Comprehensive Traffic Signals System Evaluation

Prepared for:

The City of Corner Brook

Prepared by:
Harbourside Transportation Consultants

Contact:
Robin King, P.Eng.
Email: rking@harboursideengineering.ca
Tel: 709.579.6435

Michael MacDonald, P.Eng.
Email: mmacdonald@harboursideengineering.ca
Tel: 902.405.4696

October 10, 2018

Status: Final Report

HTC File #172083

HARBOURSIDE
Transportation Consultants

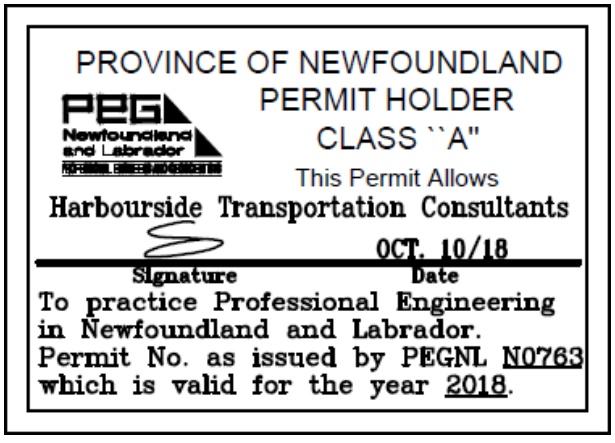
Project Name: Comprehensive Traffic Signals System Evaluation

Project Number: 172083

Client:	City of Corner Brook
Status:	Final Report – Issued October 10, 2018 Draft Report – Issued for Client Review July 11, 2018

Engineering Seal

Permit to Practice



	Prepared By:	Reviewed By:	Approved By:
Name:	F. Allaire	M. MacDonald	R. King
Initial:			
Date:	October 10, 2018	October 10, 2018	October 10, 2018

Executive Summary

The City of Corner Brook retained Harbourside Transportation Consultants (HTC) in November of 2017 to complete a comprehensive evaluation of the City's traffic signal systems; the goal was to document existing conditions at each traffic signal system location in the City and to recommend upgrading as required. The City's traffic signal systems consist of 15 signalized intersections and five signalized pedestrian crossing locations, including:

1. Lewin Parkway & Griffin Drive
2. Lewin Parkway & Mill Road
3. Lewin Parkway & St. Mark's Avenue/Prince George Avenue
4. Lewin Parkway & Murphy's Square Entrance
5. Lewin Parkway & Confederation Drive
6. Confederation Drive & West Valley Road
7. West Valley Road & O'Connell Drive
8. O'Connell Drive & University Drive/Mount Bernard Avenue
9. University Drive – pedestrian crossing near Canada Games Drive
10. O'Connell Drive & Elizabeth Street
11. O'Connell Drive – pedestrian crossing near Union Street
12. O'Connell Drive – pedestrian crossing near Westmount Road
13. O'Connell Drive – pedestrian crossing near Crestview Avenue
14. Main Street & Mount Bernard Avenue
15. Main Street & Mill Road/Brook Street
16. Main Street & West Street
17. Main Street & Riverside Drive/Humber Road
18. Broadway & Caribou Road/Herald Avenue
19. Corporal Pinksen Memorial Drive & Grenfell Drive
20. Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

The comprehensive evaluation included the following eight components:

- **Traffic Counting Program:** Collection of traffic counts at five signalized intersections to complete the City's inventory of traffic counts for signalized intersections.
- **Intersection Traffic Signals Drawings:** Preparation of intersection traffic signals drawings documenting existing conditions at each of the signalized locations.
- **Signal Timing and Phasing Data:** A review of the existing signal timing and phasing data for each signalized location to ensure their conformance to relevant standards and guidelines.
- **Controller and Equipment Assessment:** A detailed assessment of traffic control systems and equipment including traffic controllers and cabinets, vehicle detection systems, emergency vehicle preemption systems, pedestrian systems, traffic poles, signal displays and intersection signage. The results of the various assessments were used to determine the improvements required at each signalized location to ensure the traffic signals reflect industry standards and conform to the TAC MUTCD guidelines.
- **Communications Assessment:** An assessment to identify how to provide communications capabilities to each of the signalized locations in the City in order to implement an Advance Traffic Management Systems (ATMS).

- **Intersection Capacity Analysis:** Construction of Synchro models of the morning (AM) and evening (PM) peak hours for all 15 signalized intersections. The models were coded with the existing geometry, volumes and signal timing and phasing data. The models were used to assess existing conditions and to develop new signal timing plans to optimize operations at each intersection.
- **Operations and Maintenance Program:** Preparation of a traffic signal operations and maintenance manual. The program will provide necessary guidance to ensure traffic signals are properly maintained to industry standards.
- **Roundabout Feasibility:** A brief investigation for each intersection to determine the ability of converting the intersection to a roundabout. A conceptual layout and brief description of the benefits and challenges was provided for each intersection deemed feasible.

Traffic Counting Program

Traffic counts were gathered at five of the 15 signalized intersections where recent counts (collected in the last 3 years) were not available. Counts from 2015 or 2017 were available for the other 10 intersections. Traffic data were collected Tuesday, Wednesday or Thursday between 7:00 to 9:00 am and 4:00 to 6:00 pm. The counts were scheduled around events that may cause serious disruptions to normal traffic flow such as construction or holidays.

Intersection Signals Drawings

Intersection traffic signals drawings of existing conditions were prepared for the 20 signalized locations in the City. The drawings document the following items:

- traffic pole locations,
- size and reach of traffic poles,
- signal head locations and configurations,
- signal head mounting hardware,
- pedestrian pushbutton locations,
- pedestrian pushbutton type,
- approximate layout of underground electrical conduit or overhead wiring,
- location of electrical junction boxes,
- location of the traffic controller,
- location of the power supply,
- location of preformed inductive loops or camera detection systems and pavement markings.

Phasing and Timing Data Review

The existing signal timing and phasing data for each signalized location was reviewed to ensure their conformance to relevant standards and guidelines.

The signal timing review included conformance checks for the amber and all-red clearance intervals, the pedestrian walk intervals and the pedestrian clearance intervals at each signalized location to ensure their conformance to the ITE Traffic Engineering Handbook. The signal timing review indicated that the existing signal timing at 19 signalized locations does not conform to at least one of the applicable standards; 18 locations have amber and all-red clearance intervals that do not conform to ITE standards, 2 locations have pedestrian walk intervals less than 7 seconds and 13 locations have pedestrian clearance intervals

that do not provide sufficient time for a pedestrian to clear the crosswalk. The signalized locations that do not conform to the applicable standard for each interval are listed below:

Non-conforming amber and all-red clearance intervals:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Mill Road
- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- Lewin Parkway & Murphy's Square Entrance
- Lewin Parkway & Confederation Drive
- Confederation Drive & West Valley Road
- West Valley Road & O'Connell Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- University Drive – pedestrian crossing near Canada Games Drive
- O'Connell Drive & Elizabeth Street
- O'Connell Drive – pedestrian crossing near Union Street
- O'Connell Drive – pedestrian crossing near Westmount Road
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Main Street & West Street
- Main Street & Riverside Drive/Humber Road
- Broadway & Caribou Road/Herald Avenue
- Corporal Pinksen Memorial Drive & Grenfell Drive

Non-conforming pedestrian walk interval:

- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street

Non-conforming pedestrian clearance interval:

- Lewin Parkway & Mill Road
- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- Lewin Parkway & Confederation Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- University Drive – pedestrian crossing near Canada Games Drive
- O'Connell Drive & Elizabeth Street
- O'Connell Drive – pedestrian crossing near Union Street
- O'Connell Drive – pedestrian crossing near Westmount Road
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Main Street & Riverside Drive/Humber Road
- Broadway & Caribou Road/Herald Avenue
- Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

A priority list was developed to prioritize improvements required to the signal timing at each signalized location. For the City's signalized systems, 18 locations were identified as Priority 1 (Immediate attention

required), one location was identified as Priority 2 (Adjust during signal timing updates) and one location was identified as Priority 3 (Signal timing to be reviewed in future).

In total, 19 of the 20 signalized locations require timing improvements; 18 locations were identified as Priority 1 and one location was identified as Priority 2. The remaining location was identified as Priority 3. The 20 signalized locations by priority level include:

Priority 1 – Immediate attention required:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Mill Road
- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- Lewin Parkway & Murphy's Square Entrance
- Lewin Parkway & Confederation Drive
- Confederation Drive & West Valley Road
- West Valley Road & O'Connell Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- University Drive – pedestrian crossing near Canada Games Drive
- O'Connell Drive & Elizabeth Street
- O'Connell Drive – pedestrian crossing near Union Street
- O'Connell Drive – pedestrian crossing near Westmount Road
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Main Street & West Street
- Main Street & Riverside Drive/Humber Road
- Broadway & Caribou Road/Herald Avenue
- Corporal Pinksen Memorial Drive & Grenfell Drive

Priority 2 – Adjust during signal timing updates:

- Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

Priority 3 – Signal timing to be reviewed in future:

- O'Connell Drive – pedestrian crossing near Crestview Avenue

All Priority 1 issues were addressed with the implementation of the new signal timing plans which were field entered into all the controllers by Harbourside staff on June 26-27th, 2018.

The existing signal phasing data for each signalized location was reviewed to ensure their conformance to the standard National Electrical Manufacturers Association (NEMA) phasing schemes. The phasing data review indicated that the existing phasing at the 15 signalized intersections and at one pedestrian crossing location do not conform to the NEMA phasing standards. The remaining four locations consist of the pedestrian crossings controlled by timers which do not use phasing. The cabinets should be rewired to be compliant with NEMA standard phasing when upgrades are completed at these intersections.

Signal indications at each signalized location were reviewed to ensure their compliance to the guidelines from Transportation Association of Canada's (TAC) Manual of Uniform Traffic Control Devices (MUTCD). Arrow indications are present at the 15 signalized intersections. The MUTCD guidelines indicate that left

or right green arrows should be flashing arrow indications. The review indicated that the arrow indications at 12 signalized intersections are steady arrow indications and do not conform to MUTCD guidelines. These arrow indications at the 12 signalized intersections should be set to flash mode in the controller. The 12 signalized intersections include:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Mill Road
- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- Lewin Parkway & Murphy's Square Entrance
- Lewin Parkway & Confederation Drive
- Confederation Drive & West Valley Road
- West Valley Road & O'Connell Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive & Elizabeth Street
- Main Street & Mount Bernard Avenue
- Main Street & West Street
- Broadway & Caribou Road/Herald Avenue

All arrows were set to flashing mode on June 26-27th, 2018 with the exception of the arrow indications at:

- Lewin Parkway & St. Mark's Avenue/Prince George Avenue – The coding for the multiple overlaps does not allow the arrows to be simply set to flashing mode.
- O'Connell Drive & University Drive/Mount Bernard Avenue – The arrows could not be set to flashing mode due to issues with the MMU. The MMU should be replaced.

A flashing green ball indication is provided at Lewin Parkway and Griffin Drive on the southbound approach (Griffin Drive). MUTCD guidelines indicate that the green ball indication should be a steady ball signal indication. The flashing green ball indication at Lewin Parkway and Griffin Drive does not conform to MUTCD guidelines and should be removed. The indications for the southbound and northbound split phases should consist of a steady green ball indication and a flashing green arrow indication. It should be noted that the green ball indication was removed from flashing mode on June 26-27th, 2018.

Controller and Equipment Assessment

A detailed assessment of traffic control systems and equipment was completed for the 20 signalized locations. The assessment included of traffic controllers and cabinets, vehicle detection systems, emergency vehicle preemption systems, pedestrian systems, traffic poles, signal displays and intersection signage.

Traffic Controllers and Cabinets Assessment: A detailed assessment of the traffic controller and cabinet equipment was completed. The assessment included a thorough review of all traffic cabinet components including the controller unit, the power supply, the BIU's, the detector and pre-emption cards, card racks and related interface panels, heating and cooling systems, the conflict monitor and the back panel.

The 15 signalized intersections are controlled by 5 Econolite ASC/2 controllers, 3 Econolite ASC3 controllers, 2 Econolite Cobalt controllers and 4 Naztec Series 900 controllers (Model 980 NEMA TS2 Type 1). The five half-signals are controlled by one Naztec Series 900 controllers (Model 980 NEMA TS2 Type 1), one Electromega MCA250 timers and 3 unknown timers. The cabinet at Main Street & West Street and

the four cabinets with the pedestrian crossing timers are not NEMA TS2 compliant. All other cabinets are NEMA TS2 compliant.

Econolite ASC/2 controllers are 1990's technology. While these controllers are NEMA compliant and use a conflict monitor, these controllers are past their useful life and should be scheduled for replacement. Econolite ASC/3 controllers are still considered relatively modern controllers and do not need to be replaced at this time. Econolite Cobalt controllers are the most advanced type of controllers currently available on the market. The model 980 NEMA TS2 Type 1 controllers are an older type of controller manufactured by Trafficware (formerly Naztec). The newer controller model manufactured by Trafficware is the 980 ATC TS2 Type 1 controller.

The pedestrian timers are not NEMA standard and are typically intended for pedestrian crossings that feature a flashing light such as an RA-5 crossing. At a signalized pedestrian crossing location, where vehicular traffic is controlled by red, amber and green indications, a NEMA standard traffic controller with a conflict monitor should be used instead of a timer.

Traffic controllers and cabinets should be replaced at fourteen intersections. Priority should be given to replacing the Econolite ASC/2 controllers, the Naztec Model 980 NEMA controllers and the pedestrian crossing timers at the following intersections:

Econolite ASC/2 controllers:

1. Lewin Parkway & St. Mark's Avenue/Prince George Avenue and Lewin Parkway & Murphy's Square Entrance
2. Lewin Parkway & Confederation Drive
3. O'Connell Drive & University Drive/Mount Bernard Avenue
4. O'Connell Drive & Elizabeth Street
5. Main Street & West Street

Naztec Model 980 NEMA controllers:

6. Lewin Parkway & Griffin Drive
7. Lewin Parkway & Mill Road
8. Main Street & Riverside Drive/Humber Road
9. Corporal Pinksen Memorial Drive & Grenfell Drive
10. Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

Pedestrian crossing timers:

11. University Drive – pedestrian crossing near Canada Games Drive
12. O'Connell Drive – pedestrian crossing near Union Street
13. O'Connell Drive – pedestrian crossing near Westmount Road
14. O'Connell Drive – pedestrian crossing near Crestview Avenue

The City of Corner Brook should standardize the type of controller used at signalized intersections through the City. There are a number of benefits to standardizing cabinets and controllers to a single provider such as reduced inventory for spare parts and reduced training of maintenance staff. Using the same provider also creates the possibility for the City to explore the use of Advanced Transportation

Management Systems (ATMS) to provide real time communications capabilities between intersections. It is recommended that the City move towards using Econolite Cobalt controllers with Econolite cabinets.

Once the fourteen controllers above have been upgraded, the City should then replace the three Econolite ASC/3 controllers. These controllers are still relatively modern and are compatible with ATMS but will eventually need to be upgraded. General maintenance should be performed at all intersections where the cabinets are not being replaced.

A number of existing traffic controller cabinets are mounted to the upright of traffic poles at the intersection. Traffic controller cabinets should be mounted on raised concrete controller pads. All new traffic controller cabinets should be installed on controller pads and the existing cabinets for ASC3 and Cobalt controllers should be relocated to controller pads where they are mounted to traffic poles.

Vehicle Detection Systems Assessment: An assessment of the existing vehicle detection systems was completed to identify whether there are detection systems present at each intersection and if the existing systems are operating properly. Vehicle detection systems are present at five signalized intersections. The systems include three GridSmart video detection systems and two inductive loop systems. None of the five vehicle detection systems are operating properly.

The three GridSmart video detection systems are not operational, some of the systems are missing components or are not hooked up properly. There were no configuration files or cables to connect to the camera systems available from the City's maintenance contractor to allow Econolite to identify the issues with these systems.

The GridSmart detection systems should be properly hook up at the Lewin Parkway and Griffin Drive, Lewin Parkway and Mill Road, and Corporal Pinksen Memorial and Grenfell Drive or replaced with preformed inductive loops. It is recommended that they be replaced with preformed inductive loops which require less maintenance and expertise to maintain.

If the City wishes to keep using the video detection systems, all equipment, software and files required to maintain and troubleshoot the camera systems should be obtained. Maintenance staff should be trained to perform basic maintenance and troubleshooting of the video detection systems.

Inductive loops are present at two intersections, both loop systems are not working properly. There are loops wired into the cabinet at the intersection of O'Connell Avenue and Elizabeth Street, but there no detector racks are present. It is unclear if any of the loops functional; the loops should be tested to identify if any of the loops are functional, any broken loops should be replaced with preformed inductive loops. Detector racks should be installed in the cabinet.

There are loops present at the intersection of Main Street and Mill Road/Brook Street, however the majority of the loops are broken and the intersection is on recall. All loops should be replaced with preformed inductive loops.

The City should install preformed inductive loops systems at the 10 signalized intersections where no detection systems are currently in place.

Emergency Vehicle Preemption Systems Assessment: An assessment of the existing emergency vehicle preemption systems was completed to identify whether there are preemption systems present at each

intersection and if the systems are operating properly. The preemption systems were tested for operations from the controller side only for the assessment.

Opticom GPS preemption systems are present at six signalized intersections. None of the six preemption systems are operational from the controller side. It is recommended that the City contact the provider of these systems to get a technician on-site to restore the preemption systems to proper operating conditions. Once the systems are operational from the controller side, these systems should also be tested from an emergency vehicle to ensure the receiving unit is operational.

If the City wishes to keep using the preemption systems, all equipment and/or software required to maintain and troubleshoot the systems should be obtained. Maintenance staff should be trained to perform basic maintenance and troubleshooting of the preemption systems.

Pedestrian Systems Assessment: An assessment of the pedestrian systems at was completed to identify whether the appropriate pedestrian facilities are provided at each intersection. The pedestrian systems were assessed for pedestrian signals displays, pedestrian pushbuttons and accessibility. Pedestrian facilities are provided at 17 of the 20 signalized locations.

There are no pedestrian facilities present at three signalized intersections including Lewin Parkway & Griffin Drive, Lewin Parkway & Murphy's Square Entrance and Confederation Drive & West Valley Road. Pedestrian infrastructure should be installed at these locations including pedestrian signals displays with LED lighting modules and countdown modules, crosswalks, pedestrian pushbuttons and signage. The pedestrian facilities should be made accessible for users of all ages and abilities.

The adequate number of pedestrian signal displays at all locations with pedestrian facilities with the exception of O'Connell Drive and Elizabeth Street. Overall pedestrian displays are generally in good condition.

The pedestrian signal displays provided include LED indications with countdown models at 15 of the 17 signalized locations.

Three of the 17 signalized locations with pedestrian facilities do not include pedestrian pushbuttons. These intersections include Lewin Parkway & Mill Road, Main Street & West Street and Broadway & Caribou Road/Herald Avenue. Pedestrian pushbuttons should be installed at these intersections.

The appropriate number of pedestrian pushbuttons are provided all other locations with the exception of O'Connell Drive and Elizabeth Street. Overall pedestrian pushbuttons are generally in good condition and functional.

Pedestrian pushbutton signage is only provided at five of the 14 signalized locations where pedestrian pushbuttons are present. Signage is missing for one or more pushbutton and/or in poor condition at four of these locations. Different types of signs are used at each location, the pushbutton signage provided should be consistent across all intersections. The existing signage associated with the pedestrian pushbuttons should be replaced and new signage installed at all other signalized locations so that a sign is provided with each pushbutton.

The locations of pushbuttons were assessed to identify if the location of the pushbuttons appear to be accessible. The accessibility of the pushbutton was based on factors such the location of the pole and obstacles leading to it, its distance from the crosswalk it controls, grades, presence of sidewalk, paraplegic

curb ramps, etc. Paraplegic curb ramps are provided for all crosswalks at six locations and curb ramps are provided for at least one crosswalk approach at four locations with pedestrian facilities. Tactile warnings surfaces are provided for all crosswalk approaches at O'Connell Drive and Elizabeth Street. Paraplegic curb ramps, preferably with tactile surfaces, should be provided at all crosswalks.

Audible beaconing systems are provided for all crosswalks at four signalized locations. The audible beaconing systems provided are these locations are an older type of system which include speakers mounted over the pedestrian signals. These systems are not considered an Accessible Pedestrian Signal (APS) solution since they provide limited information compared to newer APS solutions. APS pedestrian pushbuttons should be installed when intersections are upgraded and the pedestrian facilities are designed to be accessible.

At least one pushbutton is considered as "not accessible" at 11 of the 14 locations where pushbuttons are present. Consideration should be given to accessibility when upgrading these signalized locations. The locations include:

- Lewin Parkway & St. Marks Avenue/Prince George Avenue
- Lewin Parkway & Confederation Drive
- West Valley Road & O'Connell Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive – pedestrian crossing near Union Street
- O'Connell Drive – pedestrian crossing near Westmount Road
- O'Connell Drive – pedestrian crossing near Crestview Avenue
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Main Street & Riverside Drive/Humber Road
- Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

Traffic Pole Assessment: A visual examination of condition of traffic poles was conducted. Poles were inspected for any signs of visible damage or corrosion. Visible corrosion was identified at seven of the 20 signalized locations, corrosion was mainly observed in older poles of the "Pole System" type. The poles at the seven locations were classified as poor or very poor conditions. Poles at the seven locations should be replaced, priority should be given to replacing the poles in very poor condition first.

Poor condition:

- Confederation Drive & West Valley Road
- O'Connell Drive & Elizabeth Street

Very poor condition:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Mill Road
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive pedestrian crossing near Westmount Road
- O'Connell Drive pedestrian crossing near Crestview Avenue

The traffic pole located on the southwest corner at the intersection Lewin Parkway & St. Mark's Avenue/Prince George Avenue (Pole 5) has been damaged by an impact creating a hole in the wall of the pole. This pole should be replaced immediately.

In addition, holes have been drilled in a number of traffic poles throughout the City to accommodate conduit and/or mount traffic controller cabinets. The City should have a structural engineer review poles in which holes were drilled to provide an opinion on the structural integrity of the poles and whether or not the poles should be replaced.

Signals Display Assessment: The signal displays at each of the 20 signalized locations were reviewed to ensure the signal displays conform to section B3 - Display and Configurations for Traffic Control Signals of the MUTCD. Overall, the signal systems do not conform to MUTCD guidelines, 10 key points creating safety and/or liability concerns were identified.

- A secondary head is not provided on at least one approach at seven signalized locations.
- The traffic signals do not meet the signal visibility distance in advance of the stop line on at least one approach at three locations.
- The overhead signal indications are located less than 15 metres from the stop bar on at least one approach at eight locations.
- Where provided, the required signal assemblies (primary and secondary heads) are mounted less than 3.0 metres apart on at least one approach at seven locations.
- The primary signal head is not located within the 10-degree cone of vision on at least one approach at 14 locations.
- Backboards are not used on the primary signal heads at all signalized locations. However, backboards are not typically used in Newfoundland due to the wind loadings.
- The secondary signal head is not located within the 40-degree cone of vision on at least one approach at six locations.
- The secondary head does not include all the signal indications shown on the primary head on at least one approach at six signalized locations. At these locations, the primary signal head includes a left turn arrow indication which is not duplicated on a secondary signal head. It should be noted that the left turn indications are duplicated at other intersections throughout the City, creating inconsistencies between intersections.
- The arrow indications at 12 signalized intersections are steady arrow indications.
- At least one of the pedestrian signal heads is not placed directed in line with the pedestrian crosswalk it controls at five locations.

In addition to the 10 points identified above, a number of vehicle and pedestrian signal heads at each intersection do not meet proper placement guidelines such as location and mounting height.

The right turn arrow signal indication displayed on the West Street approach at the intersection of Main Street & West Street creates a conflict with the pedestrian crossing across Main Street. The arrow indication which is typically used to indicate a protected phase is displayed at the same time as the pedestrian walk signal which is also used to indicate a protected phase. The indications at the intersection are a significant safety concern, the arrow indication on the West Street approach should be replaced with a green ball indication.

Signage Assessment: The street name signage and mounting systems at each signalized location were reviewed. It should be noted that typically there is no street name signage present at mid-block pedestrian crossings, therefore the five half-signal locations were excluded from the assessment. Some level of street name signage is provided at 13 of the 15 signalized intersections. Of the 13 signalized intersections with street name signage present, six intersections are missing street name signage for at least one of the roadways. Various mounting devices and arrangements are used for street name signage.

Intersections where signage is missing should be upgraded to include street name signage for all roadways. For each individual intersection, the City should identify the type of pole present and contact the manufacturer to establish if, from a structural perspective, the pole can accommodate overhead signage measuring 300 x 1800 mm mounted rigidly to the mast arm between the primary and secondary signal head displays. Where that is not possible, the City should consider ground mounted signage in advance of all intersection approaches.

The regulatory and warning signage requirements at each signalized location were reviewed. The intersections were reviewed for Yield, Keep Right, Checkerboard, Added Lane, Double Arrow and Object Markers signs.

- Yield signs should be provided for all channelized right turns where added lanes are not provided. Yield signs are missing on at least one approach at four intersections.
- Keep Right signs should be provided on all raised medians. Keep right signs are missing on one median at two locations.
- Checkerboard signs should be provided at 3-leg intersections. Checkerboard signs are not provided at the four 3-leg intersections.
- Added Lane signs should be provided where added lanes are provided at channelized right turns. Added lanes are provided without the required signage at two locations
- Double Arrow signs should be provided at all raised islands and Object Markers can be used as an alternative or to supplement Double Arrow signs on raised islands. There are 11 signalized intersections with one or more raised concrete islands, none of which have Double Arrow signs or Object Markers signs.

Improvement Plan and Cost Estimates

The results of the various assessments were used to determine the improvements required at each signalized location to ensure the traffic signals reflect industry standards and conform to the MUTCD guidelines.

Class “D” cost estimates were developed to upgrade each of the 20 signalized locations based on the proposed improvements. All cost estimates include a 25 percent contingency and 15 percent engineering (preliminary and detailed design work). The cost estimates do not include property acquisitions, utility pole relocations, topographic survey or construction phase services. The estimated costs for each intersection are shown in the table below, the total cost to upgrade all 20 signalized locations is estimated at approximately $4,614,375 plus harmonized sales tax (HST).

Signalized Location	Estimated Cost	Contingency (25%)	Engineering (15%)	Total Cost
Lewin Parkway & Griffin Drive	$ 360,000	$ 90,000	$ 67,500	**$ 517,500**
Lewin Parkway & Mill Road	$ 290,000	$ 72,500	$ 54,375	**$ 416,875**
Lewin Parkway & St. Mark's Avenue/Prince George Avenue	$ 110,000	$ 27,500	$ 20,625	**$ 158,125**
Lewin Parkway & Murphy's Square Entrance	$ 130,000	$ 32,500	$ 24,375	**$ 186,875**
Lewin Parkway & Confederation Drive	$ 160,000	$ 40,000	$ 30,000	**$ 230,000**
Confederation Drive & West Valley Road	$ 230,000	$ 57,500	$ 43,125	**$ 330,625**
West Valley Road & O'Connell Drive	$ 170,000	$ 42,500	$ 31,875	**$ 244,375**
O'Connell Drive & University Drive/Mount Bernard Avenue	$ 300,000	$ 75,000	$ 56,250	**$ 431,250**
University Drive – pedestrian crossing near Canada Games Drive	$ 70,000	$ 17,500	$ 13,125	**$ 100,625**
O'Connell Drive & Elizabeth Street	$ 230,000	$ 57,500	$ 43,125	**$ 330,625**
O'Connell Drive – pedestrian crossing near Union Street	$ 100,000	$ 25,000	$ 18,750	**$ 143,750**
O'Connell Drive – pedestrian crossing near Westmount Road	$ 120,000	$ 30,000	$ 22,500	**$ 172,500**
O'Connell Drive – pedestrian crossing near Crestview Avenue	$ 110,000	$ 27,500	$ 20,625	**$ 158,125**
Main Street & Mount Bernard Avenue	$ 90,000	$ 22,500	$ 16,875	**$ 129,375**
Main Street & Mill Road/Brook Street	$ 90,000	$ 22,500	$ 16,875	**$ 129,375**
Main Street & West Street	$ 170,000	$ 42,500	$ 31,875	**$ 244,375**
Main Street & Riverside Drive/Humber Road	$ 110,000	$ 27,500	$ 20,625	**$ 158,125**
Broadway & Caribou Road/Herald Avenue	$ 210,000	$ 52,500	$ 39,375	**$ 301,875**
Corporal Pinksen Memorial Drive & Grenfell Drive	$ 50,000	$ 12,500	$ 9,375	**$ 71,875**
Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road	$ 110,000	$ 27,500	$ 20,625	**$ 158,125**
Total Costs for Improvements	$ 3,210,000	$ 802,500	$ 601,875	**$ 4,614,375**

A priority ranking system was developed to rank the 20 signalized locations in order to identify which locations should be upgraded based on a number of priorities including:

- Signal Displays (maximum points = 45):
  - Presence of conflicts
  - Visibility requirements
  - Improper signal display configurations (no secondary signal head is provided or improper signal indications are provided)
- Controller and Cabinet (maximum points = 15):
  - Controller and/or cabinet do not meet NEMA standards
  - Controller vintage is outdated (Econolite ASC/2 or Naztec Model 980 NEMA)
- Traffic Poles (maximum points = 15):
  - Condition of poles (very poor or poor condition)
  - Presence of damaged poles or poles with drilled holes
- Pedestrian System (maximum points = 25):
  - Lack of pedestrian facilities
  - System completeness (lack of pedestrian pushbuttons, pedestrian displays and/or crosswalks)
  - Pedestrian pushbuttons are not accessible

Priorities in each category were allocated a point value for a maximum of 100 points. Signalized locations ranking with the highest points should be prioritized. An implementation plan was developed based on the priority ranking exercise. The implementation plan, shown in the table below, assumes a capital cost budget of approximately $1,000,000 plus HST per year over five years and a maximum of five intersections per year.

Implementation Year	Priority Rank	Signalized Location	Intersection Cost	Total Cost per Year
1	1	Main Street & West Street	$ 244,375	$1,092,500
	2	Lewin Parkway & Griffin Drive	$ 517,500	
	3	Confederation Drive & West Valley Road	$ 330,625	
2	3	Lewin Parkway & Mill Road	$ 416,875	$1,006,250
	4	O'Connell Drive & University Drive/Mount Bernard Avenue	$ 431,250	
	5	Main Street & Riverside Drive/Humber Road	$ 158,125	
3	5	O'Connell Drive – pedestrian crossing near Westmount Road	$ 172,500	$ 963,125
	5	O'Connell Drive – pedestrian crossing near Crestview Avenue	$ 158,125	
	6	Broadway & Caribou Road/Herald Avenue	$ 301,875	
	6	O'Connell Drive & Elizabeth Street	$ 330,625	
4	6	Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road	$ 158,125	$ 876,875
	6	Lewin Parkway & Confederation Drive	$ 230,000	
	7	West Valley Road & O'Connell Drive	$ 244,375	
	7	University Drive – pedestrian crossing near Canada Games Drive	$ 100,625	
	7	O'Connell Drive – pedestrian crossing near Union Street	$ 143,750	
5	7	Lewin Parkway & Murphy's Square Entrance	$ 186,875	$ 675,625
	7	Main Street & Mount Bernard Avenue	$ 129,375	
	8	Lewin Parkway & St. Mark's Avenue/Prince George Avenue	$ 158,125	
	9	Main Street & Mill Road/Brook Street	$ 129,375	
	10	Corporal Pinksen Memorial Drive & Grenfell Drive	$ 71,875	

Communications Assessment

A communications assessment was completed to identify how to provide communications capabilities to each of the 20 signalized locations in the City in order to implement an Advance Traffic Management Systems (ATMS). The primary benefit of an ATMS is to improve mobility, safety and the productivity of transportation systems by providing the ability to connect a traffic signal controller to intelligent networks.

The communications assessment included the following components:

1. Assessing methods and technologies available and identifying how to provide ethernet communications to each intersection.
2. Developing cost estimates for the capital and maintenance costs associated with providing ethernet communications at each intersection and the required software.
3. Identifying zones in which intersections should be coordinated.

It is recommended that the City acquire the basic package of the Centracs 2.0 Advance Traffic Management System provided by Econolite. Amongst other features, the basic package of software will allow for automatic email or text message alerts upon detection of problems with the system or any devices and remote programming of intersection controller databases.

An access point network was identified as the City's most cost-effective solution to provide communication capabilities to all intersections. It is recommended that the City use a secure APN with static IP addresses, and Microhard VIP4G modems. These modems use SIM card technology and therefore do not require any civil works to install.

With communications capabilities in place, the City will have the ability to coordinate intersections. Coordination consists of synchronizing multiple intersections to enhance the operation of one or more directional movements in a corridor. Three zones were identified that could benefit from coordination:

- Zone 1: Lewin Parkway from Griffin Drive to Mill Road, and Main Street from Mount Bernard Avenue to Mill Road (4 intersections).
- Zone 2: Lewin Parkway from St. Mark's Avenue/Prince George Avenue to Confederation Drive (3 intersections).
- Zone 3: O'Connell Drive from Elizabeth Street to Mount Bernard Avenue/University Drive (2 intersections).

The initial cost to build the network and provide communications capabilities at all 20 signalized locations is estimated at $26,760 plus HST. The cost of a Centracs software license which can support up to 50 intersections is $78,000. A software maintenance package can be purchased for an additional $13,700 per year on a five-year term. In addition to the initial cost, a monthly fee for cellular data of approximately $300 plus HST will apply.

Intersection Capacity Analysis

The performance of an intersection can be evaluated using a number of measures of effectiveness. Delay and level of service (LOS), volume-to-capacity ratio (v/c) and vehicle queuing are the primary measures of effectiveness used in traffic analyses. The Synchro Studio (Version 10) software package was used as the primary evaluation tool. Synchro, an analysis and optimization software package, was used to analyze network intersections based on the methodology of the Highway Capacity Manual 6th edition (2016) published by the Transportation Research Board.

Synchro models of the 15 signalized intersections were built for the morning (AM) and evening (PM) peak hours of traffic. The models were coded using existing geometry, phasing and timings and traffic volumes to reflect existing conditions. Traffic volumes from 2015 traffic counts were factored to represent 2017 traffic volumes using a background traffic growth rate of 0.5 percent per year to reflect normal increases in traffic. These models were used to assess existing conditions at each intersection. Results of the Synchro analysis show operational problems at five signalized intersections during the peak hours. These five intersections are:

- Lewin Parkway & Griffin Drive
- West Valley Road & O'Connell Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive & Elizabeth Street
- Broadway & Caribou Road/Herald Avenue

New signal timing plans were developed to optimize operations at each intersection. The timing plans were optimized using the Synchro software. It should be noted that the new signal timing plans reflect the timing improvements for the red and amber clearance intervals, the pedestrian walk intervals and pedestrian clearance intervals.

Operations and Maintenance Program

An operations and maintenance manual was developed for the City's traffic signal system. The Traffic Signals Operations and Maintenance Manual, provides guidance for City staff and/or electrical maintenance contractors to develop a program to ensure the traffic signals within the City are properly maintained to industry standards. The manual outlines a 7-step program to establish the City's operations and maintenance program, the steps include:

- Step 1 – Develop a staff organizational chart and municipal guidelines
- Step 2 – Define the maintenance items
- Step 3 – Inventory equipment
- Step 4 – Develop the Preventative Maintenance Plan
- Step 5 – Develop the Response Maintenance Plan
- Step 6 – Develop the Design Modification Plan
- Step 7 – Determine Costs

The manual includes inventory recommendations for the City, preventative maintenance checklists, intersection inspection checklists, recommendations for the frequency of maintenance and testing of various components as well as guidelines for proper documentation and record keeping.

Roundabout Feasibility

A brief investigation was conducted at 10 of the 15 signalized intersections to determine the feasibility of converting each intersection to a roundabout. The five signalized intersections along the Lewin Parkway were excluded from this exercise since the Lewin Parkway is a provincially owned roadway.

There are a number of benefits associated with roundabouts; the two primary benefits of roundabouts are reductions in collisions and improved traffic operations. While roundabouts have a higher initial construction cost, when comparing cost and benefits of roundabouts and traffic signals over a long-term period, roundabout have a lower overall cost.

Commentary was provided for each intersection discussing the benefits and challenges of converting the intersection to a roundabout. At intersections where a roundabout was deemed feasible, an operational analysis of the roundabout was performed to identify the configuration required to accommodate existing traffic volumes and evaluate operations during peak hours. A conceptual layout was developed for each roundabout based on the results of the operational analysis.

The investigation identified that it was feasible to convert the following five intersections to roundabouts:

- Confederation Drive & West Valley Road
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive & Elizabeth Street
- Main Street & Riverside Drive/Humber Road
- Corporal Pinksen Memorial Drive & Grenfell Drive

Roundabouts were deemed not reasonably feasible at five locations primarily due to constraints created by the location of existing buildings and the associated property acquisition costs that would be required to install a roundabout. These locations include:

- West Valley Road & O'Connell Drive
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Main Street & West Street
- Broadway & Caribou Road/Herald Avenue

Table of Contents

1.0 Introduction 1
2.0 Traffic Counting Program 2
3.0 Intersection Traffic Signals Drawings 3
4.0 Signal Timing and Phasing Data 4
4.1 Signal Timing Review 4
4.2 Priority List for Signal Timing Improvements 6
4.3 Signal Phasing Review 8
4.4 Signal Indication Conformance 8
5.0 Controller and Equipment Assessment 10
5.1 Traffic Controller and Cabinet Assessment 10
5.2 Vehicle Detection Systems Assessment 13
5.3 Emergency Vehicle Preemption Systems Assessment 15
5.4 Pedestrian Systems Assessment 16
5.5 Traffic Pole Assessment 21
5.6 Signals Display Assessment 22
5.7 Intersection Signage Assessment 27
6.0 Intersection Improvements 33
6.1 Lewin Parkway & Griffin Drive 33
6.2 Lewin Parkway & Mill Road 33
6.3 Lewin Parkway & St. Mark's Avenue/Prince George Avenue 34
6.4 Lewin Parkway & Murphy's Square Entrance 34
6.5 Lewin Parkway & Confederation Drive 34
6.6 Confederation Drive & West Valley Road 35
6.7 West Valley Road & O'Connell Drive 35
6.8 O'Connell Drive & University Drive/Mount Bernard Avenue 36
6.9 University Drive – pedestrian crossing near Canada Games Drive 36
6.10 O'Connell Drive & Elizabeth Street 36
6.11 O'Connell Drive – pedestrian crossing near Union Street 37
6.12 O'Connell Drive – pedestrian crossing near Westmount Road 37
6.13 O'Connell Drive – pedestrian crossing near Crestview Avenue 38
6.14 Main Street & Mount Bernard Avenue 38
6.15 Main Street & Mill Road/Brook Street 38
6.16 Main Street & West Street 39
6.17 Main Street & Riverside Drive/Humber Road 39
6.18 Broadway & Caribou Road/Herald Avenue 39
6.19 Corporal Pinksen Memorial Drive & Grenfell Drive 40
6.20 Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road 40
7.0 Cost Estimates 41
8.0 Improvement Priority Ranking and Implementation Plan 41
9.0 Communications Assessment 43
9.1 Communications System Software 43
9.2 Communications and Device Support 44
9.3 Coordination Zones 45

9.4 Cost Estimates for the Implementation of an ATMS System 45
10.0 Intersection Performance Analysis 46
10.1 Existing Conditions 2017 47
10.2 New Signal Timing Plans 51
11.0 Operations and Maintenance Program 52
12.0 Roundabout Feasibility 52
12.1 Benefits of Roundabouts 52
12.2 Confederation Drive & West Valley Road 54
12.3 West Valley Road & O'Connell Drive 55
12.4 O'Connell Drive & University Drive/Mount Bernard Avenue 55
12.5 O'Connell Drive & Elizabeth Street 57
12.6 Main Street & Mount Bernard Avenue 58
12.7 Main Street & Mill Street/Brook Street 58
12.8 Main Street & West Street 58
12.9 Main Street & Riverside Drive/Humber Road 59
12.10 Broadway & Caribou Road/Herald Avenue 60
12.11 Corporal Pinksen Memorial Drive & Grenfell Drive 60
13.0 Conclusions and Recommendations 61

List of Figures

Figure 1: NEMA phase numbering schemes 8
Figure 2: Signalized Intersection Crossing Sing (ID-20) and Pedestrian Pushbutton sign (ID-21) 17
Figure 3: Examples of corrosion at O'Connell Drive & Elizabeth Street, classified as poor condition 21
Figure 4: Examples of corrosion at Lewin Parkway & Mill Road, classified as very poor condition 22
Figure 5: Overhead mast arm rigid mount 29
Figure 6: Overhead mast arm free-swinging mount 29
Figure 8: Roundabout reductions in collisions 53
Figure 9: Conflict points at a four-leg intersection 53
Figure 10: Roundabout concept for Confederation Drive & W Valley Road 54
Figure 11: Roundabout concept for O'Connell Drive & University Drive/Mount Bernard Avenue 56
Figure 12: Roundabout concept for O'Connell Drive & Elizabeth Street 57
Figure 13: Roundabout concept for Main Street & Riverside Drive/Humber Road 59
Figure 14: Roundabout concept for Corporal Pinksen Memorial Drive & Grenfell Drive 60

List of Tables

Table 1: Intersection traffic signal drawings 3
Table 2: Existing traffic controller and cabinet assemblies 11
Table 3: Vehicle detection systems assessment 14
Table 4: Emergency vehicle preemption systems assessment 15
Table 5: Pedestrian systems assessment 19
Table 6: TAC's signal visibility distances requirements 23
Table 7: Inventory of street name signage 28
Table 8: Inventory of regulatory and warning signage 32
Table 9: Cost estimates for intersection improvements 41
Table 10: Priority ranking 42
Table 11: 5-year implementation plan 43
Table 12: LOS Criteria signalized and unsignalized intersections 47
Table 13: Existing Conditions (2017) - Synchro analysis results 49
Table 14: ARCADY analysis results for Confederation Drive & West Valley Road 55
Table 15: ARCADY analysis results for O'Connell Drive & University Drive/Mount Bernard Avenue 57
Table 16: ARCADY analysis results for O'Connell Drive & Elizabeth Street 58
Table 17: ARCADY analysis results for Main Street & Riverside Drive/Humber Road 60
Table 18: ARCADY analysis results for Corporal Pinksen Memorial Drive & Grenfell Drive 61

Appendices

Appendix A – Traffic Counts
Appendix B – Intersection Traffic Signal Drawings
Appendix C – Signal Timing and Phasing Review Sheets
Appendix D – Econolite Traffic Controller Preventative Maintenance Report
Appendix E – Intersection Conformance to MUTCD
Appendix F – Communications Assessment - Product Datasheets
Appendix G – Synchro Reports
Appendix H – Traffic Signal Timing Plans
Appendix I – Traffic Signal Operations and Maintenance Manual
Appendix J – ARCADY Reports
Appendix K – Roundabout Concept Plans

1.0Introduction

Traffic signal systems are typically installed to service pre-existing or potential traffic flow problems. Once these systems are in place, consideration must be given to their operational and maintenance requirements. The complexity and technical capacities of the equipment make it essential to implement a program to maintain these devices up to industry standards and have clear policies in place to monitor their operation.

A comprehensive evaluation of the City of Corner Brook's traffic signals was completed to establish and document existing conditions at each signalized location in the City and recommend upgrades. This information will form the basis for establishing the City's operation and maintenance program.

The City's traffic signals system is comprised of 15 signalized intersections and five signalized pedestrian crossing locations, including:

1. Lewin Parkway & Griffin Drive
2. Lewin Parkway & Mill Road
3. Lewin Parkway & St. Mark's Avenue/Prince George Avenue
4. Lewin Parkway & Murphy's Square Entrance
5. Lewin Parkway & Confederation Drive
6. Confederation Drive & West Valley Road
7. West Valley Road & O'Connell Drive
8. O'Connell Drive & University Drive/Mount Bernard Avenue
9. University Drive – pedestrian crossing near Canada Games Drive
10. O'Connell Drive & Elizabeth Street
11. O'Connell Drive – pedestrian crossing near Union Street
12. O'Connell Drive – pedestrian crossing near Westmount Road
13. O'Connell Drive – pedestrian crossing near Crestview Avenue
14. Main Street & Mount Bernard Avenue
15. Main Street & Mill Road/Brook Street
16. Main Street & West Street
17. Main Street & Riverside Drive/Humber Road
18. Broadway & Caribou Road/Herald Avenue
19. Corporal Pinksen Memorial Drive & Grenfell Drive
20. Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

The comprehensive evaluation included the following components:

- Traffic Counting Program: Collection of traffic counts at five signalized intersections to complete the City's inventory of traffic counts for signalized intersections.
- Intersection Traffic Signals Drawings: Preparation of intersection traffic signals drawings documenting existing conditions at each of the 20 signalized locations.
- Signal Timing and Phasing Data: A review of the existing signal timing and phasing data for each signalized location to ensure their conformance to relevant standards and guidelines.
- Controller and Equipment Assessment: A detailed assessment of traffic control systems and equipment. including of traffic controllers and cabinets, vehicle detection systems, emergency vehicle preemption systems, pedestrian systems, traffic poles, signal displays and intersection signage. The results of the various assessments were used to determine the improvements

required at each signalized location to ensure the traffic signals reflect industry standards and conform to the MUTCD guidelines.

- **Communications Assessment:** An assessment to identify how to provide communications capabilities to each of the signalized locations in the City in order to implement an Advance Traffic Management Systems (ATMS).
- **Intersection Capacity Analysis:** Construction of Synchro models of the morning (AM) and evening (PM) peak hours for all 15 signalized intersections. The models were coded with the existing geometry, volumes and signal timing and phasing data. The models were used to assess existing conditions and to develop new signal timing plans to optimize operations at each intersection.
- **Operations and Maintenance Program:** Preparation of a traffic signal operations and maintenance manual. The program will provide necessary guidance to ensure traffic signals are properly maintained to industry standards.
- **Roundabout Feasibility:** A brief investigation for each intersection to determine the ability of converting the intersection to a roundabout. A conceptual layout and brief description of the benefits and challenges was provided for each intersection deemed feasible.

2.0Traffic Counting Program

Traffic counts were gathered at five of the 15 signalized intersections where recent counts (collected in the last 3 years) were not available. With the exception of the two manual counts completed for the Lewin Parkway & St Mark's Avenue/Prince George Avenue and the Lewin Parkway & Murphy's Square Entrance, all counts were collected using Miovision Scout video data collection devices.

Traffic data were collected Tuesday, Wednesday or Thursday between 7:00 to 9:00 am and 4:00 to 6:00 pm. The counts were scheduled around events that may cause serious disruptions to normal traffic flow such as construction or holidays.

For completeness, all traffic counts for the 15 signalized intersections in the City were included in Appendix A. The date of data collection for the intersections are listed below.

1. Lewin Parkway & Griffin Drive – October 15th, 2015
2. Lewin Parkway & Mill Road – October 20th, 2015
3. Lewin Parkway & St. Mark's Avenue/Prince George Avenue - September 25th, 2017
4. Lewin Parkway & Murphy's Square Entrance – November 1st, 2017
5. Lewin Parkway & Confederation Drive – November 28th, 2017
6. Confederation Drive & West Valley Road – November 28th, 2017
7. West Valley Road & O'Connell Drive – October 16th, 2015
8. O'Connell Drive & University Drive/Mount Bernard Avenue – October 19th, 2015
9. O'Connell Drive & Elizabeth Street – November 29th, 2017
10. Main Street & Mount Bernard Avenue – October 14th, 2015
11. Main Street & Mill Road/Brook Street – October 20th, 2015
12. Main Street & West Street – November 29th, 2017
13. Main Street & Riverside Drive/Humber Road – October 20th, 2015
14. Broadway & Caribou Road/Herald Avenue – October 19th, 2015
15. Corporal Pinksen Memorial Drive & Grenfell Drive – November 29th, 2017

For the analysis of existing conditions, 2017 was used as the base year. To represent 2017 traffic volumes at intersections where new counts were not obtained, traffic volumes from the 2015 traffic counts were

factored using a background traffic growth rate of 0.5 percent per year to reflect normal increases in traffic.

3.0Intersection Traffic Signals Drawings

Intersection traffic signals drawings of existing conditions were prepared for the 20 signalized locations in the City. The drawings include the following items:

- traffic pole locations,
- size and reach of traffic poles,
- signal head locations and configurations,
- signal head mounting hardware,
- pedestrian pushbutton locations,
- pedestrian pushbutton type,
- approximate layout of underground electrical conduit or overhead wiring,
- location of electrical junction boxes,
- location of the traffic controller,
- location of the power supply,
- location of preformed inductive loops or camera detection systems and
- pavement markings.

The full-size drawings are included in Appendix B, the drawing titles and numbers are listed in Table 1.

Table 1: Intersection traffic signal drawings

Drawing Title	Drawing Number
Key Map	00
Lewin Parkway & Griffin Drive	01
Lewin Parkway & Mill Road	02
Lewin Parkway & St. Mark's Avenue/Prince George Avenue	03
Lewin Parkway & Murphy's Square Entrance	04
Lewin Parkway & Confederation Drive	05
Confederation Drive & West Valley Road	06
West Valley Road & O'Connell Drive	07
O'Connell Drive & University Drive/Mount Bernard Avenue	08
University Drive – pedestrian crossing near Canada Games Drive	09
O'Connell Drive & Elizabeth Street	10
O'Connell Drive – pedestrian crossing near Union Street	11
O'Connell Drive – pedestrian crossing near Westmount Road	12
O'Connell Drive – pedestrian crossing near Crestview Avenue	13
Main Street & Mount Bernard Avenue	14
Main Street & Mill Road/Brook Street	15
Main Street & West Street	16
Main Street & Riverside Drive/Humber Road	17
Broadway & Caribou Road/Herald Avenue	18
Corporal Pinksen Memorial Drive & Grenfell Drive	19
Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road	20

4.0Signal Timing and Phasing Data

The existing signal timing and phasing data for each signalized location was reviewed to ensure their conformance to relevant standards and guidelines. A signal timing and phasing review sheet was prepared for each intersection, documenting the existing signal timing and phasing data and the calculations used to check the amber and all-red clearance intervals and the pedestrian clearance intervals. The detailed signal timing and phasing review sheets for each location can be found in Appendix C.

4.1 Signal Timing Review

The existing signal timing data for each signalized location was reviewed to ensure their conformance to relevant standards and guidelines. The following calculations were used to check the amber and all-red clearance intervals and the pedestrian clearance intervals at each signalized location.

The **amber clearance interval** warns drivers of an impending change in right-of-way and is displayed following each green indication. The amber interval should allow for a driver to comfortably decelerate to a stop prior to entering the intersection. The duration of this interval is based on the driver's perception-reaction time, deceleration rate, the approach speed and the approach grade. The existing amber clearance intervals were checked using the following equation from the ITE *Traffic Engineering Handbook*.

$$Y = t + \frac{0.278v}{2(a + Gg)}$$

Where:

Y = length of yellow (amber) interval (seconds)
t = perception-reaction time (used 1 second)
v = speed of approaching vehicles (km/hr)
a = deceleration rate in response to the onset of a yellow (amber) indication (used 3.048 m/s^2)
G = grade, with uphill positive and downhill negative (percent grade/100)
g = acceleration due to gravity (used 9.81 m/s^2)

The **all-red clearance interval** is an interval displayed following each amber indication in which all approaches receive a red indication. The interval is used to provide additional time for vehicles to clear the intersection before conflicting movements receive a green indication. Without an all-red clearance interval, the amber indication is immediately followed by a green indication for conflicting movements.

It is standard practice to use an all-red clearance interval; the duration of this interval is based on factors such as intersection width, length of vehicle and speed. The existing red clearance intervals were checked using the following equation from the Institute of Transportation Engineer's (ITE) *Traffic Engineering Handbook*.

$$R = \frac{W + L}{0.278v}$$

Where:

R = length of all-red interval (seconds)
W = total traversed width, from the approach stop bar to the far side of no-conflict point (meters). The no conflict point is taken as the far side of the furthest traffic lane or the far side of the crosswalk where present.
L = length of vehicle (used 7 meters)
v = speed of approaching vehicles (km/hr)

The pedestrian walk interval is the time for which the 'WALK' indication is provided before the pedestrian clearance interval. Standard practice is to provide a minimum pedestrian walk interval of seven seconds. The pedestrian walk intervals were checked to ensure a minimum of seven seconds is provided.

The pedestrian clearance interval is used to provide time for a pedestrian who entered the crosswalk at the end of the 'WALK' indication to reach the designated refuge area at a comfortable walking speed before a conflicting traffic movement begins. The pedestrian clearance interval is based on the length of the crossing and pedestrian walking speed. The existing pedestrian crossing clearance intervals were checked using the following equation.

$$PC = \frac{d}{v}$$

Where:

PC = pedestrian clearance interval (seconds)
d = walking distance from safety to safety (meters)
v = pedestrian walking speed (typically 1.2 m/s or 1.0 m/s for areas with high pedestrian volumes of children or seniors)

A pedestrian walking speed of 1.2 m/s was used at all intersections with the exception of the Lewin Parkway & St. Mark's Avenue/Prince George Avenue. Due to the intersection's proximity to the Eastside Elementary school, a pedestrian walking speed of 1.0 m/s was used at the intersection to accommodate young children walking to school.

Where the minimum green time of the vehicle phase associated with the pedestrian phase is longer than the walk interval plus the pedestrian clearance interval, at the City's discretion, a longer walk interval can be provided. The walk interval can be extended so that the walk interval plus the pedestrian clearance interval equals the minimum green time. However, to maintain efficient operations at the intersection the pedestrian intervals should not be extended to exceed the minimum green time required for the vehicle phase.

The signal timing review indicated that the existing signal timing at 19 signalized locations do not conform to at least one of the applicable standards; 18 locations have amber and all-red clearance intervals that do not conform to ITE standards, 2 locations have pedestrian walk intervals less than 7 seconds and 13 locations have pedestrian clearance intervals that do not provide sufficient time for a pedestrian to clear the crosswalk. The signalized locations that do not conform to the applicable standard for each interval are listed below:

Non-conforming amber and all-red clearance intervals:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Mill Road
- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- Lewin Parkway & Murphy's Square Entrance
- Lewin Parkway & Confederation Drive
- Confederation Drive & West Valley Road
- West Valley Road & O'Connell Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- University Drive – pedestrian crossing near Canada Games Drive
- O'Connell Drive & Elizabeth Street
- O'Connell Drive – pedestrian crossing near Union Street
- O'Connell Drive – pedestrian crossing near Westmount Road
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Main Street & West Street
- Main Street & Riverside Drive/Humber Road
- Broadway & Caribou Road/Herald Avenue
- Corporal Pinksen Memorial Drive & Grenfell Drive

Non-conforming pedestrian walk interval:

- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street

Non-conforming pedestrian clearance interval:

- Lewin Parkway & Mill Road
- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- Lewin Parkway & Confederation Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- University Drive – pedestrian crossing near Canada Games Drive
- O'Connell Drive & Elizabeth Street
- O'Connell Drive – pedestrian crossing near Union Street
- O'Connell Drive – pedestrian crossing near Westmount Road
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Main Street & Riverside Drive/Humber Road
- Broadway & Caribou Road/Herald Avenue
- Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

4.2 Priority List for Signal Timing Improvements

A priority list was developed to prioritize improvements required to the signal timing at each signalized location. Each location was assigned one of three priority levels, as follows:

- **Priority 1 – Immediate attention required:** The amber and all-red clearance intervals do not meet ITE standards. The pedestrian clearance interval does not meet standards, where the required pedestrian clearance time is greater than the total time provided by the pedestrian clearance interval and the amber and all-red clearance intervals (PC+Y+R).
- **Priority 2 – Adjust during signal timing updates:** The pedestrian clearance interval does not meet standards, where the required pedestrian clearance time is less than the total time provided by the pedestrian clearance interval and the amber and all-red clearance intervals (PC+Y+R). Sufficient time is provided by the combined pedestrian clearance interval and the amber and all-red clearance intervals for pedestrians to clear the intersection.
- **Priority 3 – Signal timing to be reviewed in future:** The signal timing conforms to the applicable standards. Opportunities for improvements should be reviewed in the future.

In total, 19 of the 20 signalized locations require timing improvements; 18 locations were identified as Priority 1 and one location was identified as Priority 2. The remaining location was identified as Priority 3. The 20 signalized locations by priority level include:

Priority 1 – Immediate attention required:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Mill Road
- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- Lewin Parkway & Murphy's Square Entrance
- Lewin Parkway & Confederation Drive
- Confederation Drive & West Valley Road
- West Valley Road & O'Connell Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- University Drive – pedestrian crossing near Canada Games Drive
- O'Connell Drive & Elizabeth Street
- O'Connell Drive – pedestrian crossing near Union Street
- O'Connell Drive – pedestrian crossing near Westmount Road
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Main Street & West Street
- Main Street & Riverside Drive/Humber Road
- Broadway & Caribou Road/Herald Avenue
- Corporal Pinksen Memorial Drive & Grenfell Drive

Priority 2 – Adjust during signal timing updates:

- Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

Priority 3 – Signal timing to be reviewed in future:

- O'Connell Drive – pedestrian crossing near Crestview Avenue

All timing improvements were implemented when new signal timing plans were entered into the controllers on June 26-27th, 2018.

4.3 Signal Phasing Review

The existing signal phasing data for each signalized location were reviewed to ensure their conformance to the standard National Electrical Manufacturers Association (NEMA) phasing schemes. The NEMA phase numbering schemes are shown in Figure 1.

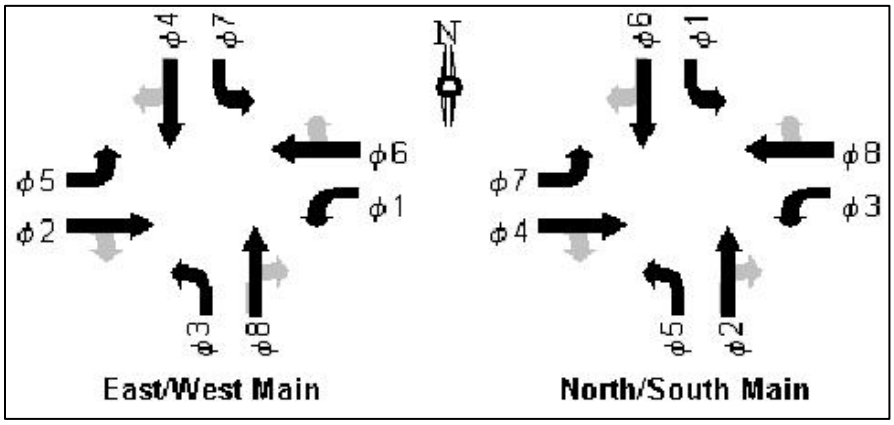


Figure 1: NEMA phase numbering schemes

The phasing data review indicated that the existing phasing at the 15 signalized intersections and at one pedestrian crossing location do not conform to the NEMA phasing standards. The remaining four locations consist of the pedestrian crossings controlled by timers which do not use phasing. The 16 signalized locations include:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Mill Road
- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- Lewin Parkway & Murphy's Square Entrance
- Lewin Parkway & Confederation Drive
- Confederation Drive & West Valley Road
- West Valley Road & O'Connell Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive & Elizabeth Street
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Main Street & West Street
- Main Street & Riverside Drive/Humber Road
- Broadway & Caribou Road/Herald Avenue
- Corporal Pinksen Memorial Drive & Grenfell Drive
- Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

The cabinets should be rewired to be compliant with NEMA standard phasing. Since the non-NEMA standard phasing does not affect the operational aspects of the intersections, it is recommended that cabinets be rewired as necessary when upgrades are completed at these intersections.

4.4 Signal Indication Conformance

Signal indications at each signalized location were reviewed to ensure their compliance to the guidelines from Transportation Association of Canada's (TAC) *Manual of Uniform Traffic Control Devices*.

4.4.1 Arrow Indications

The arrow signal indications at each signalized location (where present) were reviewed to ensure their compliance to the MUTCD guidelines. The MUTCD indicates that left or right green arrows should be flashing arrow indications and that arrow indications should flash at a flash rate of 100-120 flash/min.

Arrow indications are present at the 15 signalized intersections; there are no arrow indications at the 5 half signal locations. The review indicated that the arrow indications at 12 signalized intersections are steady arrow indications and do not conform to MUTCD guidelines. These arrow indications should be set to flash mode in the controller. The 12 signalized intersections include:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Mill Road
- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- Lewin Parkway & Murphy's Square Entrance
- Lewin Parkway & Confederation Drive
- Confederation Drive & West Valley Road
- West Valley Road & O'Connell Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive & Elizabeth Street
- Main Street & Mount Bernard Avenue
- Main Street & West Street
- Broadway & Caribou Road/Herald Avenue

All arrows were set to flashing mode on June 26-27th, 2018 with the exception of the arrow indications at:

- Lewin Parkway & St. Mark's Avenue/Prince George Avenue – The coding for the multiple overlaps does not allow the arrows to be simply set to flashing mode.
- O'Connell Drive & University Drive/Mount Bernard Avenue – The arrows could not be set to flashing mode due to issues with the MMU. The MMU should be replaced.

4.4.2 Green Ball Indications

The MUTCD defines the meaning for each type of signal indication. There are three main types of indications that relate to regular vehicle traffic: steady ball signal indications, arrow signal indications and flashing ball signal indications. The green ball indication is only included under the steady ball signal indications, meaning that a green ball indication should not flash.

Some jurisdictions have previously adopted the flashing green ball indication to provide a separate advanced left turn phase for single approach at the intersection. The flashing green ball indicates that the approach has a protected left and through movement. This practice does not conform with MUTCD guidelines and has been phased out in a number of jurisdictions due to liability and safety concerns with the confusion it may cause for unfamiliar motorists.

A flashing green ball indication is provided at Lewin Parkway and Griffin Drive on the southbound approach (Griffin Drive). The indication is not used to indicate an advance left turn phase, since the intersection currently operates with split phasing on the side street approaches, meaning that the side street approaches do not receive simultaneous green indications. A flashing green ball indication is provided for the southbound approach, while a steady green ball indication is provided for the

northbound approach. The use of different types of indications for the same type of phase on the two approaches increases the potential confusion to motorists.

The flashing green ball indication at Lewin Parkway and Griffin Drive does not conform to MUTCD guidelines and should be removed. The indications for both split phases should consist of a steady green ball indication and a flashing green arrow indication. It should be noted that the green ball indication was removed from flashing mode on June 26-27th, 2018.

5.0Controller and Equipment Assessment

A detailed assessment of the traffic control systems and equipment was completed for the 20 signalized locations. The assessment included the following components:

1. Traffic Controller Assessment – Assessment of the traffic controller and cabinet equipment performed in collaboration with Econolite Canada. Included a thorough review of all traffic cabinet components including the controller unit, the power supply, the BIU's, the detector and pre-emption cards, card racks and related interface panels, heating and cooling systems, the conflict monitor and the back panel.
2. Vehicle Detection Systems Assessment – An assessment of the vehicle detection systems currently in place. The systems were assessed to determine whether they are working or not.
3. Emergency Vehicle Preemption Systems Assessment – An assessment of the preemption systems currently in place. The systems were assessed to determine whether they are working or not.
4. Pedestrian Systems Assessment – An assessment of the pedestrian signal displays, push buttons and signage. The accessibility of the traffic signals was assessed.
5. Traffic Pole Assessment – A visual assessment of the condition of the pole systems.
6. Signal Display Indications Assessment: The signal displays were reviewed to ensure they conform to the TAC MUTCD.
7. Intersection Signage Assessment – An assessment of the overhead street name signage and mounting systems and the regulatory, warning and information signage requirements for each intersection.
8. Detailed Improvement List and Cost Estimates – A summary of improvements required at each intersection and cost estimates for the associated equipment and contractor costs.

5.1 Traffic Controller and Cabinet Assessment

In collaboration with Econolite Canada, a detailed assessment of the traffic controller and cabinet equipment was completed. The assessment included a thorough review of all traffic cabinet components including the controller unit, the power supply, the BIU's, the detector and pre-emption cards, card racks and related interface panels, heating and cooling systems, the conflict monitor and the back panel. The Preventative Maintenance Report from Econolite Canada can be found in Appendix D.

The existing controller and cabinet assemblies at each location are listed in Table 2. The 15 signalized intersections are controlled by 5 Econolite ASC/2 controllers, 3 Econolite ASC3 controllers, 2 Econolite Cobalt controllers and 4 Naztec Series 900 controllers (Model 980 NEMA TS2 Type 1). The five half-signals are controlled by one Naztec Series 900 controllers (Model 980 NEMA TS2 Type 1), one Electromega MCA250 timers and 3 unknown timers.

Brief descriptions of the four types of traffic controllers are provided below:

- Econolite ASC/2 controllers are 1990's technology. While these controllers are NEMA compliant and use a conflict monitor, these controllers are past their useful life and should be scheduled for replacement.
- Econolite ASC/3 controllers are still considered relatively modern controllers and do not need to be replaced at this time.
- Econolite Cobalt controllers are the most advanced type of controllers currently available on the market.
- The model 980 NEMA TS2 Type 1 controllers are an older type of controller manufactured by Trafficware (formerly Naztec). The newer controller model manufactured by Trafficware is the 980 ATC TS2 Type 1 controller.

Table 2: Existing traffic controller and cabinet assemblies

Intersection	Cabinet Standard	Controller Unit
Lewin Parkway & Griffin Drive	NEMA TS2	Naztec TS2 Series 900
Lewin Parkway & Mill Road	NEMA TS2	Naztec TS2 Series 900
Lewin Parkway & St. Marks Avenue/Prince George Avenue	NEMA TS2	Econolite ASC/2S-1000
Lewin Parkway & Murphy's Square Entrance		
Lewin Parkway & Confederation Drive	NEMA TS2	Econolite ASC/2-2100
Confederation Drive & West Valley Road	NEMA TS2	Econolite Cobalt
West Valley Road & O'Connell Drive	NEMA TS2	Econolite Cobalt
O'Connell Drive & University Drive/Mount Bernard Avenue	NEMA TS2	Econolite ASC/2S-1000
University Drive - pedestrian crossing near Canada Games Drive	Non NEMA Standard	Electromega MCA250
O'Connell Drive & Elizabeth Street	NEMA TS2	Econolite ASC/2S-1000
O'Connell Drive - pedestrian crossing near Union Street	Non NEMA Standard	Unknown Timer
O'Connell Drive - pedestrian crossing near Westmount Road	Non NEMA Standard	Unknown Timer
O'Connell Drive - pedestrian crossing near Crestview Avenue	Non NEMA Standard	Unknown Timer
Main Street & Mount Bernard Avenue	NEMA TS2	Econolite ASC/3-1000
Main Street & Mill Road/Brook Street	NEMA TS2	Econolite ASC/3-1000
Main Street & West Street	Econolite CBD	Econolite ASC/2S-1000
Main Street & Riverside Drive/Humber Road	NEMA TS2	Naztec TS2 Series 900
Broadway & Caribou Road/Herald Avenue	NEMA TS2	Econolite ASC/3-1000
Corporal Pinksen Memorial Drive & Grenfell Drive	NEMA TS2	Naztec TS2 Series 900
Corporal Pinksen Memorial Drive - pedestrian crossing near Wheeler's Road	NEMA TS2	Naztec TS2 Series 900

The four timers are not NEMA standard and are typically intended for pedestrian crossings that feature a flashing light such as an RA-5 crossing. At a signalized pedestrian crossing location, where vehicular traffic is controlled by red, amber and green indications, a NEMA standard traffic controller with a conflict monitor should be used instead of a timer. The pedestrian crossing on Corporal Pinksen Memorial is the only signalized pedestrian crossing controlled by a traffic controller (Naztec 980 NEMA controller). The timers provided at the other four locations should be replaced by NEMA standard traffic controllers.

The cabinet at Main Street and West Street and the four cabinets with the pedestrian crossing timers are not NEMA TS2 compliant. All other cabinets are NEMA TS2 compliant. However, in some instances, cabinets are from a different provider than the provider of the controller. It is recommended that the City use a cabinet provided by the same manufacturer as the controller used in the particular cabinet to minimize issues caused by the different mapping of the wires between the controller and the main panel. For example, an Econolite controller should be installed in an Econolite cabinet.

5.1.1 Traffic Controller and Cabinet Improvements

The City of Corner Brook should standardize the type of controller used at signalized intersections through the City. There are a number of benefits to standardizing cabinets and controllers to a single

provider such as reduced inventory for spare parts and reduced training of maintenance staff. Using the same provider also creates the possibility for the City to explore the use of Advanced Transportation Management Systems (ATMS) to provide real time communications capabilities between intersections. ATMS are further discussed in Section 6.0.

At this time, Econolite Canada is the leading provider of traffic signal control solutions in Canada. Their new Cobalt controller is a superior product to other traffic controllers currently available on the market. Should the City decide to standardize its cabinets and controllers, it is recommended that the City move towards using Econolite Cobalt controllers with Econolite cabinets.

Traffic controllers and cabinets should be replaced at fourteen intersections. Priority should be given to replacing the Econolite ASC/2 controllers, the Naztec Model 980 NEMA controllers and the pedestrian crossing timers at the following intersections:

Econolite ASC/2 controllers:

1. Lewin Parkway & St. Mark's Avenue/Prince George Avenue and Lewin Parkway & Murphy's Square Entrance
2. Lewin Parkway & Confederation Drive
3. O'Connell Drive & University Drive/Mount Bernard Avenue
4. O'Connell Drive & Elizabeth Street
5. Main Street & West Street

Naztec Model 980 NEMA controllers:

6. Lewin Parkway & Griffin Drive
7. Lewin Parkway & Mill Road
8. Main Street & Riverside Drive/Humber Road
9. Corporal Pinksen Memorial Drive & Grenfell Drive
10. Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

Pedestrian crossing timers:

11. University Drive – pedestrian crossing near Canada Games Drive
12. O'Connell Drive – pedestrian crossing near Union Street
13. O'Connell Drive – pedestrian crossing near Westmount Road
14. O'Connell Drive – pedestrian crossing near Crestview Avenue

Once the fourteen controllers above have been upgraded, the City should then replace the three Econolite ASC/3 controllers. These controllers are still relatively modern and are compatible with ATMS but will eventually need to be upgraded.

General maintenance should be performed at all intersections where the cabinets are not being replaced. The traffic controller and cabinet maintenance should include the following items:

- Cleaning and vacuuming the inside of the cabinet,
- Re-termination of the field wires using forks,
- Termination of loose wires,
- Identifying and labelling all wires,
- Replacing the door filter,

- Testing of the heating and cooling systems,
- Sealing the cabinet using foam to prevent the infiltration of water, and
- Performing software upgrades as required.

5.1.2 Traffic Controller Pads

A number of existing traffic controller cabinets are mounted to the upright of traffic poles at the intersection. A total of 12 traffic controller cabinets are mounted to the upright of traffic poles and two traffic controller cabinets are mounted to utility poles. The 14 locations are:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Mill Road
- Confederation Drive & West Valley Road
- West Valley Road & O'Connell Drive
- University Drive – pedestrian crossing near Canada Games Drive
- O'Connell Drive & Elizabeth Street
- O'Connell Drive – pedestrian crossing near Union Street
- O'Connell Drive – pedestrian crossing near Westmount Road
- O'Connell Drive – pedestrian crossing near Crestview Avenue – mounted to utility pole
- Main Street & Mill Road/Brook Street
- Main Street & West Street – mounted to utility pole
- Main Street & Riverside Drive/Humber Road
- Broadway & Caribou Road/Herald Avenue
- Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

Traffic controller cabinets should be mounted on raised concrete controller pads. All new traffic controller cabinets should be installed on controller pads. The existing cabinets for ASC3 and Cobalt controllers should be relocated to controller pads where they are mounted to traffic poles.

5.2 Vehicle Detection Systems Assessment

An assessment of the existing vehicle detection systems was completed to identify whether there are detection systems present at each intersection and if the existing systems are operating properly. The results of the assessment are summarized in Table 3. It should be noted that vehicle detection is not required at signalized pedestrian crossings, therefore the five half-signal locations were excluded from the assessment. Detection systems are present at five signalized intersections, including:

- Lewin Parkway & Griffin Drive – GridSmart video detection system
- Lewin Parkway & Mill Road – GridSmart video detection system
- O'Connell Drive & Elizabeth Street – Inductive loops
- Main Street & Mill Road/Brook Street – Inductive loops
- Corporal Pinksen Memorial & Grenfell Drive – GridSmart video detection system

The three GridSmart video detection systems are not operational, some of the systems are missing components or are not hooked up properly. There were no configuration files or cables to connect to the camera systems available from the City's maintenance contractor to allow Econolite to identify the issues with these systems.

It should be noted that the City's electrical contractor indicated that the video detection system at Corporal Pinksen Memorial and Grenfell Drive was only temporarily disconnected at the time of the site visit because they had recently relocated the cabinet on a raised concrete pad. As a result, the original camera cable was not long enough to reach the new controller set up. The contractor indicated a new cable had been ordered to replace the original cable.

Inductive loops are present at two intersections, both loop systems are not working properly. There are loops wired into the cabinet at the intersection of O'Connell Avenue and Elizabeth Street, but there no detector racks are present. It is unclear if any of the loops functional; the loops should be tested to identify if they are working. There are loops present at the intersection of Main Street and Mill Road/Brook Street, however the majority of the loops are broken and the intersection is on recall.

Table 3: Vehicle detection systems assessment

Intersection	Detection Operational	Notes
Lewin Parkway & Griffin Drive	N	GridSmart Video Detection System
Lewin Parkway & Mill Road	N	GridSmart Video Detection System - There is no unit present in the cabinet.
Lewin Parkway & St. Marks Avenue/Prince George Avenue	-	No existing detection system.
Lewin Parkway & Murphy's Square Entrance		
Lewin Parkway & Confederation Drive	-	No existing detection system.
Confederation Drive & West Valley Road	-	No existing detection system.
West Valley Road & O'Connell Drive	-	No existing detection system.
O'Connell Drive & University Drive/Mount Bernard Avenue	-	No existing detection system.
O'Connell Drive & Elizabeth Street	N	There are loops are wired into the cabinet, but there are no detection cards in the detector rack.
Main Street & Mount Bernard Avenue	-	No existing detection system.
Main Street & Mill Road/Brook Street	N	Loops are present at the intersection, but the loops are only operational on some movements.
Main Street & West Street	-	No existing detection system.
Main Street & Riverside Drive/Humber Road	-	No existing detection system.
Broadway & Caribou Road/Herald Avenue	-	No existing detection system.
Corporal Pinksen Memorial Drive & Grenfell Drive	N	GridSmart Video Detection System - The camera is not hooked up to the unit.

The following recommendations are suggested to restore the vehicle detection systems to proper operating conditions:

- Properly hook up the GridSmart detection systems at the Lewin Parkway and Griffin Drive, Lewin Parkway and Mill Road, and Corporal Pinksen Memorial and Grenfell Drive or replace the video detection systems with preformed inductive loops. Preformed inductive loops require less maintenance and expertise to maintain.
- If the City wishes to keep using the video detection systems, all equipment, software and files required to maintain and troubleshoot the camera systems should be obtained. Maintenance staff should be trained to perform basic maintenance and troubleshooting of the video detection systems.
- The existing loops at the intersection of O'Connell Avenue and Elizabeth Street should be tested to identify if any of the loops are functional, any broken loops should be replaced with preformed inductive loops. Detector racks should be installed in the cabinet.
- Replace the existing loops at the intersection of Main Street and Mill Road/Brook Street with preformed inductive loops.
- Install preformed inductive loops systems at the 10 signalized intersections where no detection systems are currently in place.

5.3 Emergency Vehicle Preemption Systems Assessment

An assessment of the existing emergency vehicle preemption systems was completed to identify whether there are preemption systems present at each intersection and if the systems are operating properly. The preemption systems were tested for operations from the controller side only for the assessment. The results of the assessment are summarized in Table 4. It should be noted that preemption systems are not typically provided at signalized pedestrian crossings, therefore the five half-signal locations were excluded from the assessment. Preemption systems are present at six signalized intersections, including:

- Lewin Parkway & Griffin Drive – Opticom GPS system
- Lewin Parkway & Mill Road – Opticom GPS system
- Main Street & Mt. Bernard Avenue – Opticom GPS system
- Main Street & Mill Road/Brook Street – Opticom GPS system
- Broadway & Caribou Road/Herald Avenue – Opticom GPS system
- Corporal Pinksen Memorial & Grenfell Drive – Opticom GPS system

None of the six preemption systems are operational from the controller side. It is recommended that the City contact the provider of these systems to get a technician on-site to restore the preemption systems to proper operating conditions. Once the systems are operational from the controller side, these systems should also be tested from an emergency vehicle to ensure the receiving unit is operational.

If the City wishes to keep using the preemption systems, all equipment and/or software required to maintain and troubleshoot the systems should be obtained. Maintenance staff should be trained to perform basic maintenance and troubleshooting of the preemption systems.

Table 4: Emergency vehicle preemption systems assessment

Intersection	Preemption Operational	Notes
Lewin Parkway & Griffin Drive	N	Opticom GPS System
Lewin Parkway & Mill Road	N	Opticom GPS System
Lewin Parkway & St. Marks Avenue/Prince George Avenue	-	No existing preemption system.
Lewin Parkway & Murphy's Square Entrance		
Lewin Parkway & Confederation Drive	-	No existing preemption system.
Confederation Drive & West Valley Road	-	No existing preemption system.
West Valley Road & O'Connell Drive	-	No existing preemption system.
O'Connell Drive & University Drive/Mount Bernard Avenue	-	No existing preemption system.
O'Connell Drive & Elizabeth Street	-	No existing preemption system.
Main Street & Mount Bernard Avenue	N	Opticom GPS System
Main Street & Mill Road/Brook Street	N	Opticom GPS System
Main Street & West Street	-	No existing preemption system.
Main Street & Riverside Drive/Humber Road	-	No existing preemption system.
Broadway & Caribou Road/Herald Avenue	N	Opticom GPS System
Corporal Pinksen Memorial Drive & Grenfell Drive	N	Opticom GPS System

5.4 Pedestrian Systems Assessment

An assessment of the pedestrian systems was completed to identify whether the appropriate pedestrian facilities are provided at each intersection. The pedestrian systems were assessed for the following components:

- Pedestrian Signal Displays:
  - Adequate number of signal displays are provided
  - Displays are in good condition
  - Displays provided are LED displays with countdown modules
- Pedestrian pushbuttons:
  - Adequate number of pedestrian pushbuttons are provided
  - Pedestrian pushbuttons are functional
  - Appropriate signage is provided with each individual pushbutton
- Accessibility
  - Pedestrian pushbuttons appear to be accessible. The pushbutton should be located no more than 1.5m away from the crosswalk it controls and should be mounted 1.1m ± 0.15m above the ground on the same side as the crosswalk.
  - Paraplegic curb ramps are provided at each crosswalk
  - Detectable warnings are provided for the visually impaired such as tactile plates.
  - Audible signals are provided for the visually impaired

Results of the pedestrian systems assessment can be found in Table 5. It should be noted that the poles at each intersection are numbered according to the intersection signal drawings discussed in Section 3.0. Pedestrian facilities are provided at 17 of the 20 signalized locations. There are no pedestrian facilities present at the following three signalized intersections:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Murphy's Square Entrance
- Confederation Drive & West Valley Road

Pedestrian infrastructure should be installed at these locations including pedestrian signals displays with LED lighting modules and countdown modules, crosswalks, pedestrian pushbuttons and signage. The pedestrian facilities should be made accessible for users of all ages and abilities.

The adequate number of pedestrian signal displays are provided at 16 of the 17 signalized locations with pedestrian facilities. At the intersection of O'Connell Drive and Elizabeth Street, there are no displays provided for the east-west crosswalk along the Colemans Drive approach.

Overall pedestrian displays are generally in good condition, displays in poor condition typically indicates that visors are missing. The displays at the O'Connell Drive pedestrian crossing near Union Street and O'Connell Drive pedestrian crossing near Westmount Road are in very poor condition and should be replaced.

The pedestrian signal displays provided include LED indications with countdown models at 15 of the 17 signalized locations. The displays at the O'Connell Drive pedestrian crossing near Union Street and O'Connell Drive pedestrian crossing near Westmount Road should be upgraded to include LED lamps and countdown modules. Countdown modules enhance pedestrian safety by providing information to pedestrians regarding the amount of time remaining to safely complete their crossing.

Three of the 17 signalized locations with pedestrian facilities do not include pedestrian pushbuttons. These intersections include:

- Lewin Parkway & Mill Road
- Main Street & West Street
- Broadway & Caribou Road/Herald Avenue

Pedestrian pushbuttons should be installed at these intersections. The appropriate number of pedestrian pushbuttons are provided all other locations with the exception of O'Connell Drive and Elizabeth Street. At the intersection of O'Connell Drive and Elizabeth Street, pushbuttons are only provided for one of the three crosswalks. Pedestrian pushbuttons should be installed for the east-west crosswalks along the Elizabeth Street and Coleman's Driveway approaches.

Overall pedestrian pushbuttons are generally in good condition and functional. One or more pushbuttons was not functioning at three of the 14 signalized locations with pushbuttons, pushbuttons at these locations should be replaced. The three locations include:

- Lewin Parkway & Confederation Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- Main Street & Mill Road/Brook Street

Pedestrian pushbutton signage is only provided at five of the 14 signalized locations where pedestrian pushbuttons are present. Signage is missing for one or more pushbutton and/or in poor condition at four of these locations. In addition, different types of signs are used at each location, the pushbutton signage provided should be consistent across all intersections.

The existing signage associated with the pedestrian pushbuttons should be replaced and new signage installed at all other signalized locations so that a sign is provided with each pushbutton. Where two pushbuttons are used on each pole to control the two crosswalks separately, the appropriate left or right version of MUTCD's ID-21 sign or ID-20 sign, shown in Figure 2, should be used for each button so that the arrow points in the direction of the crosswalk the button controls.

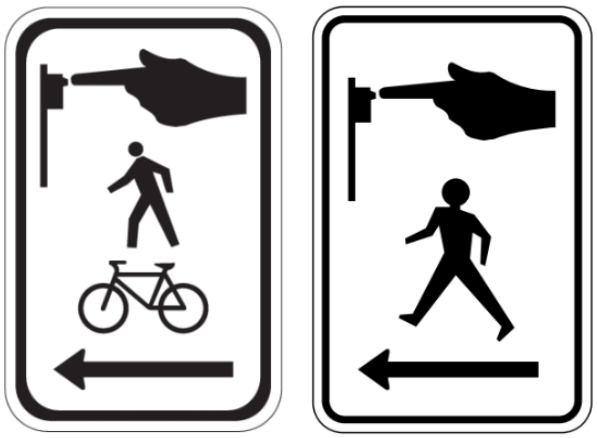


Figure 2: Signalized Intersection Crossing Sing (ID-20) and Pedestrian Pushbutton sign (ID-21)

The locations of pushbuttons were assessed to identify if the location of the pushbuttons appear to be accessible. The accessibility of the pushbutton was based on factors such the location of the pole and obstacles leading to it, its distance from the crosswalk it controls, grades, presence of sidewalk, paraplegic curb ramps, etc.

Paraplegic curb ramps are provided for all crosswalks at six locations and curb ramps are provided for at least one crosswalk approach at four locations with pedestrian facilities. Tactile warnings surfaces are provided for all crosswalk approaches at O'Connell Drive and Elizabeth Street. Paraplegic curb ramps, preferably with tactile surfaces, should be provided at all crosswalks.

Audible beaconing systems are provided for all crosswalks at four signalized locations, including:

- University Drive – pedestrian crossing near Canada Games Drive
- Main Street & Riverside Drive/Humber Road
- Corporal Pinksen Memorial & Grenfell Drive
- Corporal Pinksen Memorial Drive - pedestrian crossing near Wheeler's Road

The audible beaconing systems provided are these locations are an older type of system which include speakers mounted over the pedestrian signals. The speakers on either end of the crosswalk emit loud sounds during the pedestrian "walk" interval. Typically, one sounds is used for one direction of crossing and another sound is used for the other crossing direction. For example, the "cuckoo" sound is used for all north-south crosswalks and the "cheep" sound is used for the east-west crosswalks. It should be noted that these systems are not considered an Accessible Pedestrian Signal (APS) solution since they provide limited information. The two-sound system does not clearly indicate the crosswalk direction, only provides information during the "walk" interval and does not indicate the presence or location of the pushbutton all of which are key features of APS systems.

Newer APS solutions are integrated into the pedestrian pushbuttons. The APS pushbuttons typically include continuous pushbutton locator tones during the flashing and steady "don't walk" intervals, tactile arrows that point in the direction of travel of the crosswalk, both audible and vibrotactile indications during the "walk" interval and automatic volume adjustment. APS pedestrian pushbuttons should be installed when intersections are upgraded and the pedestrian facilities are designed to be accessible.

At least one pushbutton is considered as "not accessible" at 11 of the 14 locations where pushbuttons are present. Consideration should be given to accessibility when upgrading these signalized locations. The locations include:

- Lewin Parkway & St. Marks Avenue/Prince George Avenue
- Lewin Parkway & Confederation Drive
- West Valley Road & O'Connell Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive – pedestrian crossing near Union Street
- O'Connell Drive – pedestrian crossing near Westmount Road
- O'Connell Drive – pedestrian crossing near Crestview Avenue
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Main Street & Riverside Drive/Humber Road
- Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

Table 5: Pedestrian systems assessment

Intersection	Pole No.	Pedestrian Signal Displays				Pedestrian Pushbuttons			Accessibility				Notes
		# of Displays	Condition	LED	Countdown Module	# of Pushbuttons	Operational	Signage Present	Paraplegic Curb Ramp	Tactile Warnings	Audible Signals	Pushbutton Accessible	
Lewin Parkway & Griffin Drive	1	-	-	-	-	-	-	-	-	-	-	-	No pedestrians facilities present. Trail crossing location.
	2	-	-	-	-	-	-	-	-	-	-	-	
	3	-	-	-	-	-	-	-	-	-	-	-	
Lewin Parkway & Mill Road	1	-	-	-	-	-	-	-	-	-		-	No pedestrian pushbuttons are provided.
	2	1	Ok	Y	Y	0	N/A	N/A	N	N	N	N/A	
	3	2	Ok	Y	Y	0	N/A	N/A	N	N	N	N/A	
	4	-	-	-	-	-	-	-	-	-	-	-	
	5	1	Ok	Y	Y	0	N/A	N/A	N	N	N	N/A	
	6	-	-	-	-	-	-	-	-	-	-	-	
Lewin Parkway & St. Marks Avenue/Prince George Avenue	1	-	-	-	-	-	-	-	-	-	-	-	
	2	2	Ok	Y	Y	2	Y	Y	Y	N	N	Y	
	3	1	Ok	Y	Y	1	Y	Y	Y	N	N	Y	
	4	1	Ok	Y	Y	1	Y	Y	Y	N	N	Y	
	5	2	Ok	Y	Y	2	Y	Y	N	N	N	N	
	6	2	Ok	Y	Y	2	Y	Y	N	N	N	N	
	7	-	-	-	-	-	-	-	-	-	-	-	
Lewin Parkway & Murphy's Square Entrance	1	-	-	-	-	-	-	-	-	-	-	-	No pedestrians facilities present.
	2	-	-	-	-	-	-	-	-	-	-	-	
	3	-	-	-	-	-	-	-	-	-	-	-	
	4	-	-	-	-	-	-	-	-	-	-	-	
Lewin Parkway & Confederation Drive	1	-	-	-	-	-	-	-	-	-	-	-	
	2	1	Ok	Y	Y	1	N	N	N	N	N	N	
	3	2	Ok	Y	Y	2	N	N	N	N	N	N	
	4	1	Ok	Y	Y	1	N	N	N	N	N	N	
Confederation Drive & West Valley Road	1	-	-	-	-	-	-	-		-	-	-	No pedestrians facilities present.
	2	-	-	-	-	-	-	-		-	-	-	
West Valley Road & O'Connell Drive	1	-	-	-	-	-	-	-	-	-	-	-	
	2	-	-	-	-	1	Y	-	Y	N	N	N	
	3	1	Ok	Y	Y	-	-	-	-	-	-	-	
	4	1	Poor	Y	Y	1	Y	N	Y	N	N	N	
O'Connell Drive & University Drive/Mount Bernard Avenue	1	2	Ok	Y	Y	2	N	Y	Y	N	N	N	Signage in poor condition.
	2	2	Ok	Y	Y	2	Y	Y	Y/N	N	N	N	
	3	2	Ok	Y	Y	2	Y	Y	N	N	N	N	
	4	2	Ok	Y	Y	2	Y	Y	Y	N	N	N	
University Drive - pedestrian crossing near Canada Games Drive	1	1	Ok	Y	Y	1	Y	N	Y	N	Y	Y	
	2	1	Ok	Y	Y	1	Y	N	N	N	Y	Y	
O'Connell Drive & Elizabeth Street	1	0	-	-	-	0	N/A	N/A	Y	Y	N	N/A	No pedestrian displays or pushbuttons are provided for the E-W crosswalk along the Coleman's Drive approach. No pedestrian pushbuttons are provided for the E-W crosswalk along the Elizabeth Street approach.
	2	1	Poor	Y	Y	1	Y	N	Y	Y	N	Y	
	3	2	Ok	Y	Y	1	Y	N	Y	Y	N	Y	
	4	-	-	-	-	-	-	-	-	-	-	-	
	5	1	Ok	Y	Y	0	N/A	N/A	Y	Y	N	N/A	
O'Connell Drive - pedestrian crossing near Union Street	1	1	Poor	N	N	1	Y	Y	Y	N	N	N	P1 signage in poor condition.
	2	1	Poor	N	N	1	Y	N	N	N	N	N	
O'Connell Drive - pedestrian crossing near Westmount Road	1	1	Poor	N	N	1	Y	Y	N	N	N	N	P2 Signage in poor condition.
	2	1	Poor	N	N	1	Y	N	N	N	N	N	
O'Connell Drive - pedestrian crossing near Crestview Avenue	1	1	Ok	Y	Y	1	Y	N	N	N	N	N	P2 Signage in poor condition.
	2	1	Ok	Y	Y	1	Y	Y	N	N	N	N	

Intersection	Pole No.	Pedestrian Signal Displays				Pedestrian Pushbuttons			Accessibility				Notes
		# of Displays	Condition	LED	Countdown Module	# of Pushbuttons	Operational	Signage Present	Paraplegic Curb Ramp	Tactile Warnings	Audible Signals	Pushbutton Accessible	
Main Street & Mount Bernard Avenue	1	2	Ok	Y	Y	2	Y	N	Y	N	N	Y	
	2	1	Ok	Y	Y	1	Y	N	Y	N	N	N	
	3	1	Ok	Y	Y	1	Y	N	Y	N	N	Y	
	4	1	Ok	Y	Y	1	Y	N	Y	N	N	N	
	5	1	Ok	Y	Y	1	Y	N	Y	N	N	N	
Main Street & Mill Road/Brook Street	1	1	Ok	Y	Y	1	N	N	N	N	N	N	Pedestrian phases are on recall.
	2	2	Ok	Y	Y	2	N	N	N	N	N	N	
	3	2	Ok	Y	Y	2	N	N	N	N	N	N	
	4	1	Ok	Y	Y	1	N	N	N	N	N	N	
Main Street & West Street	1	1	Ok	Y	Y	0	N/A	N/A	Y	N	N	N/A	No pedestrian pushbuttons are provided.
	2	-	-	-	-	-	-	-		-	-	-	
	3	2	Ok/Poor	Y	Y	0	N/A	N/A	Y	N	N	N/A	
	4	1	Ok	Y	Y	0	N/A	N/A	Y	N	N	N/A	
Main Street & Riverside Drive/Humber Road	1	-	-	-	-	-	-	-		-	-	-	
	2	1	Ok	Y	Y	1		N	Y	N	Y	Y	
	3	2	Ok	Y	Y	1		N	N	N	Y	N	
	4	2	Ok	Y	Y	2		N	Y	N	Y	Y	
	5	1	Ok	Y	Y	1		N	N	N	Y	Y	
Broadway & Caribou Road/Herald Avenue	1	2	Ok	Y	Y	0	N/A	N/A	N/A	N	N	N/A	No pedestrian pushbuttons are provided.
	2	2	Ok	Y	Y	0	N/A	N/A	N/A	N	N	N/A	
	3	2	Ok	Y	Y	0	N/A	N/A	N/A	N	N	N/A	
	4	2	Ok	Y	Y	0	N/A	N/A	N/A	N	N	N/A	
Corporal Pinksen Memorial Drive & Grenfell Drive	1	2	Ok	Y	Y	2	Y	N	Y	N	Y	Y	
	2	2	Ok	Y	Y	2	Y	N	Y	N	Y	Y	
	3	2	Ok	Y	Y	2	Y	N	Y	N	Y	Y	
	4	2	Ok	Y	Y	2	Y	N	Y	N	Y	Y	
Corporal Pinksen Memorial Drive - pedestrian crossing near Wheeler's Road	1	1	Ok	Y	Y	1	Y	N	Y	N	Y	N	
	2	1	Ok	Y	Y	1	Y	N	Y	N	Y	N	

5.5 Traffic Pole Assessment

A visual examination of condition of traffic poles was conducted. Poles were inspected for any signs of visible damage or corrosion. Visible corrosion was identified at seven of the 20 signalized locations, corrosion was mainly observed in older poles of the "Pole System" type. The poles at the seven locations were classified as poor or very poor conditions. Examples of poor and very poor condition are shown in Figure 3 and Figure 4.

Poor condition:

- Confederation Drive & West Valley Road – Both traffic poles with mast arms are older "Pole System" poles.
- O'Connell Drive & Elizabeth Street – The two traffic poles with mast arms on O'Connell Drive (Poles 1 and 3) are older "Pole System" poles. All other traffic poles appear to be newer and do not need replacement.

Very poor condition:

- Lewin Parkway & Griffin Drive – Both traffic poles with mast arms (Poles 1 and 3) are older "Pole System" poles, there is also a short upright pole (Pole 2) in very poor condition.
- Lewin Parkway & Mill Road – The three traffic poles with mast arms (Poles 1, 3 and 6) are older "Pole System" poles, there are also three pedestal poles; one is in very poor condition (Pole 5) and the other two appear to be newer and does not need replacement.
- O'Connell Drive & University Drive/Mount Bernard Avenue – All four traffic poles with mast arms are older "Pole System" poles.
- O'Connell Drive pedestrian crossing near Westmount Road – Both traffic poles with mast arms are older "Pole System" poles.
- O'Connell Drive pedestrian crossing near Crestview Avenue – Both traffic poles with mast arms are older "Pole System" poles.

Upon consultation with Harbourside Engineering Consultants, it was determined that any "Pole System" exhibiting signs of corrosion or excessive wear should be replaced. It is recommended that the poles at all seven locations described above be replaced, priority should be given to replacing the poles in very poor condition first.

Figure 3: Examples of corrosion at O'Connell Drive & Elizabeth Street, classified as poor condition

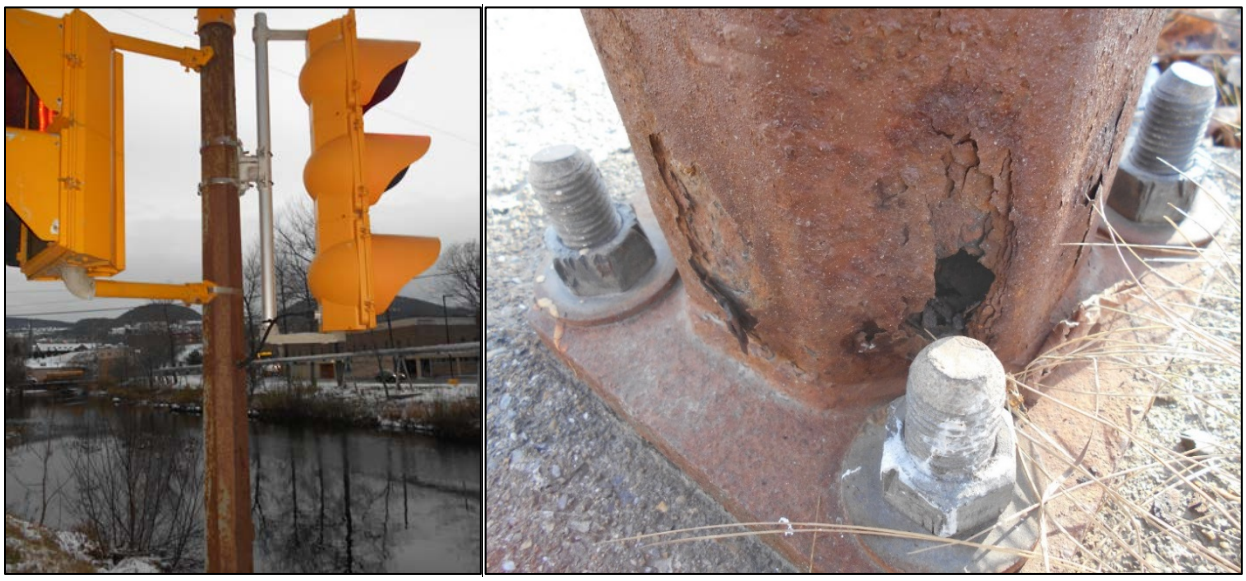


Figure 4: Examples of corrosion at Lewin Parkway & Mill Road, classified as very poor condition

The traffic pole located on the southwest corner at the intersection Lewin Parkway & St. Mark's Avenue/Prince George Avenue (Pole 5) has been damaged by an impact creating a hole in the wall of the pole. This pole should be replaced immediately.

In addition, holes have been drilled in a number of traffic poles throughout the City to accommodate conduit and/or mount traffic controller cabinets. In some instances, holes were observed to be drilled at the base of the pole. It is possible that the structural integrity of the poles has been affected by the holes. The City should have a structural engineer review poles in which holes were drilled and provide an opinion on the structural integrity of the poles.

5.6 Signals Display Assessment

The signal displays at each of the 20 signalized locations were reviewed to ensure the signal displays conform to section B3 - Display and Configurations for Traffic Control Signals of the MUTCD.

5.6.1 MUTCD Guidelines

The MUTCD provides the following guidelines with respect to the display and configuration for traffic control signals. Signal heads for vehicles are defined as follows:

- Primary signal head: the main signal head provided on each approach to the intersection.
- Secondary signal head: the signal head used to supplement the primary signal head. The secondary signal head includes all the indications shown on the primary signal head. The primary and secondary signal heads must be used to provide duplicate indications on each approach.
- Auxiliary signal head: used to supplement the primary and secondary signal head.

Visibility of Traffic Control Signals

- Signal visibility distance: the distance in advance of the stop line from which a signal must be continuously seen by the approaching driver based on the speed of the approach (See Table 6).
- The primary signal head should be located within a 10-degree cone of vision and the secondary head located within a 40-degree cone. The cone of vision usually originates at the stop line and is

centered on the approach lane, excluding any parking lanes. Separate turn lanes should be included unless they have their own signal head.

- Overhead indications should be placed at least 15m beyond the stop line. Signal heads should be placed within a 15-degree vertical sight angle.
- Backboards should be used on all primary heads. Backboards may also be used with secondary and auxiliary signal heads.
- Flash rate requirements: the duration of the 'ON' period should be approximately equal to the duration of the 'OFF' period. For the arrow indication, the flash rate should be 100-120 flash/min.

Table 6: TAC's signal visibility distances requirements

85th Percentile Speed (km/h)	Minimum Visibility (m)	Desirable Visibility (m)	Add for % Downgrade (m)		Subtract for % Upgrade (m)	
			5%	10%	5%	10%
40	65	100	3	6	3	5
50	85	125	5	9	3	6
60	110	160	7	16	5	9
70	135	195	11	23	8	13
80	165	235	15	37	11	20

Number and Location of Signal Heads

- Primary and secondary heads must be provided at each approach and mounted no less than 3.0m apart, measured horizontally between the centers of the faces.
- The primary signal head location should be mounted on the far side of the intersection, directly over the travelled portion of the road. The mounting height should be between 5.0 to 6.0m above the roadway.
- The secondary signal head should be mounted on the far side of the intersection. When the secondary head is mounted clear of the travel roadway, the bottom of the signal head should not be less than 2.5m above the sidewalk. Where sidewalk does not exist, the head may have to be mounted 4.5m above the roadway where vehicles may encroach beyond the travel lane.
- The location of the secondary head should not interfere with the visibility of the primary signal head for the opposing direction and should not be blocked by the primary signal head.
- Where the nearest signal head is located between 30 and 45m beyond the stop line, either a 300mm red lens should be used in the primary signal head or an auxiliary signal head should be placed at a near-side location.
- An auxiliary near-side signal should be used in all cases where the primary signal head is located more than 45m from the stop line.
- Near-side auxiliary heads should be placed as close as possible to the stop line. An auxiliary head may be required for the following situations:
  - Approach widths are in excess of three through lanes.
  - The intersecting street width is greater than 25m.
  - Drivers are uncertain of the proper location to stop.
  - There is a high percentage of heavy vehicles which obstruct the view of the signal heads.
  - The approach geometry makes it impossible to maintain continuous visibility of the signal heads.
  - To accommodate right or left-turn signal phasing.

- The pedestrian signal head should be mounted at a lower height than the signal heads but no less than 2.5m above the sidewalk. Pedestrian heads should be placed directly in line with the pedestrian crosswalk they control.
- The pedestrian signal indication should be visible for a minimum distance of 30m.

Size, Colour and Shape of Traffic Control Signal Lenses

- Lenses are round and no less than 200mm in diameter.
- Red ball indications should be 300mm in diameter.
- 300mm lenses are recommended for:
  - All arrow indications.
  - Signal heads located 30m beyond the stop line.
  - All intersection approaches where drivers may be confused when both traffic control and lane control signals are viewed at the same time.
  - Specific problem locations, such as locations conflicting/competing with background light.
  - Locations that require increased visibility.

Position of Traffic Control Signal Indications

- Signal heads should follow relative vertical or horizontal positions for the various signal indications.
- No more than six indications should be combined in one signal head.

5.6.2 Signal Display and Indication Conformance

Results of the traffic signal display assessment for each of the 20 signalized locations can be found in Appendix E. Overall, the signal systems do not conform to MUTCD guidelines, 10 key points creating safety and/or liability concerns are discussed below.

A secondary head is not provided on at least one approach at seven signalized locations, including:

- Lewin Parkway & Griffin Drive – northbound approach (Griffin Drive)
- Confederation Drive & West Valley Road – eastbound approach (West Valley Road)
- West Valley Road & O'Connell Drive – all approaches
- University Drive – pedestrian crossing near Canada Games Drive – all approaches
- Main Street & West Street – all approaches
- Broadway & Caribou Road/Herald Avenue - northbound (Caribou Road) and southbound (Herald Avenue) approaches
- Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road – all approaches

The traffic signals do not meet the signal visibility distance in advance of the stop line on at least one approach at three locations, including:

- Main Street & Mount Bernard Avenue – eastbound approach (Main Street)
- Main Street & West Street – northbound (Main Street) and westbound (West Street) approach
- Main Street & Humber Road – northbound (Main Street), westbound (Humber Road) and eastbound (Service Road) approaches

The overhead signal indications are located less than 15 metres from the stop bar on at least one approach at eight locations, including:

- West Valley Road & O'Connell Drive – westbound approach (West Valley Road)
- University Drive – pedestrian crossing near Canada Games Drive – all approaches
- O'Connell Drive – pedestrian crossing near Union Street – all approaches
- O'Connell Drive – pedestrian crossing near Westmount Road – all approaches
- O'Connell Drive – pedestrian crossing near Crestview Avenue – all approaches
- Main Street & Mill Road/Brook Street – westbound and eastbound approaches (Main Street)
- Main Street & West Street – southbound approach (Main Street)
- Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road – all approaches

Where provided, the required signal assemblies (primary and secondary heads) are mounted less than 3.0 metres apart on at least one approach at seven locations, including:

- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- Lewin Parkway & Murphy's Square Entrance
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive & Elizabeth Street
- O'Connell Drive – pedestrian crossing near Union Street
- Main Street & Mill Road/Brook Street
- Main Street & Riverside Drive/Humber Road

Consideration should be given to adjusting the locations of these signal heads to provide appropriate spacing, while ensuring that the signal heads are located within the appropriate cone of vision.

The primary signal head is not located within the 10-degree cone of vision on at least one approach at 14 locations, including:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Mill Road
- Lewin Parkway & Murphy's Square Entrance
- Lewin Parkway & Confederation Drive
- Confederation Drive & West Valley Road
- West Valley Road & O'Connell Drive
- University Drive – pedestrian crossing near Canada Games Drive
- O'Connell Drive – pedestrian crossing near Union Street
- O'Connell Drive – pedestrian crossing near Westmount Road
- O'Connell Drive – pedestrian crossing near Crestview Avenue
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Corporal Pinksen Memorial Drive/Grenfell Drive
- Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

Backboards are not used on the primary signal heads at all signalized locations. Backboards are not typically used in Newfoundland due to the wind loadings. Backboards are unable to withstand the high winds and tend to break off, creating a hazard to vehicles and pedestrians.

The secondary signal head is not located within the 40-degree cone of vision on at least one approach at six locations, including:

- Lewin Parkway & Murphy's Square Entrance
- O'Connell Drive – pedestrian crossing near Union Street
- O'Connell Drive – pedestrian crossing near Westmount Road
- O'Connell Drive – pedestrian crossing near Crestview Avenue
- Main Street & Mill Road/Brook Street
- Corporal Pinksen Memorial Drive/Grenfell Drive

The secondary head does not include all the signal indications shown on the primary head on at least one approach at six signalized locations. At these locations, the primary signal head includes a left turn arrow indication which is not duplicated on a secondary signal head. The locations include:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Murphy's Square Entrance
- Lewin Parkway & Confederation Drive
- Confederation Drive & West Valley Road
- O'Connell Drive & University Drive/Mount Bernard Avenue
- Main Street & Riverside Drive/Humber Road

It should be noted that the left turn indications are duplicated at other intersections throughout the City, creating inconsistencies between intersections.

Arrow indications are present at the 15 signalized intersections; there are no arrow indications at the 5 pedestrian crossing locations. The arrow indications at 12 signalized intersections are steady arrow indications and do not conform to flashing rates. These arrow indications should be set to flash mode in the controller. The locations include:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Mill Road
- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- Lewin Parkway & Murphy's Square Entrance
- Lewin Parkway & Confederation Drive
- Confederation Drive & West Valley Road
- West Valley Road & O'Connell Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive & Elizabeth Street
- Main Street & Mount Bernard Avenue
- Main Street & West Street
- Broadway & Caribou Road/Herald Avenue

At least one of the pedestrian signal heads is not placed directed in line with the pedestrian crosswalk it controls at five locations, including:

- Lewin Parkway & Mill Road
- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- Lewin Parkway & Confederation Drive

- Main Street & Mill Road/Brook Street
- Broadway & Caribou Road/Herald Avenue

In addition to the 10 points identified above, a number of vehicle and pedestrian signal heads at each intersection do not meet proper placement guidelines such as location and mounting height. Details regarding the individual signal heads at each intersection are included in Appendix E.

The right turn arrow signal indication displayed on the West Street approach at the intersection of Main Street & West Street creates a conflict with the pedestrian crossing across Main Street. The arrow indication which is typically used to indicate a protected phase is displayed at the same time as the pedestrian walk signal which is also used to indicate a protected phase. The indications at the intersection are a significant safety concern, the arrow indication on the West Street approach should be replaced with a green ball indication.

5.7 Intersection Signage Assessment

5.7.1 Street Name Signage

The street name signage and mounting systems at each signalized location were reviewed. An inventory of street name signs, mounting hardware and location of signs can be found in Table 7. It should be noted that typically there is no street name signage present at mid-block pedestrian crossings, therefore the five half-signal locations were excluded from the assessment.

Some level of street name signage is provided at 13 of the 15 signalized intersections. There are no street name signs provided at intersections of Main Street & Riverside Drive/Humber Road and the Lewin Parkway & Murphy's Square Entrance. Of the 13 signalized intersections with street name signage present, six intersections are missing street name signage for at least one of the roadways.

Various mounting devices and arrangements are used for street name signage. The street name signs at eight signalized intersections consist of overhead signs which are mounted to mast arms using rigid mounts (Figure 5) or using free-swinging mounts (Figure 6). At five signalized intersections, street name signs are mounted to separate posts using post top mounts or to the upright of traffic poles using wing brackets.

Intersections where signage is missing should be upgraded to include street name signage for all roadways. For each individual intersection, the City should identify the type of pole present and contact the manufacturer to establish if, from a structural perspective, the pole can accommodate overhead signage measuring 300 x 1800 mm mounted rigidly to the mast arm between the primary and secondary signal head displays. Where that is not possible, the City should consider ground mounted signage in advance of all intersection approaches.

Table 7: Inventory of street name signage

Intersection	Approach	Street Name	Signage	Mounting Type	Location
Lewin Parkway & Griffin Drive	North	Griffin Drive	Y	Post top mount	Northeast corner
	South	Unnamed Road	N/A	-	-
	East	Lewin Parkway	N	-	-
	West	Lewin Parkway			
Lewin Parkway & Mill Road	North	Mill Road	Y	Free-swinging mount on mast arm	P6
	South	Driveway	N/A	-	-
	East	Lewin Parkway	Y	Free-swinging mount on mast arm	P1
	West	Lewin Parkway			
Lewin Parkway & St. Marks Avenue/Prince George Avenue	North	St. Mark's Avenue	N	-	-
	South	Prince George Avenue	Y	Post top mount	Southeast corner
	East	Lewin Parkway	N	-	-
	West	Lewin Parkway			
Lewin Parkway & Murphy's Square Entrance	North	Unnamed Road	N/A	-	-
	East	Lewin Parkway	N	-	-
	West	Lewin Parkway			
Lewin Parkway & Confederation Drive	North	Confederation Drive	Y	Post top mount	Southwest corner
	South	Confederation Drive			
	East	Lewin Parkway	N	-	-
	West	Lewin Parkway			
Confederation Drive & West Valley Road	North	Confederation Drive	N	-	-
	South	Confederation Drive			
	East	Driveway	N/A	-	-
	West	W Valley Road	Y	Free-swinging mount on mast arm	P1 and P2
West Valley Road & O'Connell Drive	North	O'Connell Drive	Y	Post top mount	Southwest corner
	East	W Valley Road	Y	Post top mount	Southwest corner
	West	W Valley Road			
O'Connell Drive & University Drive/Mount Bernard Avenue	North	University Drive	Y	Free-swinging mount on mast arm	P4
	South	Mt. Bernard Avenue	Y	Free-swinging mount on mast arm	P1
	East	O'Connell Drive	Y	Free-swinging mount on mast arm	P2 and P3
	West	O'Connell Drive			
O'Connell Drive & Elizabeth Street	North	Driveway	N/A	-	-
	South	Elizabeth Street	Y	Free-swinging mount on mast arm	P1 and P3
	East	O'Connell Drive	y	Rigid mount on mast arm	P2 and P4
	West	O'Connell Drive			
Main Street & Mount Bernard Avenue	North	Driveway	N/A	-	-
	South	Mt. Bernard Avenue	Y	Rigid mount on mast arm	P1 and P3
	East	Main Street	Y	Rigid mount on mast arm	P4
	West	Herald Avenue	Y	Rigid mount on mast arm	P2
Main Street & Mill Road/Brook Street	North	Mill Road	Y	Rigid mount on mast arm	P3
	South	Brook Street	Y	Rigid mount on mast arm	P1
	East	Main Street	Y	Rigid mount on mast arm	P2 and P4
	West	Main Street			
Main Street & West Street	North	Main Street	N	-	-
	South	Main Street			
	East	West Street	y	Rigid mount on mast arm	P2
Main Street & Riverside Drive/Humber Road	North	Riverside Drive	N	-	-
	South	Main Street	N	-	-
	East	Humber Road	N	-	-
	West	Unnamed Road	N/A	-	-
Broadway & Caribou Road/Herald Avenue	North	Herald Avenue	N	-	-
	South	Caribou Road	Y	Post top mount	Southeast corner
	East	Broadway	Y	Bracket mount	P2
	West	Broadway			
Corporal Pinksen Memorial Drive & Grenfell Drive	North	Corporal Pinksen Memorial Drive	Y	Rigid mount on mast arm	P1 and P3
	South	Corporal Pinksen Memorial Drive			
	East	Grenfell Drive	Y	Rigid mount on mast arm	P2 and P4
	West	Grenfell Drive			

Figure 5: Overhead mast arm rigid mount

Figure 6: Overhead mast arm free-swinging mount

5.7.2 Regulatory, Warning and Information Signage

The regulatory and warning signage requirements at each signalized location were reviewed. An inventory of regulatory and warning signage at each intersection can be found in Table 8. The intersections were reviewed for the following types of signs:

Regulatory Signage

Yield (RA-2) – Used for right-turn channels at an at-grade intersection.

Keep Right Sign (RB-25) – Used to indicate that traffic is required to pass to the right of obstructions such as medians or islands.

Warning signage

Checkerboard Sign (WA-8B) – Indicates the termination of a road. It may be used at T intersection, where it should be located directly in line with the path of approaching vehicles on the road that is terminating on the far side of the approach.

Added Lane Sign (WA-35R) – Where two roads converge and merging movements are not required. The sign should be installed before the convergence point and visible from both roads, it may be necessary to use a sign on each road.

Double Arrow Sign (WA-17) – Indicates that traffic is permitted to pass on either side of an island or obstruction in the road.

Object Marker (WA-36) – Used to mark obstructions adjacent to or within the road such as traffic islands. The marker may be used alone or mounted below other signs. The direction of the lines on the sign are used to indicate to the road users in which direction the object should be passed

Yield signs should be provided for all channelized right turns where added lanes are not provided. Yield signs are missing on at least one approach at four intersections:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Murphy's Square Entrance
- Lewin Parkway & Confederation Drive
- Main Street & Mill Road/Brook Street

Keep Right signs should be provided on all raised medians. Keep right signs are missing on one median at two locations, including:

- Lewin Parkway & Mill Road
- Main Street & Riverside Drive/Humber Road

Checkerboard signs should be provided at 3-leg intersections. Checkerboard signs are not provided at the four 3-leg intersections, including:

- Lewin Parkway & Murphy's Square Entrance
- Confederation Drive & West Valley Road
- West Valley Road & O'Connell Drive
- Main Street & West Street

Added Lane signs should be provided where added lanes are provided at channelized right turns. Added lanes are provided without the required signage at two locations, including:

- Confederation Drive & West Valley Road
- O'Connell Drive & University Drive/Mount Bernard Avenue

Double Arrow signs should be provided at all raised islands and Object Markers can be used as an alternative or to supplement Double Arrow signs on raised islands. There are 11 signalized intersections with one or more raised concrete islands, none of which have Double Arrow signs or Object Markers signs. These locations include:

- Lewin Parkway & Griffin Drive
- Lewin Parkway & Mill Road
- Lewin Parkway & Murphy's Square Entrance
- Lewin Parkway & Confederation Drive
- Confederation Drive & West Valley Road
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive & Elizabeth Street
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Main Street & Riverside Drive/Humber Road
- Corporal Pinksen Memorial Drive & Grenfell Drive

Table 8: Inventory of regulatory and warning signage

Intersection	Approach	Street Name	Regulatory		Warning				Notes/Other Signs
			Yield	Keep Right	Checkerboard	Added Lane	Double Arrow	Object Marker	
Lewin Parkway & Griffin Drive	North	Griffin Drive	Y	-	-	-	N	-	-
	South	Unnamed Road	N	-	-	-	N	-	-
	East	Lewin Parkway	Y	-	-	-	N	-	-
	West	Lewin Parkway	N	-	-	-	N	-	-
Lewin Parkway & Mill Road	North	Mill Road	Y	-	-		N	-	Crosswalk Sign, the sign is not a standard crosswalk sign.
	South	Driveway	-	-	-		-	-	-
	East	Lewin Parkway	-	N	-		-	-	Crosswalk Sign
	West	Lewin Parkway	-	Y	-		-	-	-
Lewin Parkway & St. Marks Avenue/Prince George Avenue	North	St. Mark's Avenue	-	-	-	-	-	-	-
	South	Prince George Avenue	-	-	-	-	-	-	-
	East	Lewin Parkway	-	-	-	-	-	-	Truck route sign
	West	Lewin Parkway	-	-	-	-	-	-	-
Lewin Parkway & Murphy's Square Entrance	North	Unnamed Road	N	-	N	-	N	-	-
	East	Lewin Parkway	-	-	-	-	-	-	-
	West	Lewin Parkway	-	-	-	-	-	-	-
Lewin Parkway & Confederation Drive	North	Confederation Drive	-	-	-	-	-	-	-
	South	Confederation Drive	N	-	-	-	N	-	Stop sign is provided instead of yield
	East	Lewin Parkway	Y	-	-	-	N	-	-
	West	Lewin Parkway	Y	-	-	-	N	-	-
Confederation Drive & West Valley Road	North	Confederation Drive	-	-	-	-	-	-	-
	South	Confederation Drive	Y	-	-	-	N	-	-
	East	Driveway	-	-	-	-	-	-	-
	West	West Valley Road	-	-	N	N	N	-	-
West Valley Road & O'Connell Drive	North	O'Connell Drive	-	-	N	-	-	-	-
	East	West Valley Road	-	-	-	-	-	-	-
	West	West Valley Road	-	-	-	-	-	-	-
O'Connell Drive & University Drive/Mount Bernard Avenue	North	University Drive	Y	-	-	-	N	-	-
	South	Mount Bernard Avenue	-	-	-	N	N	-	-
	East	O'Connell Drive	-	-	-	-	-	-	-
	West	O'Connell Drive	-	-	-	-	-	-	-
University Drive - pedestrian crossing near Canada Games Drive	North	University Drive	-	-	-	-	-	-	Crosswalk Sign
	South	University Drive	-	-	-	-	-	-	Crosswalk Sign
O'Connell Drive & Elizabeth Street	North	Driveway	-	-	-	-	-	-	-
	South	Elizabeth Street	Y	-	-	-	N	-	-
	East	O'Connell Drive	Y	-	-	-	N	-	-
	West	O'Connell Drive	-	-	-	-	-	-	-
O'Connell Drive - pedestrian crossing near Union Street	East	O'Connell Drive	-	-	-	-	-	-	-
	West	O'Connell Drive	-	-	-	-	-	-	-
O'Connell Drive - pedestrian crossing near Westmount Road	East	O'Connell Drive	-	-	-	-	-	-	Crosswalk Sign
	West	O'Connell Drive	-	-	-	-	-	-	-
O'Connell Drive - pedestrian crossing near Crestview Avenue	East	O'Connell Drive	-	-	-	-	-	-	-
	West	O'Connell Drive	-	-	-	-	-	-	Crosswalk Sign
Main Street & Mount Bernard Avenue	North	Driveway	-	-	-	-	-	-	-
	South	Mount Bernard Avenue	Y	-	-	-	N	-	-
	East	Main Street	-	-	-	-	-	-	-
	West	Herald Avenue	Y	-	-	-	N	-	-
Main Street & Mill Road/Brook Street	North	Mill Road	Y	-	-	-	N	-	-
	South	Brook Street	N	-	-	-	N	-	-
	East	Main Street	Y	-	-	-	N	-	-
	West	Main Street	-	-	-	-	-	-	Prohibited left turn sign
Main Street & West Street	North	Main Street	-	-	-	-	-	-	-
	South	Main Street	-	-	-	-	-	-	-
	East	West Street	-	-	N	-	-	-	-
Main Street & Riverside Drive/Humber Road	North	Riverside Drive	Y	-	-	-	N	-	-
	South	Main Street	Y	-	-	-	N	-	-
	East	Humber Road	-	N	-	-	-	-	-
	West	Unnamed Road	-	Y	-	-	-	-	-
Broadway & Caribou Road/Herald Avenue	North	Herald Avenue	-	-	-	-	-	-	One Way Sign with Do Not Enter sign
	South	Caribou Road	-	-	-	-	-	-	-
	East	Broadway	-	-	-	-	-	-	-
	West	Broadway	-	-	-	-	-	-	Pedestrian and Bicycle Crossing Ahead Sign with CROSSING tab
Corporal Pinksen Memorial Drive & Grenfell Drive	North	Corporal Pinksen Memorial Drive	Y	-	-	-	N	-	-
	South	Corporal Pinksen Memorial Drive	-	-	-	-	-	-	-
	East	Grenfell Drive	Y	-	-	-	-	-	A Yield Sign is provided where there is no channelized right-turn
	West	Grenfell Drive	Y	-	-	-	N	-	-
Corporal Pinksen Memorial Drive - pedestrian crossing near Wheeler's Road	North	Corporal Pinksen Memorial Drive	-	-	-	-	-	-	Crosswalk Sign
	South	Corporal Pinksen Memorial Drive	-	-	-	-	-	-	Crosswalk Sign

6.0Intersection Improvements

The results of the various assessments were used to determine the improvements required at each signalized location to ensure the traffic signals reflect industry standards and conform to the MUTCD guidelines. Detailed descriptions of the improvements required at each location are detailed in the following sections.

6.1 Lewin Parkway & Griffin Drive

The intersection of the Lewin Parkway and Griffin Drive requires a **complete redesign**. The following improvements are required and should be incorporated in the new design:

- Replace the controller and cabinet.
- Install the new controller on a controller pad.
- Install new traffic poles.
- Redo the underground conduit and wiring.
- Redo the concrete islands.
- Install pedestrian facilities (sidewalks, crosswalks, signal displays and pushbuttons), design the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces.
- Replace the GridSmart video detection system with preformed inductive loops. Install preformed inductive loops on the side street approaches and the main street exclusive left-turn lanes
- Restore the vehicle pre-emption system.
- New phasing to conform to NEMA standards and a new signal timing plan. The split phasing operations on the side streets should be removed.
- Provide both a primary and secondary signal head for the northbound approach (Private Road)
- Provide new signal displays with appropriate indications for the northbound and southbound approaches (Private Road and Griffin Drive).
- Provide duplicate arrow indications on all approaches with arrow indications. Ensure all arrow indications are flashing arrow indications.

6.2 Lewin Parkway & Mill Road

The intersection of the Lewin Parkway and Mill Road requires a **complete redesign**. The following improvements are required and should be incorporated in the new design:

- Replace the controller and cabinet.
- Install the new controller on a controller pad.
- Replace the two older mast arm poles and the older pedestal pole.
- Redo the underground conduit and wiring.
- Redo the concrete islands.
- Redesign the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces.
- Restore the vehicle pre-emption system.
- Replace the GridSmart video detection system with preformed inductive loops. Install preformed inductive loops on the side street approaches and the main street exclusive left-turn lanes.
- New phasing to conform to NEMA standards and a new signal timing plan. The split phasing operations on the side streets should be removed.

- Provide new signal displays with appropriate indications for the northbound and southbound approaches (Mill Road).
- Provide duplicate arrow indications on all approaches with arrow indications. Ensure all arrow indications are flashing arrow indications.

6.3 Lewin Parkway & St. Mark's Avenue/Prince George Avenue

The following improvements are required at the intersection of Lewin Parkway and St. Mark's Avenue/Prince George Avenue:

- Separate the intersection from the Lewin Parkway and Murphy's Square intersection. Replace the traffic controller unit only and keep the existing TS2 cabinet. Perform cabinet maintenance and reprogram the MMU.
- Install preformed inductive loops on the side street approaches and the main street exclusive left-turn lanes.
- Replace the damaged mast arm traffic pole on the southwest corner (Pole 5) and replace the damaged junction box adjacent to the pole.
- Relocate the existing crosswalks to shorten crossing lengths. This will require relocating the three pedestal traffic poles with pushbuttons and pedestrian signals and installing a new pedestal traffic pole on the southwest corner of the intersection. Re-design the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces.
- New phasing to conform to NEMA standards and a new signal timing plan.
- Set all arrow indications to the flashing mode in the controller.

6.4 Lewin Parkway & Murphy's Square Entrance

The following improvements are required at the intersection of Lewin Parkway and Murphy's Square:

- Install a new cabinet and controller to separate the intersection from the Lewin Parkway and St. Mark's Avenue/Prince George Avenue intersection.
- Install the new controller on a controller pad.
- Install preformed inductive loops on the side street approach and the main street exclusive left-turn lane.
- Replace Pole 3 with a 4.0m pedestal pole and install two new signal displays with appropriate indications for the southbound approach (Murphy's Square). The signal displays should be mounted on 4 ft Sentinel arms using flanged plumbizers to provide appropriate spacing.
- Install pedestrian facilities (crosswalks, signal displays and pushbuttons), design the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces. It is recommended that only one crosswalk be provided across the Murphy's Square Entrance approach.
- New phasing to conform to NEMA standards and a new signal timing plan.
- Provide duplicate arrow indications on the eastbound approach (Lewin Parkway). Ensure all arrow indications are flashing arrow indications.

6.5 Lewin Parkway & Confederation Drive

The following improvements are required at the intersection of Lewin Parkway and Confederation Drive:

- Replace the traffic controller unit only and keep the existing TS2 cabinet. Perform cabinet maintenance.

- Install preformed inductive loops on the side street approaches and the main street exclusive left-turn lanes.
- Install new crosswalks on the north, south and east approaches, this will require relocating stop bars.
- Install a new concrete island on the northwest corner and redo the existing islands on the southwest and southeast corners.
- Pole 2 should be relocated to the new concrete island on the northwest corner, this may require installing a new mast arm traffic pole if the length of Pole 2 is inadequate for the new location.
- Re-design the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces.
- New phasing to conform to NEMA standards and a new signal timing plan.
- Provide duplicate arrow indications on all approaches with arrow indications. Ensure all arrow indications are flashing arrow indications.

6.6 Confederation Drive & West Valley Road

The intersection of Confederation Drive and West Valley Road requires a **complete redesign**. The only existing equipment that can be salvaged at the existing intersection is the Econolite Cobalt controller and cabinet. The following improvements are required and should be incorporated in the new design:

- Relocate the existing controller and cabinet to a new controller pad.
- Install new traffic poles.
- Install preformed inductive loops on the side street approach and the main street exclusive left-turn lanes.
- Remove the overhead wiring and replace with underground electrical conduit.
- Replace all signal heads to 300mm LED displays, new mounting hardware will be required.
- Provide both a primary and secondary signal head for the eastbound approach (West Valley Road).
- Install pedestrian facilities (sidewalks, crosswalks, signal displays and pushbuttons), design the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces.
- Geometric modification to narrow the Irving Driveway.
- New phasing to conform to NEMA standards and a new signal timing plan.
- Provide duplicate arrow indications on all approaches with arrow indications. Ensure all arrow indications are flashing arrow indications.

6.7 West Valley Road & O'Connell Drive

The intersection of West Valley Road and O'Connell Drive requires a **complete redesign**. The only existing equipment that can be salvaged at the intersection is the Econolite Cobalt controller and cabinet. The following improvements are required and should be incorporated in the new design:

- Relocate the existing controller and cabinet to a new controller pad.
- Install preformed inductive loops on the side street approach and the main street exclusive left-turn lanes.
- Remove the overhead wiring and replace with underground electrical conduit and replace the existing underground conduit and wiring.
- Improve sight distance at the northbound approach (O'Connell Drive).

- Relocate the crosswalk crossing West Valley Road to the west approach and install a new crosswalk on the O'Connell Drive approach, design the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces.
- Provide both a primary and secondary signal head for each approach, this will require new traffic poles.
- New phasing to conform to NEMA standards and a new signal timing plan.
- Provide duplicate arrow indications on all approaches with arrow indications. Ensure all arrow indications are flashing arrow indications.

6.8 O'Connell Drive & University Drive/Mount Bernard Avenue

The intersection of O'Connell Drive and University Drive/Mount Bernard Avenue requires a **complete redesign**. The following improvements are required and should be incorporated in the new design:

- Replace the traffic controller unit only and keep the existing TS2 cabinet. Perform cabinet maintenance and replace the MMU.
- Install new traffic poles.
- Redo the underground conduit and wiring.
- Redo the concrete islands.
- Install preformed inductive loops on the side street approaches and the main street exclusive left-turn lanes.
- Replace all signal heads to 300mm LED displays, new mounting hardware will be required.
- Re-design the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces.
- New phasing to conform to NEMA standards and a new signal timing plan.
- Provide duplicate arrow indications on all approaches with arrow indications. Ensure all arrow indications are flashing arrow indications.

6.9 University Drive – pedestrian crossing near Canada Games Drive

The following improvements are required at the signalized pedestrian crossing on University Drive near Canada Games Drive:

- Install a new controller and cabinet.
- Install the new controller on a controller pad. The structural integrity of the pole to which the controller is currently mounted should be reviewed, the pole may have to be replaced.
- Provide both a primary and secondary signal head for each approach.
- Remove the overhead wiring and replace with underground electrical conduit.
- Re-design the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces. The existing pedestrian displays with countdown modules do not need to be replaced, however, this may require relocating the mast arms traffic poles.

6.10 O'Connell Drive & Elizabeth Street

The intersection of O'Connell Drive and Elizabeth Street requires a **complete redesign**. The only existing equipment that can be salvaged at the intersection is the cabinet and the two newer mast arm traffic poles. The following improvements are required and should be incorporated in the new design:

- Replace the traffic controller unit only and keep the existing TS2 cabinet. Perform cabinet maintenance.

- Relocate the existing cabinet to a controller pad.
- Install new poles to replace the older mast arm traffic poles (Poles 1 and 3) and the newer pedestal pole (Pole 5). The existing pedestal pole is too short to mount traffic signal displays and pedestrian displays.
- Remove the overhead wiring and replace with underground electrical conduit and replace the existing underground conduit and wiring.
- Redo concrete islands and install a new concrete island on the southwest corner.
- Install preformed inductive loops on the side street approaches and the main street exclusive left-turn lanes.
- Re-design the pedestrian facilities to be fully accessible with APS pushbuttons and proper placement of detectable warning surfaces. Ensure pedestrian signal displays and pushbuttons are provided for all crosswalks.
- New phasing to conform to NEMA standards and a new signal timing plan.
- Provide duplicate arrow indications on all approaches with arrow indications. Ensure all arrow indications are flashing arrow indications.

6.11 O'Connell Drive – pedestrian crossing near Union Street

The signalized pedestrian crossing on O'Connell Drive near Union Street requires a **complete redesign**. The only existing equipment that can be salvaged are the mast arm traffic poles. The following improvements are required and should be incorporated in the new design:

- Install a new controller and cabinet.
- Install the new controller on a controller pad. The structural integrity of the pole to which the controller is currently mounted should be reviewed, the pole may have to be replaced.
- Remove the overhead wiring and replace with underground electrical conduit.
- Re-design the pedestrian facilities to be fully accessible with pedestrian signal heads to LED displays with countdown modules, APS pushbuttons and detectable warning surfaces. This may require relocating the existing traffic poles.
- Replace all signal heads to 300mm LED displays, new mounting hardware will be required.
- Relocate the stop bars to provide a minimum distance of 15 metres between the stop bar and the traffic signals.

6.12 O'Connell Drive – pedestrian crossing near Westmount Road

The signalized pedestrian crossing on O'Connell Drive near Westmount Road requires a **complete redesign**. The following improvements are required and should be incorporated in the new design:

- Install a new controller and cabinet.
- Install the new controller on a controller pad.
- Install new traffic poles.
- Remove the overhead wiring and replace with underground electrical conduit.
- Re-design the pedestrian facilities to be fully accessible with pedestrian signal heads to LED displays with countdown modules, APS pushbuttons and detectable warning surfaces.
- Replace all signal heads to 300mm LED displays, new mounting hardware will be required.
- Relocate the stop bars to provide a minimum distance of 15 metres between the stop bar and the traffic signals.

6.13 O'Connell Drive – pedestrian crossing near Crestview Avenue

The signalized pedestrian crossing on O'Connell Drive near Crestview Avenue requires a **complete redesign**. When redesigning the intersection, consideration should be given to relocating the crosswalk to French's Road. The following improvements are required and should be incorporated in the new design:

- Install a new controller and cabinet.
- Install the new controller on a controller pad.
- Install new traffic poles.
- Remove the overhead wiring and replace with underground electrical conduit and replace the existing underground conduit and wiring.
- Re-design the pedestrian facilities to be fully accessible with pedestrian signal heads to LED displays with countdown modules, APS pushbuttons and detectable warning surfaces.
- Replace all signal heads to 300mm LED displays, new mounting hardware will be required.
- Relocate the stop bars to provide a minimum distance of 15 metres between the stop bar and the traffic signals.

6.14 Main Street & Mount Bernard Avenue

The following improvements are required at the intersection of Main Street and Mount Bernard Avenue:

- Perform cabinet maintenance.
- Restore the vehicle pre-emption system.
- Install preformed inductive loops on the side street approaches and the main street exclusive left-turn lanes.
- Redo wiring.
- Install pedestrian pushbutton signage.
- New phasing to conform to NEMA standards and a new signal timing plan.
- Set all arrow indications to the flashing mode in the controller.

6.15 Main Street & Mill Road/Brook Street

The following improvements are required at the intersection of Main Street and Mill Road/Brook Street:

- Relocate existing controller and cabinet to a new controller pad. Perform cabinet maintenance and install new locking system on the cabinet. The structural integrity of the pole to which the controller is currently mounted should be reviewed, the pole may have to be replaced.
- Redo the existing island on the southeast corner of the intersection.
- Restore the vehicle pre-emption system.
- Install preformed inductive loops on the side street approaches and the main street exclusive left-turn lanes.
- Re-design the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces.
- New phasing to conform to NEMA standards and a new signal timing plan. Protected left turn phases are provided for the northbound (Brook Street) and southbound (Mill Road) approaches while the approaches do no have exclusive left turn lanes; the protected left turn phase for the northbound approach should be removed and a lead phase should be provided for the southbound approach.

6.16 Main Street & West Street

The intersection of Main Street & West Street requires a **complete redesign**. The following improvements are required and should be incorporated in the new design:

- Install a new controller and cabinet.
- Install the new controller on a controller pad.
- Redo underground conduit and wiring
- Install preformed inductive loops on the side street approach.
- Re-design the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces.
- Provide both a primary and secondary signal head for each approach. This will require new pedestal poles.
- Install new signal displays with the appropriate indications for the westbound approach (West Street). The signal displays should be mounted on 4 ft Sentinel arms using flanged plumbizers to provide appropriate spacing.
- New phasing to conform to NEMA standards and a new signal timing plan.

6.17 Main Street & Riverside Drive/Humber Road

The following improvements are required at the intersection of Main Street and Riverside Drive/Humber Road:

- Install a new controller and cabinet.
- Install the new controller on a controller pad. The structural integrity of the pole to which the controller is currently mounted should be reviewed, the pole may have to be replaced.
- Install preformed inductive loops on the side street approaches and the main street exclusive left-turn lanes.
- Install pedestrian pushbutton signage.
- New phasing to conform to NEMA standards and a new signal timing plan.
- Provide duplicate arrow indications on all approaches with arrow indications. Ensure all arrow indications are flashing arrow indications.

The intersection should eventually be reviewed to improve accessibility, this would likely require a full re-design of the pedestrian facilities.

6.18 Broadway & Caribou Road/Herald Avenue

The intersection of Broadway & Caribou Road/Herald Avenue requires a **complete redesign**. The existing mast arm pole can be salvaged. The following improvements are required and should be incorporated in the new design:

- Relocate the existing controller and cabinet to a new controller pad.
- Restore the vehicle pre-emption system.
- Install new mast arm traffic poles for Poles 2 and 3.
- Redo the underground conduit and wiring.
- Install preformed inductive loops on the side street approaches.
- Re-design the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces.

- Provide both a primary and secondary signal head for the northbound (Caribou Road) and southbound (Herald Avenue) approaches.
- New phasing to conform to NEMA standards and a new signal timing plan.
- Provide duplicate arrow indications on all approaches with arrow indications. Ensure all arrow indications are flashing arrow indications.

6.19 Corporal Pinksen Memorial Drive & Grenfell Drive

The following improvements are required at the intersection of Corporal Pinksen Memorial Drive & Grenfell Drive:

- Install a new controller and cabinet.
- Replace the GridSmart video detection system with preformed inductive loops. Install preformed inductive loops on the side street approaches and the main street exclusive left-turn lanes
- Restore the vehicle pre-emption system.
- Install pedestrian pushbutton signage.
- New phasing to conform to NEMA standards and a new signal timing plan.

The intersection should eventually be reviewed to improve accessibility, this would likely require a full re-design of the pedestrian facilities.

6.20 Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road

Complete redesign

The signalized pedestrian crossing on Corporal Pinksen Memorial Drive near Wheeler's Road requires a complete redesign. The existing signal installation is configured as a midblock pedestrian crossing, since the crossing is located at an intersection it should be re-designed properly as a half signal.

The following improvements are required and should be incorporated in the new design:

- Install a new controller and cabinet.
- Install the new controller on a controller pad. The structural integrity of the pole to which the controller is currently mounted should be reviewed, the pole may have to be replaced.
- The two poles are mounted on conversion plates, replace the existing pole bases to match the poles.
- Provide both a primary and secondary signal head for each approach.
- Re-design the pedestrian facilities to be fully accessible with APS pushbuttons and detectable warning surfaces.
- Relocate the crosswalk on the Wheeler's Road approach to provide a 1.0 metre setback from the adjacent travel lane.
- Relocate the stop bars to provide a minimum distance of 15 metres between the stop bar and the traffic signals.

7.0Cost Estimates

Class "D" cost estimates were developed to upgrade each of the 20 signalized locations based on the proposed improvements detailed in Section 6.0. All cost estimates include a 25 percent contingency and 15 percent engineering (preliminary and detailed design work). The cost estimates do not include property acquisitions, utility pole relocations, topographic survey or construction phase services. The estimated costs for each intersection are shown in Table 9, the total cost to upgrade all 20 signalized locations is estimated at approximately $4,614,375 plus harmonized sales tax (HST).

Table 9: Cost estimates for intersection improvements

Signalized Location	Estimated Cost	Contingency (25%)	Engineering (15%)	Total Cost
Lewin Parkway & Griffin Drive	$ 360,000	$ 90,000	$ 67,500	**$ 517,500**
Lewin Parkway & Mill Road	$ 290,000	$ 72,500	$ 54,375	**$ 416,875**
Lewin Parkway & St. Mark's Avenue/Prince George Avenue	$ 110,000	$ 27,500	$ 20,625	**$ 158,125**
Lewin Parkway & Murphy's Square Entrance	$ 130,000	$ 32,500	$ 24,375	**$ 186,875**
Lewin Parkway & Confederation Drive	$ 160,000	$ 40,000	$ 30,000	**$ 230,000**
Confederation Drive & West Valley Road	$ 230,000	$ 57,500	$ 43,125	**$ 330,625**
West Valley Road & O'Connell Drive	$ 170,000	$ 42,500	$ 31,875	**$ 244,375**
O'Connell Drive & University Drive/Mount Bernard Avenue	$ 300,000	$ 75,000	$ 56,250	**$ 431,250**
University Drive – pedestrian crossing near Canada Games Drive	$ 70,000	$ 17,500	$ 13,125	**$ 100,625**
O'Connell Drive & Elizabeth Street	$ 230,000	$ 57,500	$ 43,125	**$ 330,625**
O'Connell Drive – pedestrian crossing near Union Street	$ 100,000	$ 25,000	$ 18,750	**$ 143,750**
O'Connell Drive – pedestrian crossing near Westmount Road	$ 120,000	$ 30,000	$ 22,500	**$ 172,500**
O'Connell Drive – pedestrian crossing near Crestview Avenue	$ 110,000	$ 27,500	$ 20,625	**$ 158,125**
Main Street & Mount Bernard Avenue	$ 90,000	$ 22,500	$ 16,875	**$ 129,375**
Main Street & Mill Road/Brook Street	$ 90,000	$ 22,500	$ 16,875	**$ 129,375**
Main Street & West Street	$ 170,000	$ 42,500	$ 31,875	**$ 244,375**
Main Street & Riverside Drive/Humber Road	$ 110,000	$ 27,500	$ 20,625	**$ 158,125**
Broadway & Caribou Road/Herald Avenue	$ 210,000	$ 52,500	$ 39,375	**$ 301,875**
Corporal Pinksen Memorial Drive & Grenfell Drive	$ 50,000	$ 12,500	$ 9,375	**$ 71,875**
Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road	$ 110,000	$ 27,500	$ 20,625	**$ 158,125**
Total Costs for Improvements	$ 3,210,000	$ 802,500	$ 601,875	**$ 4,614,375**

8.0Improvement Priority Ranking and Implementation Plan

A priority ranking system was developed to rank the 20 signalized locations in order to identify which locations should be upgraded based on a number of priorities including:

- Signal Displays:
  - Presence of conflicts
  - Visibility requirements
  - Improper signal display configurations (no secondary signal head is provided or improper signal indications are provided)
- Controller and Cabinet:
  - Controller and/or cabinet do not meet NEMA standards
  - Controller vintage is outdated (Econolite ASC/2 or Naztec Model 980 NEMA)
- Traffic Poles:
  - Condition of poles (very poor or poor condition)
  - Presence of damaged poles or poles with drilled holes
- Pedestrian System:
  - Lack of pedestrian facilities

- System completeness (lack of pedestrian pushbuttons, pedestrian displays and/or crosswalks)
- Pedestrian pushbuttons are not accessible

Priorities in each category were allocated a point value for a maximum of 100 points. The point allocations for each category and results of the priority ranking are shown in Table 10. Signalized locations ranking with the highest points should be prioritized.

Table 10: Priority ranking

Categories	Signal Displays			Controller and Cabinet		Traffic Poles			Pedestrian System			Point Totals	Priority Rank
Priorities	Presence of Conflict	Does Not Meet Visibility Requirements	Improper Signal Display Configurations	Non-NEMA Controller and/or Cabinet	Outdated Controller Vintage	Very Poor Condition	Poor Condition	Presence of Damage or Holes	No Facilities	System is Incomplete	Pushbuttons are not Accessible		
Point Allocation	20	15	10	10	5	15	10	5	25	15	10	**100**	
Maximum Points per Category	45			15		15			25				
Main Street & West Street	20	15	10	10	5	-	-	-	-	15	-	**75**	**1**
Lewin Parkway & Griffin Drive	-	-	10	-	5	15	-	-	25	-	-	**55**	**2**
Confederation Drive & West Valley Road	-	-	10	-	-	-	10	-	25	-	-	**45**	**3**
Lewin Parkway & Mill Road	-	-	10	-	5	15	-	-	-	15	-	**45**	**3**
O'Connell Drive & University Drive/Mount Bernard Avenue	-	-	10	-	5	15	-	-	-	-	10	**40**	**4**
Main Street & Riverside Drive/Humber Road	-	15	-	-	5	-	-	5	-	-	10	**35**	**5**
O'Connell Drive – pedestrian crossing near Westmount Road	-	-	-	10	-	15	-	-	-	-	10	**35**	**5**
O'Connell Drive – pedestrian crossing near Crestview Avenue	-	-	-	10	-	15	-	-	-	-	10	**35**	**5**
Broadway & Caribou Road/Herald Avenue	-	-	10	-	-	-	-	5	-	15	-	**30**	**6**
O'Connell Drive & Elizabeth Street	-	-	-	-	5	-	10	-	-	15	-	**30**	**6**
Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road	-	-	10	-	5	-	-	5	-	-	10	**30**	**6**
Lewin Parkway & Confederation Drive	-	-	-	-	5	-	-	-	-	15	10	**30**	**6**
West Valley Road & O'Connell Drive	-	-	10	-	-	-	-	5	-	-	10	**25**	**7**
University Drive – pedestrian crossing near Canada Games Drive	-	-	10	10	-	-	-	5	-	-	-	**25**	**7**
O'Connell Drive – pedestrian crossing near Union Street	-	-	-	10	-	-	-	5	-	-	10	**25**	**7**
Lewin Parkway & Murphy's Square Entrance	-	-	-	-	-	-	-	-	25	-	-	**25**	**7**
Main Street & Mount Bernard Avenue	-	15	-	-	-	-	-	-	-	-	10	**25**	**7**
Lewin Parkway & St. Mark's Avenue/Prince George Avenue	-	-	-	-	5	-	-	5	-	-	10	**20**	**8**
Main Street & Mill Road/Brook Street	-	-	-	-	-	-	-	5	-	-	10	**15**	**9**
Corporal Pinksen Memorial Drive & Grenfell Drive	-	-	-	-	5	-	-	-	-	-	-	**5**	**10**

An implementation plan was developed based on the priority ranking exercise. The implementation plan, shown in Table 11, assumes a capital cost budget of approximately $1,000,000 plus HST per year over five years and a maximum of five intersections per year.

Table 11: 5-year implementation plan

Implementation Year	Priority Rank	Signalized Location	Intersection Cost	Total Cost per Year
1	1	Main Street & West Street	$ 244,375	$1,092,500
	2	Lewin Parkway & Griffin Drive	$ 517,500	
	3	Confederation Drive & West Valley Road	$ 330,625	
2	3	Lewin Parkway & Mill Road	$ 416,875	$1,006,250
	4	O'Connell Drive & University Drive/Mount Bernard Avenue	$ 431,250	
	5	Main Street & Riverside Drive/Humber Road	$ 158,125	
3	5	O'Connell Drive – pedestrian crossing near Westmount Road	$ 172,500	$ 963,125
	5	O'Connell Drive – pedestrian crossing near Crestview Avenue	$ 158,125	
	6	Broadway & Caribou Road/Herald Avenue	$ 301,875	
	6	O'Connell Drive & Elizabeth Street	$ 330,625	
4	6	Corporal Pinksen Memorial Drive – pedestrian crossing near Wheeler's Road	$ 158,125	$ 876,875
	6	Lewin Parkway & Confederation Drive	$ 230,000	
	7	West Valley Road & O'Connell Drive	$ 244,375	
	7	University Drive – pedestrian crossing near Canada Games Drive	$ 100,625	
	7	O'Connell Drive – pedestrian crossing near Union Street	$ 143,750	
5	7	Lewin Parkway & Murphy's Square Entrance	$ 186,875	$ 675,625
	7	Main Street & Mount Bernard Avenue	$ 129,375	
	8	Lewin Parkway & St. Mark's Avenue/Prince George Avenue	$ 158,125	
	9	Main Street & Mill Road/Brook Street	$ 129,375	
	10	Corporal Pinksen Memorial Drive & Grenfell Drive	$ 71,875	

9.0Communications Assessment

A communications assessment was completed to identify how to provide communications capabilities to each of the 20 signalized locations in the City in order to implement an Advance Traffic Management Systems (ATMS). The primary benefit of an ATMS is to improve mobility, safety and the productivity of transportation systems by providing the ability to connect a traffic signal controller to intelligent networks. The communications assessment included the following components:

1. Assessing methods and technologies available and identifying how to provide ethernet communications to each intersection.
2. Developing cost estimates for the capital and maintenance costs associated with providing ethernet communications at each intersection and the required software.
3. Identifying zones in which intersections should be coordinated.

9.1 Communications System Software

ATMS provide the ability to connect traffic signal controllers to intelligent networks, and these systems allow for coordination and flexible timing and phasing of traffic signals and enhanced data collection and analysis. Manufacturers of traffic management products have developed a variety of systems, all of which include similar features such as:

- Graphical user interface systems
- Provision of real-time information
- Map support
- Time/space diagrams
- System and operational reports
- Maintenance alerts through text or email

The controller and equipment assessment identified that the majority of existing controllers in the City are Econolite Canada controllers. In recent traffic signal upgrades, the City has installed Econolite

Canada's 'Cobalt' traffic controller and Econolite cabinets. Econolite Canada offers 'Centracs 2.0' as an Advance Traffic Management System. It is recommended that the City adopt this software to maintain consistency in traffic signal hardware and avoid any incompatibilities between software and hardware. The datasheet for the Centracs 2.0 ATMS can be found in Appendix F.

The basic software provides an intersection control and traffic management software platform. Some functions include, but are not limited to:

- Programming of intersection controller databases.
- Upload/download of the programmable database to/from the device.
- Automatic email or text message alerts upon detection of problems with the system or any devices. Alert notifications consist of three priority levels, including informational, warning and critical.
- Systems analysis and engineering tools including interface to third party traffic plan optimization software, time-space diagrams, split monitor displays, traffic system and operational analysis reports, traffic responsive reports and raw detector reports.

The Centracs ATMS can also be supplemented by various Intelligent Transportation System (ITS) modules all which are integrated seamlessly into the single user interface and simply activated by a product key. These include:

- Traffic Monitoring and Surveillance – Combines transportation management with video surveillance to improve operations.
- Adaptive Traffic Control – Samples traffic data in real-time and uses this data to dynamically adjust offsets and splits to accommodate changing traffic conditions.
- Data Collection Management System – Turns Autoscope and RTMS sensors into virtual count stations that gather continuous traffic data.
- Maintenance Management System – Maintenance and asset management tools.
- Interagency Communications and Sharing – Provides the ability to share data and manage arterial traffic across agency boundaries.
- Travel Times – Travel time and speed displays for agencies using BlueTOAD devices for origin-destination data.
- Dynamic Message Sign Management – Provides direct and instantaneous control to update and display valuable traveler information messages.
- Advanced Measures of Effectiveness – Graphical reports that combine detector date with controller state information to provide traffic engineers with a new set of analytical tools for diagnosing timing problems and optimizing traffic.

9.2 Communications and Device Support

The key to a successful ATMS system is provide robust, dependable communications to controllers. Centracs 2.0 supports fiber optics, twisted-pair, leased lines and wireless communications media. In the past, communications capabilities were typically provided at intersections by installing conduit and running communications cables from a utility pole. This method requires civil works and can be costly to implement at existing intersections. Advancements in technology have led to more sophisticated wireless systems using wireless internet or cellular data.

Through discussions with Econolite Canada and Bell, the City's communications provider, an Access Point Network (APN) was identified as the City's most cost-effective solution to provide communication capabilities at all intersections. An APN is a private network provisioned by cellular companies that is isolated from other networks and cellular traffic. The City should use a secure APN with static IP addresses. The network provided by Bell Mobility includes the Bell Control Centre powered by Jasper, a platform that allows the user to monitor and manage modems in real time. The product datasheet for the Bell Control Centre can be found in Appendix F.

Communications will be provided at each traffic controller through the use of modems that use SIM card technology. The modems can easily be installed inside the cabinet. Microhard VIP4G modems should be used, these modems are a product both approved by Econolite Canada and provided by Bell Mobility. The modems include the Microhard VIP modem management software and Microhard NMS software. The product datasheet for the Microhard VIP4G modem can be found in Appendix F.

The installation of these modems consists of placing and securing the modem inside the cabinet and programming the modem. The modems are simply connected to a power source and connected to the controller unit using either Ethernet, USB or RS232 cables. Intersections may require a small external antenna if the cellular signal is not sufficient inside the cabinet.

9.3 Coordination Zones

With communications capabilities in place, the City will have the ability to coordinate intersections. Coordination consists of synchronizing multiple intersections to enhance the operation of one or more directional movements in a corridor. The intersections are synchronized using offsets, which represent the time relationship between the reference point of coordinated phases and a defined master reference (master intersection).

The Synchro Studio (Version 10) software was used to identify coordination zones, further detail about the Synchro models is provided in Section 10.0. Three zones were identified, the zones are shown in

- Zone 1: Lewin Parkway from Griffin Drive to Mill Road, and Main Street from Mount Bernard Avenue to Mill Road (4 intersections).
- Zone 2: Lewin Parkway from St. Mark's Avenue/Prince George Avenue to Confederation Drive (3 intersections).
- Zone 3: O'Connell Drive from Elizabeth Street to Mount Bernard Avenue/University Drive (2 intersections).

9.4 Cost Estimates for the Implementation of an ATMS System

Cost estimates were prepared for the provision of communication capabilities at each intersection in the City. The initial cost includes building the network, purchasing SIM cards, modems and external antennas, and installing the modems at each intersection.

Bell Mobility charges a one-time fee to build an APN network based on the number of IP addresses. The cost is estimated at approximately $3,200, for Jasper Private IP environment with up to 61 private static IP addresses.

The cost of a Microhard VIP4G modem is approximately $750. Installation of the modems can be done by the City or by Bell Mobility, the installation fee is estimated at $400 per installation to complete the installation. External antennas may be required where cellular signal is weak inside the controller, an

external mag mount antenna costs approximately $50. An allowance was made for ten external antennae to be purchased. The cost of a SIM card is approximately $3.

The total initial cost to implement a communications network for the 20 signalized locations in the City is approximately $26,760 plus HST.

Private APN network	$	3,200
SIM cards (20 in total)	$	60
Microhard VIP4G modems (20 in total)	$	15,000
External antennas (10 in total)	$	500
Modem installation (20 in total)	$	8,000
Total	**$**	**26,760**

It should be noted that the cost estimate does not include any engineering fees for assistance in coordinating and/or implementing the communications systems should the City require any.

The basic Centracs software provides an intersection control and traffic management software platform capable of meeting all of the City's current needs. Budgetary pricing for a license of the software which can support up to 50 intersections is $78,000 (includes integration and training). A software maintenance package can be purchased for an additional $13,700 per year on a five-year term. The software maintenance package includes additional training for the software every year and subsequent software upgrades.

A typical controller will require approximately 4 GB of cellular data per year, therefore a monthly plan with 500 MB is required for each intersection. There is the possibility to use a monthly pooled plan to share data between intersections and reduce the monthly cost. For the purpose of developing a cost estimate, a plan including 500 MB of cellular data was assumed for each signalized location. A monthly fee of $15 plus HST per modem will apply, for a total monthly fee of $300 plus HST.

10.0 Intersection Performance Analysis

The performance of an intersection can be evaluated using a number of measures of effectiveness. Delay and level of service (LOS), volume-to-capacity ratio (v/c) and vehicle queuing are the primary measures of effectiveness used in traffic analyses.

Delay is defined in the Highway Capacity Manual as the additional travel time experienced by a motor vehicle, pedestrian or cyclist attributable to the presence of traffic control (unsignalized or signalized intersection) and conflicting traffic. Delay is used as the basis to calculate LOS, a qualitative measure used to describe operational conditions based on service measures such as freedom to maneuver, travel time, speed, and traffic interruptions. LOS is expressed as a scale from 'A' to 'F', where LOS A represents free flow conditions or very low delay and LOS F represents delay times that are unacceptable to motorists using the facility. The level of service criteria for unsignalized (stop/yield controlled and roundabouts) and signalized intersections are described in Table 12.

The volume-to-capacity ratio relates the estimated traffic volume (demand volume) to the theoretical maximum volume that could be accommodated (capacity volume/adjusted saturation flow rate). As the v/c ratio approaches 1.0, the movement has reduced ability to accommodate any additional volume of traffic.

Vehicle queuing at intersections is critical to the performance of the network. The 95th percentile queue length is typically used to determine if sufficient vehicle storage is available to maintain efficient traffic flow. The 95th percentile queue length is the length of queue which is exceeded only 5 percent of the time.

Table 12: LOS Criteria signalized and unsignalized intersections

LOS	Level of Service (LOS) Description	Signalized Intersection Control Delay	Unsignalized Intersection Control Delay
A	Very low delay. Majority of through traffic on main street does not stop at all. **(Excellent)**	≤ 10 sec/veh	≤ 10 sec/veh
B	Somewhat higher delay. More vehicles have to stop for red lights. **(Very Good)**	10-20 sec/veh	10-15 sec/veh
C	Higher level of congestion and vehicles wait through more than one signal indication, occasionally backups may develop, however traffic flow is still stable and acceptable. **(Good)**	20-35 sec/veh	15-25 sec/veh
D	Congestion is noticeable and delays may become extensive. Most cars have to wait more than one red light to pass. This threshold is the upper limit for design. **(Satisfactory)**	35-55 sec/veh	25-35 sec/veh
E	Congested conditions. Traffic fills intersection capacity with long queues and delays. Many vehicles need to wait more than one green indication. The LOS is nearing capacity and is unsatisfactory. **(Unsatisfactory)**	55-80 sec/veh	35-50 sec/veh
F	Very congested conditions. Traffic demand exceeds capacity of the intersection with very long queues and delays. The LOS is generally considered to be unacceptable. **(Unacceptable)**	≥ 80 sec/veh	≥ 50 sec/veh

The Synchro Studio (Version 10) software package was used as the primary evaluation tool. Synchro, an analysis and optimization software package, was used to analyze network intersections based on the methodology of the *Highway Capacity Manual* 6th edition (2016) published by the Transportation Research Board.

10.1 Existing Conditions 2017

Synchro models of the 15 signalized intersections were built for the morning (AM) and evening (PM) peak hours of traffic. The models were coded using existing geometry, phasing and timings and traffic volumes to reflect existing conditions. Traffic volumes from 2015 traffic counts were factored to represent 2017 traffic volumes using a background traffic growth rate of 0.5 percent per year to reflect normal increases in traffic. The models were used to assess existing conditions at each intersection.

Results of the Synchro analysis for the AM and PM peak hours of existing conditions, including level of service, average delay per vehicle, volume-to-capacity ratio and 95th percentile queue lengths of each movement at the individual intersections are summarized in Table 13. The detailed Synchro reports can be found in Appendix G.

Results of the Synchro analysis show operational problems at five signalized intersections during the peak hours. Operations at these intersections are discussed below:

Lewin Parkway & Griffin Drive: The eastbound shared through/right movement on the Lewin Parkway operates at LOS E and is at capacity during the AM peak hour. Overall, the signalized intersection operates at an acceptable level of service (LOS D).

All northbound movements (Private Road) operate at LOS F and are over capacity during the PM peak hour. Overall, the signalized intersection operates at LOS E.

West Valley Road & O'Connell Drive: The westbound left turn movement on West Valley Road operates at LOS F and is over capacity during the AM peak hour. Overall, the signalized intersection operates at an acceptable level of service (LOS D).

The westbound left turn movement on West Valley Road also operates at LOS F and is over capacity during the PM peak hour. Overall, the signalized intersection operates at LOS F.

O'Connell Drive & University Drive/Mount Bernard Avenue: The signalized intersection operates at acceptable levels of service during the AM peak hour.

The eastbound and westbound through movements on O'Connell Drive operate at LOS E during the PM peak hour. The westbound through movement is nearing capacity. Overall, the signalized intersection operates at an acceptable level of service (LOS D).

O'Connell Drive & Elizabeth Street: The signalized intersection operates at acceptable levels of service during the AM peak hour.

The northbound and southbound shared left/though movements on Elizabeth Street operate at LOS F during the PM peak hour. The northbound shared left/though movement is over capacity and the southbound shared left/though movement is nearing capacity. Overall, the signalized intersection operates at an acceptable level of service (LOS C).

Broadway & Caribou Road/Herald Avenue: The signalized intersection operates at acceptable levels of service during the AM peak hour.

The westbound through movement on Herald Avenue operates at LOS E during the PM peak hour. Overall, the signalized intersection operates at an acceptable level of service (LOS C).

Table 13: Existing Conditions (2017) - Synchro analysis results

Existing Conditions (2017)												
Intersection		AM Peak Hour					PM Peak Hour					
Street	Movement	Delay/ Veh (s)	APP LOS	MVT LOS	V/C	Queue (m) 95th%ile	Delay/ Veh (s)	APP LOS	MVT LOS	V/C	Queue (m) 95th%ile
Lewin Parkway & Griffin Drive		**44.7**	**D**				**67.1**	**E**			
Lewin Parkway	EB Left - Turn	0.0	E	A	0.00	0.0	17.0	D	B	0.00	1.0
	EB Through	78.8		E	1.00	126.0	40.2		D	0.66	72.2
	EB Right - Turn										
	WB Left - Turn	28.9	C	C	0.61	33.5	24.6	C	C	0.53	37.7
	WB Through	35.2		D	0.46	49.3	43.4		D	0.71	77.7
	WB Right - Turn	3.3		A	0.20	3.2	6.7		A	0.37	13.2
Griffin Drive	NB Left - Turn	22.2	C	C	0.50	28.8	157.2	F	F	1.24	142.1
	NB Through										
	NB Right - Turn										
	SB Left - Turn	37.7	D	D	0.61	73.0	31.1	C	C	0.35	42.6
	SB Through										
	SB Right - Turn										
Lewin Parkway & Mill Road		**27.0**	**C**				**29.5**	**C**			
Lewin Parkway	EB Left - Turn	34.1	C	C	0.73	64.6	39.6	D	D	0.79	65.6
	EB Through										
	EB Right - Turn										
	WB Left - Turn	27.0	C	C	0.62	42.1	24.1	C	C	0.53	32.5
	WB Through	22.4		C	0.49	78.0	28.5		C	0.71	113.2
	WB Right - Turn										
Mill Road	NB Left - Turn	26.6	B	C	0.10	13.9	29.3	B	C	0.29	37.3
	NB Through	9.4		A	0.29	13.8	6.2		A	0.37	16.7
	NB Right - Turn										
	SB Left - Turn	33.1	C	C	0.07	4.6	30.9	C	C	0.24	16.9
	SB Through										
	SB Right - Turn										
Lewin Parkway & St. Marks Avenue/Prince George Avenue		**23.5**	**C**				**26.1**	**C**			
Lewin Parkway	EB Left - Turn	24.8	C	C	0.41	33.3	31.6	C	C	0.62	45.7
	EB Through	31.0		C	0.28	37.5	32.8		C	0.42	55.3
	EB Right - Turn										
	WB Left - Turn	17.9	B	B	0.28	18.1	21.3	C	C	0.42	27.8
	WB Through	20.3		C	0.47	25.4	24.6		C	0.54	40.6
	WB Right - Turn										
Prince George Avenue	NB Left - Turn	16.9	B	B	0.06	8.2	16.6	C	B	0.03	5.6
	NB Through	30.9		C	0.22	35.5	32.5		C	0.32	49.6
	NB Right - Turn	1.4		A	0.15	1.9	6.1		A	0.25	14.6
St. Marks Avenue	SB Left - Turn	18.4	C	B	0.20	25.8	18.9	C	B	0.25	29.8
	SB Through	29.9		C	0.46	60.5	27.8		C	0.45	58.3
	SB Right - Turn										
Lewin Parkway & Murphy's Square Entrance		**16.7**	**B**				**17.6**	**B**			
Lewin Parkway	EB Left - Turn	9.9	A	A	0.10	5.4	9.9	A	A	0.15	7.3
	EB Through	9.9		A	0.24	21.6	9.8		A	0.35	31.9
	WB Through	18.4	B	B	0.46	67.7	17.0	B	B	0.50	69.8
	WB Right - Turn										
Murphy's Square Entrance	SB Left - Turn	32.2	C	C	0.29	43.0	41.4	C	D	0.66	99.4
	SB Right - Turn	9.5		A	0.08	7.9	5.8		A	0.31	16.5
Lewin Parkway & Confederation Drive		**22.6**	**C**				**22.9**	**C**			
Lewin Parkway	EB Left - Turn	16.9	B	B	0.29	19.8	16.0	C	B	0.22	19.5
	EB Through	19.7		B	0.41	40.8	27.4		C	0.62	80.6
	EB Right - Turn										
	WB Left - Turn	17.9	C	B	0.38	29.0	15.4	C	B	0.16	10.9
	WB Through	29.2		C	0.55	68.6	26.7		C	0.41	51.4
	WB Right - Turn										
Confederation Drive	NB Left - Turn	19.5	B	B	0.26	25.8	25.5	C	C	0.55	61.7
	NB Through	15.7		B	0.12	11.1	10.5		B	0.26	18.4
	NB Right - Turn										
	SB Left - Turn	17.1	B	B	0.05	7.3	17.9	B	B	0.13	13.3
	SB Through	26.5		C	0.03	6.1	27.8		C	0.13	17.1
	SB Right - Turn	0.3		A	0.07	0.0	5.7		A	0.32	6.6

Existing Conditions (2017) - Continued											
Intersection		AM Peak Hour					PM Peak Hour				
Street	Movement	Delay/ Veh (s)	APP LOS	MVT LOS	V/C	Queue (m) 95th%ile	Delay/ Veh (s)	APP LOS	MVT LOS	V/C	Queue (m) 95th%ile
Confederation Drive & West Valley Road		**14.0**	**B**				**14.0**	**B**			
West Valley Road	EB Left - Turn	19.2	B	B	0.40	43.0	21.4	B	C	0.52	58.1
	EB Through										
	EB Right - Turn	4.2		A	0.14	6.3	3.5		A	0.39	8.7
Irving Driveway	WB Left - Turn	0.2	A	A	0.04	0.0	1.0	A	A	0.07	0.0
	WB Through										
	WB Right - Turn										
Confederation Drive	NB Left - Turn	18.2	B	B	0.58	53.9	13.6	B	B	0.30	22.7
	NB Through	12.0		B	0.08	9.8	11.9		B	0.06	7.6
	NB Right - Turn										
	SB Left - Turn	23.9	A	C	0.04	4.8	24.4	B	C	0.08	8.5
	SB Through	24.4		C	0.11	14.6	30.3		C	0.48	44.9
	SB Right - Turn	6.2		A	0.46	18.2	6.6		A	0.57	12.4
West Valley Road & O'Connell Drive		**48.0**	**D**				**96.8**	**F**			
West Valley Road	EB Through	35.7	D	D	0.41	71.9	42.1	D	D	0.64	102.6
	EB Right - Turn										
	WB Left - Turn	103.6	F	F	1.12	244.5	274.1	F	F	1.53	262.3
	WB Through	19.0		B	0.16	33.4	21.1		C	0.30	54.9
O'Connell Drive	NB Left - Turn	20.0	A	B	0.10	20.7	20.5	A	C	0.14	29.4
	NB Right - Turn	4.2		A	0.58	11.5	5.7		A	0.69	16.3
O'Connell Drive & University Drive/Mount Bernard Avenue		**31.2**	**C**				**38.4**	**D**			
O'Connell Drive	EB Left - Turn	30.6	C	C	0.68	52.4	37.6	D	D	0.70	71.3
	EB Through	50.1		D	0.72	93.5	57.5		E	0.83	140.5
	EB Right - Turn	6.9		A	0.33	11.0	3.7		A	0.15	6.2
	WB Left - Turn	28.9	C	C	0.66	52.4	24.5	D	C	0.50	38.5
	WB Through	52.7		D	0.77	97.4	70.4		E	0.93	136.7
	WB Right - Turn	6.6		A	0.39	10.0	8.6		A	0.23	11.6
University Drive	NB Left - Turn	19.2	C	B	0.19	19.3	19.4	D	B	0.21	25.0
	NB Through	36.8		D	0.60	88.8	46.2		D	0.81	114.4
	NB Right - Turn										
Mount Bernard Avenue	SB Left - Turn	21.6	C	C	0.37	26.2	26.4	B	C	0.55	39.7
	SB Through	41.4		D	0.61	76.2	34.0		C	0.30	50.8
	SB Right - Turn	7.2		A	0.43	8.3	5.8		A	0.50	22.0
O'Connell Drive & Elizabeth Street		**15.5**	**B**				**30.6**	**C**			
O'Connell Drive	EB Left - Turn	15.3	B	B	0.33	33.2	13.5	B	B	0.20	26.7
	EB Through										
	EB Right - Turn										
	WB Left - Turn	7.7	A	A	0.34	25.7	8.0	A	A	0.38	33.2
	WB Through										
	WB Right - Turn	1.6		A	0.08	4.3	1.4		A	0.16	6.7
Elizabeth Street	NB Left - Turn	39.3	C	D	0.60	58.9	103.4	E	F	1.02	87.8
	NB Through										
	NB Right - Turn	12.8		B	0.42	27.5	13.8		B	0.40	27.7
Coleman's Driveway	SB Left - Turn	29.3	C	C	0.19	15.8	83.7	E	F	0.95	74.7
	SB Through										
	SB Right - Turn	0.0		A	0.00	0.0	1.8		A	0.06	0.4
Main Street & Mount Bernard Avenue		**22.9**	**C**				**23.2**	**C**			
Main Street	EB Left - Turn	7.4	C	A	0.03	4.2	7.4	C	A	0.03	4.1
	EB Through	34.5		C	0.64	92.0	36.9		D	0.70	102.6
	EB Right - Turn	6.4		A	0.16	10.5	5.8		A	0.20	12.0
	WB Left - Turn	14.4	B	B	0.61	53.6	16.6	C	B	0.65	65.4
	WB Through	26.9		C	0.31	44.1	32.8		C	0.60	86.8
	WB Right - Turn										
Mount Bernard Avenue	NB Left - Turn	25.3	B	C	0.27	26.7	27.1	B	C	0.39	42.0
	NB Through										
	NB Right - Turn	4.6		A	0.34	12.3	4.5		A	0.44	19.5
	SB Through	44.8	D	D	0.62	51.9	41.2	C	D	0.51	51.9
	SB Right - Turn	0.1		A	0.03	0.0	1.1		A	0.10	1.0

Existing Conditions (2017) - Continued											
Intersection		AM Peak Hour					PM Peak Hour				
Street	Movement	Delay/ Veh (s)	APP LOS	MVT LOS	V/C	Queue (m) 95th%ile	Delay/ Veh (s)	APP LOS	MVT LOS	V/C	Queue (m) 95th%ile
Main Street & Mill Road/Brook Street		**17.4**	**B**				**16.8**	**B**			
Main Street	EB Left - Turn	8.6	A	A	0.26	11.8	9.1	B	A	0.31	14.8
	EB Through	10.0		B	0.42	46.3	11.3		B	0.52	69.8
	EB Right - Turn	0.8		A	0.05	1.1	0.1		A	0.02	0.0
	WB Through	25.3	C	C	0.71	87.1	27.2	C	C	0.75	103.6
	WB Right - Turn	0.5		A	0.10	0.4	4.0		A	0.23	11.0
Brook Street	NB Left - Turn	21.1	B	C	0.16	8.0	24.1	B	C	0.32	18.7
	NB Through										
	NB Right - Turn	0.2		A	0.04	0.0	0.4		A	0.07	0.0
Mill Road	SB Left - Turn	36.5	C	D	0.67	43.3	30.4	B	C	0.54	33.1
	SB Through										
	SB Right - Turn	9.0		A	0.45	14.4	8.8		A	0.46	15.7
Main Street & West Street		**18.5**	**B**				**17.8**	**B**			
West Street	WB Left - Turn	16.7	B	B	0.44	64.4	20.7	B	C	0.64	82.6
	WB Right - Turn	3.0		A	0.13	7.8	2.6		A	0.27	6.4
Main Street	NB Through	20.3	C	C	0.32	43.1	20.7	C	C	0.35	51.1
	SB Through	23.8	C	C	0.52	70.2	21.9	C	C	0.42	53.3
Main Street/Riverside Drive & Humber Road		**26.3**	**C**				**22.5**	**C**			
Humber Road	EB Left - Turn	16.9	C	B	0.15	15.3	18.0	C	B	0.25	28.6
	EB Through	31.0		C	0.20	23.6	30.9		C	0.19	26.0
	EB Right - Turn	0.0		A	0.00	0.0	0.0		A	0.01	0.0
	WB Left - Turn	20.6	C	C	0.44	48.3	18.7	C	B	0.31	34.2
	WB Through	29.1		C	0.15	21.1	27.7		C	0.17	22.0
	WB Right - Turn										
Main Street	NB Left - Turn	15.5	B	B	0.01	1.7	15.8	B	B	0.05	6.1
	NB Through	30.7		C	0.18	21.8	32.5		C	0.30	37.5
	NB Right - Turn	6.6		A	0.34	9.6	6.5		A	0.48	16.4
Riverside Drive	SB Left - Turn	15.5	D	B	0.00	1.5	15.4	D	B	0.01	2.6
	SB Through	41.3		D	0.72	83.4	36.0		D	0.63	46.2
	SB Right - Turn										
Broadway & Caribou Road/Herald Avenue		**14.3**	**B**				**26.7**	**C**			
Caribou Road	EB Left - Turn	7.3	A	A	0.07	8.7	7.8	A	A	0.15	10.4
	EB Right - Turn	4.9		A	0.49	19.6	4.9		A	0.48	7.2
Herald Avenue	WB Left - Turn	2.1	C	A	0.05	3.9	1.5	D	A	0.12	6.3
	WB Through	30.5		C	0.39	58.4	56.9		E	0.91	178.0
	WB Right - Turn	7.5		A	0.09	7.9	14.7		B	0.20	20.7
Broadway	SB Through	32.9	C	C	0.20	29.5	33.0	C	C	0.21	33.8
	SB Right - Turn	8.2		A	0.15	9.6	7.4		A	0.19	12.8
Corporal Pinksen Memorial Drive & Grenfell Drive		**20.5**	**C**				**19.4**	**B**			
Grenfell Drive	EB Left - Turn	17.7	B	B	0.18	23.4	17.1	B	B	0.13	15.5
	EB Through	29.5		C	0.06	11.5	29.2		C	0.04	7.6
	EB Right - Turn	0.0		A	0.01	0.0	0.1		A	0.04	0.0
	WB Left - Turn	16.0	B	B	0.00	1.4	16.4	C	B	0.05	6.5
	WB Through	17.4		B	0.04	3.5	24.4		C	0.08	9.1
	WB Right - Turn										
Corporal Pinksen Memorial Drive	NB Left - Turn	16.4	C	B	0.05	8.5	16.1	C	B	0.02	4.9
	NB Through	33.1		C	0.31	40.2	30.5		C	0.14	21.4
	NB Right - Turn	0.3		A	0.07	0.0	0.0		A	0.01	0.0
	SB Left - Turn	16.2	B	B	0.03	5.0	16.0	B	B	0.01	3.5
	SB Through	30.4		C	0.12	17.9	31.9		C	0.22	29.0
	SB Right - Turn	1.1		A	0.15	0.0	3.9		A	0.20	6.3

10.2 New Signal Timing Plans

New signal timing plans were developed to reflect the improvements to the signal timings discussed in Section 4.1 and to optimize operations at each intersection. The timing plans were optimized using the Synchro software. The new signal timing plans for each intersection can be found in Appendix H. It should be noted that the new signal timing plans include the timing improvements for the red and amber clearance intervals, the pedestrian walk intervals and pedestrian clearance intervals. The signal timing plans were implemented on June 26-27th, 2018.

11.0 Operations and Maintenance Program

An operations and maintenance manual was developed for the City's traffic signal system. The Traffic Signals Operations and Maintenance Manual, included in Appendix I, provides guidance for City staff and/or electrical maintenance contractors to develop a program to ensure the traffic signals within the City are properly maintained to industry standards. The manual includes preventative maintenance checklists, intersection inspection checklists, recommendations for the frequency of maintenance and testing of various components as well as guidelines for proper documentation and record keeping.

12.0 Roundabout Feasibility

A brief investigation was conducted at 10 of the 15 signalized intersections to determine the feasibility of converting the intersection to a roundabout. The five signalized intersections along the Lewin Parkway were not included in this exercise since the Lewin Parkway is a provincially owned roadway. The following 10 locations were considered:

1. Confederation Drive & West Valley Road
2. West Valley Road & O'Connell Drive
3. O'Connell Drive & University Drive/Mount Bernard Avenue
4. O'Connell Drive & Elizabeth Street
5. Main Street & Mount Bernard Avenue
6. Main Street & Mill Street/Brook Street
7. Main Street & West Street
8. Main Street & Riverside Drive/Humber Road
9. Broadway & Caribou Road/Herald Avenue
10. Corporal Pinksen Memorial Drive & Grenfell Drive

For each intersection, commentary was provided discussing the benefits and challenges of converting the intersection to a roundabout. At intersections where a roundabout was deemed feasible, an operational analysis of the roundabout was performed to identify the configuration required to accommodate existing traffic volumes and evaluate operations during the AM and PM peak hours. The Junctions 8 ARCADY software was used to analyze roundabouts. ARCADY uses an empirical model based on the application of statistical regression of a large data set of observed roundabout operations in the United Kingdom. The tool is intended to aid designers in selecting the best geometry for a given location and traffic demand.

A conceptual layout was developed for each roundabout based on the results of the operational analysis. Detailed reports of the ARCADY analysis and full size conceptual drawings of the roundabouts can be found in Appendix J and K respectively.

12.1 Benefits of Roundabouts

The two primary benefits of roundabouts relate to ***safety*** and ***traffic operations***. A number of studies have indicated that roundabouts reduce collisions at intersections where stop signs or traffic signals were previously used. Roundabouts, by their geometric configuration, also reduce the severity of collisions – side swipes instead of rear-ends and t-bones. Studies by the Insurance Institute for Highway Safety (IIHS) and the Federal Highway Administration (FHWA) have shown that roundabouts typically result in reductions in overall collisions, reductions in injury collisions, reduction in fatality collisions and reductions in pedestrian collisions (Figure 7).

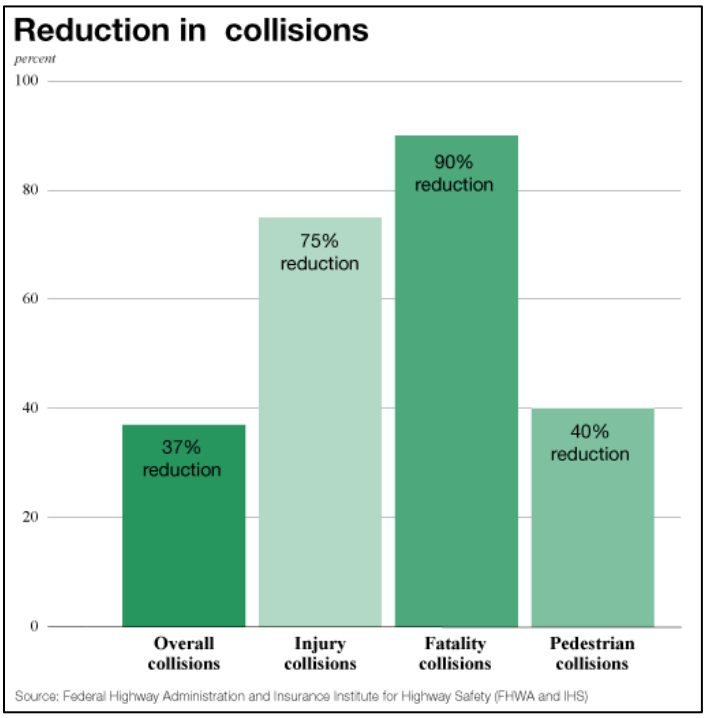


Figure 7: Roundabout reductions in collisions

Roundabouts reduce collisions by forcing vehicles to travel at slower speeds and reducing the number of potential conflict points between vehicles and vehicles and vehicles and pedestrians at the intersection. A comparison of conflict points at a four-leg intersection with and without a roundabout is shown in Figure 8.

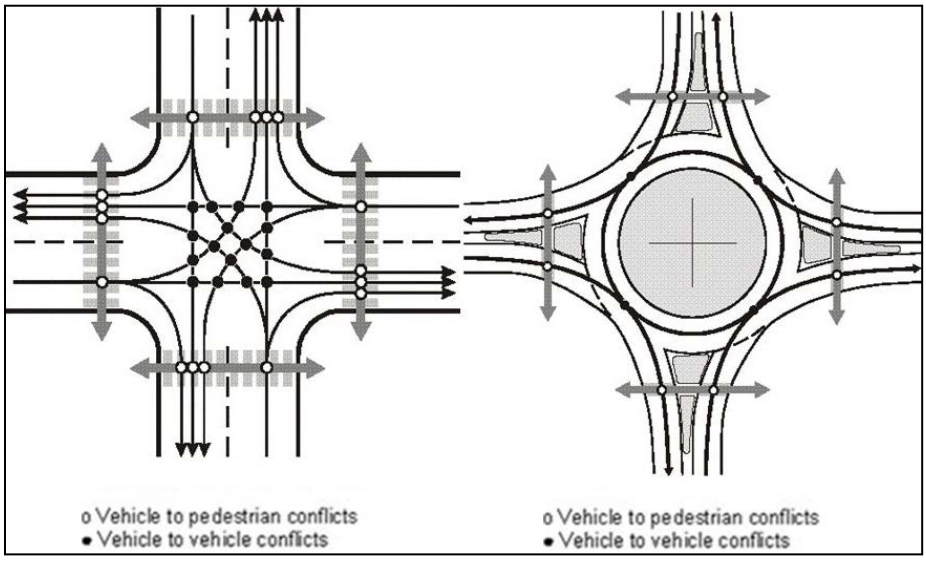


Figure 8: Conflict points at a four-leg intersection

In addition to improving safety, roundabouts also reduce delay and improve traffic flow at intersections. Roundabouts promote flow of traffic, where motorists are not always required to stop to get through the intersection resulting in less congestion on approach roads. Before and after studies by the IIHS have shown that roundabouts can reduce delays by 89 percent and vehicle stops by 56 percent.

Other benefits of roundabouts include:

- Improved aesthetics: Enhancements can be placed on the central island as well as the perimeter of the intersection.
- Reductions in emissions: Roundabouts reduce emission by reductions in delays and vehicle stops.
- Reductions in vehicle noises.
- Improved pedestrian safety: Pedestrians have the right-of-way at roundabouts and vehicles a required to yield to pedestrians. Pedestrians only have to cross lanes one or two lanes with one direction of travel at a time.
- Improved cyclist safety: Cyclists have two options at roundabouts, they can choose to travel with vehicles throughout the roundabout or to travel with pedestrians on the sidewalk.
- Reduced maintenance costs: Roundabouts require less maintenance costs that traffic signals
- Improved efficiency: Roundabouts are more effective in power outages.

12.2 Confederation Drive & West Valley Road

It is feasible to install a roundabout at the intersection of Confederation Drive and West Valley Road. The concept plan shown in Figure 9 includes a single-lane roundabout with a 40-metre inscribed circle diameter. The roundabout would have a right-turn only lane on the O'Connell Drive eastbound approach.

Figure 9: Roundabout concept for Confederation Drive & W Valley Road

The average delay per vehicle, level of service, volume-to-capacity ratio and 95th percentile queues length results for each approach of the roundabout are summarized in Table 14. The roundabout would operate at LOS A in both the AM and PM peak hours.

The existing signalized intersection operates at LOS B during both peak hours. While there are no existing operational problems at the signalized intersection, the roundabout configuration would reduce delay

and improve the level of service during both peak hours. The roundabout reduces the average delay per vehicle by 9.5 seconds during the AM peak hour and by 8.9 seconds during the PM peak hour.

The current configuration of the signalized intersection does not provide signal indications for the Irving Driveway (westbound) approach. This unconventional layout creates safety concerns for vehicles exiting the Irving gas station. These vehicles are required to treat the signalized intersection as a unsignalized intersection and wait for a gap in traffic to enter the intersection. Signal displays for other approaches are not all clearly visible to vehicles on the Irving approach, therefore motorist may not be able to distinguish which approach is receiving a green indication. Converting the intersection to a four-leg roundabout, where the Irving Driveway consists of the westbound approach to the roundabout will eliminate this safety concern.

Table 14: ARCADY analysis results for Confederation Drive & West Valley Road

Existing Conditions 2017									
Intersection		AM Peak Hour				PM Peak Hour			
Street	Movement	Delay/ Veh (s)	APP LOS	V/C	Queue (m) 95th%ile	Delay/ Veh (s)	APP LOS	V/C	Queue (m) 95th%ile
Confederation Drive & West Valley Road		**4.5**	**A**			**5.1**	**A**		
West Valley Road	EB Left - Turn	4.0	A	0.26	7.0	6.6	A	0.52	7.0
	EB Through								
	EB Right - Turn								
Irving Driveway	WB Left - Turn	4.2	A	0.02	7.0	3.8	A	0.01	7.0
	WB Through								
	WB Right - Turn								
Confederation Drive	NB Left - Turn	5.5	A	0.41	7.0	4.3	A	0.22	7.0
	NB Through								
	NB Right - Turn								
	SB Left - Turn	3.6	A	0.05	7.0	3.7	A	0.18	7.0
	SB Through								
	SB Right - Turn								

12.3 West Valley Road & O'Connell Drive

A roundabout is not reasonably feasible at the intersection of West Valley Road and O'Connell Drive. While the intersection experiences poor levels of service and significant queues and could greatly benefit from a roundabout, a significant amount of property acquisition would be required to construct a roundabout. With the presence of residential properties on all corners, houses would need to be demolished to accommodate the construction of a roundabout. The option would be cost prohibitive.

12.4 O'Connell Drive & University Drive/Mount Bernard Avenue

It is feasible to install a roundabout at the intersection of O'Connell Drive and University Drive/Mount Bernard Avenue. The concept plan shown in Figure 10 includes a single-lane roundabout with a 50-metre inscribed circle diameter. The roundabout would have a segregated right-turn by-pass lane on the Mount Bernard Avenue approach (southbound) and a right-turn only lane on the O'Connell Drive eastbound approach.

Figure 10: Roundabout concept for O'Connell Drive & University Drive/Mount Bernard Avenue

The average delay per vehicle, level of service, volume-to-capacity ratio and 95th percentile queues length results for each approach of the roundabout are summarized in Table 15. The roundabout would operate at LOS A in both the AM and PM peak hours.

The existing signalized intersection experiences operates at LOS C during the AM peak hour and LOS D during the PM peak hour. Operational problems are experienced during the PM peak hour, where the eastbound and westbound through movements operate at LOS E. Converting the intersection to a roundabout configuration would significantly improve operations at the intersection. The roundabout reduces the average delay per vehicle by 23.5 seconds during the AM peak hour and by 30.7 seconds during the PM peak hour. With the roundabout the problematic eastbound and westbound through movements will be improved to LOS A and LOS B respectively.

In addition, the roundabout configuration would significantly reduce queues at the intersection. During the PM peak hour, queues on O'Connell Drive would be reduced from approximately 140.0 metres on both the eastbound and westbound approaches to 7.0 and 21.0 metres respectively.

Table 15: ARCADY analysis results for O'Connell Drive & University Drive/Mount Bernard Avenue

Existing Conditions 2017									
Intersection		AM Peak Hour				PM Peak Hour			
Street	Movement	Delay/ Veh (s)	APP LOS	V/C	Queue (m) 95th%ile	Delay/ Veh (s)	APP LOS	V/C	Queue (m) 95th%ile
O'Connell Drive & University Drive/Mount Bernard Avenue		7.7	A			7.7	A		
O'Connell Drive	EB Left - Turn	2.9	A	0.36	7.0	2.8	A	0.36	7.0
	EB Through								
	EB Right - Turn								
	WB Left - Turn	13.5	B	0.74	49.0	11.7	B	0.68	21.0
	WB Through								
	WB Right - Turn								
University Drive	NB Left - Turn	6.9	A	0.43	7.0	11.4	B	0.62	14.0
	NB Through								
	NB Right - Turn								
Mount Bernard Avenue	SB Left - Turn	6.6	A	0.41	7.0	6.3	A	0.37	7.0
	SB Through								
	SB Right - Turn								

12.5 O'Connell Drive & Elizabeth Street

It is feasible to install a roundabout at the intersection of O'Connell Drive and Elizabeth Street. The concept plan shown in Figure 11 includes a multi-lane roundabout with a 50-metre inscribed circle diameter. The roundabout would have two-lane entries and exits on O'Connell Drive and single lane entries on Elizabeth Street and the Coleman's driveway. The roundabout would likely require significant property acquisition on the northwest and southeast corners of the intersection.

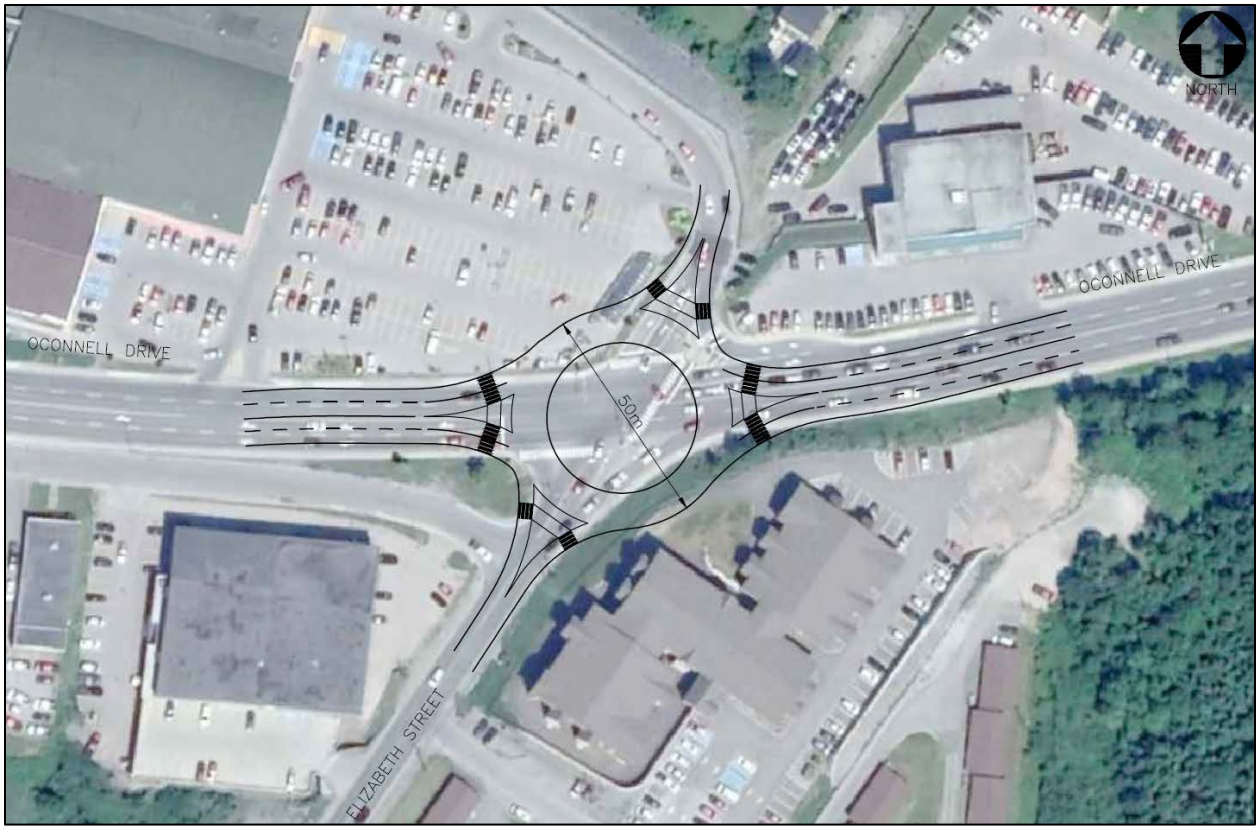


Figure 11: Roundabout concept for O'Connell Drive & Elizabeth Street

The average delay per vehicle, level of service, volume-to-capacity ratio and 95th percentile queues length results for each approach of the roundabout are summarized in Table 16. The roundabout would operate at LOS A in both the AM and PM peak hours.

The existing signalized intersection experiences operates at LOS B during the AM peak hour and LOS C during the PM peak hour. Operational problems are experienced during the PM peak hour, where the shared northbound and southbound through/left-turn movements operate at LOS F. Converting the intersection to a roundabout configuration would significantly improve operations at the intersection. The roundabout reduces the average delay per vehicle by 12.3 seconds during the AM peak hour and by 26.9 seconds during the PM peak hour. With the roundabout the problematic northbound and southbound through/left-turn movements will be improved to LOS A. In addition, the roundabout configuration would significantly reduce queues at the intersection.

Table 16: ARCADY analysis results for O'Connell Drive & Elizabeth Street

Existing Conditions 2017									
Intersection		AM Peak Hour				PM Peak Hour			
Street	Movement	Delay/ Veh (s)	APP LOS	V/C	Queue (m) 95th%ile	Delay/ Veh (s)	APP LOS	V/C	Queue (m) 95th%ile
O'Connell Drive & Elizabeth Street		**3.2**	**A**			**3.7**	**A**		
O'Connell Drive	EB Left - Turn	2.0	A	0.19	7.0	2.1	A	0.17	7.0
	EB Through								
	EB Right - Turn								
	WB Left - Turn	2.2	A	0.26	7.0	2.6	A	0.37	7.0
	WB Through								
	WB Right - Turn								
Elizabeth Street	NB Left - Turn	5.8	A	0.39	7.0	6.0	A	0.40	7.0
	NB Through								
	NB Right - Turn								
Coleman's Driveway	SB Left - Turn	4.2	A	0.06	7.0	6.1	A	0.27	7.0
	SB Through								
	SB Right - Turn								

12.6 Main Street & Mount Bernard Avenue

Constructing a roundabout at the intersection of Main Street and Mount Bernard Avenue is not reasonably feasible. There is insufficient space to construct a roundabout due to the proximity of buildings and parking lots surrounding the intersection and the adjacent Main Street Bridge. A significant amount of property acquisition would be required to construct a roundabout making the option cost prohibitive.

12.7 Main Street & Mill Street/Brook Street

Constructing a roundabout at the intersection of Main Street and Mill Street/Brook Street is not reasonably feasible. There is insufficient space to construct a roundabout due to the proximity of buildings surrounding the intersection and the adjacent Main Street Bridge. A significant amount of property acquisition and building demolition would be required to construct a roundabout, making the option cost prohibitive.

12.8 Main Street & West Street

Constructing a roundabout at the intersection of Main Street and O'Connell is not reasonably feasible. There is insufficient space to construct a roundabout. The Bank of Montreal building and church are located too close to the intersection. A significant amount of property acquisition and building demolition would be required to construct a roundabout, making the option cost prohibitive.

12.9 Main Street & Riverside Drive/Humber Road

It is feasible to install a roundabout at the intersection of Main Street and Riverside Drive/Humber Road. The concept plan shown in Figure 12 includes a single-lane roundabout with a 50-metre inscribed circle diameter.

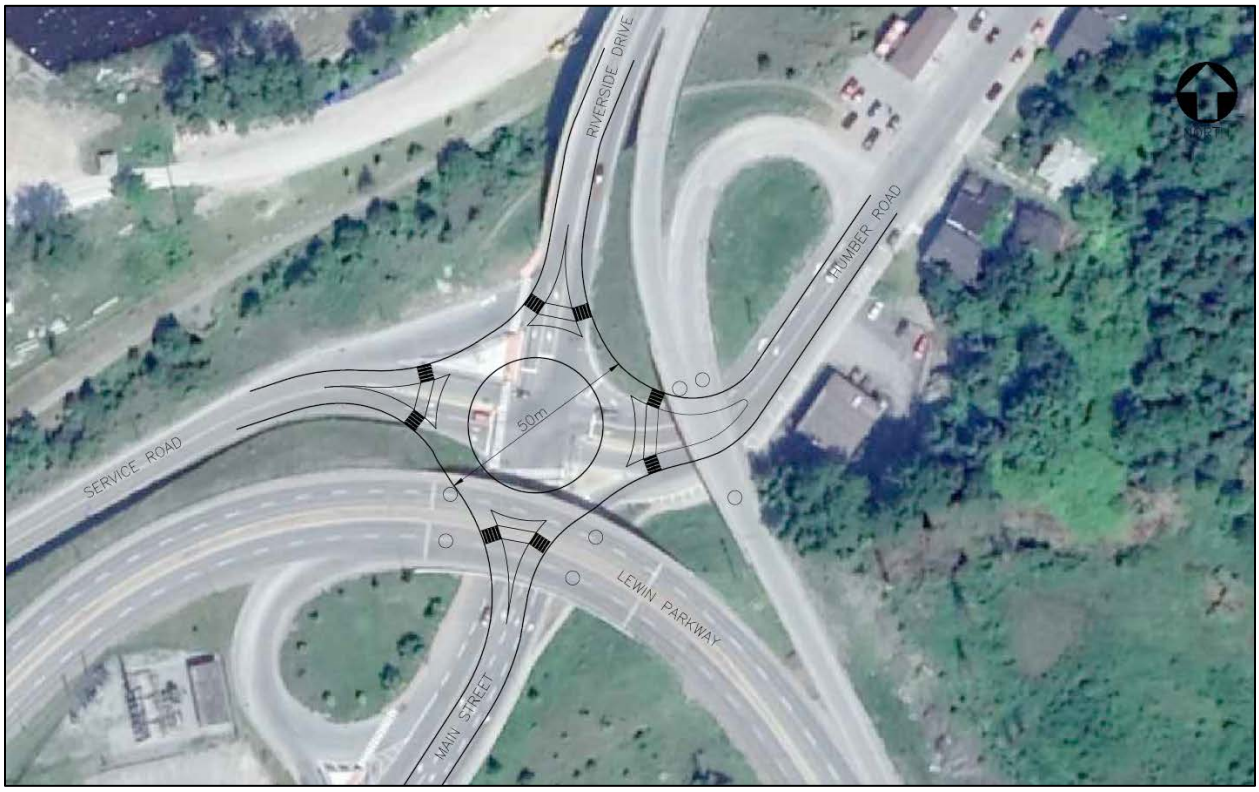


Figure 12: Roundabout concept for Main Street & Riverside Drive/Humber Road

The average delay per vehicle, level of service, volume-to-capacity ratio and 95th percentile queues length results for each approach of the roundabout are summarized in Table 17. The roundabout would operate at LOS A in both the AM and PM peak hours.

The existing signalized intersection operates at LOS C during both peak hours. While there are no existing operational problems at the signalized intersection, the roundabout configuration would reduce delay and improve the level of service during both peak hours. The roundabout reduces the average delay per vehicle by 22.1 seconds during the AM peak hour and by 18.1 seconds during the PM peak hour.

Table 17: ARCADY analysis results for Main Street & Riverside Drive/Humber Road

Existing Conditions 2017									
Intersection		AM Peak Hour				PM Peak Hour			
Street	Movement	Delay/ Veh (s)	APP LOS	V/C	Queue (m) 95th%ile	Delay/ Veh (s)	APP LOS	V/C	Queue (m) 95th%ile
Main Street & Riverside Drive/Humber Road		4.2	A			4.4	A		
Humber Road	EB Left - Turn	4.1	A	0.14	7.0	4.1	A	0.21	7.0
	EB Through								
	EB Right - Turn								
	WB Left - Turn	4.1	A	0.26	7.0	4.2	A	0.22	7.0
	WB Through								
	WB Right - Turn								
Main Street	NB Left - Turn	3.7	A	0.19	7.0	5.0	A	0.37	7.0
	NB Through								
	NB Right - Turn								
Riverside Drive	SB Left - Turn	4.6	A	0.28	7.0	3.9	A	0.18	7.0
	SB Through								
	SB Right - Turn								

12.10 Broadway & Caribou Road/Herald Avenue

Constructing a roundabout at the intersection of Broadway and Caribou Road/Herald Avenue is not reasonably feasible. There is insufficient space to construct a roundabout due to the proximity of buildings surrounding the intersection. A significant amount of property acquisition and building demolition would be required to construct a roundabout, making the option cost prohibitive.

12.11 Corporal Pinksen Memorial Drive & Grenfell Drive

It is feasible to install a roundabout at the intersection of Corporal Pinksen Memorial Drive and Grenfell Drive. The concept plan shown in Figure 13 includes a single-lane roundabout with a 40-metre inscribed circle diameter.

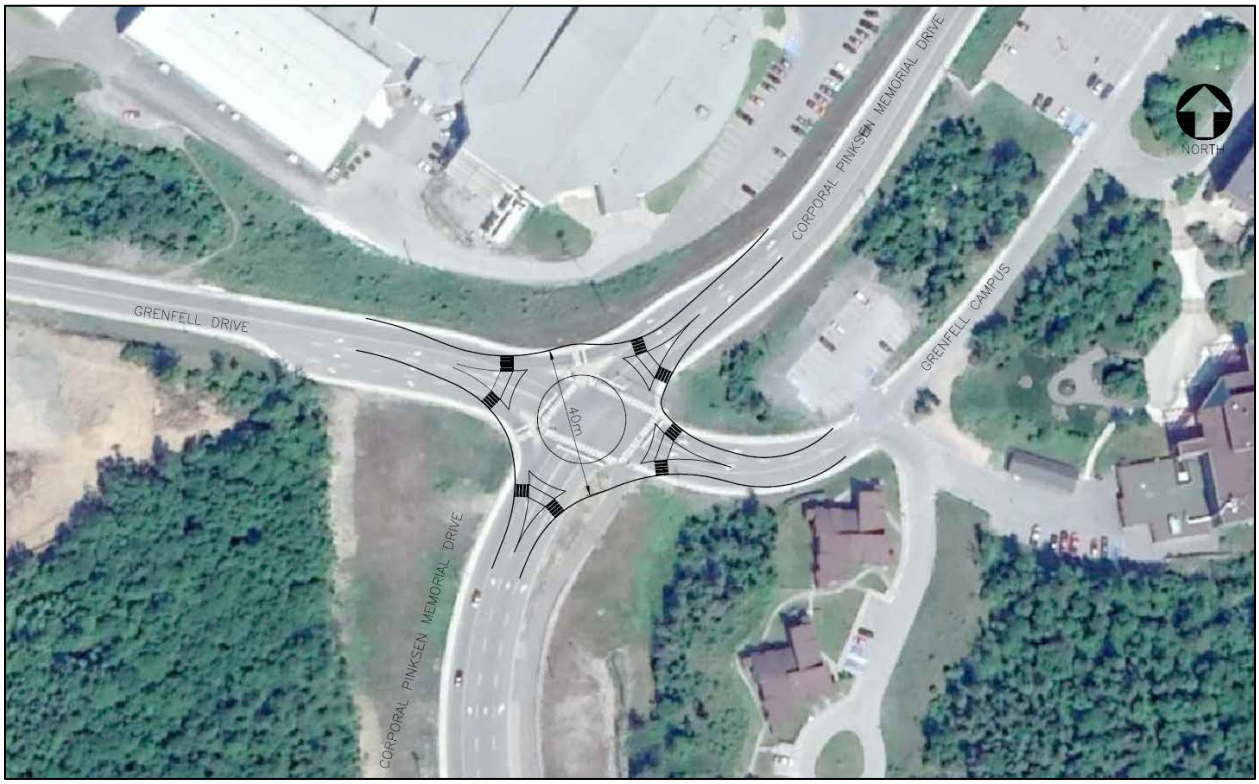


Figure 13: Roundabout concept for Corporal Pinksen Memorial Drive & Grenfell Drive

The average delay per vehicle, level of service, volume-to-capacity ratio and 95th percentile queues length results for each approach of the roundabout are summarized in Table 18. The roundabout would operate at LOS A in both the AM and PM peak hours.

The existing signalized intersection operates at LOS C during the AM peak hour and LOS B during the PM peak hour. While there are no existing operational problems at the signalized intersection, the roundabout configuration would reduce delay and improve the level of service during both peak hours. The roundabout reduces the average delay per vehicle by 17.1 seconds during the AM peak hour and by 16.1 seconds during the PM peak hour.

Table 18: ARCADY analysis results for Corporal Pinksen Memorial Drive & Grenfell Drive

Existing Conditions 2017									
Intersection		AM Peak Hour				PM Peak Hour			
Street	Movement	Delay/ Veh (s)	APP LOS	V/C	Queue (m) 95th%ile	Delay/ Veh (s)	APP LOS	V/C	Queue (m) 95th%ile
Corporal Pinksen Memorial Drive & Grenfell Drive		**3.4**	**A**			**3.3**	**A**		
Grenfell Drive	EB Left - Turn	3.3	A	0.11	7.0	3.3	A	0.08	7.0
	EB Through								
	EB Right - Turn								
	WB Left - Turn	3.3	A	0.01	7.0	3.2	A	0.04	7.0
	WB Through								
	WB Right - Turn								
Corporal Pinksen Memorial Drive	NB Left - Turn	3.7	A	0.17	7.0	3.2	A	0.07	7.0
	NB Through								
	NB Right - Turn								
	SB Left - Turn	3.2	A	0.10	7.0	3.5	A	0.16	7.0
	SB Through								
	SB Right - Turn								

13.0 Conclusions and Recommendations

A comprehensive evaluation of the City of Corner Brook's traffic signals was completed to establish and document existing conditions at each signalized location in the City and recommend upgrades. The City's traffic signals system is comprised of 15 signalized intersections and five signalized pedestrian crossing locations. The comprehensive evaluation included the following components:

- Traffic Counting Program
- Intersection Signals Drawings
- Signal Timing and Phasing Review
- Controller and Equipment Assessment
- Communications Assessment
- Intersection Capacity Analysis
- Operations and Maintenance Program
- Roundabout Feasibility

Traffic Counting Program

Traffic counts were gathered at five of the 15 signalized intersections where recent counts (collected in the last 3 years) were not available. Counts from 2015 or 2017 were available for the other 10 intersections. Traffic data were collected Tuesday, Wednesday or Thursday between 7:00 to 9:00 am and 4:00 to 6:00 pm. The counts were scheduled around events that may cause serious disruptions to normal traffic flow such as construction or holidays.

Intersection Traffic Signals Drawings

Intersection traffic signals drawings of existing conditions were prepared for the 20 signalized locations in the City. The drawings document traffic pole locations, size and reach of traffic poles, signal head locations and configurations, signal head mounting hardware, pedestrian pushbutton locations, pedestrian pushbutton type, approximate layout of underground electrical conduit or overhead wiring, location of electrical junction boxes, location of the traffic controller, location of the power supply, location of preformed inductive loops or camera detection systems and pavement markings.

Phasing and Timing Review

The existing signal timing and phasing data for each signalized location was reviewed to ensure their conformance to relevant standards and guidelines.

The signal timing review included conformance checks for the amber and all-red clearance intervals, the pedestrian walk intervals and the pedestrian clearance intervals at each signalized location to ensure their conformance to the ITE Traffic Engineering Handbook. The signal timing review indicated that the existing signal timing at 19 signalized locations does not conform to at least one of the applicable standards; 18 locations have amber and all-red clearance intervals that do not conform to ITE standards, 2 locations have pedestrian walk intervals less than 7 seconds and 13 locations have pedestrian clearance intervals that do not provide sufficient time for a pedestrian to clear the crosswalk.

A priority list was developed to prioritize improvements required to the signal timing at each signalized location. For the City's signalized systems, 18 locations were identified as Priority 1 (Immediate attention required), one location was identified as Priority 2 (Adjust during signal timing updates) and one location was identified as Priority 3 (Signal timing to be reviewed in future).

The existing signal phasing data for each signalized location was reviewed to ensure their conformance to the standard National Electrical Manufacturers Association (NEMA) phasing schemes. The phasing data review indicated that the existing phasing at the 15 signalized intersections and at one pedestrian crossing location do not conform to the NEMA phasing standards. The remaining four locations consist of the pedestrian crossings controlled by timers which do not use phasing. The cabinets should be rewired to be compliant with NEMA standard phasing when upgrades are completed at these intersections.

Signal indications at each signalized location were reviewed to ensure their compliance to the guidelines from Transportation Association of Canada's (TAC) Manual of Uniform Traffic Control Devices. Arrow indications are present at the 15 signalized intersections. The MUTCD guidelines indicate that left or right green arrows should be flashing arrow indications. The review indicated that the arrow indications at 12 signalized intersections are steady arrow indications and do not conform to MUTCD guidelines. These arrow indications at the 12 signalized intersections should be set to flash mode in the controller.

A flashing green ball indication is provided at Lewin Parkway and Griffin Drive on the southbound approach (Griffin Drive). MUTCD guidelines indicate that the green ball indication should be a steady ball signal indication. The flashing green ball indication at Lewin Parkway and Griffin Drive does not conform to MUTCD guidelines and should be removed. The indications for the southbound and northbound split phases should consist of a steady green ball indication and a flashing green arrow indication.

All timing improvements were implemented when new signal timing plans were entered into the controllers on June 26-27th, 2018 with the exception of the flashing arrow indications at:

- Lewin Parkway & St. Mark's Avenue/Prince George Avenue
- O'Connell Drive & University Avenue/Mount Bernard Avenue

Controller and Equipment Assessment

A detailed assessment of traffic control systems and equipment was completed for the 20 signalized locations. The assessment included of traffic controllers and cabinets, vehicle detection systems, emergency vehicle preemption systems, pedestrian systems, traffic poles, signal displays and intersection signage.

Traffic Controllers and Cabinets Assessment: A detailed assessment of the traffic controller and cabinet equipment was completed. The assessment included a thorough review of all traffic cabinet components including the controller unit, the power supply, the BIU's, the detector and pre-emption cards, card racks and related interface panels, heating and cooling systems, the conflict monitor and the back panel.

The 15 signalized intersections are controlled by 5 Econolite ASC/2 controllers, 3 Econolite ASC3 controllers, 2 Econolite Cobalt controllers and 4 Naztec Series 900 controllers (Model 980 NEMA TS2 Type 1). The five half-signals are controlled by one Naztec Series 900 controllers (Model 980 NEMA TS2 Type 1), one Electromega MCA250 timers and 3 unknown timers. The cabinet at Main Street & West Street and the four cabinets with the pedestrian crossing timers are not NEMA TS2 compliant. All other cabinets are NEMA TS2 compliant.

The City of Corner Brook should standardize the type of controller used at signalized intersections through the City. There are a number of benefits to standardizing cabinets and controllers to a single provider such as reduced inventory for spare parts and reduced training of maintenance staff. Using the same provider also creates the possibility for the City to explore the use of Advanced Transportation Management Systems (ATMS) to provide real time communications capabilities between intersections. It is recommended that the City move towards using Econolite Cobalt controllers with Econolite cabinets.

Once the fourteen controllers (timers, ASC/2 and Models 980) have been upgraded, the City should then replace the three Econolite ASC/3 controllers. These controllers are still relatively modern and are compatible with ATMS but will eventually need to be upgraded. General maintenance should be performed at all intersections where the cabinets are not being replaced.

A number of existing traffic controller cabinets are mounted to the upright of traffic poles at the intersection. Traffic controller cabinets should be mounted on raised concrete controller pads. All new traffic controller cabinets should be installed on controller pads and the existing cabinets for ASC3 and Cobalt controllers should be relocated to controller pads where they are mounted to traffic poles.

Vehicle Detection Systems Assessment: An assessment of the existing vehicle detection systems was completed to identify whether there are detection systems present at each intersection and if the existing systems are operating properly. Vehicle detection systems are present at five signalized intersections. The systems include three GridSmart video detection systems and two inductive loop systems. None of the five vehicle detection systems are operating properly. It is recommended that new preformed inductive loops be installed at all 15 signalized intersections.

Emergency Vehicle Preemption Systems Assessment: An assessment of the existing emergency vehicle preemption systems was completed to identify whether there are preemption systems present at each intersection and if the systems are operating properly. The preemption systems were tested for operations from the controller side only for the assessment.

Opticom GPS preemption systems are present at six signalized intersections. None of the six preemption systems are operational from the controller side. It is recommended that the City contact the provider of these systems to get a technician on-site to restore the preemption systems to proper operating conditions. Once the systems are operational from the controller side, these systems should also be tested from an emergency vehicle to ensure the receiving unit is operational.

Pedestrian Systems Assessment: An assessment of the pedestrian systems at was completed to identify whether the appropriate pedestrian facilities are provided at each intersection. The pedestrian systems were assessed for pedestrian signals displays, pedestrian pushbuttons and accessibility. Pedestrian facilities are provided at 17 of the 20 signalized locations. The following points were noted:

- There are no pedestrian facilities present at three signalized intersections.
- The adequate number of pedestrian signal displays at all locations with pedestrian facilities with the exception of O'Connell Drive and Elizabeth Street. Overall pedestrian displays are generally in good condition.
- The pedestrian signal displays provided include LED indications with countdown models at 15 of the 17 signalized locations.
- Three of the 17 signalized locations with pedestrian facilities do not include pedestrian pushbuttons.
- The appropriate number of pedestrian pushbuttons are provided all other locations with the exception of O'Connell Drive and Elizabeth Street. Overall pedestrian pushbuttons are generally in good condition and functional.
- Pedestrian pushbutton signage is only provided at five of the 14 signalized locations where pedestrian pushbuttons are present. Signage is missing for one or more pushbutton and/or in poor condition at four of these locations.
- Paraplegic curb ramps are provided for all crosswalks at six locations and curb ramps are provided for at least one crosswalk approach at four locations with pedestrian facilities.
- Tactile warnings surfaces are provided for all crosswalk approaches at O'Connell Drive and Elizabeth Street. Audible beaconing systems are provided for all crosswalks at four signalized locations. The audible beaconing systems provided are these locations are an older type of system which include speakers mounted over the pedestrian signals. These systems are not considered an Accessible Pedestrian Signal (APS) solution.
- At least one pushbutton is considered as "not accessible" at 11 of the 14 locations where pushbuttons are present.

Traffic Pole Assessment: A visual examination of condition of traffic poles was conducted. Poles were inspected for any signs of visible damage or corrosion. Visible corrosion was identified at seven of the 20 signalized locations, corrosion was mainly observed in older poles of the "Pole System" type. The poles at the seven locations were classified as poor or very poor conditions. Poles at the seven locations should be replaced, priority should be given to replacing the poles in very poor condition first.

The traffic pole located on the southwest corner at the intersection Lewin Parkway & St. Mark's Avenue/Prince George Avenue (Pole 5) has been damaged by an impact creating a hole in the wall of the pole. This pole should be replaced immediately.

In addition, holes have been drilled in a number of traffic poles throughout the City to accommodate conduit and/or mount traffic controller cabinets. The City should have a structural engineer review poles in which holes were drilled to provide an opinion on the structural integrity of the poles.

Signals Display Assessment: The signal displays at each of the 20 signalized locations were reviewed to ensure the signal displays conform to section B3 - Display and Configurations for Traffic Control Signals of the MUTCD. Overall, the signal systems do not conform to MUTCD guidelines, 10 key points creating safety and/or liability concerns were identified.

- A secondary head is not provided on at least one approach at seven signalized locations.
- The traffic signals do not meet the signal visibility distance in advance of the stop line on at least one approach at three locations.
- The overhead signal indications are located less than 15 metres from the stop bar on at least one approach at eight locations.
- Where provided, the required signal assemblies (primary and secondary heads) are mounted less than 3.0 metres apart on at least one approach at seven locations.
- The primary signal head is not located within the 10-degree cone of vision on at least one approach at 14 locations.
- Backboards are not used on the primary signal heads at all signalized locations. However, backboards are not typically used in Newfoundland due to the wind loadings.
- The secondary signal head is not located within the 40-degree cone of vision on at least one approach at six locations.
- The secondary head does not include all the signal indications shown on the primary head on at least one approach at six signalized locations. At these locations, the primary signal head includes a left turn arrow indication which is not duplicated on a secondary signal head. It should be noted that the left turn indications are duplicated at other intersections throughout the City, creating inconsistencies between intersections.
- The arrow indications at 12 signalized intersections are steady arrow indications.
- At least one of the pedestrian signal heads is not placed directed in line with the pedestrian crosswalk it controls at five locations.

In addition to the 10 points identified above, a number of vehicle and pedestrian signal heads at each intersection do not meet proper placement guidelines such as location and mounting height.

The right turn arrow signal indication displayed on the West Street approach at the intersection of Main Street & West Street creates a conflict with the pedestrian crossing across Main Street. The arrow indication which is typically used to indicate a protected phase is displayed at the same time as the pedestrian walk signal which is also used to indicate a protected phase. The indications at the intersection are a significant safety concern, the arrow indication on the West Street approach should be replaced with a green ball indication.

Signage Assessment: The street name signage and mounting systems at each signalized location were reviewed. It should be noted that typically there is no street name signage present at mid-block pedestrian crossings, therefore the five half-signal locations were excluded from the assessment. Some

level of street name signage is provided at 13 of the 15 signalized intersections. Of the 13 signalized intersections with street name signage present, six intersections are missing street name signage for at least one of the roadways. Various mounting devices and arrangements are used for street name signage.

Intersections where signage is missing should be upgraded to include street name signage for all roadways. For each individual intersection, the City should identify the type of pole present and contact the manufacturer to establish if, from a structural perspective, the pole can accommodate overhead signage measuring 300 x 1800 mm mounted rigidly to the mast arm between the primary and secondary signal head displays. Where that is not possible, the City should consider ground mounted signage in advance of all intersection approaches.

The regulatory and warning signage requirements at each signalized location were reviewed. The intersections were reviewed for Yield, Keep Right, Checkerboard, Added Lane, Double Arrow and Object Markers signs.

- Yield signs should be provided for all channelized right turns where added lanes are not provided. Yield signs are missing on at least one approach at four intersections.
- Keep Right signs should be provided on all raised medians. Keep right signs are missing on one median at two locations.
- Checkerboard signs should be provided at 3-leg intersections. Checkerboard signs are not provided at the four 3-leg intersections.
- Added Lane signs should be provided where added lanes are provided at channelized right turns. Added lanes are provided without the required signage at two locations
- Double Arrow signs should be provided at all raised islands and Object Markers can be used as an alternative or to supplement Double Arrow signs on raised islands. There are 11 signalized intersections with one or more raised concrete islands, none of which have Double Arrow signs or Object Markers signs.

Improvement Plan and Cost Estimates

The results of the various assessments were used to determine the improvements required at each signalized location to ensure the traffic signals reflect industry standards and conform to the MUTCD guidelines.

Class “D” cost estimates were developed to upgrade each of the 20 signalized locations based on the proposed improvements. All cost estimates include a 25 percent contingency and 15 percent engineering (preliminary and detailed design work). The cost estimates do not include property acquisitions, utility pole relocations, topographic survey or construction phase services. The total cost to upgrade all 20 signalized locations is estimated at approximately $4,614,375 plus harmonized sales tax (HST).

A priority ranking system was developed to rank the 20 signalized locations in order to identify which locations should be upgraded based on a number of priorities including upgrades/replacement of signal displays, controllers and cabinets, traffic poles and pedestrian facilities.

Priorities in each category were allocated a point value for a maximum of 100 points. Signalized locations ranking with the highest points should be prioritized. An implementation plan was developed based on the priority ranking exercise. The implementation plan assumes a capital cost budget of approximately $1,000,000 plus HST per year over five years and a maximum of five intersections per year.

Communications Assessment

A communications assessment was completed for the 20 signalized locations in the City to identify how to provide an ethernet connection to each intersection. It is recommended that the City acquire the basic package of the Centracs 2.0 Advance Traffic Management System provided by Econolite. Amongst other features, the basic package of software will allow for automatic email or text message alerts upon detection of problems with the system or any devices and remote programming of intersection controller databases.

An access point network was identified as the City's most cost-effective solution to provide communication capabilities to all intersections. It is recommended that the City use a secure APN with static IP addresses, and Microhard VIP4G modems. These modems use SIM card technology and therefore do not require any civil works to install.

With communications capabilities in place, the City will have the ability to coordinate intersections. Coordination consists of synchronizing multiple intersections to enhance the operation of one or more directional movements in a corridor. Three zones were identified that could benefit from coordination: along the Lewin Parkway and Main Street in the downtown area, along the Lewin Parkway in the commercial area and along O'Connell Drive.

The initial cost to build the network and provide communications capabilities at all 20 signalized locations is estimated at $26,760 plus HST. The cost of a Centracs software license which can support up to 50 intersections is $78,000. A software maintenance package can be purchased for an additional $13,700 per year on a five-year term. In addition to the initial cost, a monthly fee for cellular data of approximately $300 plus HST will apply.

Intersection Capacity Analysis

The performance of an intersection can be evaluated using a number of measures of effectiveness. Delay and level of service (LOS), volume-to-capacity ratio (v/c) and vehicle queuing are the primary measures of effectiveness used in traffic analyses. The Synchro Studio (Version 10) software package was used as the primary evaluation tool. Synchro, an analysis and optimization software package, was used to analyze network intersections based on the methodology of the *Highway Capacity Manual* 6th edition (2016) published by the Transportation Research Board.

Synchro models of the 15 signalized intersections were built for the morning (AM) and evening (PM) peak hours of traffic. The models were coded using existing geometry, phasing and timings and traffic volumes to reflect existing conditions. Traffic volumes from 2015 traffic counts were factored to represent 2017 traffic volumes using a background traffic growth rate of 0.5 percent per year to reflect normal increases in traffic. These models were used to assess existing conditions at each intersection. Results of the Synchro analysis show operational problems at five signalized intersections during the peak hours. These five intersections are:

- Lewin Parkway & Griffin Drive
- West Valley Road & O'Connell Drive
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive & Elizabeth Street
- Broadway & Caribou Road/Herald Avenue

New signal timing plans were developed to optimize operations at each intersection. The timing plans were optimized using the Synchro software. It should be noted that the new signal timing plans reflect the timing improvements for the red and amber clearance intervals, the pedestrian walk intervals and pedestrian clearance intervals. The timing plans were implemented on June 26-27th, 2018.

Operations and Maintenance Program

An operations and maintenance manual was developed for the City's traffic signal system. The Traffic Signals Operations and Maintenance Manual, provides guidance for City staff and/or electrical maintenance contractors to develop a program to ensure the traffic signals within the City are properly maintained to industry standards. The manual includes preventative maintenance checklists, intersection inspection checklists, recommendations for the frequency of maintenance and testing of various components as well as guidelines for proper documentation and record keeping.

Roundabout Feasibility

A brief investigation was conducted at 10 of the 15 signalized intersections to determine the feasibility of converting each intersection to a roundabout. The five signalized intersections along the Lewin Parkway were excluded from this exercise since the Lewin Parkway is a provincially owned roadway.

There are a number of benefits associated with roundabouts; the two primary benefits of roundabouts are reductions in collisions and improved traffic operations. While roundabouts have a higher initial construction cost, when comparing cost and benefits of roundabouts and traffic signals over a long-term period, roundabout have a lower overall cost.

Commentary was provided for each intersection discussing the benefits and challenges of converting the intersection to a roundabout. At intersections where a roundabout was deemed feasible, an operational analysis of the roundabout was performed to identify the configuration required to accommodate existing traffic volumes and evaluate operations during peak hours. A conceptual layout was developed for each roundabout based on the results of the operational analysis.

The investigation identified that it was feasible to convert the following five intersections to roundabouts:

- Confederation Drive & West Valley Road
- O'Connell Drive & University Drive/Mount Bernard Avenue
- O'Connell Drive & Elizabeth Street
- Main Street & Riverside Drive/Humber Road
- Corporal Pinksen Memorial Drive & Grenfell Drive

Roundabouts were deemed not reasonably feasible at five locations primarily due to constraints created by the location of existing buildings and the associated property acquisition costs that would be required to install a roundabout. These locations include:

- West Valley Road & O'Connell Drive
- Main Street & Mount Bernard Avenue
- Main Street & Mill Road/Brook Street
- Main Street & West Street
- Broadway & Caribou Road/Herald Avenue