City of Hamilton

Red Hill Valley Parkway Analysis

(RHVP Proceedings - Privileged and Confidential)

Final Report

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SUBMITTED BY CIMA CANADA INC.
500 – 5935 Airport Road
Mississauga, ON. L4V 1W5
T: 905-695-1005 | F: 905-695-0502
cima.ca

CONTACT
Behzad Rouhieh
Behzad.Rouhieh@cima.ca
T: 905-695-1005, 5750

PREPARED BY:

Alessandra Massaro, EIT

Giovani Bottesini, M.Eng., P.Eng., RSP

REVIEWED BY:

Behzad Rouhieh, Ph.D., P.Eng.

Brian Malone, P.Eng., PTOE

VERIFIED BY:

Alireza Hadayeghi, Ph.D., P.Eng.

CIMA+
500-5935 Airport Road
Mississauga, ON. L4V1W5

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1. Introduction

The Red Hill Valley Parkway (RHVP) is a municipal expressway within the City of Hamilton (the City) that connects the Lincoln M. Alexander (LINC) to the QEW. The City undertook a significant investment in improving safety along the RHVP in 2019. The City has recently (summer 2019) completed pavement resurfacing and rehabilitation of all the northbound and southbound lanes of the RHVP. Numerous additional safety enhancements were implemented along the road as part of the resurfacing project, including:

- 10km of new steel beam guide rails, including enhanced roadside safety and improving cross-median crash protection;
- Improvements to end treatments to median barriers
- Rumble strips;
- Bright, durable lane markings;
- Post mounted reflective delineators on straightaways;
- Guiderail mounted reflective delineators on curves;
- Concrete barrier mounted reflective delineators on curves;
- Object and oversize plow marker signage replacement;
- Resetting catch basins;
- Clearing/removing obstructions;
- Installing Variable Message Signs and Oversize Maximum Speed Signs; and
- Increased numbers of “Slippery When Wet” signs.

In February 2019, the City lowered the speed limit of RHVP, from 90 km/h to 80 km/h, along the stretch between the Barton Street East and Greenhill Avenue interchange. Moreover, continuous enhanced police enforcement has been in place since the end of March 2019, averaging 12 hours each day.

Several corresponding educational safety campaigns directly related to driving on the parkways (RHVP and LINC) within the City were run in 2019, including:

- Speeding is Speeding;
- Distracted Driving; and
- Slow Down, Move Over

Summaries for all the educational safety campaigns are included in **Appendix A**.

Efforts to improve safety have been compounded and can be summarized as consisting of Engineering, Enforcement and Education activities. An overview of the timing of the initiation of specific efforts implemented by the City can be seen in Figure 1.

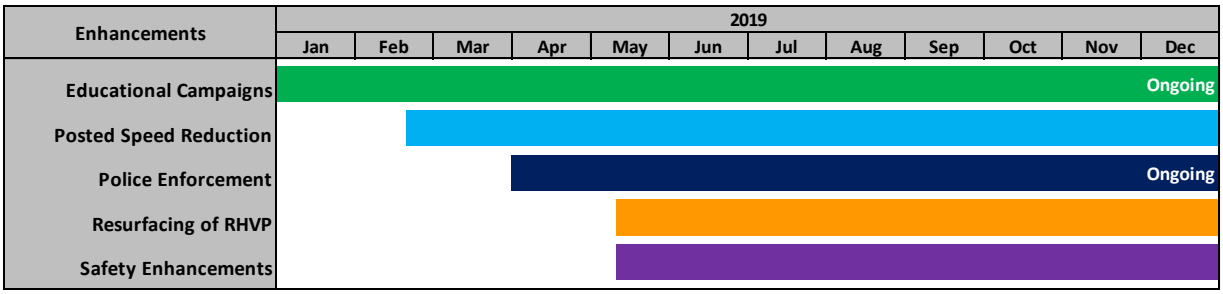


Figure 1: Implemented Enhancements (Educational, Enforcement and Engineering)

This study is a preliminary examination of what changes in outcomes have occurred as a result of the range of actions that have been implemented. CIMA+ examined the impacts that construction along RHVP, which involved road closures, had on the surrounding roadways by reviewing changes in traffic volumes and travel times during the construction period. CIMA+ also reviewed traffic speeds on the RHVP to examine the impact of the speed limit changes that were made and of enhanced police speed enforcement. Lastly, CIMA+ reviewed the impact that these multiple engineering, enforcement and education safety efforts have had on collisions on the RHVP, up to the end of 2019. Scope of Work

This study includes a traffic assessment of RHVP by using the following measures:

- Traffic volume along RHVP and major arterials;
- Travel Time along RHVP and adjacent road network;
- Traffic speed along RHVP; and
- Collision data along RHVP.

The following sections provide an overview of the scope of work for different components included as part of the analysis.

1.1. Impact Assessment of RHVP Closures

1.1.1. Traffic Volume/Vehicle Classification

The volume analysis was conducted to identify the impact of construction/closures on the traffic volumes along roadways within the study area. Figure 2 highlights the closure areas. Yellow highlights RHVP and orange indicates the Mud Street and Upper RHVP ramps. The following scenarios (Cases) were considered for the assessment (Also shown on the map in **Appendix B**):

- **Case 1-RHVP NB**: Starting May 2019 NB RHVP rehabilitation, resulting in the closure of the northbound lanes on RHVP to traffic;
- **Case 2-RHVP SB**: Starting June 2019 SB RHVP rehabilitation, resulting in the closure of the southbound lanes on RHVP to traffic;
- **Case 3-Mud IC**: Starting July 2019, the Mud Street & Upper RHVP on-ramp were completely closed to traffic;
- **Case 4-Open Aug**: In August 2019 after re-opening of RHVP ramps during summer break; and
- **Case 5-Open Sep**: In September 2019 after re-opening of RHVP ramps but after the summer break when traffic is expected to be back to normal conditions.

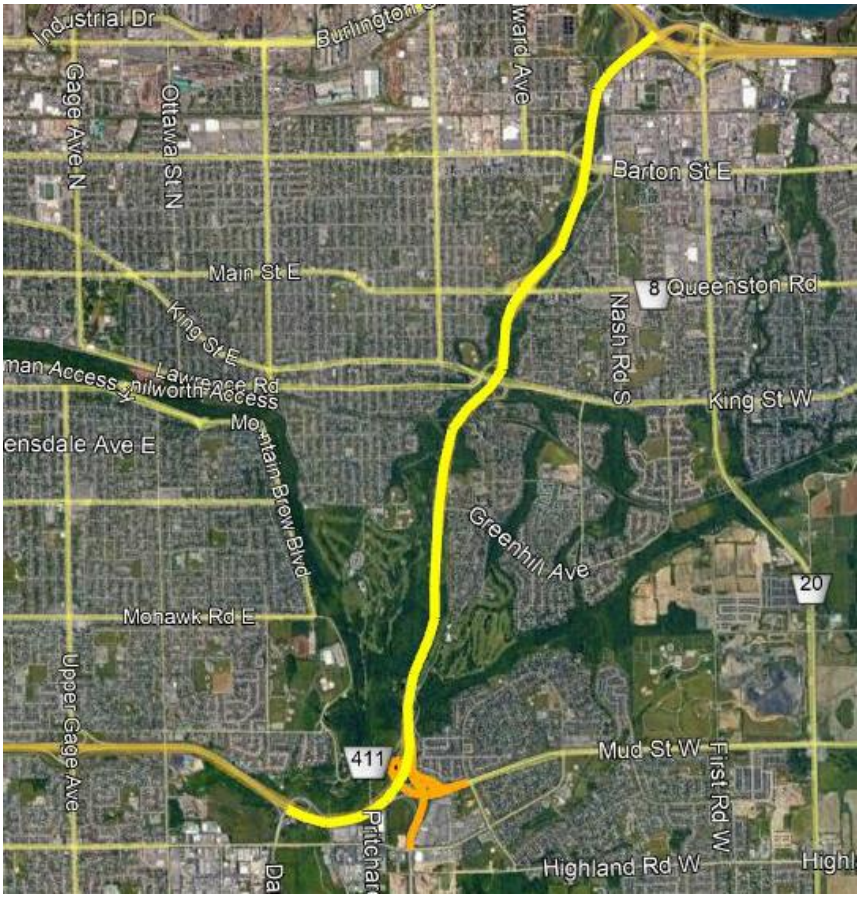


Figure 2: Closures - RHVP and Mud Street / Upper RHVP Ramps

It should be noted that no volume data was provided for the before resurfacing of RHVP in May 2019 (Case 0). Therefore, the impact assessment using traffic volumes does not consider this scenario.

1.1.2. Travel Time

The travel time analysis was conducted to identify the impact of construction/closures on the travel time along the road network adjacent to the study area. Similar to the volume analysis, the following scenarios (Cases) were considered for the travel time assessment:

- **Case 0-Before**: Before the resurfacing work on RHVP;
- **Case 1-RHVP NB**: Starting May 2019 NB RHVP rehabilitation, resulting in the closure of the northbound lanes on RHVP to traffic;
- **Case 2-RHVP SB**: Starting June 2019 SB RHVP rehabilitation, resulting in the closure of the southbound lanes on RHVP to traffic;
- **Case 3-Mud IC**: Starting July 2019, the Mud Street & Upper RHVP on-ramp were completely closed to traffic;
- **Case 4-Open Aug**: In August 2019 after re-opening of RHVP ramps during summer break; and
- **Case 5-Open Sep**: In September 2019 after re-opening of RHVP ramps but after the summer break when traffic is expected to be back to normal conditions.

The City identified several routes to be considered for travel time assessment. The following Figure 3 depicts the travel time routes used for this analysis, which are categorized into Primary and Secondary routes, shown with red and blue lines, respectively. The RHVP and Mud/North RHVP interchange are shown in yellow and orange respectively in Figure 3.

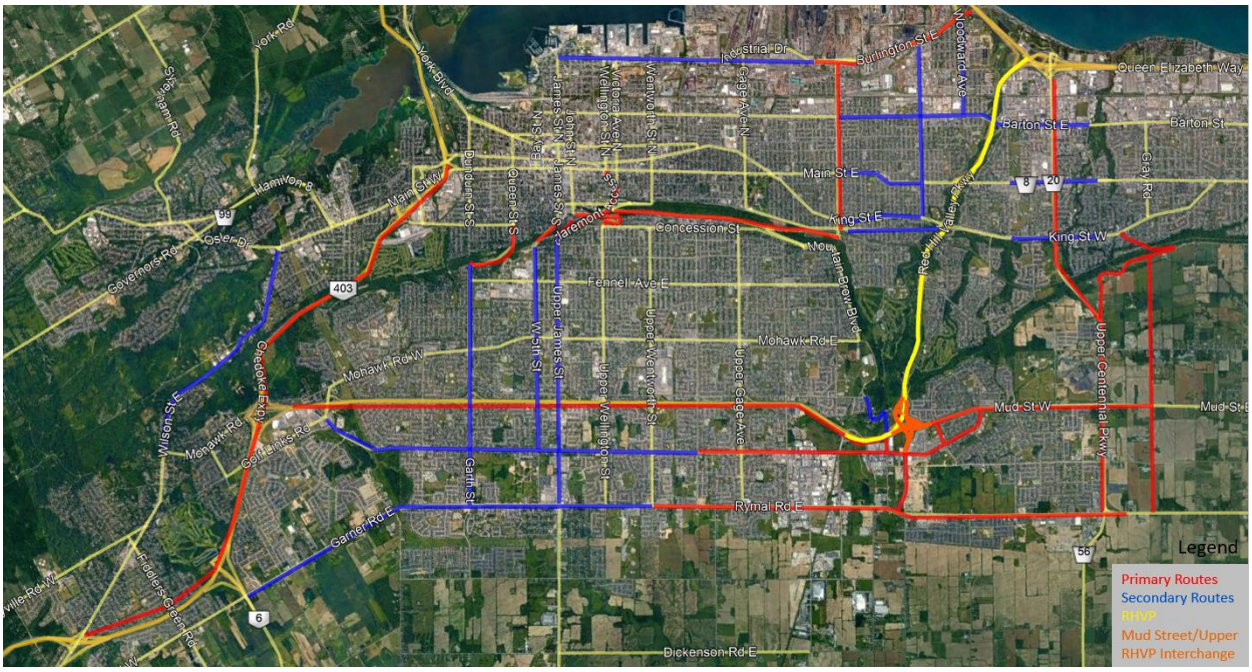


Figure 3: Travel Time Routes (Source: Google Earth©)

1.2. Analysis of Traffic Speeds

The speed analysis is conducted to identify operations along RHVP before and after the speed limit reduction. The following scenarios (Events) were considered for travel speed assessment:

- **Event 0-Before**: Before speed limit change in February 2019;
- **Event 1-SpeedLimit**: After speed limit change but before the start of police enforcement (February 16th to March 25th, 2019);
- **Event 2-Enforcement**: After the start of additional Police enforcement (March 26, 2019 to date); and
- **Event 3-Enhancements**: After resurfacing of RHVP was completed (August 2019 to date), including all the implemented educational, enforcement and engineering enhancements.

Figure 4 highlights the speed assessment study area. The green line highlights the extent of the speed limit change along the RHVP (between the Barton Street East and Greenhill Avenue interchanges) where the posted speed limit was reduced from 90 km/h to 80 km/h. The yellow line indicates the entire stretch of RHVP, the rest of which remains at a speed of 90 km/h.

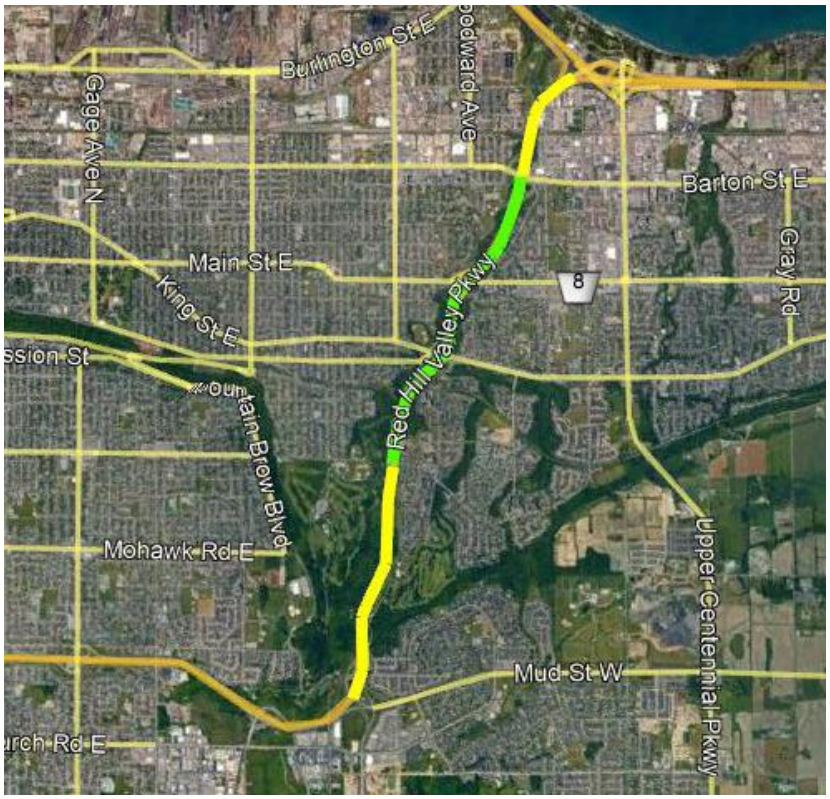


Figure 4: Speed Analysis Study Area (Source: Google Earth)

1.3. Analysis of Traffic Collisions

The collision analysis is conducted to identify the cumulative safety effects of the implemented enhancements on RHVP. For this assessment, historical collision data (excluding self-reported collisions) was reviewed between January 2013 and December 2019, to identify trends before the speed limit change and enhancements occurred and to compare with collision frequencies after these changes. Statistical tests were also conducted on the significance of the changes in collision frequencies.

2. Data Collection

The following sections provide details on the data that was provided by the City or collected by CIMA for the use of this study.

2.1. Traffic Volume

The traffic volume data were collected by the City from nine traffic count 'ATR' stations on the RHVP and the adjacent roadways to compare the changes in traffic volumes during/after the closures on RHVP. ATR stations where the traffic volume (including vehicle classification data) were collected are shown with white lines in Figure 5.

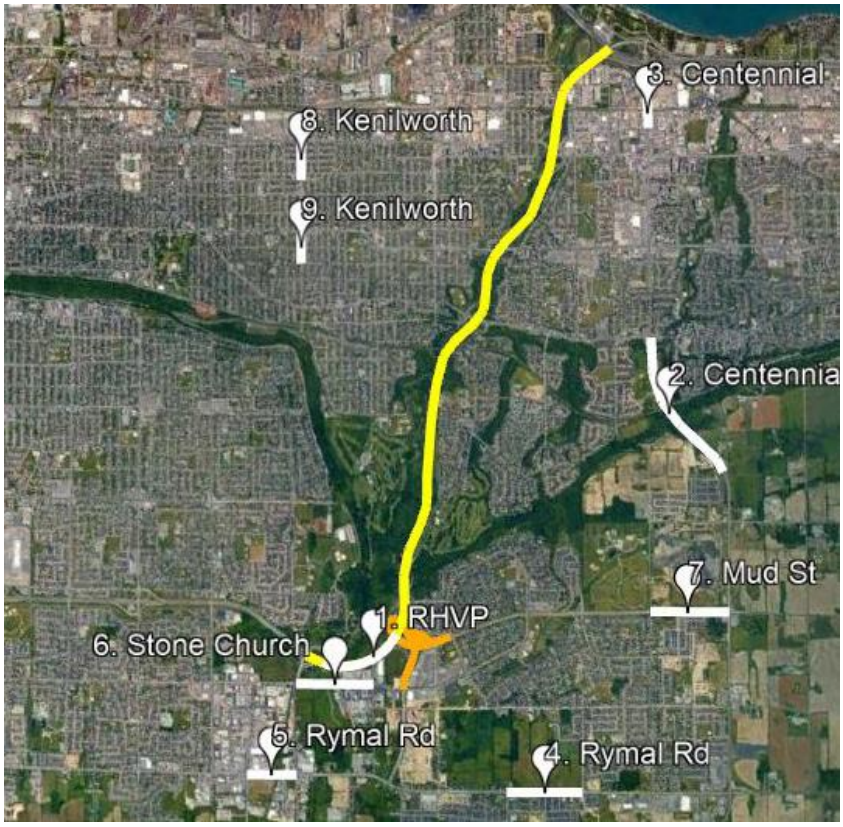


Figure 5: Volume & Class Analysis Study Area

Table 1 lists the ATR Stations used to collect traffic volume data by the City and the period for which data was collected.

Table 1: Traffic Volume Data Provided by the City

No.	Location	Date	Travel Direction
1	**Red Hill Valley Pkwy, between Dartnall Rd and Mud St**	June 1 to June 8, 2019	EB/WB
		June 18 to June 25, 2019	EB/WB
		August 17 to August 24, 2019	EB/WB
		September 13 to 20, 2019	EB/WB
2	**Centennial Pkwy, between King St E and Ridge Rd**	May 29 to June 1, 2019	NB/SB
		June 18 to June 21, 2019	NB/SB
		August 21 to 24, 2019	NB/SB
		September 17 to 20, 2019	NB/SB
3	**Centennial Pkwy, between Arrowsmith Rd and Goderich St**	May 29 to June 1, 2019	NB/SB
		June 18 to June 21, 2019	NB/SB
		August 21 to 24, 2019	NB/SB
		September 17 to 20, 2019	NB/SB
4	**Rymal Rd E, between Fletcher Rd and Second Rd W**	May 29 to June 1, 2019	EB/WB
		June 18 to June 21, 2019	EB/WB
		July 16 to July 19, 2019	EB/WB

No.	Location	Date	Travel Direction
		August 21 to 24, 2019	EB/WB
		September 17 to 20, 2019	EB/WB
5	**Rymal Rd E, between Dartnall Rd and Nebo Rd**	May 29 to June 1, 2019	EB/WB
		June 18 to June 21, 2019	EB/WB
		July 16 to July 19, 2019	EB/WB
		August 21 to 24, 2019	EB/WB
		September 17 to 20, 2019	EB/WB
6	**Stone Church Rd E, between Dartnall Rd and Pritchard Rd**	May 29 to June 1, 2019	EB/WB
		June 18 to June 21, 2019	EB/WB
		July 16 to July 19, 2019	EB/WB
		August 21 to 24, 2019	EB/WB
		September 17 to 20, 2019	EB/WB
7	**Mud St W, between First Rd W and Upper Centennial Pkwy**	May 29 to June 1, 2019	EB/WB
		June 18 to June 21, 2019	EB/WB
		July 16 to July 19, 2019	EB/WB
		August 21 to 24, 2019	EB/WB
		September 17 to 20, 2019	EB/WB
8	**Kenilworth Ave, between Barton St E and Cannon St**	May 29 to June 1, 2019	NB/SB
		June 18 to June 21, 2019	NB/SB
		August 21 to 24, 2019	NB/SB
		September 17 to 20, 2019	NB/SB
9	**Kenilworth Ave, between Central Ave and Main St E**	May 29 to June 1, 2019	NB/SB
		June 18 to June 21, 2019	NB/SB
		August 21 to 24, 2019	NB/SB
		September 17 to 20, 2019	NB/SB

2.2. Travel Time

Traffic travel time data and statistics were also accessed through a self-service web portal (TomTom Move), and the data was utilized to collect historical travel time data for the specified routes. The following inputs were used in order to extract the traffic data: Routes, Date Range, and Time Period.

The routes were defined based on the list of the primary and secondary routes identified by the City. The data is extracted for vehicles that traverse the full routes in each direction (EB/WB or NB/SB). The traffic data was retrieved for select dates, corresponding to the assessment scenarios identified before, as shown in Table 2. The data extracted includes the following information: Sample Size, Average Travel Time, Average speed, Standard deviation of Travel Time, Speed and Travel time Percentiles (5 to 85 percentile).

A list of the primary and secondary routes for which travel time data was collected can be found in **Appendix C**.

Table 2: Travel Time Data Collection Period

Scenario	Case Description	Data Collection Dates	Peak Periods
Case 0-Before	Before Construction	April 9-11, 2019	AM Peak: 7:00 – 9:00 PM Peak: 4:00 – 6:00
Case 1-RHVP NB	RHVP NB Closure	May 29, 30, June 4, 2019	
Case 2-RHVP SB	RHVP SB Closure	June 18-20, 2019	
Case 3-Muc IC	Mud St and Upper RHVP IC Ramp Closure	July 16-18, 2019	
Case 4-Open Aug	After Construction, Summer	August 20-22, 2019	
Case 5-Open Sep	After Construction, Fall	September 17-19, 2019	

2.3. Traffic Speeds

The City provided speed data that were collected from ATR stations at three locations along the RHVP, before the speed limit change in 2018 as well as after the speed limit change in 2019.

Table 3: ATR Speed Data on RHVP

No.	Location	Date	Travel Direction
1	**RHVP South of King Street**	May 24-31, 2018 March 12 - 15, 2019	NB/SB
		March 12 to March 15, 2019	NB/SB
2	**RHVP South of Barton Street**	May 24-31, 2018	NB/SB
3	**RHVP North of Mud Street**	May 24-31, 2018	NB/SB

In order to complement the ATR data collected after the speed limit change, the City collected traffic speed data utilizing radar sensors at two locations along the RHVP, as listed in Table 4. It should be noted that the collected data are different than the Police radar enforcement data.

Table 4: Speed Radar Sensor Locations

Location	Direction	Date Range
RHVP at Mount Albion Rd (South of King St)	NB	April 1, 2019 to October 31, 2019
	SB	March 1, 2019 to October 31, 2019
RHVP at Queenston Rd	NB	April 1, 2019 to October 31, 2019
	SB	April 1, 2019 to October 31, 2019

Figure 6 shows the locations where speed data were available. It should be noted that the calibration details for the radar sensors data were not available at the time of this study.

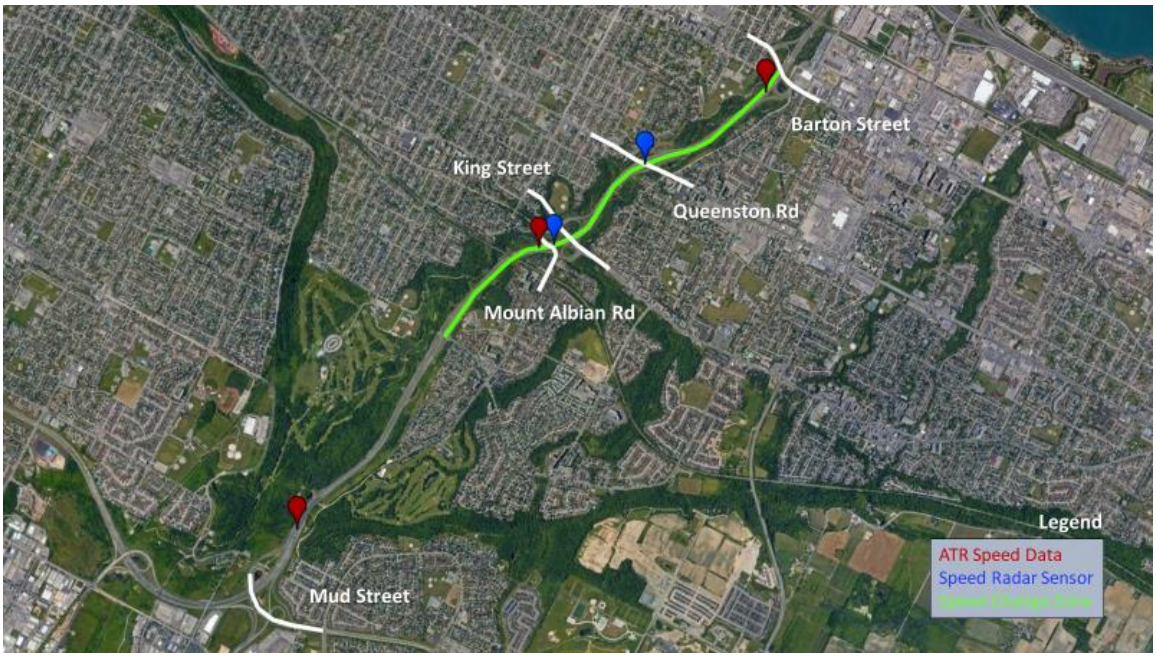


Figure 6: Speed Data Collection Stations (Radar and ATR)

In order to compare the operating speeds along RHVP before and after the speed limit reduction, the collected speed data need to be for the same location. As can be seen in Figure 6, only the speed data collected by the ATR station/Radar sensor at Mount Albion Rd (South of King St) were close to the same location and had both before/after data to be used for the analysis. The City has also provided weekly Police enforcement statistics for the RHVP, in the form of number of violations issued, which is included in **Appendix D**.

2.4. Collision Data

The City provided collision data for the RHVP for 2018 (electronic collision records) and 2019 (scanned copies of Motor Vehicle Collision Reports). Collision data for the years 2013 to 2017 had been previously provided by the City, in electronic format, for the completion of the 2018 RHVP Roadside Safety Assessment Project.

Additional collision data covering the years 2018 and 2019 were provided by the City in electronic format and scanned Motor Vehicle Collision Reports[1], respectively. For consistency of comparison with previous collision data analysis, the review of collision data only considered Police Recorded collisions (and not self-reported collisions). Using Police Recorded data allows direct comparison with collision data from previous years and also provides more accurate and more comprehensive data regarding important aspects of collisions, such as road conditions (i.e. wet / dry). Collisions which are self-reported and not recorded directly by the police typically do not include sufficient information or sufficiently reliable information to allow statically comparisons.

[1] It should be noted that some information in the provided MVCRs were not completely legible. While best efforts were made to extract the accurate information, some minor discrepancies between the numbers presented in this report and the data eventually entered into the City's electronic database may occur.

3. Analysis Results

The following sections provide the analysis results of the traffic assessment that was completed for different components of the study.

3.1. Impact Assessment of RHVP Closures

3.1.1. Traffic Volumes

Traffic volume was provided in 15-minute intervals for different days of week/dates. Our traffic team has aggregated them into hourly volume data. In order to understand variations in traffic volume during different weekdays, hourly volume data during the month of September (Case 5-Open Sep) for a Tuesday, Wednesday and Thursday along select routes were compared (as shown in Figure 7). As can be seen in Figure 7, a similar pattern is observed between different weekdays.

Figure 7: Comparison of Hourly Volume Data during Case 5-Open Sep – Typical Weekdays

In order to compare changes in traffic volume between different scenarios, Wednesday was selected as a representative day for typical weekday traffic. The following dates were used to represent each of the following scenarios (Cases) for analyzing traffic volumes:

- **Case 1-RHVP NB** (RHVP NB Lanes Closed): Wednesday, May 29, 2019;
- **Case 2-RHVP SB** (RHVP SB Lanes Closed): Wednesday, June 19, 2019;
- **Case 3-Mud IC** (Mud/Upper RHVP Ramps Closed): Wednesday, July 17, 2019;
- **Case 4-Open Aug** (After Resurfacing in August): Wednesday, August 21, 2019; and
- **Case 5-Open Sep** (After Resurfacing in September): Wednesday, September 18, 2019.

It should be noted that no traffic volume was provided for before the construction work that was started in May 2019, therefore, volume data for the after-construction periods in August/September (Case 4-Open Aug and Case 5-Open Sep) is used to understand the impact of the closures on traffic volumes along study roadways.

Figure 8 and Figure 9 below show a comparison between average peak hour volume (total for both directions) on study roadways under different scenarios. The average peak hour volume is calculated based on two-hour AM (7 am – 9 am) and PM (4 pm – 6 pm) peak periods. From the figures, it can be seen that during the resurfacing of RHVP (Case 1-RHVP NB and Case 2-RHVP SB), most of the traffic seems to be diverted to Centennial Parkway and Mud Street, in the AM and PM peak periods, when compared to the after-construction volume (Case 4-Open Aug and Case 5-Open Sep). During the closure of ramps from Mud Street and Upper RHVP (Case 3-Mud IC), an increase in traffic volume (total for both directions) along Stone Church Road was observed, when compared with Case 4-Open Aug and Case 5-Open Sep.

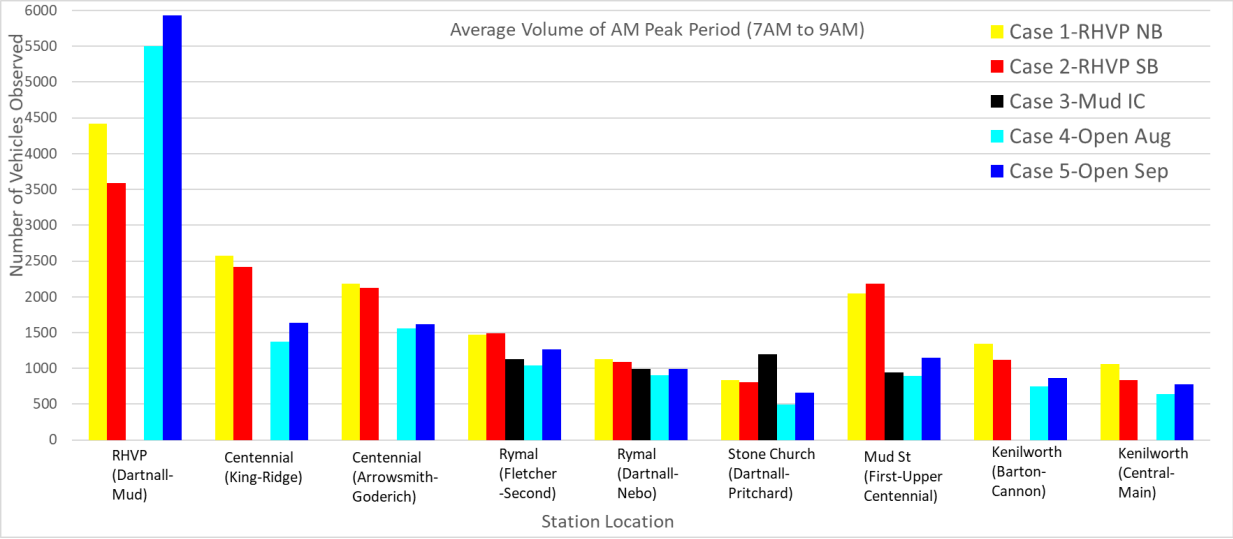


Figure 8: Comparison of Average Peak Hour Traffic Volume Along Study Roadways, for Different Cases - AM Peak

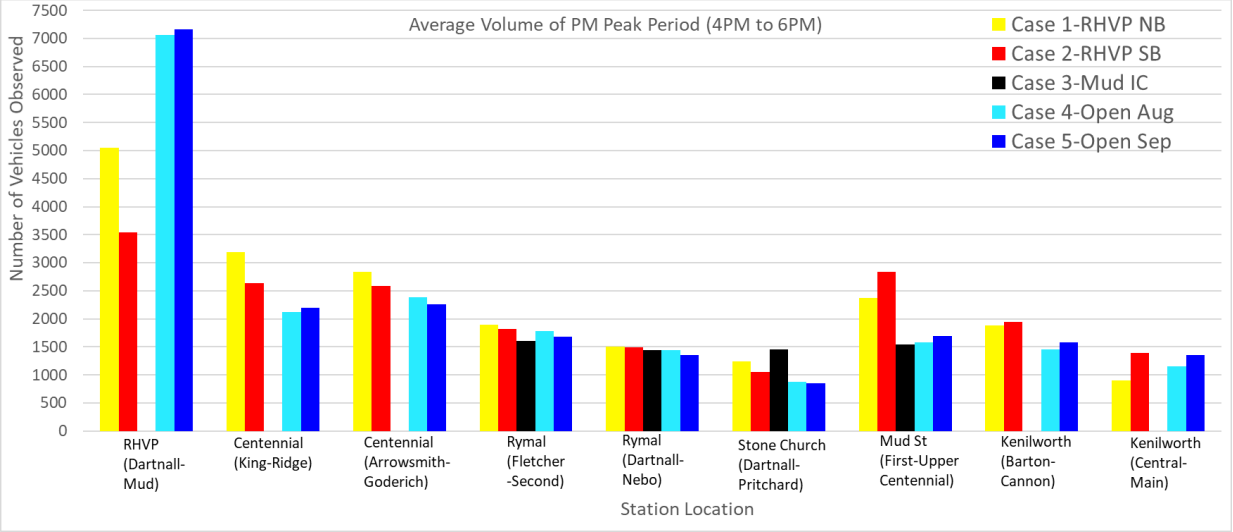


Figure 9: Comparison of Average Peak Hour Traffic Volume Along Study Roadways, for Different Cases - PM Peak

The following sections present a detailed analysis of each study roadway.

Red Hill Valley Parkway (between Dartnall Road and Mud Street)

Figure 10 shows a comparison of traffic volume (total for both directions) on RHVP, between Dartnall Road to Mud Street, over a 24-hour period between different scenarios (Case 0-Before, Case 1-RHVP NB, Case 2-RHVP SB, Case 4-Open Aug and Case 5-Open Sep). Due to the closure of RHVP lanes (north of Mud Street), it is expected to observe lower volume during the construction periods (Case 0-Before, Case 1-RHVP NB and Case 2-RHVP SB). It should be noted that no data for Case 3-Mud IC was collected for RHVP

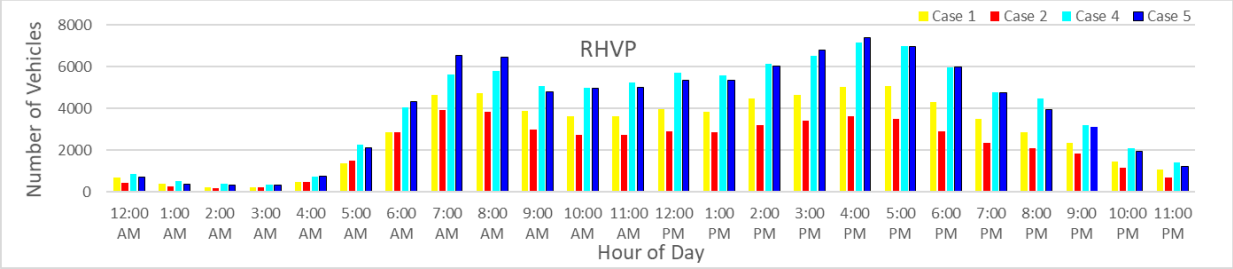


Figure 10: Hourly Volume at RHVP, between Dartnall Rd and Mud St – Total for both Directions

Directional hourly volume on RHVP, between Dartnall Road to Mud Street, for different scenarios, are shown in Figure 11 and Figure 12. Due to the closure of RHVP lanes, north of Mud Street, traffic seems to be diverted as the northbound and southbound directions along RHVP shows lower volumes when compared to after construction period. The collected data show that traffic volume along the NB and SB directions of this section of RHVP reduced by up to 70% during the closures. It should be noted that no volume data was available at this location during Case 3-Mud IC (closure of ramps from Dartnall Road and Mud Street).

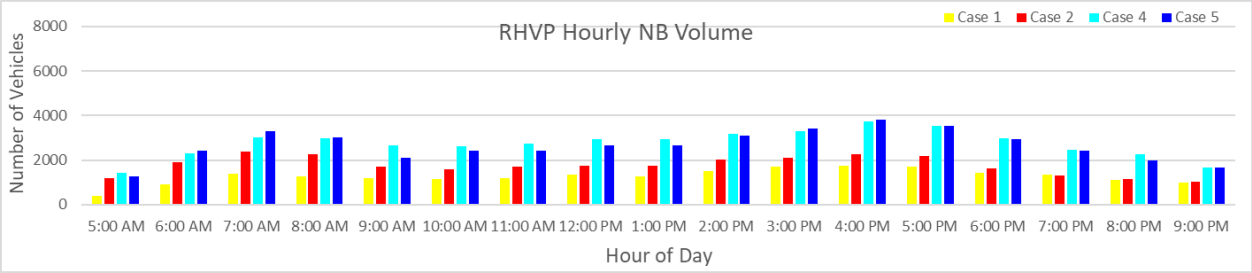


Figure 11: Hourly Volume at RHVP, between Dartnall Rd and Mud St – Northbound

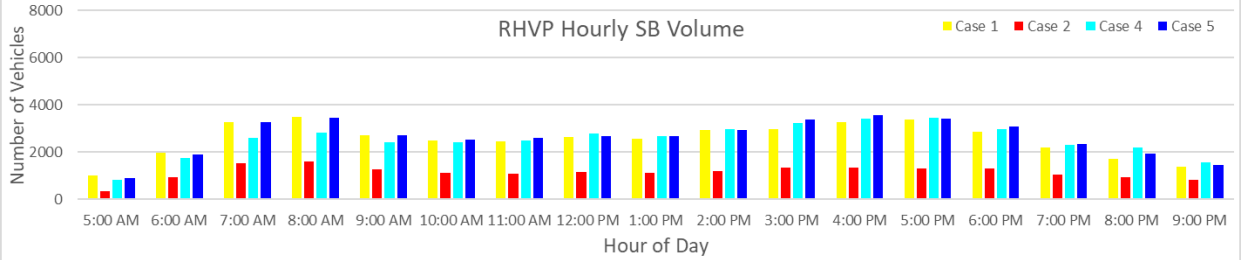


Figure 12: Hourly Volume at RHVP, between Dartnall Rd and Mud St – Southbound

Centennial Parkway (Between Arrowsmith Road and Goderich Street)

Figure 13 shows 24-hour volume (total for both directions) along Upper Centennial Parkway from Arrowsmith Road to Goderich Road. It can be seen in Figure 13 that this route experienced a lower volume diversion during the closures along RHVP compared with the segment located between Arrowsmith Road and Goderich Street. This could be due to the possibility that the rerouted traffic used other local roads before reaching to King Street.

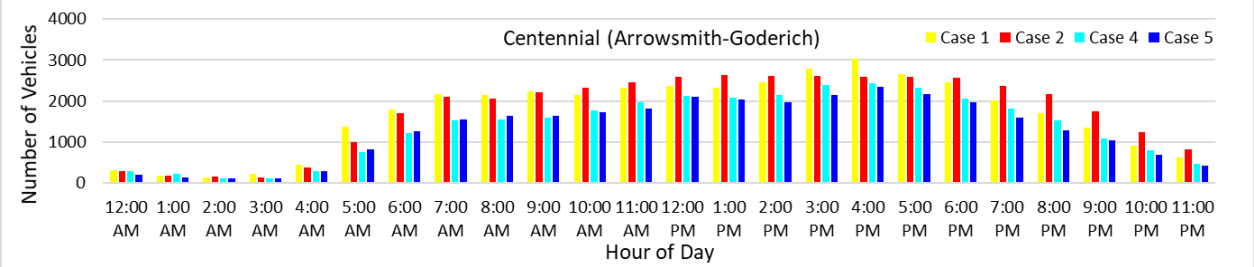


Figure 13: Hourly Volume at Centennial Pkwy (Between Arrowsmith Rd and Goderich St – Total for both Directions

Centennial Parkway (Between King Street and Ridge Road)

24-hour volume comparison (total for both directions) along Upper Centennial Parkway from King Street to Ridge Road is shown in Figure 14. During the closure of RHVP lanes (Case 1-RHVP NB and Case 2-RHVP SB), traffic volume has significantly increased along this segment of Centennial Parkway, due to large diversions from RHVP. The largest volume increase is observed during the closure of the northbound lanes along RHVP (Case 1-RHVP NB). During the morning peak (6 – 7 am), the volume along this route increased from 1,031 vehicles, as in Case 4-Open Aug and Case 5-Open Sep (after construction) to 2,472 vehicles, observed in Case 2-RHVP.

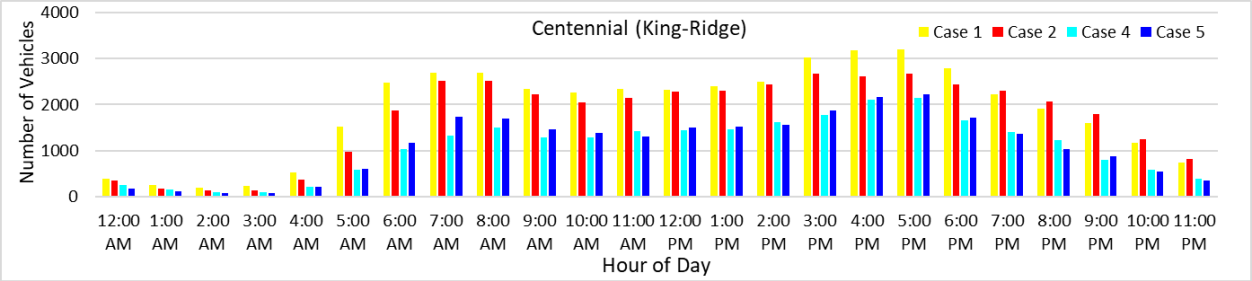


Figure 14: Hourly Volume at Centennial Pkwy (Between King St and Ridge Rd) – Total for both Directions

Rymal Road East (Between Fletcher Road and Second Road)

Figure 15 shows a comparison of traffic volume (total for both directions) along Rymal Road East between Fletcher Road and Second Road West. The data shows some diversion of traffic, mainly in the AM peak period, during the construction period along RHVP (Case 1-RHVP NB and Case 2-RHVP SB). There is a minimal increase in traffic volume along this segment in Case 3-Mud IC.

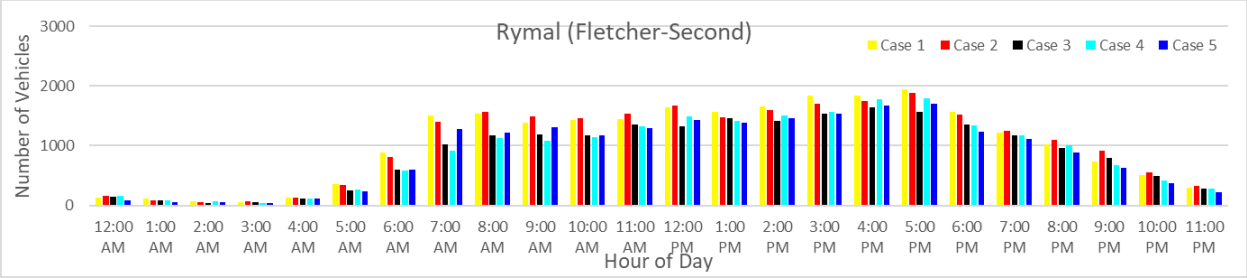


Figure 15: Hourly Volume at Rymal Rd (Between Fletcher Rd and Second Rd) – Total for both Directions

Rymal Road East (Between Dartnall Road and Nebo Road)

A comparison of traffic volume (total for both directions) along Rymal Road East between Nebo Road and Dartnall Road is shown in Figure 16. The results show a minor increase in traffic volume in the AM peak period, during the construction work (Case 1-RHVP NB, Case 2-RHVP SB, Case 3-Mud IC).

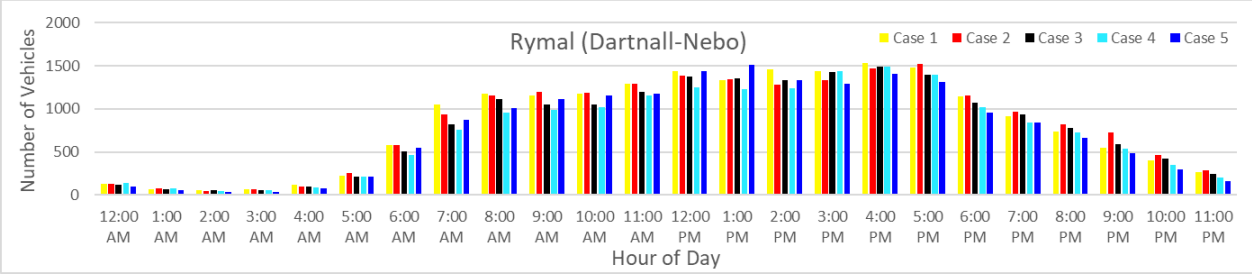


Figure 16: Hourly Volume at Rymal Rd (Between Dartnall Rd and Nebo Rd) – Total for both Directions

Stone Church Road East (Between Dartnall Road and Pritchard Road)

Figure 17 presents the 24-hour volume comparison along Stone Church Road East between Dartnall Road and Pritchard Road. The results indicate that Stone Church Road East experienced a significant volume increase during the ramp closure scenario (Case 3-Mud IC). It can be seen in Figure 17 that volume increase during the AM peak is more than double, (e.g. from 472 vehicles in Case 4-Open Aug to 1,168 vehicles in Case 3-Mud IC at 7 am). The results indicate an increase in traffic volume along this segment for Case 1-RHVP NB and Case 2-RHVP SB as well.

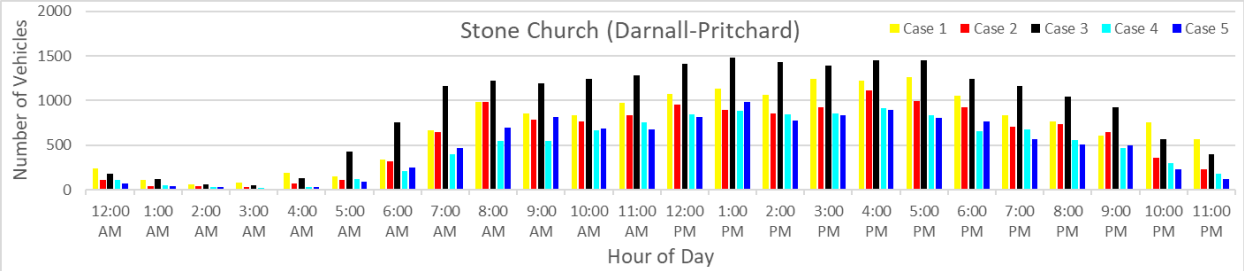


Figure 17: Hourly Volume at Stone Church Rd E (Between Dartnall Rd and Pritchard Rd) – Total for both Directions

Mud Street (Between First Road and Upper Centennial Parkway)

The 24-hour volume comparison along Mud Street East between First Road West and Upper Centennial Parkway is highlighted in Figure 18 below. The collected data indicates that this route experienced the largest growth in traffic volume due to the closures along RHVP. Traffic diversion during Case 1-RHVP NB and Case 2-RHVP SB seems to have affected this segment the most, especially in Case 2-RHVP SB where the PM peak hours show a volume increase to approximately 2,500 vehicles from 1,500 observed during Case 4-Open Aug and 5. The AM early hours also show a large influx of volume. At 5 am traffic volume increased to over 1,300 vehicles during construction (Case 2-RHVP SB) from around 250 vehicles that were observed during Case 4-Open Aug and 5. This is a 400% increase in volume along this segment. The closure during Case 3-Mud IC does not seem to have impacted traffic on this route.

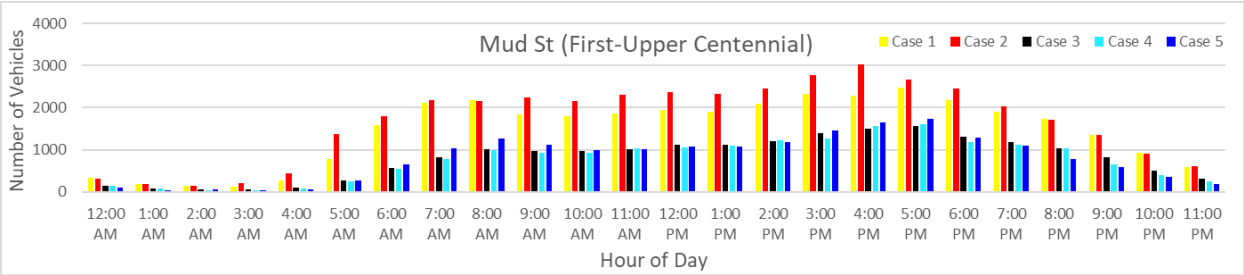


Figure 18: Hourly Weekday Volume at Mud St (Between First Rd and Upper Centennial Pkwy) – Total for both Directions

Kenilworth Avenue (Between Barton Street East and Cannon Street East)

The 24-hour volume along Kenilworth Avenue North from Cannon Street East to Barton Street East, shown in Figure 19, indicates some increase in traffic volume, due to traffic diversions, in Case 1-RHVP NB and Case 2-RHVP SB throughout the day.

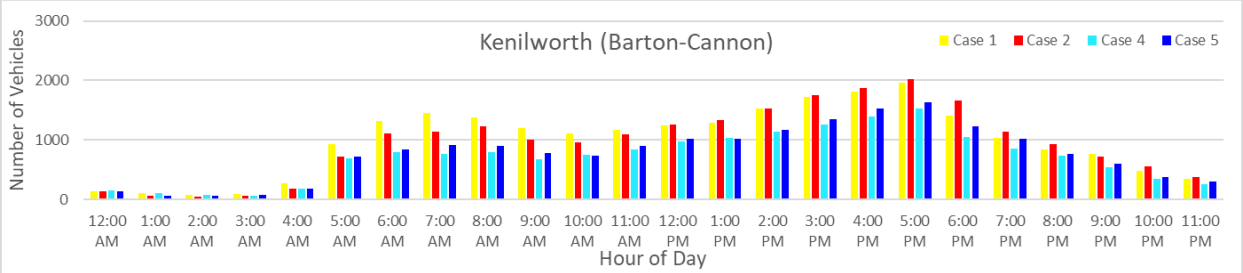


Figure 19: Hourly Weekday Volume at Kenilworth Ave (Between Barton St E and Cannon St E) – Total for both Directions

Kenilworth Avenue (Between Central Avenue and Main Street East)

Figure 20 depicts volume comparison along Kenilworth Avenue between Central Avenue and Main Street East during and after the construction work on RHVP. The results show much higher traffic volume along this segment during Case 1-RHVP NB in the AM peak hour when compared to Case 4-Open Aug and Case 5-Open Sep. For example, from 8 to 9 am, the volume doubled from 1,221 vehicles in Case 1-RHVP NB compared to 657 vehicles in Case 4-Open Aug).

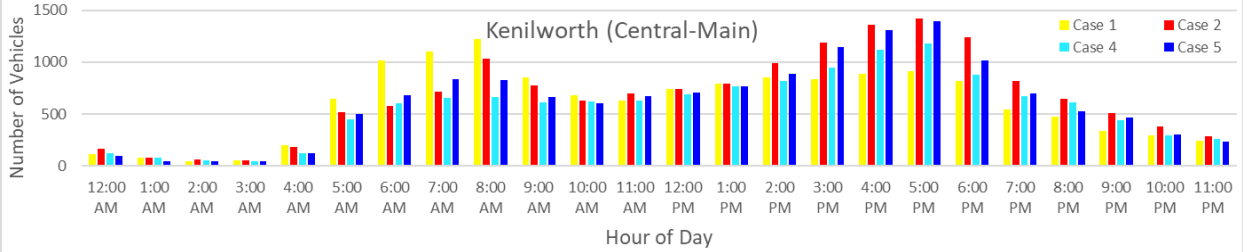


Figure 20: Hourly Weekday Volume at Kenilworth Ave (Between Central Ave and Main St E) – Total for both Directions

Summary of Traffic Volume Analysis

The changes in traffic volume observed along study corridors, by comparing the data from during (Case 0-Before, Case 1-RHVP NB, Case 2-RHVP SB, Case 3-Mud IC) and after the construction work at RHVP (Case 4-Open Aug, Case 5-Open Sep), are summarized in Figure 21 to Figure 23.

Figure 21 presents changes in traffic volume during Case 1-RHVP NB compared with Case 4-Open Aug and Case 5-Open Sep. It can be seen from this figure that the majority of the traffic diverted from RHVP during the closure of the northbound lanes in the AM and PM Peak hours, using a combination of Mud Street / Rymal Road East and Centennial Parkway.

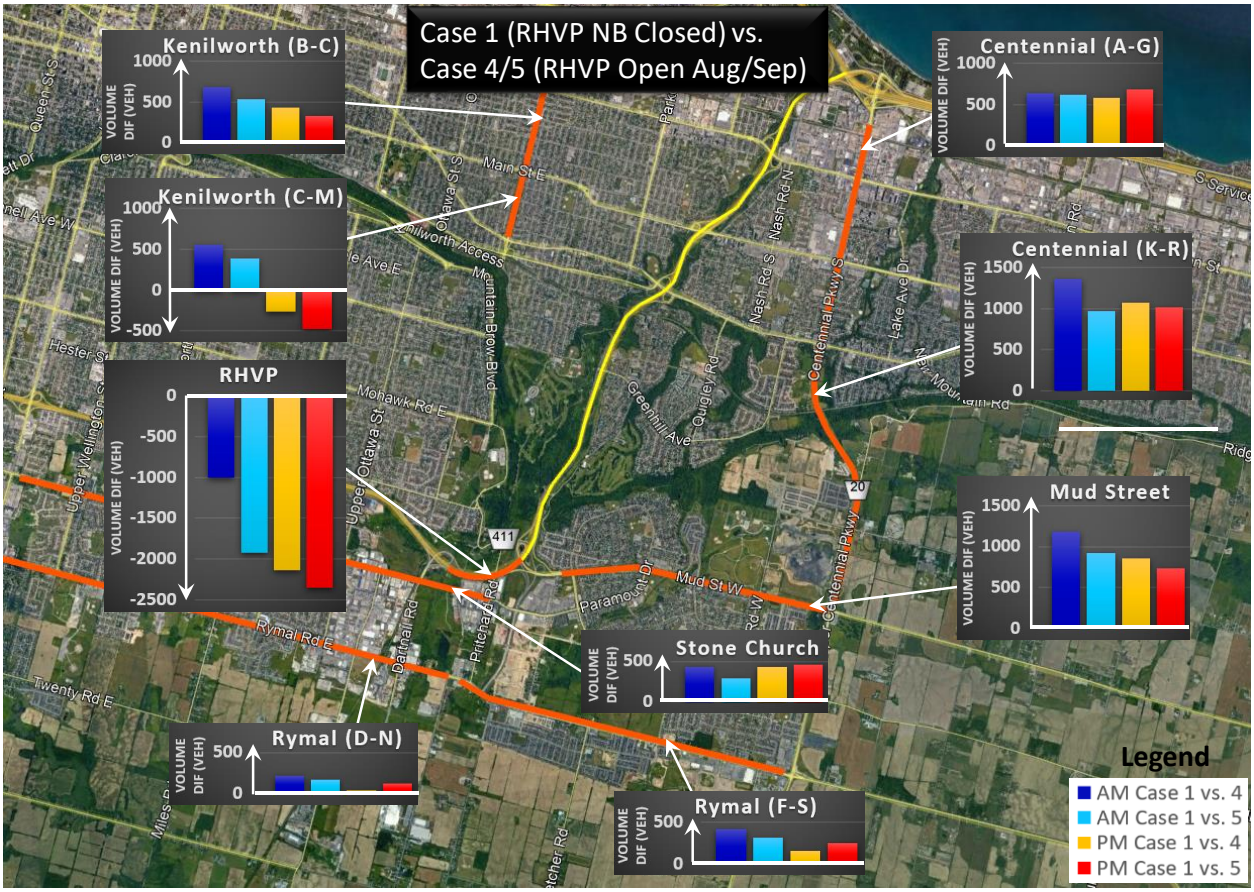


Figure 21: Volume Diversion Comparison: Case 1-RHVP NB vs. Case 4-Open Aug and Case 5-Open Sep

Similarly, Figure 22 shows changes in traffic volume during Case 2-RHVP SB compared with Case 4-Open Aug and Case 5-Open Sep. It can be seen that the majority of the traffic diverted from RHVP during the closure of the southbound lanes used a combination of Centennial Parkway and Mud Street / Rymal Road East in the AM and PM Peak hours.

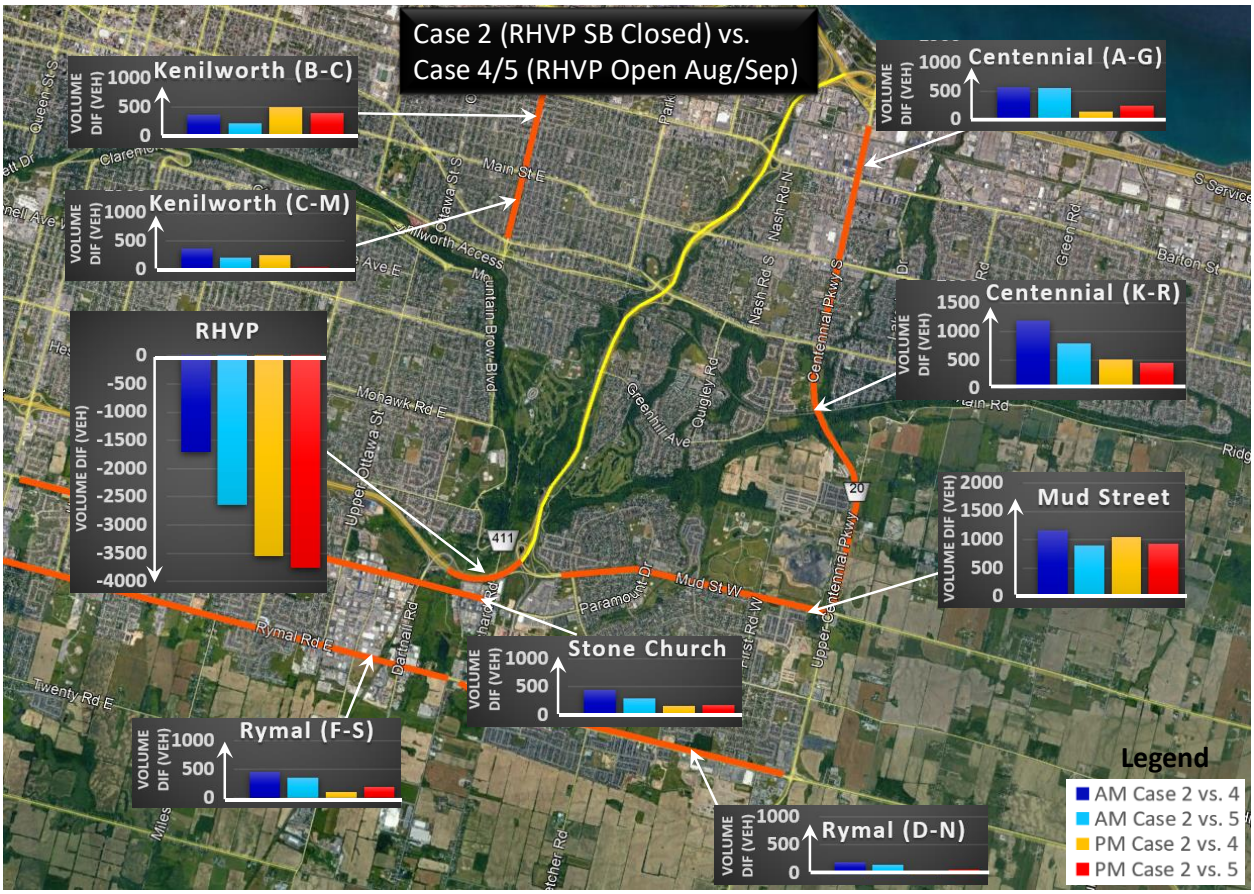


Figure 22: Volume Diversion Comparison: Case 2-RHVP SB vs. Case 4-Open Aug and Case 5-Open Sep

Figure 23 depicts changes in traffic volume during Case 3-Mud IC compared with Case 4-Open Aug and Case 5-Open Sep. The observed data indicates that most of the traffic diverted during the closure of ramps from Mud Street and Upper RHVP had used Stone Church Street during the AM and PM peak hours.

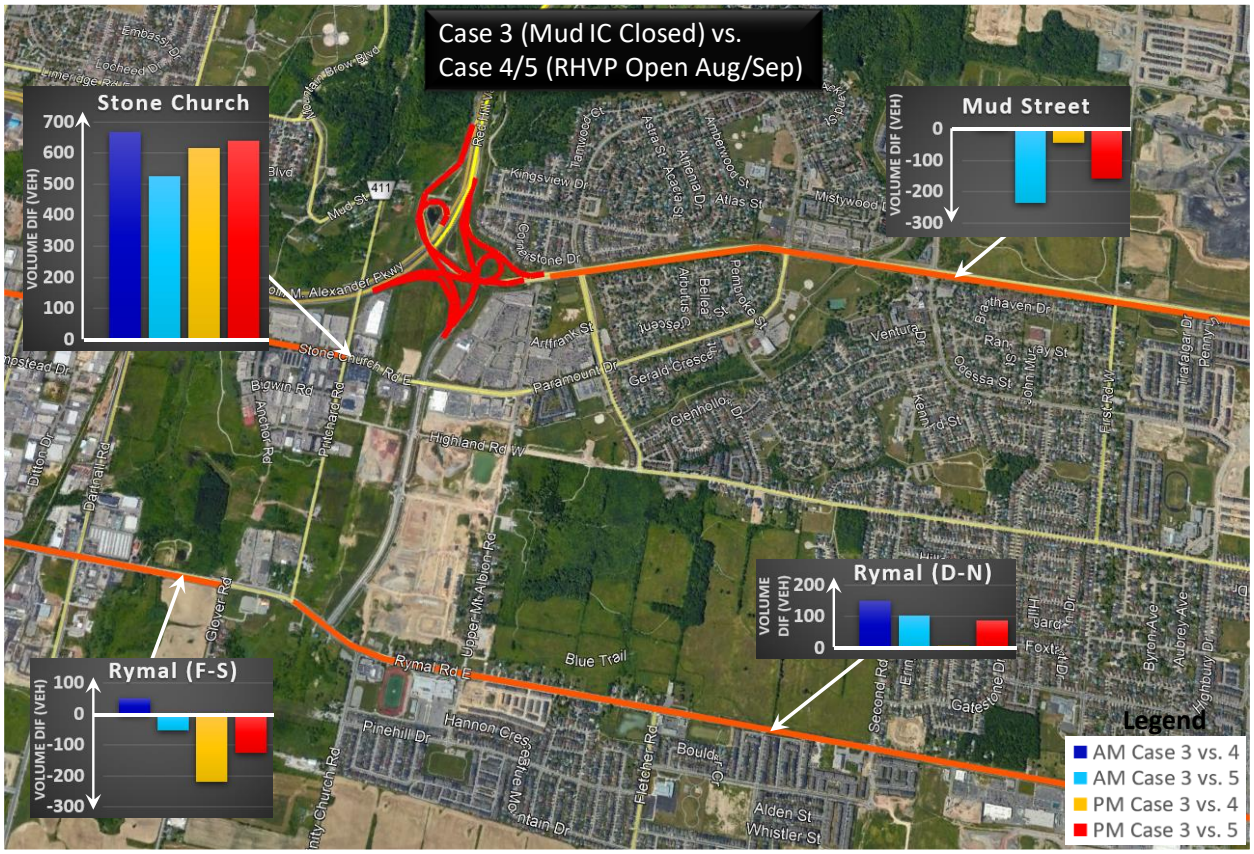


Figure 23: Volume Diversion Comparison: Case 3-Mud IC vs. Case 4-Open Aug and Case 5-Open Sep

3.1.2. Vehicle Classification

To analyze the truck infiltration into the surrounding road network of RHVP, key locations were reviewed by analyzing the vehicle classification data that was collected by the City and provided with the ATR counts. In particular, the focus was given to the locations which experienced a higher increase in traffic volume during the construction work on RHVP, including Centennial Parkway, Mud Street and Stone Church Road East. The vehicle classification included the following vehicle types: Passenger Vehicles (length less than 8.5 m), Small Trucks (length between 8.5 m and 9.9 m), Trucks/Buses (length between 10 m and 12.9 m) and Tractor Trailers (length of 13 m or more). The vehicle classification analysis was conducted based on the Small Trucks, Trucks/Buses and Tractor-trailers types.

Centennial Parkway (Between Arrowsmith Road and Goderich Street)

Figure 24 shows a comparison between the total observed number of trucks (including small trucks, trucks/buses and tractor-trailers) in Case 1-RHVP NB and Case 4-Open Aug along Centennial Parkway, between Arrowsmith Road and Goderich Street. The data shows an increase in the total number of trucks that travelled along Centennial Parkway (total both directions) during the construction work on RHVP.

Similarly, Figure 25 shows the number of tractor-trailers that travelled along this road during Case 1-RHVP NB and Case 4-Open Aug. The data indicate that this segment of Centennial Parkway experienced

an increase in the number of tractor-trailers due to the closure along RHVP, during the AM and early afternoon hours, by up to 53 total per hour.

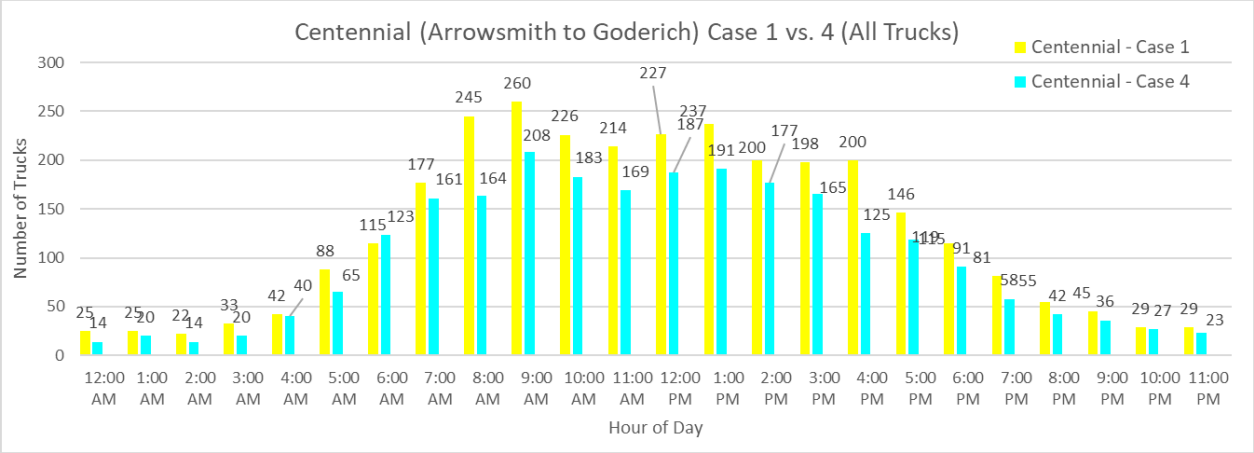


Figure 24: Total Truck Volume (Both Directions) Comparison: Case 1-RHVP NB vs. Case 4-Open Aug - Centennial Pkwy (Between Arrowsmith Rd and Goderich St)

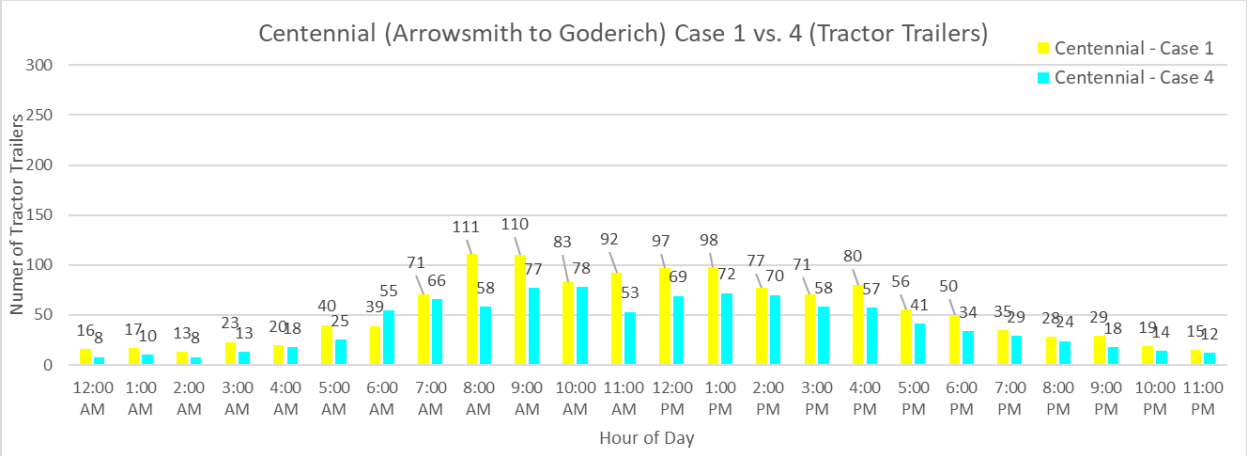


Figure 25: Tractor-trailer Volume (Both Directions) Comparison: Case 1-RHVP NB vs. Case 4-Open Aug - Centennial Pkwy (Between Arrowsmith Rd and Goderich St)

Centennial Parkway (Between King Street and Ridge Road)

Figure 26 shows a comparison between the total observed number of trucks (including small trucks, trucks/buses and tractor-trailers) in Case 1-RHVP NB and Case 4-Open Aug along Centennial Parkway, between King Street and Ridge Road. The data shows an increase in the total number of trucks that travelled along Centennial Parkway (total both directions) during the construction work on RHVP.

Similarly, Figure 27 shows the number of tractor-trailers that travelled along this road during Case 1-RHVP NB and Case 4-Open Aug. The data indicate that this segment of Centennial Parkway experienced an increase in the number of tractor-trailers due to the closure along RHVP, during the AM and early afternoon hours, by up to a maximum of 83 total per hour.

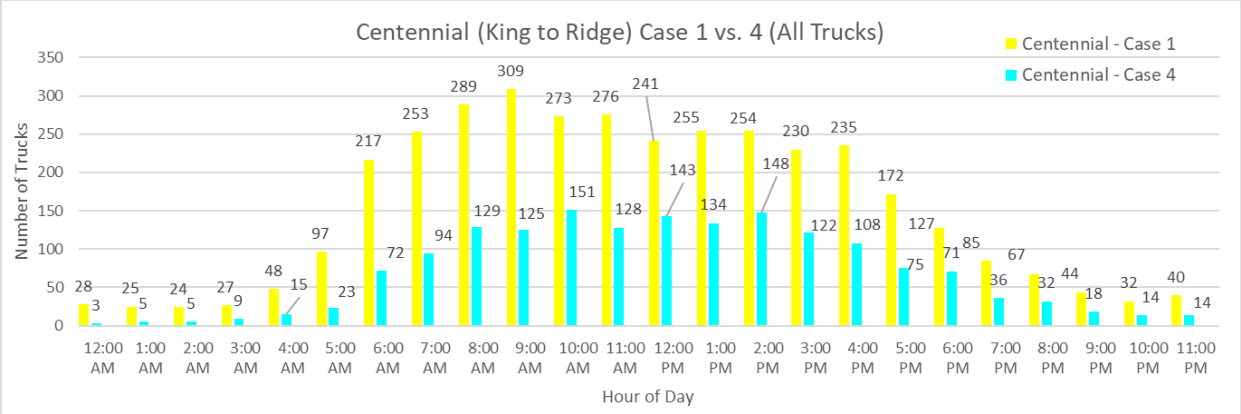


Figure 26: Total Truck Volume (Both Directions) Comparison: Case 1-RHVP NB vs. Case 4-Open Aug - Centennial Pkwy (Between King St and Ridge Rd)

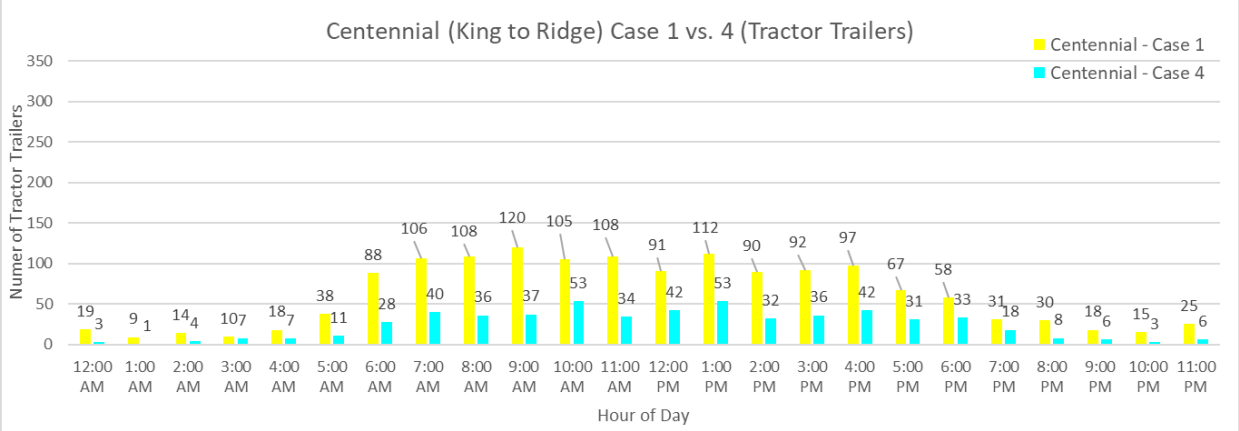


Figure 27: Tractor-trailer Volume (Both Directions) Comparison: Case 1-RHVP NB vs. Case 4-Open Aug - Centennial Pkwy (Between King St and Ridge Rd)

Mud Street (Between First Road and Upper Centennial Parkway)

A comparison between the observed number of trucks between Case 2-RHVP SB and Case 4-Open Aug along Mud Street, between First Road and Upper Centennial Parkway, is presented in Figure 28. The counts show a large increase in the total number of trucks (all types) that travelled along Mud Street (total both directions) during the construction work on RHVP. A maximum of 197 trucks was recorded in Case 2-RHVP SB during the AM peak hour, which compared to the after-construction volume observed in Case 4-Open Aug, shows a significant increase (by about 100%).

Similarly, Figure 29 compares the number of tractor-trailers that used Mud Street between Case 2-RHVP SB and Case 4-Open Aug. The observed data shows an increase in the number of tractor-trailers on Mud Street, up to 50 total per hour.

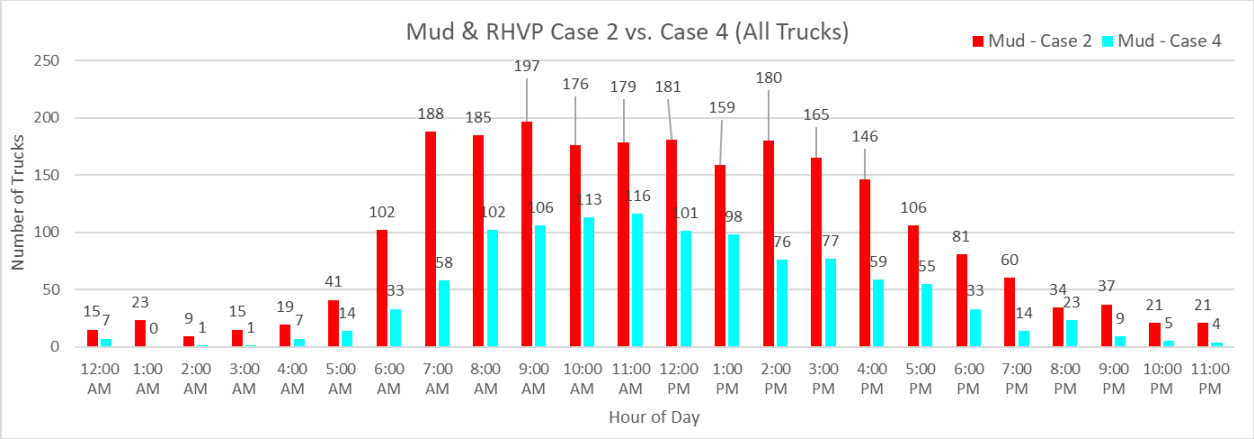


Figure 28: Total Truck Volume (Both Directions) Comparison: Case 2-RHVP SB vs. Case 4-Open Aug - Mud Street, between First Road and Upper Centennial Parkway

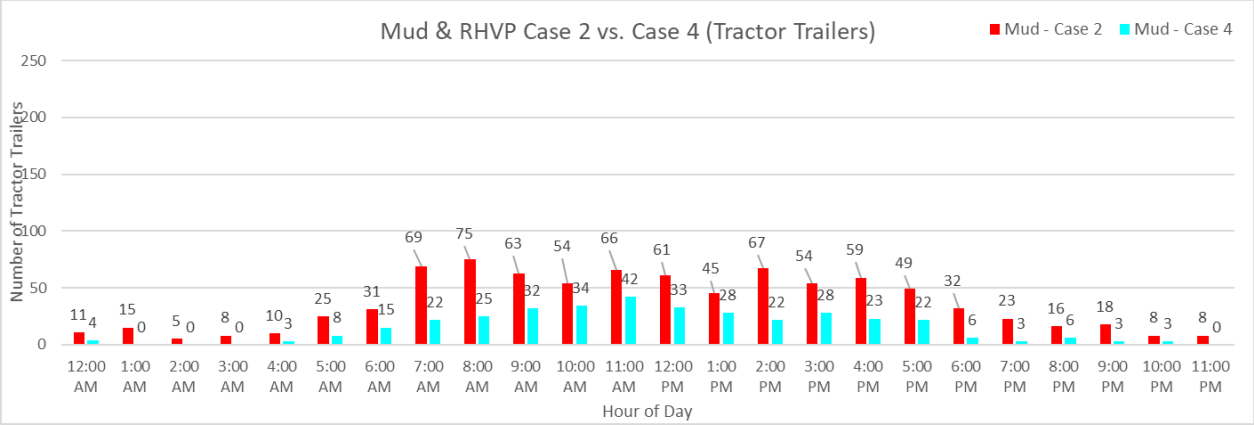


Figure 29: Tractor-trailer Volume (Both Directions) Comparison: Case 2-RHVP SB vs. Case 4-Open Aug - Mud Street, between First Road and Upper Centennial Parkway

Stone Church Road East (Between Dartnall Road and Pritchard Road)

Figure 30 shows a comparison between the total observed number of trucks (all types) in Case 3-Mud IC and Case 4-Open Aug along Stone Church Road East, between Dartnall Road and Pritchard Road. The observed volume shows a large increase in the number of trucks that travelled along Stone Church Road East (total both directions) during the closure of ramps from Mud Street and Upper RHVP. Figure 31 shows a similar trend for the number of tractor-trailers

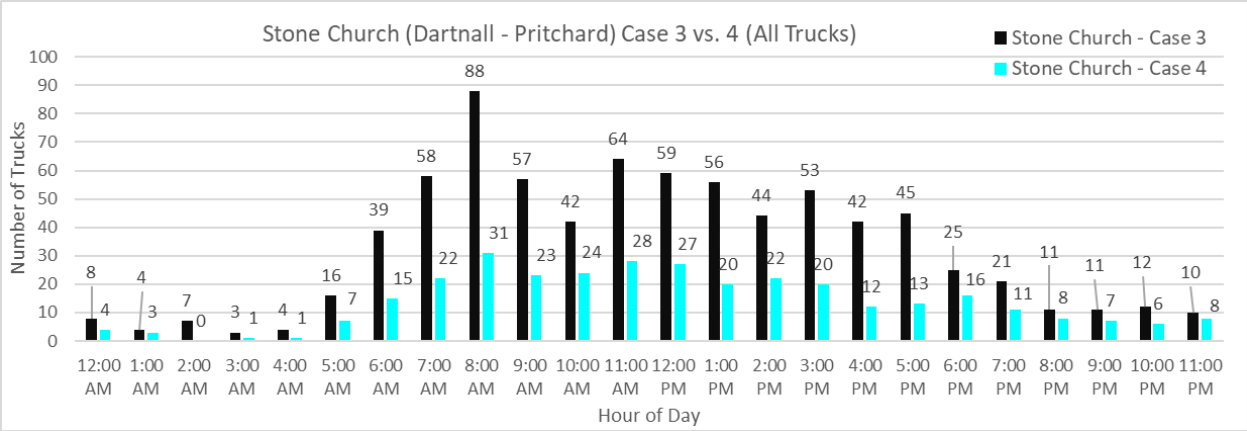


Figure 30: Total Truck Volume (Both Directions) Comparison: Case 3-Mud IC vs. Case 4-Open Aug - Stone Church Rd, between Dartnall Road and Pritchard Road

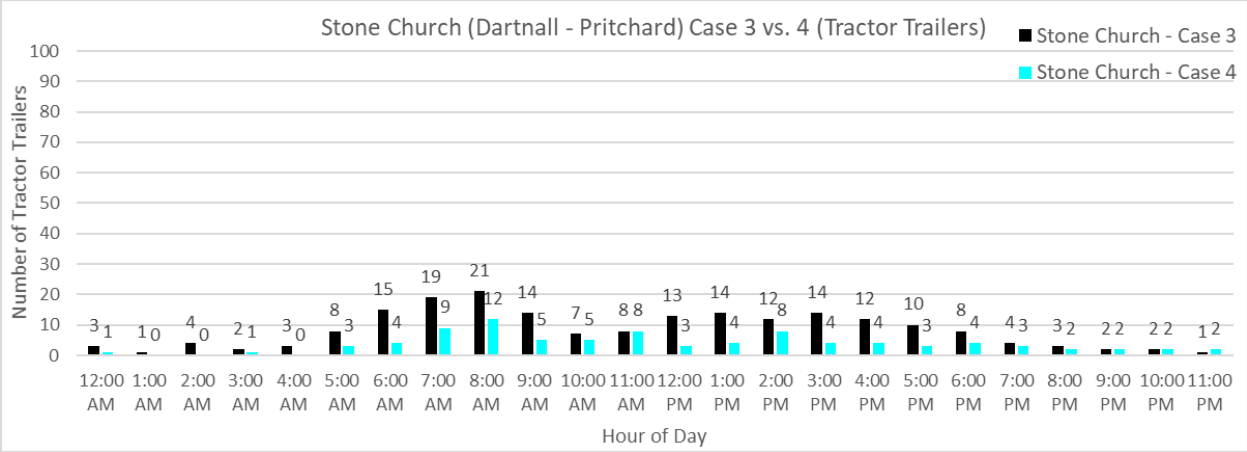


Figure 31: Tractor-trailer Volume (Both Directions) Comparison: Case 3-Mud IC vs. Case 4-Open Aug - Stone Church Rd, between Dartnall Road and Pritchard Road

3.1.3. Travel Time Assessment

The impact of construction work and closures on RHVP on adjacent road network was also evaluated by comparing the travel time along the Primary and Secondary routes (identified by the City) before construction began (Case 0-Before), during construction (Case 0-Before, Case 1-RHVP NB, Case 2-RHVP SB, Case 3-Mud IC) and after construction (Case 4-Open Aug and Case 5-Open Sep). A list of the Primary and Secondary routes is provided in **Appendix C**.

Average travel time values reported in the TomTom data were used as the performance measure for this analysis. The results are summarized in the following sections, separate for the Primary and Secondary routes.

It should be noted that travel time data provided by TomTom are averaged based on the total number of observations for each route. A detailed list of the routes and their corresponding observation numbers are provided in **Appendix C**. In order to test for the statistical validity of the observation numbers for each route, a methodology based on the Central Limit Theorem was applied that is presented in **Appendix E**. As a result of this statistical test, the reported travel times for some of the

routes/directions were found to be based on a low number of observations. These locations are highlighted in **Appendix E** and are marked in the figures that are presented in the following sections.

Primary Routes

Figure 32 to Figure 35 show a comparison between average travel time during different scenarios (Case 0-Before, Case 1-RHVP NB, Case 2-RHVP SB, Case 3-Mud IC, Case 4-Open Aug and Case 5-Open Sep) along the Primary routes. Average travel times are based on the TomTom calculated average values during the AM (7 - 9) and PM (4 - 6) Peak periods. Figure 32 and Figure 33 include the Primary routes in the north/south direction. Figure 34 and Figure 35 list the Primary routes in the east/west direction.

The analysis results show an increase in travel time along several Primary routes during **Case 1-RHVP NB** (when compared with Case 0-Before, Case 4-Open Aug and Case 5-Open Sep), as follows:

- Travel time along the NB direction of Upper Centennial Parkway increased by 50% (from 11 to 17 min) in the AM Peak and by 30% (from 11 to 15 min) during the PM Peak
- Travel time along the NB direction of Highway 403 increased by 50% (from 10 to 15 min) in the AM Peak and by 40% (from 11 to 16 min) during the PM Peak
- Travel time along the WB direction on Kenilworth Access increased by more than 200% (from 2 to 7 min) in the AM Peak
- Travel time along the EB direction of Mud Street shows a 70% increase from 7 to 12 min in the PM Peak
- Smaller travel time increase was also observed along the following routes:
  - Kenilworth Access WB in the AM Peak
  - Wilson Street EB in the PM Peak
  - Stone Church EB in the AM peak
  - Stone Church WB in the PM peak
  - Mud Street WB in the PM peak
  - Rymal Road EB in the PM peak

The observed changes in travel time are consistent with the increase in traffic volume along the analyzed routes, including Upper Centennial Parkway, Mud Street, Stone Church Street and Rymal Road.

The following routes showed an increase in travel time during **Case 2-RHVP SB** (as compared with Case 0-Before, Case 4-Open Aug and Case 5-Open Sep):

- Travel time along the SB direction of Upper Centennial Parkway increased by 50% (from 15 to 23 min) in the PM Peak
- Travel time along the NB direction of Highway 403 increased by 40% (from 10 to 14 min) in the AM Peak
- Travel time along the SB direction of First Street E shows an 80% increase from 5 to 9 min in the PM Peak
- Travel time along the WB direction of Mud Street increased by 100% (from 5 to 10 min) in the AM Peak
- Smaller travel time increase was also observed along the following routes:
  - Mud Street EB in the AM Peak
  - Rymal Road WB in the AM and PM Peak
  - Stone Church WB in the AM Peak

The following routes showed an increase in travel time during Case 3-Mud IC (as compared with Case 0-Before, Case 4-Open Aug and Case 5-Open Sep):

- Stone Church EB and WB in the PM Peak (It should be noted that travel time data reported for this road segment is based on a small number of observations and may not be a true representative of the conditions)

Similarly, the increase in travel time along Stone Church Road in Case 3-Mud IC is consistent with the volume increase that was observed from the ATR counts at this location.

The data indicates high travel time along the northbound direction of Highway 403 (during Case 5-Open Sep) in the AM peak. This could be due to an incident that was reported on September 19, 2019 on Highway 403 in Ancaster.

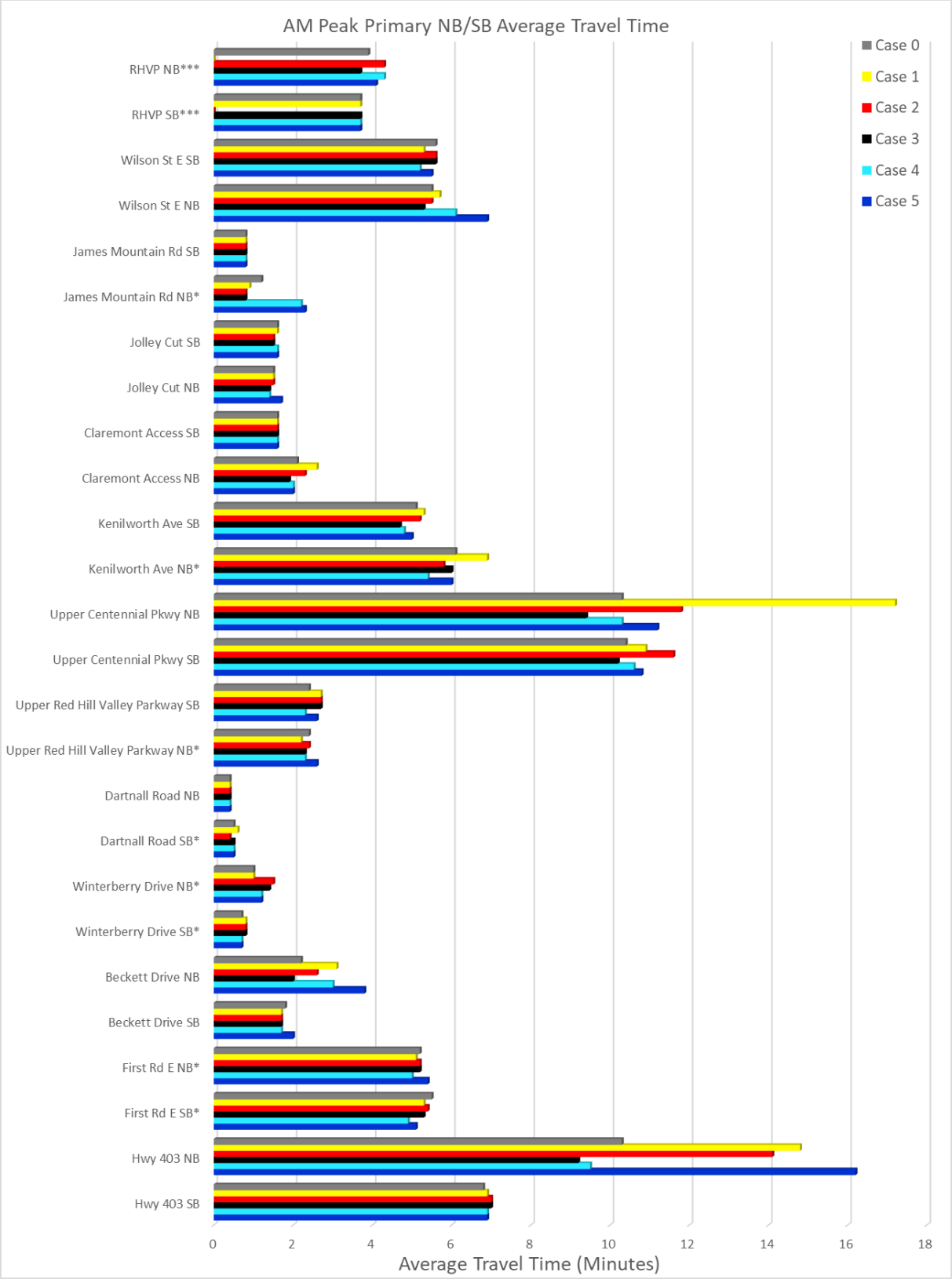


Figure 32: Average Travel Time for Primary Routes (NB/SB Direction) – AM Peak

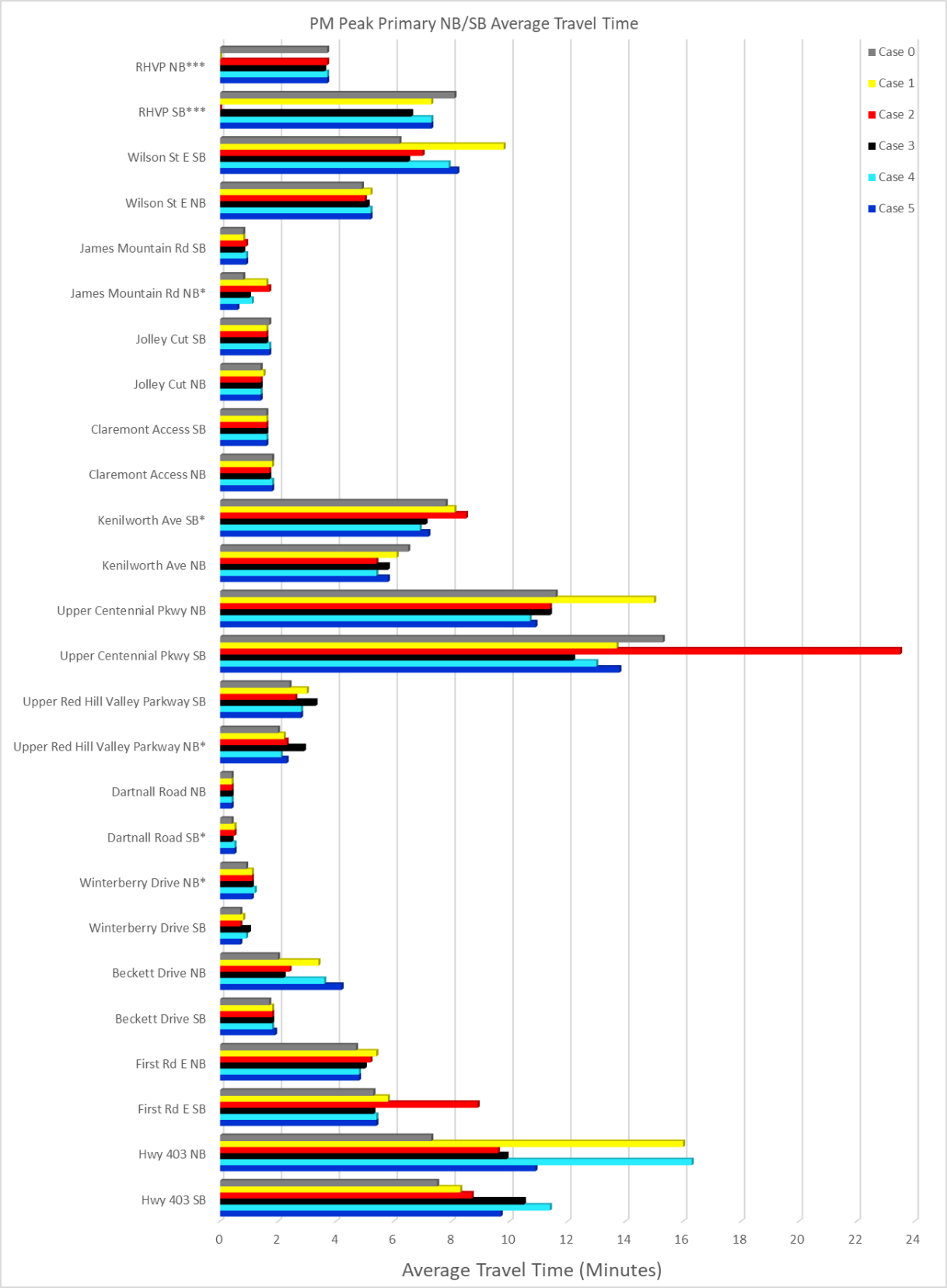


Figure 33: Average Travel Time for Primary Routes (NB/SB Direction) – PM Peak

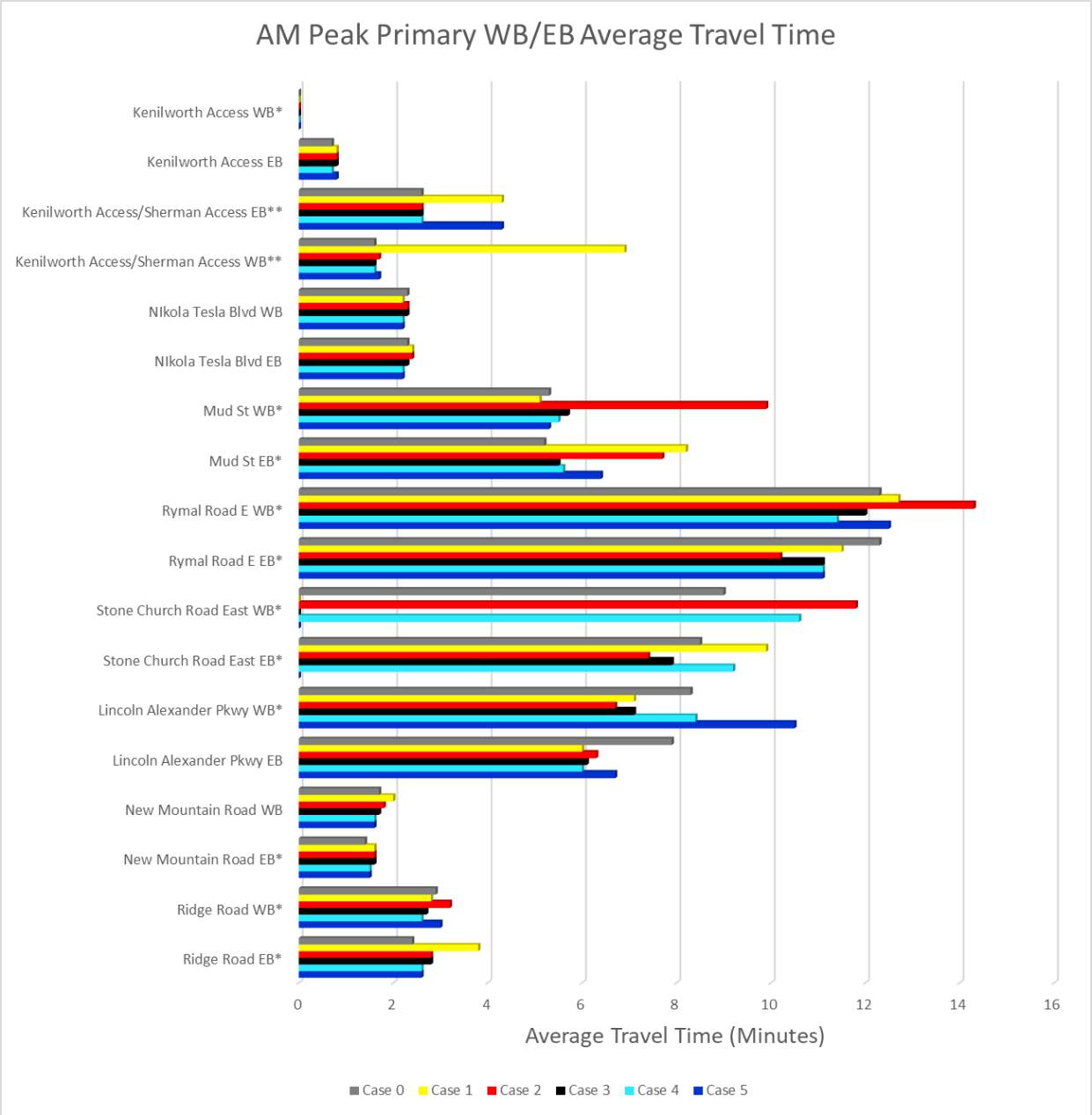


Figure 34: AM Peak - Primary Travel Time Routes (EB/WB routes)

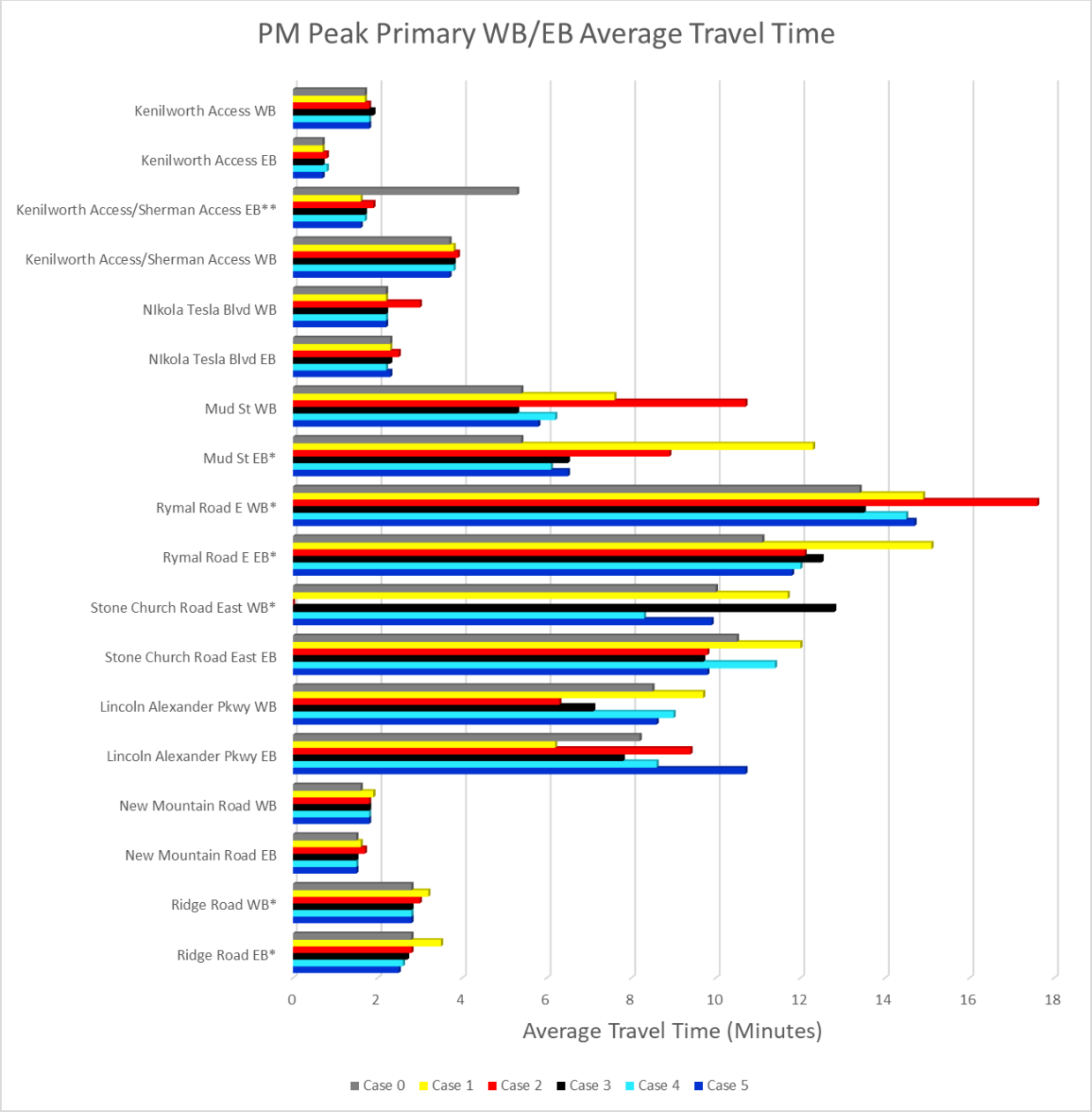


Figure 35: PM Peak - Primary Travel Time Routes (EB/WB routes)

The following should be noted in the above figures:

- * indicates that the sample size of reported travel time data is lower than what minimum required based on the statistical test. See **Appendix C** for travel time sample size calculations
- ** Kenilworth/Sherman Access has special closures during certain times of the day:
  - EB direction is closed 6:50 - 9:10 am between Charlton Ave E and Sherman Cut, and 3:55 - 6:05 pm between Sherman Cut and Kenilworth Access; and
  - WB direction is closed 6:50 - 9:10 am between Sherman Cut and Kenilworth Access.
- *** indicates RHVP road closures due to resurfacing

Secondary Routes

Similar to the Primary routes, Figure 36 to Figure 39 show a comparison between average travel time during different scenarios (Case 0-Before, Case 1-RHVP NB, Case 2-RHVP SB, Case 3-Mud IC, Case 4-Open Aug and Case 5-Open Sep) along the Secondary routes. Average travel times are based on the TomTom calculated average values during the AM (7 - 9) and PM (4 - 6) Peak periods. Figure 36 and Figure 37 include the Primary routes in the north/south direction. Figure 38 and Figure 39 list the Primary routes in the east/west direction.

The analysis results show an increase in travel time along several Secondary routes during **Case 1-RHVP NB** (as compared with Case 0-Before, Case 4-Open Aug and Case 5-Open Sep):

- Travel time for the WB direction of King Street increased by 100% (from 3 to 6 min) in the AM Peak and by more than 100% (from 3 to 7 min) during the PM Peak
- Smaller travel time increase was also observed along the following routes:
  - Mountain Brow Blvd NB During AM and PM Peak
  - Parkdale Ave NB during the AM Peak
  - Mountain Brow Blvd SB during the PM Peak
  - Mud Street SB during the PM Peak
  - Upper James St NB during the PM Peak
  - King St W EB (between Lake Avenue S and Nash Road S) during the AM and PM Peak
  - Queenston Rd WB during the AM and PM Peak
  - Stone Church WB during the PM Peak

The following Secondary routes showed an increase in travel time during **Case 2-RHVP SB** (as compared with Case 0-Before, Case 4-Open Aug and Case 5-Open Sep):

- Travel time for the SB direction of Mud Street increased by more than 100% (from 3 to 7 min) during the PM Peak.
- Travel time for the EB direction of King Street increased by 70% (from 4 to 7 min) during the PM Peak
- Smaller travel time increase was also observed along the following routes:
  - Woodward Ave NB during the AM Peak
  - Woodward Ave SB during the PM Peak
  - Upper James St SB during the PM Peak
  - King St W WB (between Lake Avenue S and 'Nash Road S) during the AM and PM Peak
  - Queenston Rd WB during the AM Peak
  - Queenston Rd EB during the PM Peak
  - Barton WB during the AM Peak
  - Barton EB during the AM Peak
  - Main St WB during the PM Peak

It should be noted that travel time data reported for some of the Secondary routes are based on a small number of observations and may not be a true representative of the conditions.

The collected data does not show any noticeable change in travel time along Secondary routes during Case 3-Mud IC when compared with Case 0-Before, Case 4-Open Aug and Case 5-Open Sep.

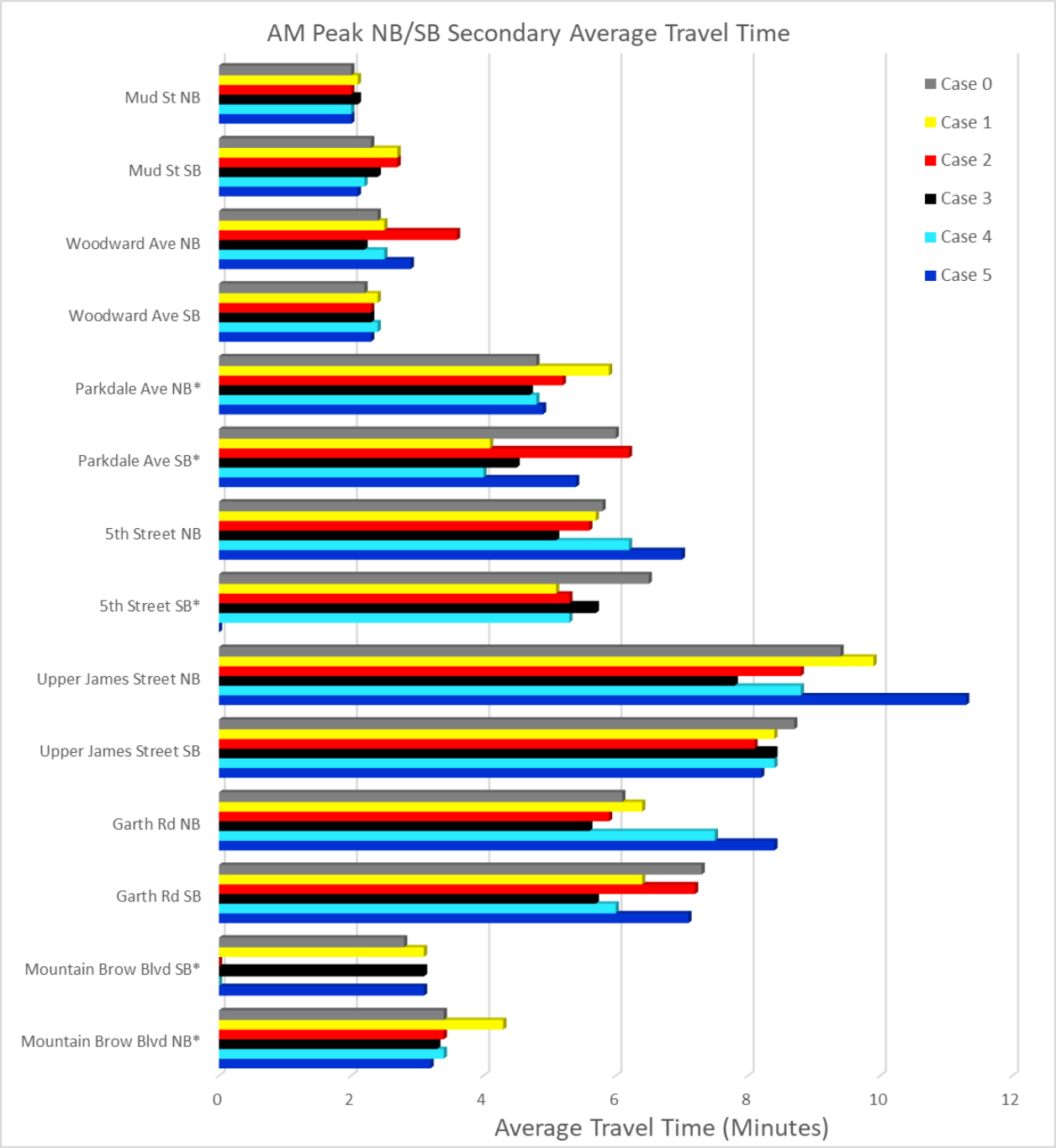


Figure 36: AM Peak - Secondary Travel Time Routes (NB/SB routes)

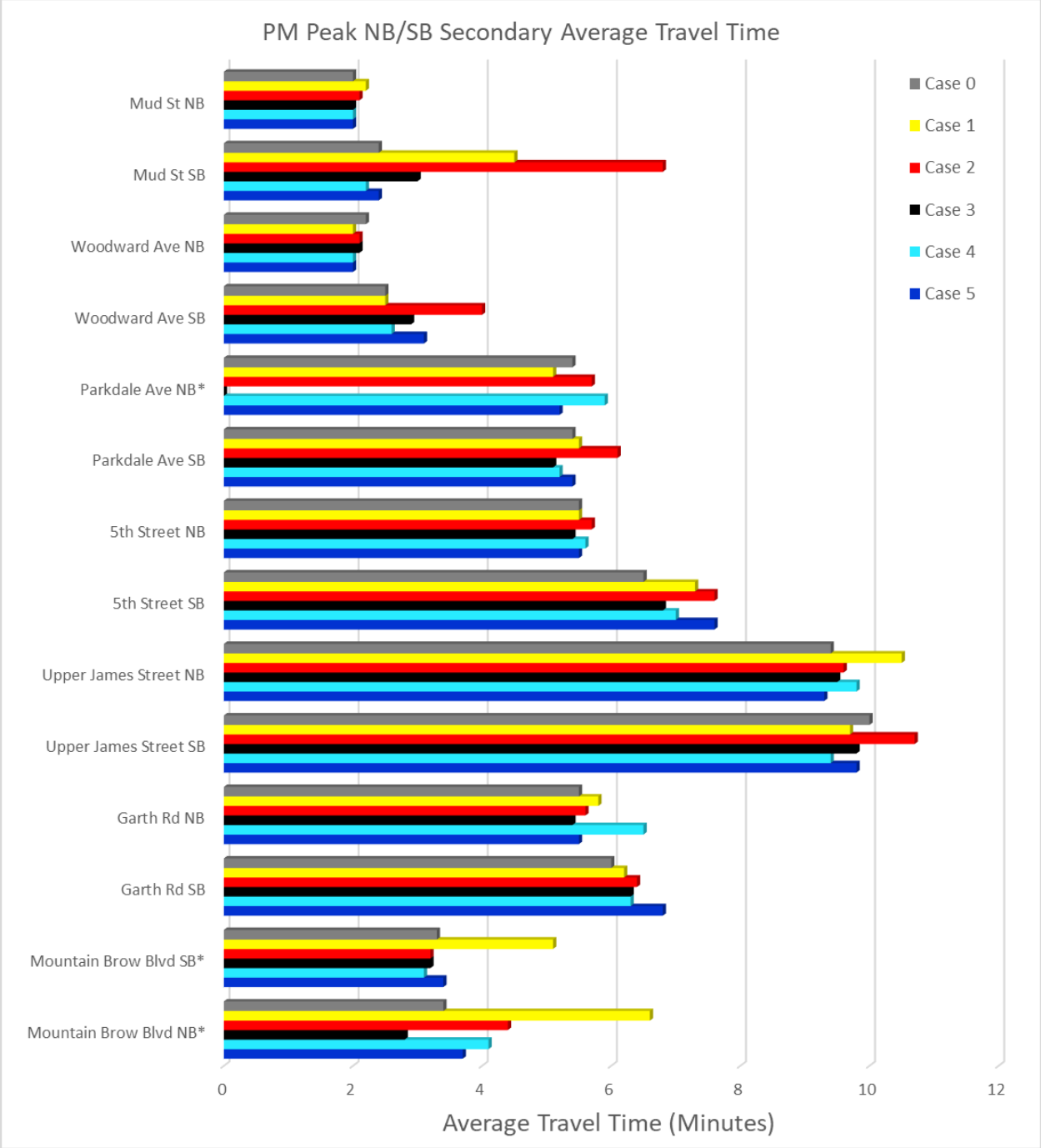


Figure 37: PM Peak - Secondary Travel Time Route (NB/SB routes)

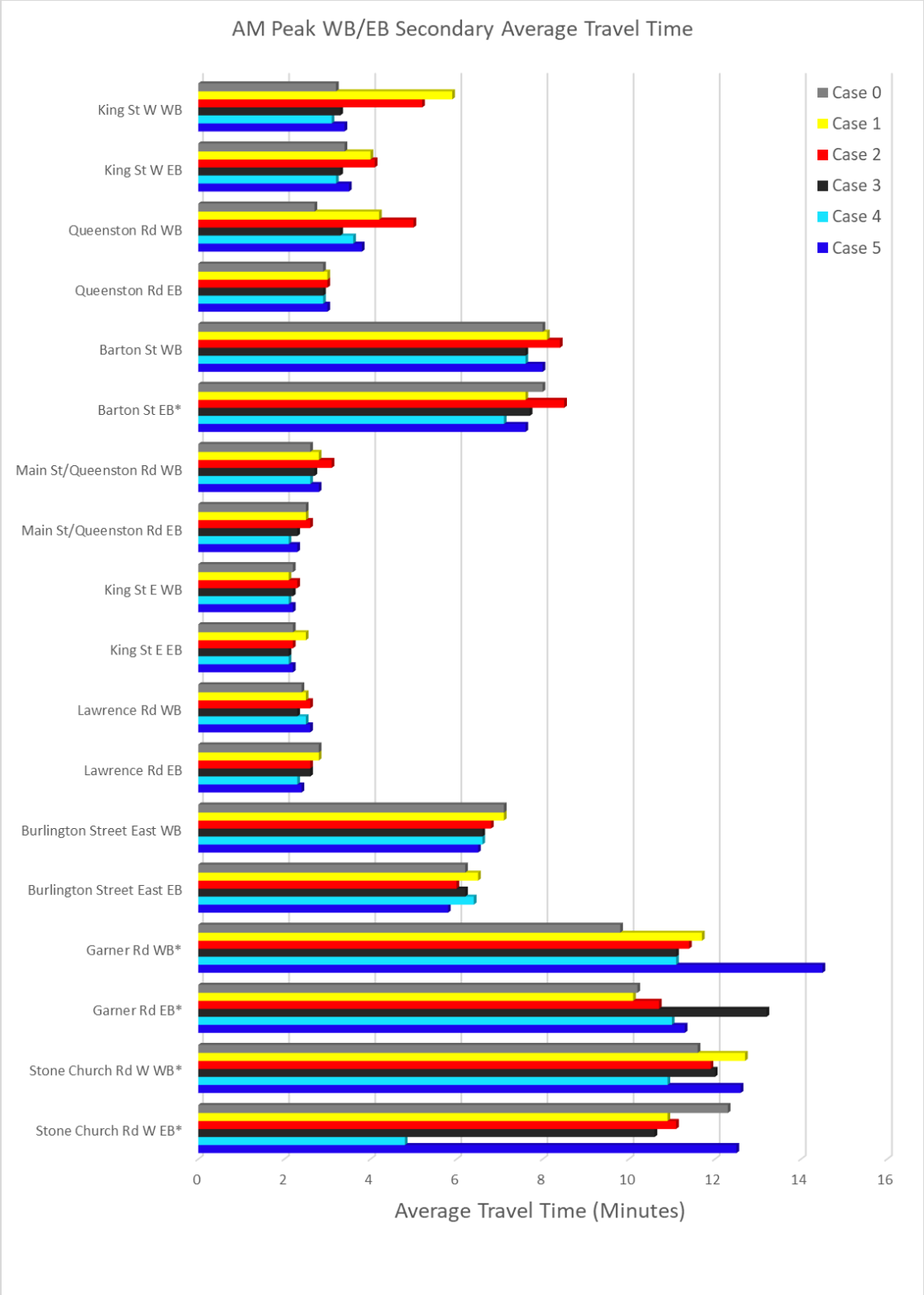


Figure 38: AM Peak – Secondary Travel Time Routes (EB/WB routes)

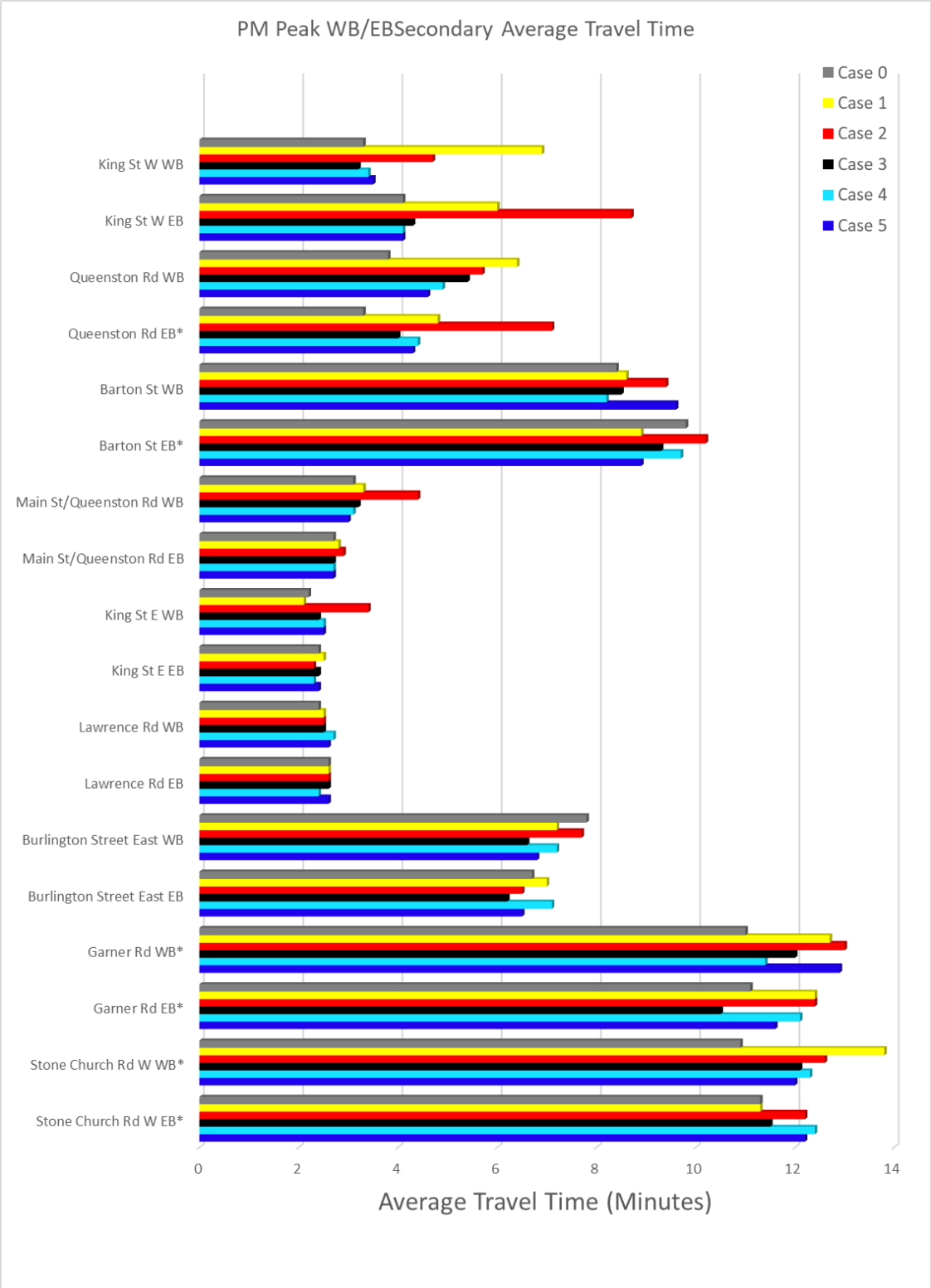


Figure 39: PM Peak – Secondary Travel Time Routes (EB/WB routes)

Note: * indicates that the sample size of reported travel time data is lower than what minimum required based on the statistical test (See **Appendix C** for travel time sample size calculations).

3.2. Analysis of Traffic Speed along RHVP

As indicated in the Scope of Work, the following scenarios (Events) were considered for travel speed assessment:

- **Event 0-Before**: Before speed limit change in February 2019;
- **Event 1-SpeedLimit**: After speed limit change (combined with the educational campaign) but before the start of police enforcement (February 16th to March 25th, 2019);
- **Event 2-Enforcement**: After the start of additional Police enforcement (March 26, 2019 to date); and
- **Event 3-Enhancements**: After resurfacing of RHVP was completed (August 2019 to date), including all the implemented educational, enforcement and engineering enhancements.

The speed data provided by the city at the study location, Mount Albion Rd (South of King St) was collected through two different sources: ATR Stations and Radar Sensors. Speed data related to the "before speed change" period (Event 0-Before), collected using an ATR station, reported speed data as number of observations for different speed ranges (bins) in 15-minute intervals. The speed bins were reported with 10 km/h ranges (e.g. 0-10 km/h, 10.1-20 km/h, …). The Radar data provided for the "after speed limit change" period (Event 1-SpeedLimit, Event 2-Enforcement, Event 3-Enhancements) included aggregated speed data with ten-second intervals.

In order to be able to compare the speed data for the before and after scenarios, after consultation with the City, the average speed for the range of each bin was used to estimate the overall weighted average speed. For example, if for 10 observed speed data in the 0 – 10 km/h "bin", then those ten observations were assumed to be at 5 km/h. This process was repeated for all the speed bins and an hourly average speed value was then calculated using a weighted average from the data. It should be noted that typically the 85th percentile speed is used for these types of analysis. However, since the provide data did not include individual measures speeds, the weighted average of speed data for each bin was used for the analysis.

Processed hourly speed data on a typical **weekday** are summarized in Figure 40 and Figure 41 for all the scenarios (Events). As expected, the average traffic speed along the SB direction of RHVP during the PM peak period is lower compared to the other periods of the day. The results show an immediate effect of reduced posted speed limit in both directions along RHVP (Event 1-SpeedLimit) during a 12-hour period (between 9 am and 9 pm). However, the average operating speed is still higher than the reduced posted speed limit (80 km/h) on average. Additional speed enforcement (Event 2-Enforcement) was most effective during the PM peak period (4 – 6 pm). No major impact on travelling speed can be seen after the resurfacing of the RHVP (Event 3-Enhancements) and before (Event 2-Enforcement). It should be noted that a summary of weekly Police enforcement statistics (number of violators) provided by the City is included in **Appendix D**.

Similarly, a comparison of hourly speed data, for all the scenarios (Events), on a typical **weekend day** is shown in Figure 42 and Figure 43. The weekend shows similar patterns to the weekday, where the initial reduction in operating speed can be noticed after the posted speed limit is changed (Event 1-SpeedLimit). Additional speed enforcement (Event 2-Enforcement) was most effective during the weekend AM peak period (10 am – 12 pm). After the resurfacing of RHVP (Event 3-Enhancements), the southbound direction had an overall higher operating speed compared to the before conditions (Event 2-Enforcement).

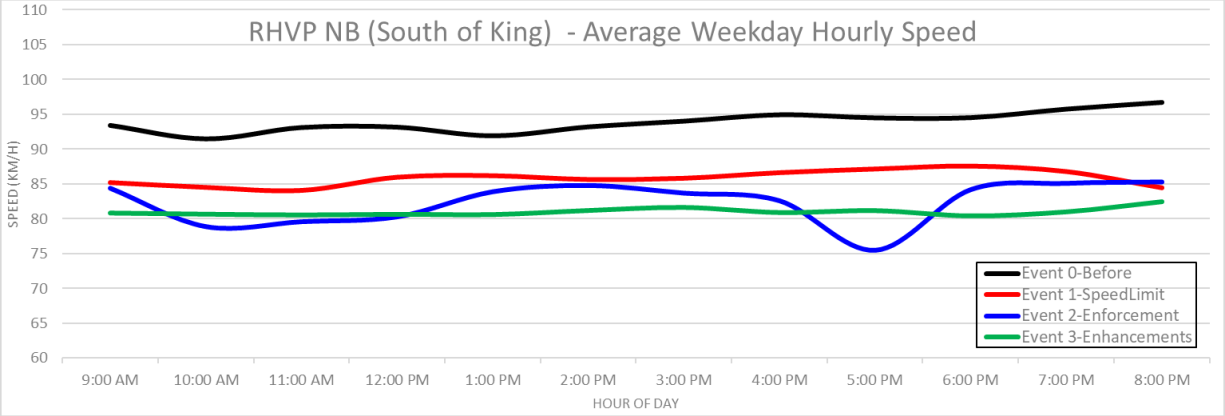


Figure 40: Average Weekday Hourly Speed Along RHVP NB

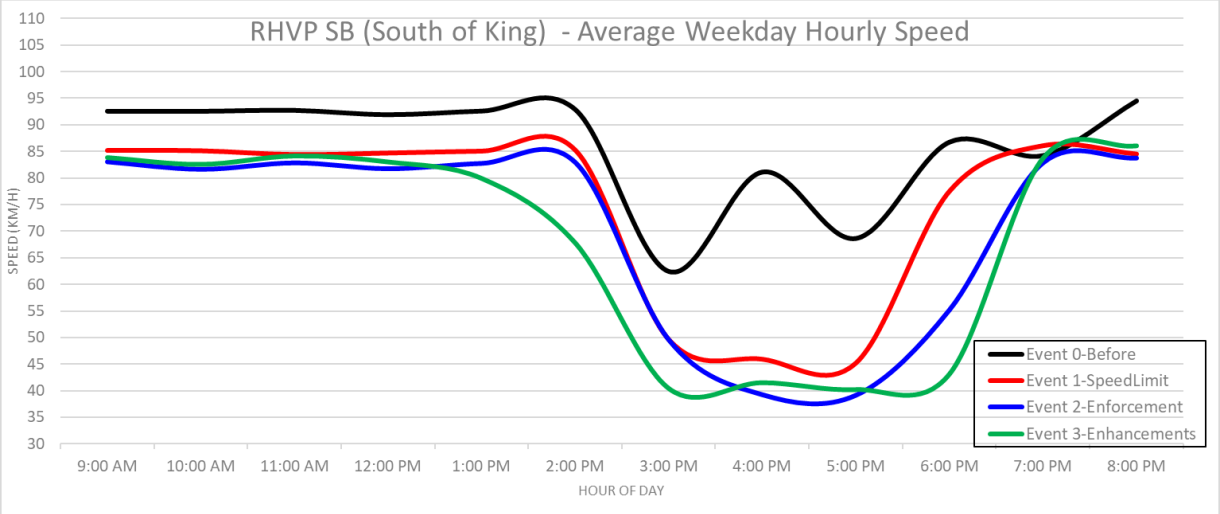


Figure 41: Average Weekday Hourly Speed Along RHVP SB

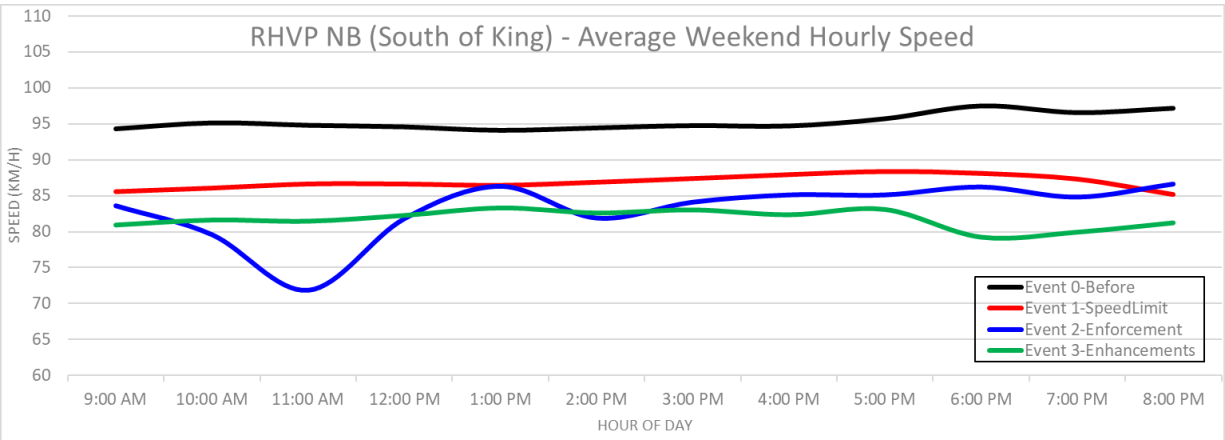


Figure 42: Average Weekend Hourly Speed Along RHVP NB

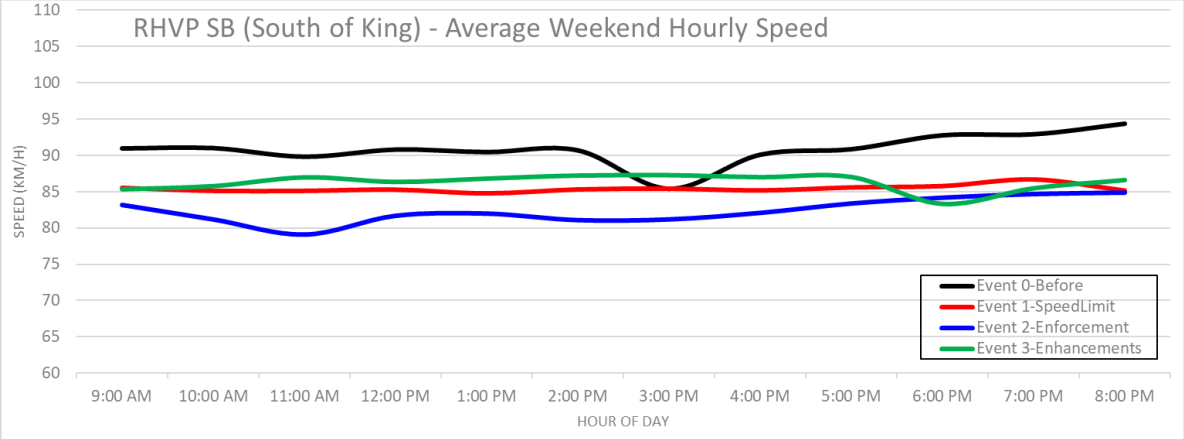


Figure 43: Average Weekend Hourly Speed Along RHVP SB

3.3. Analysis of Traffic Collisions along RHVP

The following sections present the result of the review of collision data provided by the City. The data includes only police-recorded collisions (i.e. excludes self-reported collisions) between January 2013 and December 2019. It should be noted that the "after" data, following the implementation of all the educational, enforcement and engineering enhancements on the RHVP in the Spring and summer of 2019, corresponds to a very short period of time, representing only part of one year (2019). Collision data from this short "after" period may not be fully representative of the long-term collision outcomes of the road.

Some of the conclusions reached in this report are based on the analysis of the collision data from this short timeframe. Results should not be considered definitive, because collision data, when viewed over a relatively short period of time can be skewed by a range of factors. Readers are cautioned that the results and conclusions presented in this section may not be indicative of future trends.

3.3.1. Collision Frequencies

Total Collisions

Table 5 summarizes total collisions on the RHVP Mainline by year and quarter. For the full year 2019 there was a reduction of approximately 43% (from 102 to 58) compared to the average of the previous six years. However, this data must be examined closely for proper interpretation.

The first quarter (Q1) of 2019 had 23 collisions, which is higher than 2018 (16 collisions) but at a relatively similar level compared to most previous years, which ranged between 16 and 25 collisions.

The second and third quarters (Q3, Q4) of 2019 had reductions compared to previous years; however, it must be noted that these periods include the time-period between May 29 and August 8, 2019, when closures of the RHVP were occurring to complete the resurfacing work. While the road closures alternated between the northbound and southbound directions and at least one direction of the mainline of the RHVP was open at any time, the extended road closures during these periods skew results and make comparison of collisions with similar previous time-periods impossible. The closures also skew any full-year comparisons

The fourth quarter (Q4) of 2019, which does not include any closures of the RHVP, indicates a reduction of approximately 53% (from an average of 36.5 to 17) in total collisions compared to the average of the previous six years. Figure 44 illustrates the first and fourth quarter trends.

Table 5: RHVP Total Collisions by Year and Quarter

Year	Full Year	Jan-Mar (Q1)	Apr-Jun (Q2)	Jul-Sep (Q3)	Oct-Dec (Q4)
2013	82	17	17	18	30
2014	74	16	8	17	33
2015	145	22	34	32	57
2016	107	25	18	30	34
2017	109	22	29	26	32
2018	96	16	19	28	33
2019	58	23	(10)	(8)	17

Note: Numbers in brackets indicate the periods when collision frequencies were affected by construction closures

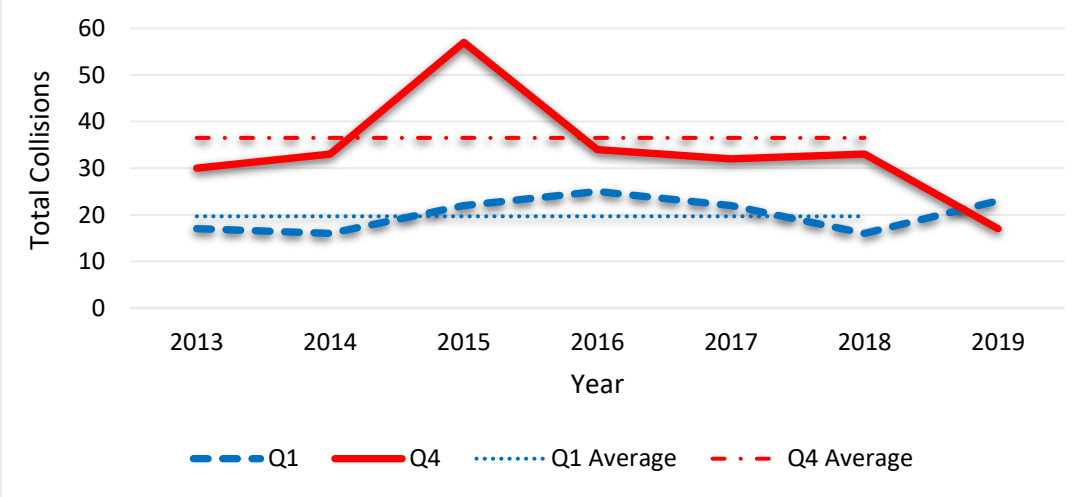


Figure 44: First and Fourth Quarter Total Collisions by Year

Injury Collisions

Table 6 summarizes injury[2] collisions on the RHVP Mainline by year and quarter and presents trends similar to total collisions. There is a 40% reduction for the full 2019 year compared to the average of the previous six years. It is highlighted that a similar caution regarding the interpretation of the full-year results, as noted in the previous section, is required.

[2] 'Injury' collisions include all collisions recorded as having a fatal or a non-fatal injury

Examining only the fourth quarter (Q4) there is a 53% reduction compared to the average of the previous 6 years. Figure 45 illustrates the first and fourth quarter trends.

Table 6: RHVP Injury Collisions by Year and Quarter

Year	Full Year	Jan-Mar (Q1)	Apr-Jun (Q2)	Jul-Sep (Q3)	Oct-Dec (Q4)
2013	35	5	5	8	17
2014	27	6	0	8	13
2015	66	10	12	16	28
2016	47	12	12	10	13
2017	47	11	12	10	14
2018	40	4	9	10	17
2019	26	10	4	4	8

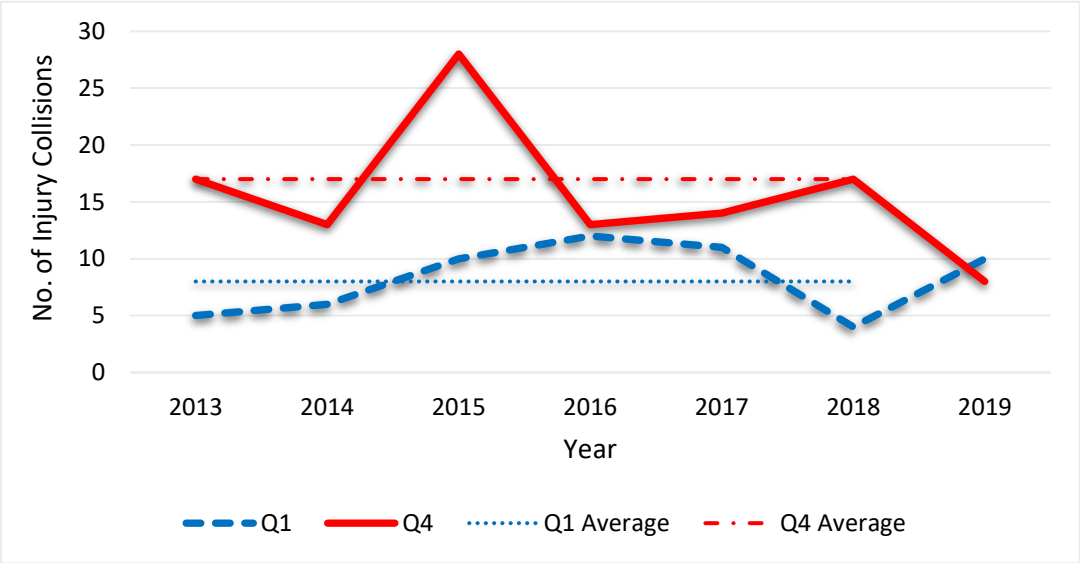


Figure 45: First and Fourth Quarter Injury Collisions by Year

Wet Surface Collisions

Table 7 summarizes collisions involving wet surface conditions on the RHVP mainline by year and quarter.

For the full year 2019, while previous years (2013-2018) presented an average of 63% wet surface[3] collisions, this proportion was reduced to 33% in 2019. A similar caution regarding the interpretation of the full-year results, as noted in previous sections, is required.

When considering only the fourth quarter (Q4) this trend is similar, with previous years (2013-2018) averaging 66% and 2019 having 29% wet surface collisions, a substantial reduction. It is noted that this proportion of wet road crashes is still higher than Provincial and City-wide averages (18% and 22%, respectively).

The first quarter (Q1) proportion of collisions on wet roads was lower for Q1 of 2019, being 35% as compared to the 2013-2018 average of 50%. The number of Q1 2019 wet surface collisions is at similar levels, being 8, as compared to the Q1 2013-2018 average of 10.

Overall, based on 2013 to 2018 data, the average number of wet road collisions in Q1 is lower than in Q4.

The Q4 proportion of collisions on wet roads was lower for Q4 of 2019, being 29% as compared to the 2013-2018 average of 67%. For Q4 of 2019, there were substantially lower numbers of wet road collisions compared to the Q4 average of previous years (2013-2018) being 5 versus an average of 25.

The 'after' data from Q4 of 2019 corresponds to a very short period of time. Because of the known aspect of the randomness of collision occurrence, a definitive conclusion cannot be drawn based on this data. The data does suggest the potential of the beginning of a reduction trend for collisions occurring on a wet surface. The Q4 data is taken following the resurfacing of the RHVP combined with the speed limit reduction and increased speed enforcement.

It must be emphasized, however, that collisions have an element of random occurrence to them and this very short-term reduction measurement could also be the result of normal variation in collision frequencies. Confirmation of the possible trend can only be determined through ongoing evaluation as additional data becomes available.

Figure 46 illustrates the Q1 and Q4 wet road collision trends.

Table 7: RHVP Percentage of Wet Surface Collisions by Year and Quarter

Year	Full Year	Jan-Mar (Q1)	Apr-Jun (Q2)	Jul-Sep (Q3)	Oct-Dec (Q4)
2013	49 (60%)	11 (65%)	10 (59%)	16 (89%)	12 (40%)
2014	45 (61%)	7 (44%)	3 (38%)	11 (65%)	24 (73%)
2015	94 (65%)	8 (36%)	19 (56%)	23 (72%)	44 (77%)
2016	68 (64%)	12 (48%)	7 (39%)	24 (80%)	25 (74%)
2017	73 (67%)	14 (64%)	18 (62%)	19 (73%)	22 (69%)
2018	58 (60%)	7 (44%)	10 (53%)	19 (68%)	22 (67%)
2019	19 (33%)	8 (35%)	5 (50%)	1 (13%)	5 (29%)

[3] Does not include winter related road surface conditions such as ice, snow or slush.

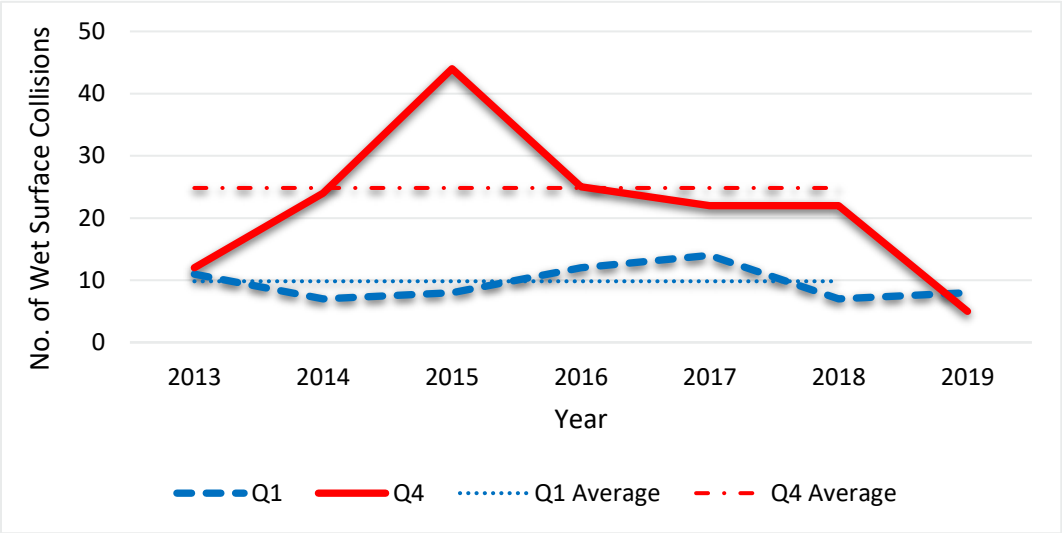


Figure 46: First and Fourth Quarter Wet Surface Collisions by Year

Lighting Conditions

Table 8 summarizes collisions relating to lighting conditions, specifically collisions involving non-daylight conditions (i.e. dark, dusk and dawn combined) on the RHVP mainline by year and quarter.

For the full year 2019, the data shows an increase in the proportion of non-daylight collisions from a 2013-2018 average of 39% to 59% in 2019. However, the absolute number of non-daylight collisions in 2019 (34) is somewhat consistent with previous years (which ranged between 30 and 45). A similar caution regarding the interpretation of the full-year results, as noted in previous sections, is required.

For Q1 of 2019, there were 16 non-daylight collisions, which is the highest of the seven years reviewed and corresponds to 70% of total collisions, as compared to the average from Q1 of 2013-2018 of 40.5%.

For Q4 of 2019there were 11 non-daylight collisions. While this was the lowest of the seven years under review it corresponds to 65% of total collisions, as compared to the average from Q4 of 2013-2018 of 46.5%.

Examination of the collision during hours of darkness data does not provide a clear trend, either an increasing or a decreasing one, for collisions occurring during non-daylight periods following the resurfacing of the RHVP combined with the speed limit reduction and increased speed enforcement. This is due to the observed collision frequencies in 2019 being close to the numbers observed for the previous year, and both the increase in Q1 and the decrease in Q4 could result from the normally expected variation in collision frequencies.

Table 8: RHVP Percentage of Non-daylight Collisions by Year and Quarter

Year	Full Year	Jan-Mar (Q1)	Apr-Jun (Q2)	Jul-Sep (Q3)	Oct-Dec (Q4)
2013	37 (45%)	8 (47%)	8 (47%)	9 (50%)	12 (40%)
2014	30 (41%)	5 (31%)	3 (38%)	6 (35%)	16 (48%)
2015	45 (31%)	3 (14%)	7 (21%)	9 (28%)	26 (46%)
2016	35 (33%)	10 (40%)	3 (17%)	7 (23%)	15 (44%)
2017	44 (40%)	8 (36%)	8 (28%)	10 (38%)	18 (56%)
2018	43 (45%)	12 (75%)	6 (32%)	10 (36%)	15 (45%)
2019	34 (59%)	16 (70%)	4 (40%)	3 (38%)	11 (65%)

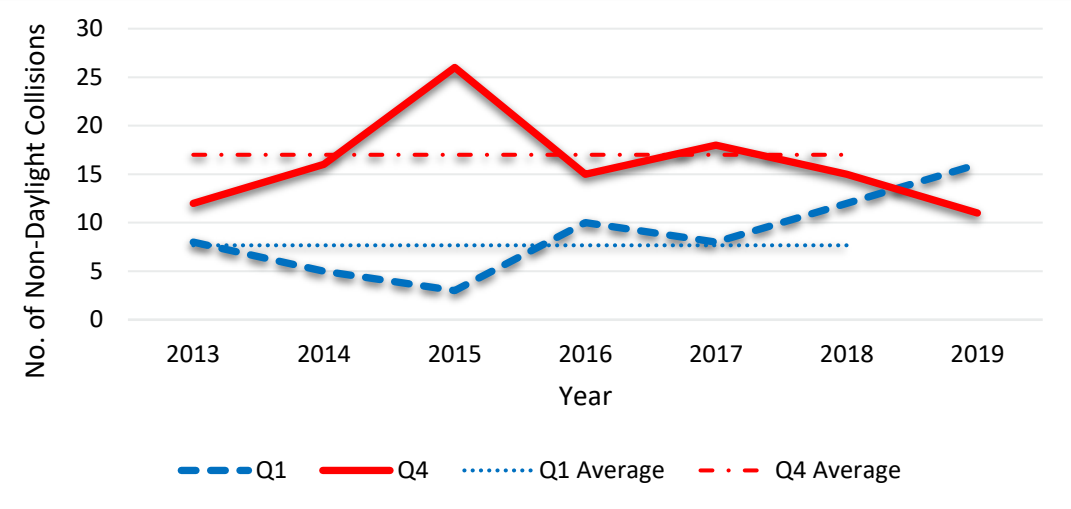


Figure 47: First and Fourth Quarter Non-Daylight Collisions by Year

3.3.2. Statistical Analysis

The AASHTO Highway Safety Manual (HSM) outlines several evaluation methods that can be employed to measure the change in safety as the result of safety countermeasure implementation, using collision data. The method recommended by the HSM is observational before/after evaluation using Safety Performance Functions (SPF) rather than a control group. This method uses the Empirical Bayes (EB) procedure to account for the regression-to-the-mean bias and avoid inaccurate estimates for the safety effectiveness of the study countermeasures (i.e., Speed Limit Reduction and Resurfacing). The method is graphically illustrated in **Figure 48** and compares the observed collision frequency in the "after" period with what would be the expected collision frequency, also in the "after" period, if the countermeasures had not been implemented.

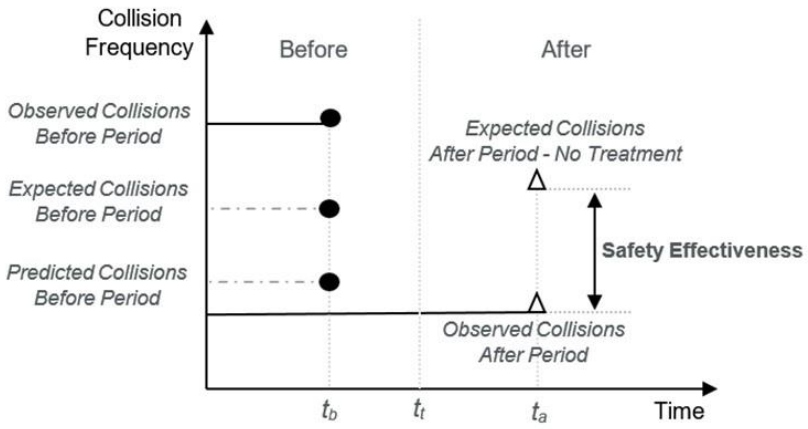


Figure 48: Before-After Safety Evaluation – HSM Recommended Method

However, the HSM SPFs outputs consist of predicted collision frequencies for study periods of one year, while the RHVP observed collision data for the "after" period is only available for a fraction of that period, therefore this method cannot be applied at this time given the limited data available from the "after" period.

As an alternative, CIMA+ conducted a statistical significance test "one-tailed t-test" with a 95% confidence level, which tests whether there is a significant difference between the mean values of two groups. This statistical analysis method is suitable for variables that follow a normal distribution. It is known that collision frequency does not follow a normal distribution curve, the average (mean) of collision frequencies does. Therefore, the "before" period used the average collision frequencies at each of the 14 mainline sections[4] of the RHVP for the years 2013 to 2018, and the "after" period used the collision frequencies for the year 2019.

Changes to the RHVP took place at different times, allowing, to some degree, an assessment of the possible impacts of the changes separately. The speed limit reduction was implemented by the City on February 16, 2019. The pavement surface was not changed until later in the spring, when on May 29th, 2019 the road was closed for resurfacing work.

The RHVP closures for resurfacing work lasted until August 8, 2019. Traffic had returned to normal after Labour Day on September 12, 2019. After that date both a lower speed limit and new pavement were present.

The spring period allows for an analysis of the impact of the speed limit change. If this spring of 2019 is compared to the same spring periods from previous years, then the analysis allows for control of known seasonal variations that occur in traffic volumes and weather conditions. It is recognized that speed enforcement during the 2019 spring period was also increased and that factor that may also influence the changes in collision outcomes.

These two distinct periods allow for an assessment of collision occurrence in the spring, and after the period for speed limit reductions only and, in the fall, for pavement changes (through resurfacing) and

[4] The following 7 segments, each taking Northbound and Southbound directions separately: LINC to Dartnall, Dartnall to Mud, Mud to Greenhill, Greenhill to King, King to Queenston, Queenston to Barton, and Barton to QEW. Only sections between Greenhill and QEW were used to assess the speed limit reduction.

speed limit reduction. It is recognized that speed enforcement during both periods, and its associated speed limit compliance is a factor that may also influence the collision performance in both periods.

The collision data were sorted into the following date ranges, for both before and after periods, for assessment of the impact of the speed limit change, knowing that enforcement was also enhanced in 2019:

- **Speed Limit Reduction (with Educational Campaigns):** February 17 to May 28 of each year

Table 9 summarizes the results of the t-test for the speed limit reduction only date range.

Using the statistical t-test allows determination of whether the difference between samples means differs significantly from the hypothesized difference between the means. If the absolute value of "t Stat" is lower than the value of "t Critical one-tail", the before and after mean is not considered to be significantly different.

Table 9: Statistical Test (t-test) Summary for Speed Limit Reduction (with Educational Campaigns)

Section	"Before" Average Collision Frequency (Average 2013 – 2018)	"After" Average Collision Frequency (2019)
RHVP NB between Greenhill and King	(2.833) [1.000]	(1.000) [0.000]
RHVP NB between King and Queenston	(0.667) [0.167]	(2.000) [1.000]
RHVP NB between Queenston and Barton	(1.000) [0.333]	(0.000) [0.000]
RHVP NB between Barton and QEW	(0.833) [0.167]	(2.000) [0.000]
RHVP SB between Greenhill and King	(1.167) [0.167]	(1.000) [0.000]
RHVP SB between King and Queenston	(1.667) [0.667]	(5.000) [1.000]
RHVP SB between Queenston and Barton	(1.500) [0.833]	(2.000) [1.000]
RHVP SB between Barton and QEW	(0.833) [0.000]	(0.000) [0.000]
Mean	**(1.313) [0.417]**	**(1.625) [0.375]**
t Stat	**(-0.506) [0.186]**	
t Critical one-tail	**(1.812) [1.771]**	
t-Test Result	**(Not Significant) [Not Significant]**	

Legend: (Total Collisions) [Injury Collisions]

The results for assessment of the **Speed Limit Reduction (with Educational Campaigns)** data shows an increase in the mean total collisions and a reduction in injury collisions after its implementation. However, these changes were not found to be statistically significant, therefore, based on the data available at this time, there is no statistical evidence that the **Speed Limit Reduction (with Educational Campaigns)** had an effect on collision frequencies.

Caution must be exercised in the interpretation of these results. The amount of data available for the "after" period (a portion of 2019) is very small. Small data sample sizes may not be indicative of a permanent trend. As noted, there is a random element to the occurrence of collisions and this short-term reduction could also be the result of normal variation in collision frequencies. It is fully possible that subsequent years may experience higher collision frequencies.

Theoretically, conclusive results would be possible to determine through the observation of data over a longer-term period. However, since other significant factors have changed, notably the resurfacing of the road, it is no longer possible to gather additional "after" date with only speed limit reductions as the controlling factor. The finding obtained above, qualified as noted, will remain.

An assessment of collision data from after the resurfacing of the road is additionally problematic. Similar analysis has been attempted for the "after" period, comparing the fall of 2019 (September 13 to December 31) collision data with similar time periods from years before the resurfacing took place. This period has previously been identified as the period with Engineering, Enforcement and Education enhancements.

However, the analysis is confounded by the fact that in the fall of 2019 the speed limit change (and enhanced enforcement) was also in place. The presence of these multiple factors, resurfacing, speed limit change, and educational campaigns, must be considered when reviewing the results.

Similar to the analysis of speed-only changes in the spring of 2019, for the fall analysis data was compared to similar time periods in previous years allowing for control for factors such as seasonal variations in traffic volumes and weather conditions. Collision data were sorted into the following date ranges, for both before and after periods. The fall time period is considered:

- **Enhancements (Educational, Enforcement and Engineering):** September 13 to December 31 of each year.

Table 10 summarizes the results of the t-test for the enhancements (Educational, Enforcement and Engineering) date range.

The same statistical t-test was applied. If the absolute value of "t Stat" is lower than the value of "t Critical one-tail", the before and after mean is not considered to be significantly different.

Table 10: Statistical Test (t-test) Summary for Enhancements (Educational, Enforcement and Engineering)

Section	"Before" Average Collision Frequency (Average 2013 – 2018)	"After" Average Collision Frequency (2019)
RHVP NB between LINC and Dartnall	(0.500) [0.167]	(2.000) [1.000]
RHVP NB between Dartnall and Mud	(1.833) [0.667]	(1.000) [0.000]
RHVP NB between Mud and Greenhill	(5.000) [2.000]	(0.000) [0.000]
RHVP NB between Greenhill and King	(14.167) [4.500]	(2.000) [2.000]
RHVP NB between King and Queenston	(3.667) [2.167]	(1.000) [1.000]
RHVP NB between Queenston and Barton	(2.000) [1.667]	(0.000) [0.000]
RHVP NB between Barton and QEW	(0.500) [0.333]	(0.000) [0.000]
RHVP SB between LINC and Dartnall	(0.667) [0.500]	(3.000) [2.000]
RHVP SB between Dartnall and Mud	(1.333) [0.333]	(1.000) [0.000]
RHVP SB between Mud and Greenhill	(2.500) [0.667]	(1.000) [0.000]
RHVP SB between Greenhill and King	(3.500) [2.500]	(2.000) [1.000]
RHVP SB between King and Queenston	(3.000) [1.667]	(1.000) [0.000]
RHVP SB between Queenston and Barton	(3.500) [1.833]	(3.000) [2.000]
RHVP SB between Barton and QEW	(0.167) [0.000]	(1.000) [0.000]
Mean	**(3.024) [1.357]**	**(1.286) [0.643]**
t Stat	**(1.778) [1.792]**	
t Critical one-tail	**(1.753) [1.714]**	
t-Test Result	**(Significant) [Significant]**	

Legend: (Total Collisions) [Injury Collisions]

The results for the enhancements do show a reduction in both total and injury collisions after implementation. These reductions were found to be statistically significant.

The challenge with this result is that it is not possible to state with certainty which of the engineering, enforcement or educational elements applied to the RVHP during the time period were the reason for

the change. It is not possible to determine if the result of the change has come from the repaving of the road, the speed limit reduction (including enforcement), some of the other safety treatments that have been applied or some combination of the engineering, enforcement or educational elements. Again, caution must be exercised in the interpretation of these results. The amount of data available for the "after" period from September to December 2019 is very small. Small data sample sizes may not be indicative of a permanent trend. As noted, there is a random element to the occurrence of collisions and this short-term reduction could also be the result of normal variations in collision frequencies, even if the statistical t-test is passed. It is fully possible that subsequent years may experience higher collision frequencies and results will change.

It is also the case that conclusive results could theoretically be possible to determine through the observation of data over a longer-term period, but if both speed limit reduction (and enforcement) remains in place then it will still not be possible to state with certainty which if any specific factor of the enhancements are the reason for sustained collision frequency reductions. The finding obtained above, qualified as noted, will remain.

With the road now resurfaced future evaluations could be conducted and confidence in collision trends would be enhanced as a sample size of the after-period increases. Additionally, should either speed limit and/or enforcement levels change there would be an opportunity to undertake further assessment which may allow for evaluation of the degree of impact those factors may have on collision outcomes.

It is highly recommended that ongoing monitoring of the collision data from the RHVP be undertaken. Absence of full separation of various treatments does not allow a definitive determination of whether one of the multiple treatments applied (speed limit, educational campaigns; Police enforcement; safety enhancements or pavement resurfacing), was a critical factor of the changes in collision occurrence or whether changes are a result of some combination of factors.

While the data does indicate statistically significant changes in the numbers of collisions, it is premature to extrapolate the data given the very short "after" period upon which the results are based. As noted, collisions have an element of randomness to their occurrence and this short-term reduction could be the result of normal variation in collision frequencies or the data could be indicating the beginning of a long-term trend. It is impossible to say at this point. We also highlight that it is fully possible that subsequent years may experience higher collision frequencies.

The City should, therefore, conduct further analysis (preferably using the HSM recommended methodology) as more collision data becomes available.

4. Conclusions

4.1. Traffic Impact Assessment

A Traffic impact assessment was conducted for the RHVP closures using volume and travel time data and the following observations can be made:

- The observed changes in travel time are consistent with the increase in traffic volume along the analyzed routes, including Upper Centennial Parkway, Mud Street, Stone Church Street and Rymal Road;
- Upper Centennial Parkway appeared to be the main north-south alternate route of choice during the RHVP closures. Collected data shows a 50% (from 11 to 17 min) and 30% (from 11 to 15 min) increase in travel time in the NB direction during the AM and PM peak hours respectively.
- Highway 403 in the northbound direction appeared to be impacted during the closure of the northbound lanes along RHVP. Travel time data indicates a 50% (from 10 to 15 min) and 40% (from 11 to 16 min) increase in travel time in the NB direction during the AM and PM peak hours respectively.
- Mud Street was the main east-west alternative local route of choice during RHVP closures. Travel time along the EB direction of Mud Street shows a 70% increase (from 7 to 12 min) in the PM Peak during the closures.
- The WB and EB directions of King Street experienced an increase in travel time by 100% (from 3 to 6 min) in the AM and PM Peak Hours;
- During the closure of the ramps from Mud Street and Upper RHVP, Stone Church Road appeared to be the main alternative route; and
- It should be noted that travel time data reported for some of the routes are based on a small number of observations and may not be a true representative of the conditions. It is recommended that travel time values for these routes be compared with data from other sources (e.g. Bluetooth sensors).

4.2. Traffic Speed Analysis

From the traffic speed analysis conducted before and after the change in posted speed limit (from 90 km/h to 80 km/h) along RHVP, between Barton Street East and Greenhill Avenue, the following observations can be made:

- An overall reduction of operating speed of approximately 10 km/h can be observed immediately following the speed limit change (during the educational campaigns) in both the northbound and southbound directions;
- The police enforcement seems to have been most effective during the weekday PM peak (4 – 6 pm) and Weekend AM peak period (10 am – 12 pm); and
- After implementing enhancements (educational, enforcement and engineering) on RHVP, no major impact was observed on the operating speed along RHVP. Only southbound direction during the weekend day showed an overall slightly higher operating speed compared to the before conditions.

4.3. Collision Analysis

This section summarizes the results of our review of collision data before and after speed limit reduction with increased police enforcement and resurfacing of the Red Hill Valley Parkway were undertaken.

DISCLAIMER: The collision analysis results presented in this report are based on a very short "after" period of time, representing only part of one year (2019). Because collisions have an element of randomness to their occurrence and present a natural variation in frequency from one year to another, these results may not be fully representative of the future long-term trends. The conclusions presented herein should not be considered definitive. Additional analysis will be necessary as new information becomes available in the future.

From the analysis of traffic collisions, the following observations were made:

- An increase in the number of total collisions and a reduction in the number of injury collisions along the section of RHVP between Barton Street East and Greenhill Avenue can be observed after the speed limit reduction and increased speed enforcement (with educational campaigns), however, these changes were not statistically significant;
- A reduction in both total and injury collisions can be observed on the RHVP after all the enhancements (educational, enforcement and engineering) were implemented, and these reductions were statistically significant;
- Assessment of the speed limit reduction (during the educational campaigns) data shows an increase in the mean total collisions and a reduction in injury collisions after its implementation. However, these changes were not found to be statistically significant; and
- Assessment of enhancement data does show a reduction in both total and injury collisions after implementation of the treatments, and these reductions were found to be statistically significant. However, it is not possible to state with certainty if the result of the change has come from the repaving, the speed limit reduction (including enforcement), safety enhancements or some combination of these factors. Collisions occurring during the non-daylight period did not present a clear trend (neither increasing nor decreasing).

Once again, we emphasize that these results should not be considered definitive since the amount of data available for the "after" period is very small and may not represent a permanent trend. The City is encouraged to undertake additional analysis as more collision data becomes available in the future.

A

Appendix A

Speeding

The "Speeding is speeding" safety campaign reminded Hamilton motorists to pay close attention to the speedometer and adjust speeds based on road conditions and surroundings. Controlling vehicle speeds decreases the likelihood of collisions and reduces the severity of impact when they occur. The campaign featured an assigned webpage, radio ads, online ads and social media promotion.

Distracted Driving

Every 30 minutes someone is injured in a distracted driving collision, recently surpassing drinking and driving as the number one cause of motor vehicle collisions in Ontario. The "Just Drive" safety campaign advised motorists to drive attentively and refrain from any activity that may impact their response time such as texting, eating, smoking or grooming. The campaign featured a designated web page, online ads, an animated video and social media promotion.

Slow Down, Move Over

The “Slow down, Move over” safety campaign educated drivers about roadside emergency vehicle protocol. The law requires drivers to slow down and pass parked emergency vehicles with caution. When travelling on a multi-lane road, drivers are required to move around and leave one lane between their vehicle and the stopped emergency vehicle. Drivers who fail to do so risk facing fines as high as $2,000. The campaign included online ads, radio ads, social media promotion and a media release.

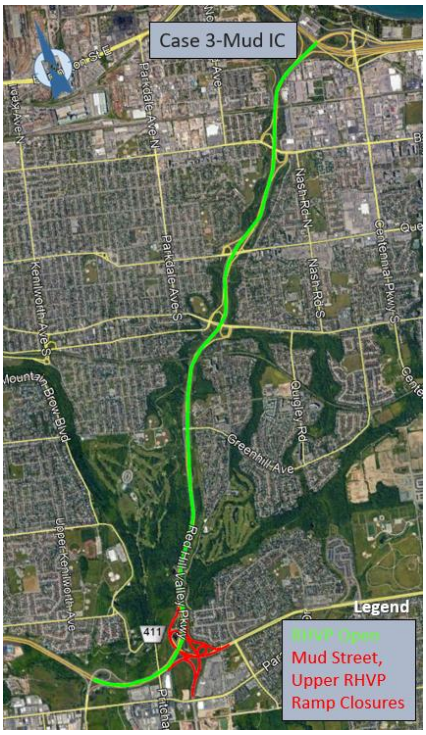
Back to School

The “Back to School” safety campaign provided safety tips to motorists, pedestrians and cyclists travelling through neighbourhoods and school zones. The campaign also reminded residents about school bus protocol, speed limits in school zones, and how to safely use a crosswalk. The safety campaign included a designated webpage, online ads, a safety tips video and social media promotion.

B

Appendix B

Closure Scenarios (Cases) along RHVP



C

Appendix C

List of Primary Routes/Observed Sample Size – AM Peak

Route Segment	Length (km)	Sample size						Calculated Minimum Sample Size					
		Case 0	Case 1	Case 2	Case 3	Case 4	Case 5	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5
Hwy 403 SB	12.3	374	521	507	630	530	517	3	3	3	4	3	3
Hwy 403 NB	12.8	287	286	300	388	256	277	13	28	39	20	21	35
First Rd E SB	4.7	5	18	19	4	3	9	8	2	3	3	6	2
First Rd E NB	4.7	4	24	9	6	6	20	4	4	4	4	2	5
Ridge Road EB	2.4	7	64	10	4	8	7	3	32	12	4	2	5
Ridge Road WB	2.4	4	2	89	4	3	6	11	2	14	8	1	21
New Mountain Road EB	1.1	14	27	64	13	11	21	8	6	14	14	7	7
New Mountain Road WB	1.1	78	363	126	98	81	117	21	15	30	21	14	14
Lincoln Alexander Pkwy EB	11.4	264	326	527	450	369	448	5	2	2	2	2	5
Lincoln Alexander Pkwy WB	11.5	34	78	59	77	38	66	11	9	9	5	75	48
Beckett Drive SB	1.3	299	295	257	254	209	391	30	12	5	12	5	35
Beckett Drive NB	1.3	494	729	628	490	519	614	20	32	46	24	61	38
Winterberry Drive SB	0.4	49	85	135	167	37	71	71	96	54	54	71	71
Winterberry Drive NB	0.4	104	68	98	203	96	115	61	138	109	96	67	67
Dartnall Road SB	0.2	151	243	12	239	199	293	138	171	96	138	246	138
Dartnall Road NB	0.3	150	221	285	575	138	206	24	24	24	24	24	24
Upper Red Hill Valley Parkway NB	1.6	333	77	341	2	313	388	24	39	33	3	36	28
Upper Red Hill Valley Parkway SB	1.3	133	137	38	123	113	145	24	43	34	43	46	28
Stone Church Road EB	5.6	2	6	1	2	1	0	1	11	0	9	0	NA
Stone Church Road WB	5.6	2	0	3	0	1	0	0	NA	1	NA	0	NA
Rymal Road E EB	8.8	4	6	2	3	1	8	5	14	1	2	0	2
Rymal Road E WB	8.7	2	15	20	7	3	6	2	3	13	7	2	1
Mud St EB	4.2	12	102	2	15	11	16	12	13	6	10	10	6
Mud St WB	4.1	34	44	78	5	15	41	11	9	66	27	10	14
Upper Centennial Pkwy SB	8.2	18	25	45	12	17	20	9	7	8	9	12	13
Upper Centennial Pkwy NB	8.2	36	78	33	26	26	41	4	8	13	7	5	7
Kenilworth Ave NB	3.1	73	275	82	78	57	76	5	16	26	15	8	11
Kenilworth Ave SB	3.1	5	11	81	6	11	9	5	60	7	4	3	2
Nikola Tesla Blvd EB	3.1	261	481	294	364	313	347	7	24	17	7	3	3
Nikola Tesla Blvd WB	3	533	692	890	725	619	810	7	7	3	7	3	7
Kenilworth Access/Sherman Access WB - Part 2	1.6	224	311	270	291	286	315	6	6	5	2	2	5
Kenilworth Access/Sherman Access EB - Part 1	1.6	0	0	0	0	0	2	NA	NA	NA	NA	NA	12
Claremont Access NB	1.9	408	675	569	429	462	712	22	36	46	10	24	15
Claremont Access SB	1.8	233	272	405	271	266	350	14	14	14	14	24	14
Jolley Cut NB	1.3	374	630	480	461	408	543	15	27	27	8	8	48
Jolley Cut SB	1.3	85	101	112	125	88	77	24	14	15	15	14	14
James Mountain Rd NB	0.6	4	2	2	3	2	3	131	5	0	6	3	105
James Mountain Rd SB	0.6	150	192	210	186	189	230	24	24	24	24	54	24
Wilson St E NB	4.5	160	265	228	162	274	287	8	6	6	7	12	23
Wilson St E SB	4.5	35	45	52	60	43	56	10	11	10	12	5	8
RHVP SB	5.5	668	820	0	732	729	873	3	1	NA	3	3	1
RHVP NB	5.5	991	0	967	1308	1243	1266	2	NA	5	3	10	2
Kenilworth Access EB	0.7	175	226	513	200	190	226	8	6	6	6	8	6
Kenilworth Access WB	1.6	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA
Kenilworth Access/Sherman Access EB - Part 2	2.5	127	248	99	85	36	116	5	41	5	2	5	2
Kenilworth Access/Sherman Access WB - Part 1	2.5	0	1	0	0	0	0	NA	0	NA	NA	NA	NA

* The highlighted indicates that the observation sample size is less than the minimum required sample size. N/A indicates that there was no observation therefore the minimum required sample size could not be calculated.

List of Primary Routes/Observed Sample Size – PM Peak

Route Segment	Length (km)	Sample size						Calculated Minimum Sample Size					
		Case 0	Case 1	Case 2	Case 3	Case 4	Case 5	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5
Hwy 403 SB	12.3	374	521	507	630	530	517	3	3	3	4	3	3
Hwy 403 NB	12.8	287	286	300	388	256	277	13	28	39	20	21	35
First Rd E SB	4.7	5	18	19	4	3	9	8	2	3	3	6	2
First Rd E NB	4.7	4	24	9	6	6	20	4	4	4	4	2	5
Ridge Road EB	2.4	7	64	10	4	8	7	3	32	12	4	2	5
Ridge Road WB	2.4	4	2	89	4	3	6	11	2	14	8	1	21
New Mountain Road EB	1.1	14	27	64	13	11	21	8	6	14	14	7	7
New Mountain Road WB	1.1	78	363	126	98	81	117	21	15	30	21	14	14
Lincoln Alexander Pkwy EB	11.4	264	326	527	450	369	448	5	2	2	2	2	5
Lincoln Alexander Pkwy WB	11.5	34	78	59	77	38	66	11	9	9	5	75	48
Beckett Drive SB	1.3	299	295	257	254	209	391	30	12	5	12	5	35
Beckett Drive NB	1.3	494	729	628	490	519	614	20	32	46	24	61	38
Winterberry Drive SB	0.4	49	85	135	167	37	71	71	96	54	54	71	71
Winterberry Drive NB	0.4	104	68	98	203	96	115	61	138	109	96	67	67
Dartnall Road SB	0.2	151	243	12	239	199	293	138	171	96	138	246	138
Dartnall Road NB	0.3	150	221	285	575	138	206	24	24	24	24	24	24
Upper Red Hill Valley Parkway NB	1.6	333	77	341	2	313	388	24	39	33	3	36	28
Upper Red Hill Valley Parkway SB	1.3	133	137	38	123	113	145	24	43	34	43	46	28
Stone Church Road EB	5.6	2	6	1	2	1	0	1	11	0	9	0	NA
Stone Church Road WB	5.6	2	0	3	0	1	0	0	NA	1	NA	0	NA
Rymal Road E EB	8.8	4	6	2	3	1	8	5	14	1	2	0	2
Rymal Road E WB	8.7	2	15	20	7	3	6	2	3	13	7	2	1
Mud St EB	4.2	12	102	2	15	11	16	12	13	6	10	10	6
Mud St WB	4.1	34	44	78	5	15	41	11	9	66	27	10	14
Upper Centennial Pkwy SB	8.2	18	25	45	12	17	20	9	7	8	9	12	13
Upper Centennial Pkwy NB	8.2	36	78	33	26	26	41	4	8	13	7	5	7
Kenilworth Ave NB	3.1	73	275	82	78	57	76	5	16	26	15	8	11
Kenilworth Ave SB	3.1	5	11	81	6	11	9	5	60	7	4	3	2
NIkola Tesla Blvd EB	3.1	261	481	294	364	313	347	7	24	17	7	3	3
NIkola Tesla Blvd WB	3	533	692	890	725	619	810	7	7	3	7	3	7
Kenilworth Access/Sherman Access WB - Part 2	1.6	224	311	270	291	286	315	6	6	5	2	2	5
Kenilworth Access/Sherman Access EB - Part 1	1.6	0	0	0	0	0	2	NA	NA	NA	NA	NA	12
Claremont Access NB	1.9	408	675	569	429	462	712	22	36	46	10	24	15
Claremont Access SB	1.8	233	272	405	271	266	350	14	14	14	14	24	14
Jolley Cut NB	1.3	374	630	480	461	408	543	15	27	27	8	8	48
Jolley Cut SB	1.3	85	101	112	125	88	77	24	14	15	15	14	14
James Mountain Rd NB	0.6	4	2	2	3	2	3	131	5	0	6	3	105
James Mountain Rd SB	0.6	150	192	210	186	189	230	24	24	24	24	54	24
Wilson St E NB	4.5	160	265	228	162	274	287	8	6	6	7	12	23
Wilson St E SB	4.5	35	45	52	60	43	56	10	11	10	12	5	8
RHVP SB	5.5	668	820	0	732	729	873	3	1	NA	3	3	1
RHVP NB	5.5	991	0	967	1308	1243	1266	2	NA	5	3	10	2
Kenilworth Access EB	0.7	175	226	513	200	190	226	8	6	6	6	8	6
Kenilworth Access WB	1.6	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA
Kenilworth Access/Sherman Access EB - Part 2	2.5	127	248	99	85	36	116	5	41	5	2	5	2
Kenilworth Access/Sherman Access WB - Part 1	2.5	0	1	0	0	0	0	NA	0	NA	NA	NA	NA

* The highlighted indicates that the observation sample size is less than the minimum required sample size. N/A indicates that there was no observation therefore the minimum required sample size could not be calculated.

List of Secondary Routes/Observed Sample Size – AM Peak

Route Segment	Length (km)	Sample size (Case #)						Calculated Min Sample Size (Case #)					
		Case 0	Case 1	Case 2	Case 3	Case 4	Case 5	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5
5th Street (Sec) NB	3.8	64	106	104	80	100	92	11	14	12	7	17	53
5th Street (Sec) SB	3.8	4	2	4	3	3	0	2	0	20	1	3	NA
Barton St (Sec) EB	4.5	6	7	14	8	4	14	9	7	4	9	4	4
Barton St (Sec) WB	4.4	16	20	16	14	18	19	5	8	9	10	3	9
Burlington Street East (Sec) EB - Part 1	2.6	29	46	37	48	28	43	11	10	12	28	7	18
Burlington Street East (Sec) EB - Part 2	1.7	186	295	230	269	196	235	24	14	22	22	15	14
Burlington Street East (Sec) WB	4.9	63	105	205	130	96	157	4	4	5	4	4	4
Garner Rd (Sec) EB	7.9	4	16	9	3	6	4	1	8	3	15	15	13
Garner Rd (Sec) WB	7.8	4	12	11	8	8	9	5	14	10	2	10	22
Garth Rd (Sec) NB	4	39	58	41	39	34	52	8	38	16	8	74	79
Garth Rd (Sec) SB	4	8	12	10	10	8	10	4	6	9	4	4	8
King St (Sec) EB	1.7	31	40	53	48	38	52	16	29	15	29	18	15
King St (Sec) WB	1.7	72	72	101	97	59	110	18	53	75	23	26	16
King St E (Sec) EB	1.5	145	283	157	148	115	176	20	22	29	14	14	13
King St E (Sec) WB	1.5	262	250	387	338	214	287	13	22	18	13	8	13
Lawrence Rd (Sec) EB	1.7	33	40	15	61	35	49	8	12	14	9	12	11
Lawrence Rd (Sec) WB	1.7	84	61	105	97	55	118	11	10	9	7	10	9
Main St (Sec) EB	1.6	134	183	150	165	146	175	22	22	28	18	22	46
Main St (Sec) WB	1.6	149	157	271	174	128	177	20	24	26	26	20	24
Mountain Brown Blvd (Sec) NB	2	6	6	3	14	7	10	16	75	0	3	16	6
Mountain Brown Blvd (Sec) SB	2	8	3	0	4	0	3	4	2	NA	0	NA	26
Mud St (Sec) NB	1.6	58	188	62	117	57	88	9	8	4	8	9	9
Mud St (Sec) SB	1.6	77	58	91	53	58	65	18	26	34	33	13	14
Parkdale Ave (Sec) NB	3.2	5	74	7	9	9	11	11	13	12	4	14	4
Parkdale Ave (Sec) SB	3.1	2	1	13	1	1	3	3	0	12	0	0	58
Queenston Rd (Sec) EB	1.6	65	76	79	62	88	96	16	21	21	46	16	21
Queenston Rd (Sec) WB	1.6	122	127	179	102	71	119	19	18	112	29	36	32
Stone Church Rd (Sec) - Part 2 EB	1.6		15	11	14	6	11	NA	4	9	18	14	5
Stone Church Rd (Sec) - Part 2 WB	5.5		21	18	20	16	24	NA	17	17	4	9	24
Stone Church Rd (Sec) EB - part 1	4.2	1	2	2	6	0	4	0	4	0	1	NA	11
Stone Church Rd (Sec) WB - part 1	4.2	1	5	4	3	1	3	0	12	4	2	0	2
Upper James Street (Sec) NB	5	64	85	88	55	76	88	6	7	8	5	20	39
Upper James Street (Sec) SB	5	14	18	27	26	24	23	6	7	8	5	16	5
Woodward Ave (Sec) NB	1.7	272	418	444	296	230	359	17	22	96	13	22	22
Woodward Ave (Sec) SB	1.7	23	28	64	40	26	29	7	54	12	12	113	18

* The highlighted indicates that the observation sample size is less than the minimum required sample size. N/A indicates that there was no observation therefore the minimum required sample size could not be calculated.

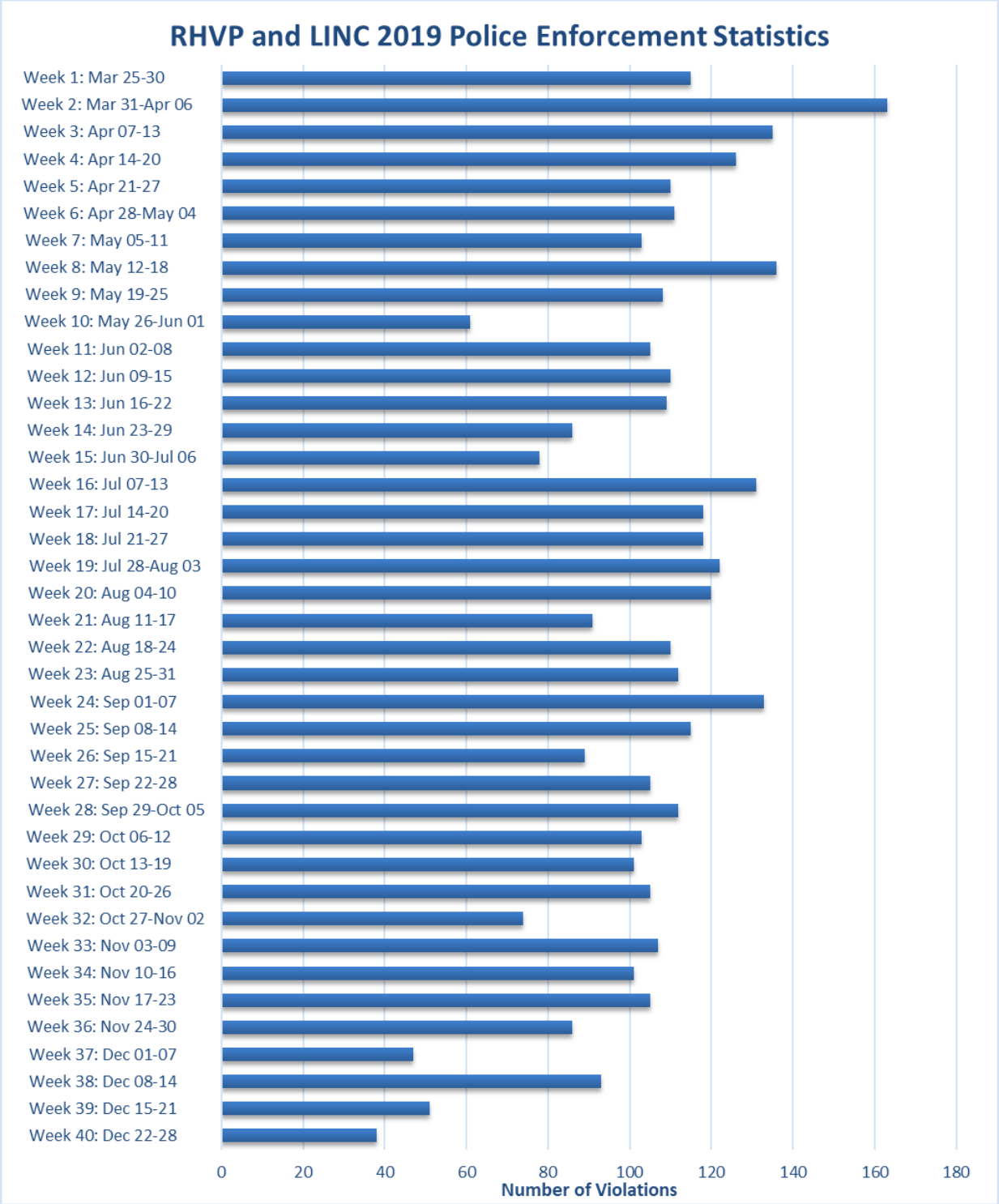
List of Secondary Routes/Observed Sample Size – PM Peak

Route Segment	Length (km)	Sample size (Case #)						Calculated Min Sample Size (Case #)					
		Case 0	Case 1	Case 2	Case 3	Case 4	Case 5	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5
5th Street (Sec) NB	2.6	23	45	39	40	46	27	8	3	3	5	2	5
5th Street (Sec) SB	3.8	7	14	10	16	15	11	4	6	5	14	9	10
Barton St (Sec) EB	4.4	5	20	13	8	14	12	3	4	15	4	4	4
Barton St (Sec) WB	3.1	14	21	18	12	18	20	5	7	6	4	3	18
Burlington Street East (Sec) EB - Part 1	4.9	62	94	87	79	77	90	13	13	11	13	14	11
Burlington Street East (Sec) EB - Part 2	1.6	311	541	347	381	363	370	17	20	17	17	12	17
Burlington Street East (Sec) WB	1.7	40	94	142	87	93	115	11	5	13	6	5	7
Garner Rd (Sec) EB	7.8	10	17	21	12	25	12	2	9	3	3	4	15
Garner Rd (Sec) WB	4	15	20	14	17	15	10	5	21	7	7	2	9
Garth Rd (Sec) NB	5	16	33	23	20	29	20	6	4	8	5	20	6
Garth Rd (Sec) SB	4	32	36	47	43	44	30	9	6	9	10	10	5
King St (Sec) EB	1.7	72	50	77	119	128	92	11	24	18	30	15	15
King St (Sec) WB	1.6	89	65	93	109	108	117	29	21	39	18	21	15
King St E (Sec) EB	1.5	246	263	224	267	279	241	17	15	18	17	18	24
King St E (Sec) WB	1.6	245	292	418	258	236	261	20	14	56	17	15	15
Lawrence Rd (Sec) EB	1.7	74	89	99	116	78	113	5	9	5	9	6	14
Lawrence Rd (Sec) WB	1.5	46	49	72	64	68	79	6	6	10	6	8	9
Main St (Sec) EB	1.6	253	301	274	317	328	325	19	18	22	13	19	19
Main St (Sec) WB	4.5	166	126	172	164	181	179	26	23	64	24	20	27
Mountain Brown Blvd (Sec) NB	2	4	7	5	3	5	6	0	69	24	2	23	4
Mountain Brown Blvd (Sec) SB	4.2	13	6	14	12	8	18	9	2	3	6	4	33
Mud St (Sec) NB	5.5	115	288	137	191	161	148	9	7	8	15	4	4
Mud St (Sec) SB	1.6	106	95	170	114	130	137	11	68	56	43	13	17
Parkdale Ave (Sec) NB	1.7	2	44	2	0	2	3	16	15	27	NA	0	17
Parkdale Ave (Sec) SB	3.2	47	55	90	17	59	55	11	8	10	7	5	8
Queenston Rd (Sec) EB	1.6	95	103	102	108	115	131	23	122	11	19	13	13
Queenston Rd (Sec) WB	1.7	94	75	82	91	101	95	27	21	23	22	19	26
Stone Church Rd (Sec) - Part 2 EB	5.5		25	53	41	31	36	NA	11	10	12	11	10
Stone Church Rd (Sec) - Part 2 WB	0.7		36	23	28	32	38	NA	16	8	9	12	10
Stone Church Rd (Sec) EB - part 1	4.2	5	12	32	26	28	26	0	13	7	4	31	3
Stone Church Rd (Sec) WB - part 1	7.9	2	16	9	16	19	15	0	22	7	2	3	3
Upper James Street (Sec) NB	3.8	24	48	42	32	27	34	5	9	7	8	6	10
Upper James Street (Sec) SB	5	36	49	51	40	47	44	8	4	6	10	11	7
Woodward Ave (Sec) NB	1.6	42	100	55	106	62	64	29	9	14	14	15	15
Woodward Ave (Sec) SB	1.7	146	171	297	214	191	147	50	10	15	37	14	102

* The highlighted indicates that the observation sample size is less than the minimum required sample size. N/A indicates that there was no observation therefore the minimum required sample size could not be calculated.

D

Appendix D


RHVP and LINC 2019 Police Enforcement Statistics
Week 1: Mar 25-30
Week 2: Mar 31-Apr 06
Week 3: Apr 07-13
Week 4: Apr 14-20
Week 5: Apr 21-27
Week 6: Apr 28-May 04
Week 7: May 05-11
Week 8: May 12-18
Week 9: May 19-25
Week 10: May 26-Jun 01
Week 11: Jun 02-08
Week 12: Jun 09-15
Week 13: Jun 16-22
Week 14: Jun 23-29
Week 15: Jun 30-Jul 06
Week 16: Jul 07-13
Week 17: Jul 14-20
Week 18: Jul 21-27
Week 19: Jul 28-Aug 03
Week 20: Aug 04-10
Week 21: Aug 11-17
Week 22: Aug 18-24
Week 23: Aug 25-31
Week 24: Sep 01-07
Week 25: Sep 08-14
Week 26: Sep 15-21
Week 27: Sep 22-28
Week 28: Sep 29-Oct 05
Week 29: Oct 06-12
Week 30: Oct 13-19
Week 31: Oct 20-26
Week 32: Oct 27-Nov 02
Week 33: Nov 03-09
Week 34: Nov 10-16
Week 35: Nov 17-23
Week 36: Nov 24-30
Week 37: Dec 01-07
Week 38: Dec 08-14
Week 39: Dec 15-21
Week 40: Dec 22-28
0
20
40
60
80
100
120
140
160
180
Number of Violations

E

Appendix E

Methodology for Sample Size Calculation

In order to assess the statistical validity of the sample size for each route, a minimum sample size threshold was calculated. In the probability theory, the Central Limit Theorem (CLT) states that the mean of a sufficiently large number of independent random variables, each with a well-defined mean and well-defined variance, will be approximately normally distributed[5]. Most statistical textbooks have stated that if the sample size is larger than 30, the distribution of the sample mean X_n can be assumed to be normally distributed[6,7,8,9,10]. Suppose a random variable X_p is normally distributed with unknown mean μ and unknown standard deviation S. Also, sample data (X_s) of size n is collected from the population with the sample mean of $\bar{x}$ and a standard deviation of σ, with the following notations:

$X_p \sim N(\mu, S^2)$ (1) $X_s \sim N(\bar{x}, \sigma^2)$ (2)

The difference between the sample mean and the true value of the population mean can be expressed as an error term (δ) as follows:

$-\delta \leq \mu - \bar{x} \leq \delta$ (3) $\delta = {Z\alpha_{/2} \cdot \sigma}\Big/{\sqrt{n}}$ (4)

Where $Z\alpha_{/2}$ is the Z-score of the standard normal distribution table with the confidence interval of $100\left(1 - {\alpha}/{2}\right)\%$ and α is the predetermined significance level (e.g. 0.05). For $\alpha = 0.05$, the $Z\alpha_{/2}$ value for the 95% confidence interval is 1.96.

Based on the equation for the error term, Equation 3 can be rephrased as follows:

$$|\mu - \bar{x}| \leq \frac{Z\alpha_{/2} \cdot \sigma}{\sqrt{n}} \quad (5)$$

In Equation 5, the absolute difference between the population and sample means (i.e. $|\mu - \bar{x}|$) is unknown. A 10% margin of error between the population mean and the sample mean was assumed in this project.

$$\frac{|\mu - \bar{x}|}{\bar{x}} \leq 0.1 \quad (6)$$

Equation 16 was then integrated into Equation 5 to determine the minimum required sample size (n_{min}), as follows:

$$\frac{Z\alpha_{/2} \cdot \sigma}{\sqrt{n} \times \bar{x}} \leq \frac{|\mu - \bar{x}|}{\bar{x}} \leq 0.1 \quad (7)$$

$$n \geq \left(\frac{Z\alpha_{/2} \cdot \sigma}{0.1\bar{x}}\right)^2 \quad (8)$$

$$n_{min} = \left(\frac{Z\alpha_{/2} \cdot \sigma}{0.1\bar{x}}\right)^2$$

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SUBMITTED BY CIMA CANADA INC.
500 – 5935 Airport Road
Mississauga, ON. L4V 1W5
T: 905-695-1005 | F: 905-695-0502
cima.ca