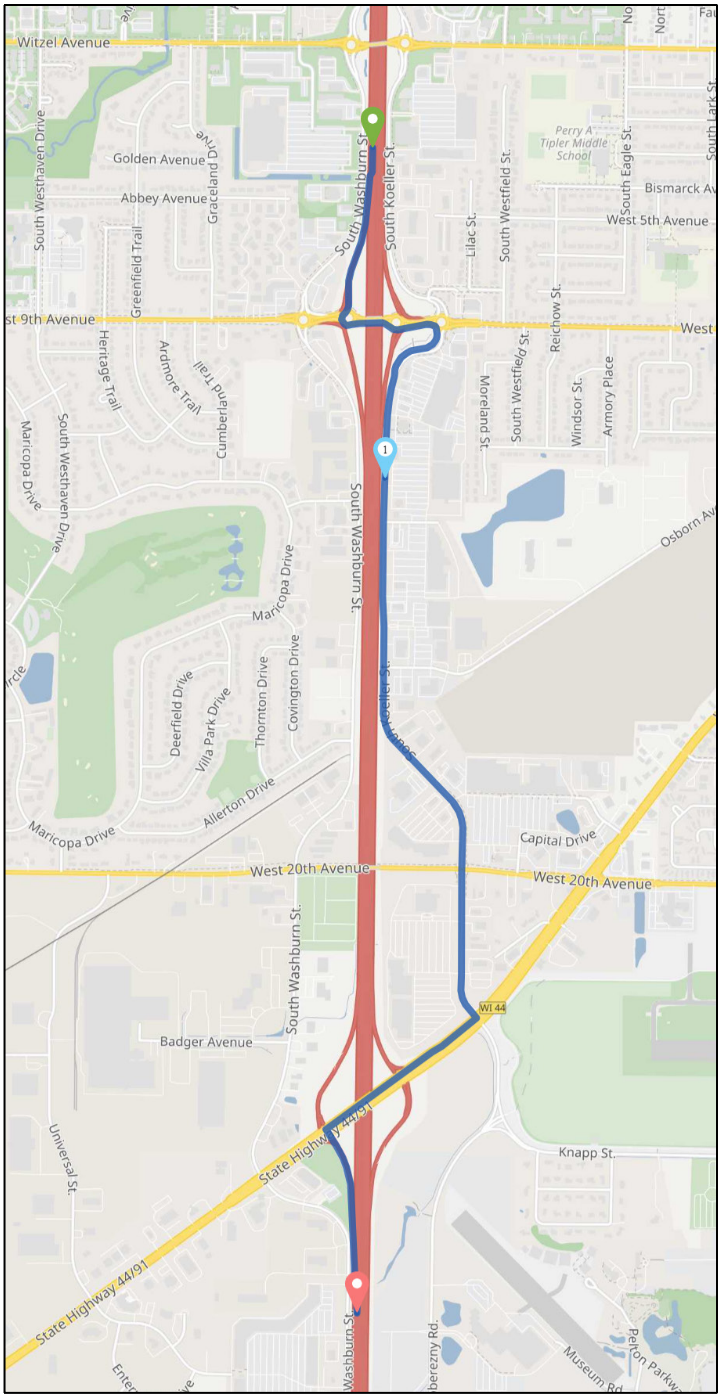


Route map obtained from GraphHopper

Iteration	County	Highway	Interchange with	Exit No.	Direction	Left or Right?
2	Kenosha	IH 94	CTH C	345	EB	Left

Route map obtained from GraphHopper

Iteration	County	Highway	Interchange with	Exit No.	Direction	Left or Right?
7	Winnebago	IH 41	9th Avenue	117	SB	Left



Route map obtained from GraphHopper