# APPENDIX E: RIDERSHIP MODELLING AND TRAFFIC

## APPENDIX E-2: WIDER AREA IMPACTS REPORT

PART 1/1

steer davies gleave

# Hamilton LRT Wider Area Traffic Impacts

Report
February 2017

City of Hamilton

Our ref: 228793

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# Executive Summary

## Overview

In May 2015 $1 billion funding was announced for the Hamilton LRT project. The project that had previously received TPAP approval has been reconfigured with its eastern terminus now being at Queenston Traffic Circle (replacing Eastgate Square), and with a new section of alignment on James Street linking West Harbour GO Station or the Waterfront.

Over the last 12 months the design of the LRT alignment along these revised routes, and their stop locations have been the subject of a detailed review. This has resulted in a re-configured alignment and many LRT stops have been redesigned, with platforms staggered either side of main intersections. Known as 'far-side' stops- the platforms are placed at the far-side of intersections- they maximize passenger catchments, and allow left-turning and u-turning traffic movements to also be accommodated.

The updates to the LRT route(s) and alignment have also created changes to the surrounding road network- some minor intersections have had turning movement restrictions introduced- to improve priority for the LRT and realize journey time and service reliability benefits. Along much of the LRT route on King Street single lane, two way traffic movements and access have been introduced, and the LRT has also been complemented by a review of local transit (bus) services, removing duplicate services and amending services to feed into new transfer facilities at McMaster University, MacNab, and Queenston.

All of these changes result in the need to update the TPAP approval for the LRT project. This includes long term ridership forecasting, and an assessment of traffic impacts, along with consideration of other environmental factors.

Common with other modern urban style LRT projects, and following the approach used for the original Hamilton LRT TPAP- the assessment of ridership and traffic uses a set of computer models to understand the benefits and impacts of the proposed LRT project. The results go through a process of testing, modification, iteration and refinement to achieve a balance of competitive LRT performance and efficient traffic operation.

## Modelling Assumptions

Two models were developed for each scenario year for the AM and PM peak hours – a 'Without LRT' Business as Usual (BAU) scenario and a 'With-LRT' scenario. The BAU and LRT network coding is consistent with the coding included in the 2031 EMME model, based on the Transportation Master Plan (TMP) and as agreed with the City/Metrolinx.

*Business as Usual model*

A number of updates were required due to changes implemented between the 2011 Base Model and the current 2015/2016 situation, as well as committed improvements between the present day and the forecast years. There were a significant number of changes within the BAU network relating to two-way conversions and the implementation of bike lanes proposed by the City as part of the TMP. Limited information was available on intersection layouts and traffic signal operation; so appropriate assumptions have been made.

The key changes made between the 2011 and 2031 models were as follows: -

- Wentworth 2-way from Delaware to Barton
- Hughson 2-way from Barton to Wilson
- Gage : Road diet to accommodate bike lane
- Victoria 2-way from Burlington to Sawyer
- Cannon – 1 lane reduction
- York – 1 lane reduction from Dundurn to Queen
- MacNab – bus only lane from King to Main

It should be noted that the BAU models have not been fully optimized. This should be considered when reviewing the comparisons between the BAU and LRT models.

An initial model run was conducted to identify the overall impacts of the introduction of the LRT compared to the projected conditions without the LRT, based on 2031 conditions. These impacts were then mitigated with a series of measures that were tested in successive iterations of the model to reach a preferred solution.

*With LRT model*

Most of the B-Line route between Highway 403 and Queenston Traffic Circle is currently a 4-lane single roadway, carrying westbound traffic only (King Street West and King Street East) and two-way traffic (Main Street East). The Main Street West segment is primarily two-way traffic, with three eastbound and two westbound lanes, and centre left-turn lanes or dedicated left turn lanes.

In designing the LRT layout along such sections, two key requirements are:

- Provision of a segregated centre-running LRT alignment; and
- Minimizing property take and loss of property access

The conversion of two existing traffic lanes to segregated LRT east of Hwy 403 removes two (or three) traffic lanes from the existing road network, and reduces the vehicular capacity (although not the person-capacity) of the roads concerned. In the segment west of Hwy 403, the lane capacity is maintained.

The project was assessed against the following criteria with respect to traffic operations:

- Changes to traffic circulation in the B-Line corridor, on adjacent local and arterial roads and across the wider Hamilton downtown highway network;
- Changes in permitted and prohibited turning movements;
- Changes in property access;
- Changes in parking and loading provisions.

Two base conditions were created: September version based on 2031 conditions and the alignment presented at PIC #1 and the December version, which built on the mitigation measures of the September version and introduced further mitigation measures. The December version was based on the refined alignment developed prior to PIC #2. This reporting ignores the changes between the two versions, presenting the overall aggregate impacts and mitigation.

The key changes to traffic circulation in the B-Line LRT corridor are set out below.

- Near the western terminus, from the McMaster stop east of Cootes Drive, to Dalewood Avenue, the LRT will operate on the north side of the street, in both directions. The existing turning movements will be maintained throughout this section of the corridor.
- East of Haddon Avenue, the centre left-turn lane will be eliminated and unsignalized intersections will be limited to right-in / right-out movements only, similar to the 2011 TPAP design.
- In the vicinity of the Highway 403 crossing, the existing one-way circulation (westbound on King Street West and Paradise Road South; eastbound on Main Street West) is retained.
- King Street, west of Dundurn, remains one-way westbound.
- East of Dundurn, King Street will be generally one lane in each direction, with centre-running LRT, with the following exceptions:
- From Queen Street to Hess Street: westbound only, with the LRT on the south side
- From Catharine Street to Wellington Street: eastbound only, with the LRT on the north side
- From the Delta to Queenston Traffic Circle, Main Street East will operate with one lane in each direction and centre-running LRT.
- The change in lane configurations introduces a variety of new intersection configurations along King Street and Main Street East between Dundurn and Queenston Traffic Circle
- Introducing eastbound traffic on King Street allows the opportunity for new southbound left turns and northbound right turns from perpendicular streets and eastbound left turns from King Street.
- Traffic movements across the LRT tracks are limited to key signalized intersections.
- Left turns from King Street are only permitted where separate left turn lanes can be accommodated.

The VISUM model is a highway only model, so transit coding is not captured, however highway impacts related to transit priority and the coding of the LRT scenario are reflected and based on the current version of the design.

**Forecast Demand**

Traffic demand was generated within the 2031 EMME model and the increment of demand between the 2011 and 2031 EMME was added to the calibrated 2011 VISUM base matrix. Traffic is forecast to grow significantly between 2011 and the 2031 forecast year and initial work indicated that the Business as Usual network was over capacity.

A peak spreading factor was assumed as it has been shown that as networks become more congested, some trips move the time of their trip to avoid the time of peak congestion. This approach allowed all demand to be included within the network and for the network to be optimized to understand the key locations that required further work. Matrices for the VISSIM model were cordoned directly from VISUM.

**Network Evaluation Process**

Once the demand for each of the scenarios had been established, traffic was assigned into the different scenarios. Intersections with high delays and queuing were examined in detail and adjustments made in order to reduce the queuing and delays and improve network operation. This process was iterative with flows being assigned and changes made and then flows being

assigned again. Quite often reducing delays in one location caused traffic re-routing and impacted on other intersections which then required mitigation.

Initial work was undertaken in the 'without LRT' BAU scenario and those changes were implemented within the 'With LRT' scenario before the optimisation was undertaken in that scenario. Two designs were tested in the model – the version presented at the Public Information Centres in September 2016, as well as the design tested and documented in this report from December 2016.

In each instance, a range of different interventions were considered and these are set out below. Some are minor changes, while some intersections require more significant measures in order to operate at an acceptable level.

- Traffic signal operations
- Timing allocation
- Staging changes
- Dedicated turn phases
- Signal cycle times
- Intersection layout
- Turning lane reallocation
- Addition of turning lanes
- Addition of a dedicated slip lane
- Turn movement bans

Within the VISUM model, the detail of the intersections within the network is included allowing the examination of turning lanes, queue storage and traffic signal timings as well as the level of service on particular turns, intersections and links. A general overview of network operation is provided below, along with details on the key intersections where modifications are required to mitigate the impacts.

**Network Operation**

Forecast traffic growth between the 2011 base year and the 2031 forecast year leads to increased congestion in both the BAU and with LRT networks. Signal timings have been optimized to minimise the impacts of the increased traffic and the slightly altered traffic patterns. It should be noted that the BAU models have not been fully optimized. This should be considered when reviewing the comparisons between the BAU and LRT models. At a few locations, lane allocations and short additional lanes on the approach to intersections have been added. It should be noted that the BAU scenario exists for comparative purposes only. The LRT is planned to be built in advance of the 2031 scenario year so a 2031 BAU network will never exist in reality, it simply provides a benchmark against which to compare the LRT scenario operation.

One of the considerations when prioritising the mitigation of intersections was the Level of Service (LoS) output from the VISUM model. The link LoS output from EMME has been used as part of the TMP process for reporting network operation, but within VISUM, detailed intersection LoS can be reviewed rather than just an average value on the links. Currently the City standard is for LoS D or above, but this standard can be relaxed on specific intersection movements and when it only occurs for short periods of time, for example within the peak of the peak hour.

There are a number of intersections that have a drop of two levels of service between 2011 and 2031. These intersections are primarily along Main, King, Barton, Cannon, James and Burlington.

Key Outcomes between 2011 and 2031 Business as Usual (BAU)

- Network changes - two-way conversions etc. change traffic patterns slightly
- Traffic growth leads to increased congestion

As set out above, the LRT introduces reduction in traffic capacity along the LRT alignment and generally there are two significant impacts of this:

- The significant reduction in westbound capacity on King Street east of the 403 to the Delta and Main Street from the Delta to Queenston Traffic Circle diverts traffic to parallel routes, particularly Cannon and Barton, but also the Hunter / Aberdeen corridor
- Turning restrictions to and from the LRT alignment funnels demand to key intersections that permit full moves or u-turns

Between 2031 BAU and 2031 LRT Models

- Network changes create changes in traffic patterns
- Reduced capacity along LRT alignment diverts traffic to parallel corridors
- Turning restrictions on and off LRT alignment funnel demand to key intersections

The principal corridors for the diversion of traffic depend on the distance to be travelled within the LRT corridor: the longer the travel distance, the further traffic will tend to divert. For example, trips from beyond the corridor to the east could divert as far north as the Burlington Street corridor, while trips from within the corridor may only divert as far as Barton and Cannon; trips within the downtown area also divert to Hunter and Aberdeen. The figure below illustrates this diversion pattern and the resulting area of congestion in the corridor from north of the corridor in the downtown through to the intersection of King and Dundurn.


This diversion of traffic and the resulting patterns create congestion in several areas:

*Main Street West segment*

Maintaining three eastbound traffic lanes results in traffic volumes within the capacity of the roadway and the intersections.

*King / Dundurn*

The diversion pattern shown in the figure above, results in considerable pressure on the route from the parallel streets back to the intersection of King Street with Dundurn Street to access Hwy 403 and King Street West. While some of the diverted traffic uses York to and from the east, and some uses Aberdeen Street to and from the west, a considerable amount of traffic still seeks a path to King Street to access Hwy 403 and west Hamilton.

*Downtown and International Village*

Intersections through the Downtown and the International Village see a reduction in the overall intersection level of service with increased congestion. Due to volume reduction on certain traffic movements some intersection level of services are improved.

*Delta Area*

The convergence of Main Street East and King Street East at the Delta results in considerable congestion in both the BAU and LRT scenarios.

*Off-Corridor Impacts*

Diversion of traffic from the LRT corridor causes a substantial increase in traffic along Cannon and Barton, as well as York Street from Queen/Cannon through Dundurn.

The initial traffic model results reflect the overall growth in traffic as a result of forecast increases in population and employment levels, and changes to the road network, with and without LRT. Traffic growth and network changes into the future cause increased levels of congestion and increased delays, with or without the introduction of LRT. LRT changes traffic patterns within the network causing traffic to reroute. The changes identified mitigate impacts and improve network operation, reducing traffic delays and maintain traffic flow, but there is still increased congestion, compared to existing conditions due to the underlying growth in population and employment between 2011 and 2031.

**Key improvements to traffic movements required for LRT**

The changes in road layout, traffic circulation and access routing have been assessed using accepted practice traffic modelling tools. In summary, these have demonstrated that the preferred scheme results in a general decline in the operational performance of the municipal road network, particularly at intersections, due to the reduction in capacity on the corridor for other motorized road users. However, alternative corridors, such as Barton Street, King Street East and Cannon Street and Wilson Street, generally have sufficient capacity to accommodate the level of re-assigned traffic.

The majority of intersections within the network can be modified to mitigate traffic flow issues within the current (or planned) intersection footprint by changing the traffic signal operations, banning turns or reallocating existing lanes to other turning movements. There are however a

number of locations where this is not possible and additional lanes are required. Information on these locations is set out below. The layouts shown are taken from VISUM and have been tested as part of the modelling effort.

*Traffic Signal Changes*

Traffic signals will be able to be adapted to ensure that the LRT encounters minimal delays, and that signal timings are optimize to maximize the flow of traffic. All traffic signal changes take account of the minimum pedestrian crossing times.

Signals throughout the network will be adapted to accommodate the changes in traffic patterns. This includes traffic diverting away from the LRT corridor, or that funnels towards the dedicated signalized crossings of the LRT alignment.

Significant work has been undertaken to optimize the signals in the LRT scenario to accommodate east-west movements along Cannon-Britannia and Barton. Other optimization has been undertaken at:

- AM only - Main/Dundurn and Aberdeen/Queen
- PM only - Queenston / RHVP West and King / RHVP West Ramp
- AM and PM – Aberdeen/Dundurn and Hunter/John

For offline signal optimization, a separate but linked package called VISTRO was used. This was used as the very final step in the process, to additionally optimize the operation of offline signals. The revised signal timings were imported back into VISUM for the final assignment and outputs.

*Turn Bans*

In order to ensure safety and improve traffic operation, certain turns have been banned. Along the LRT alignment a number of the intersections will operate as right turn in and right turn out only, except at key signalized intersections. These turning limitations can be seen on the LRT drawings. A few turns away from the LRT alignment will also have reduced movements.

The following intersections away from the LRT alignment have turns banned: -

- Locke and York
  - Westbound left turn has been banned

*Revised lane allocations and additional lanes*

Introduction of the LRT changes traffic patterns within the network and consequently there are locations where the lane allocations are changed.

Where there are significant turning volumes or anticipated queuing, lanes have been added to accommodate these additional needs. Often these take the form of an additional short section of lane on the approach to an intersection. There are however a number of locations where this is not possible and additional lanes are required.

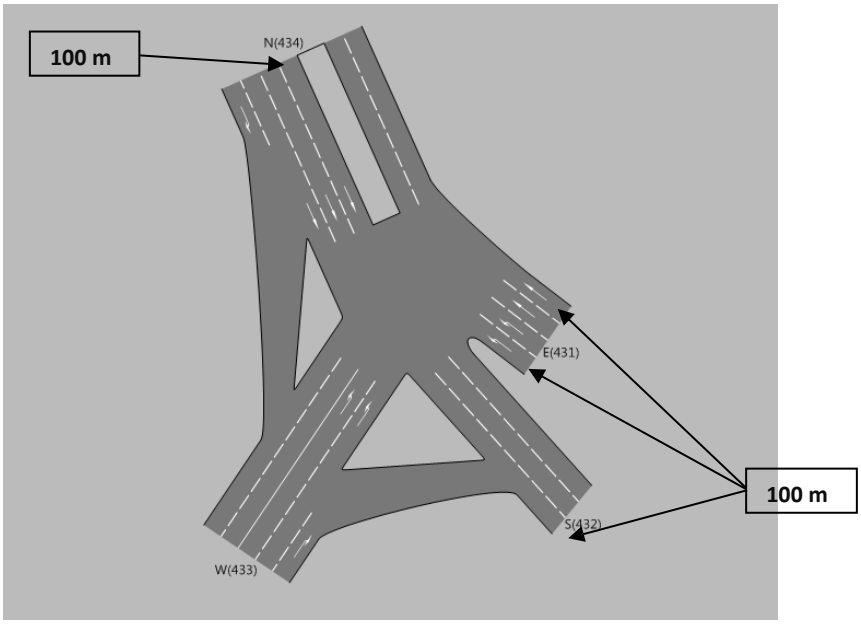
Changes have been made at the following intersections: -

- Cannon and Queen/ York
  - Three lanes on Eastbound approach (York)

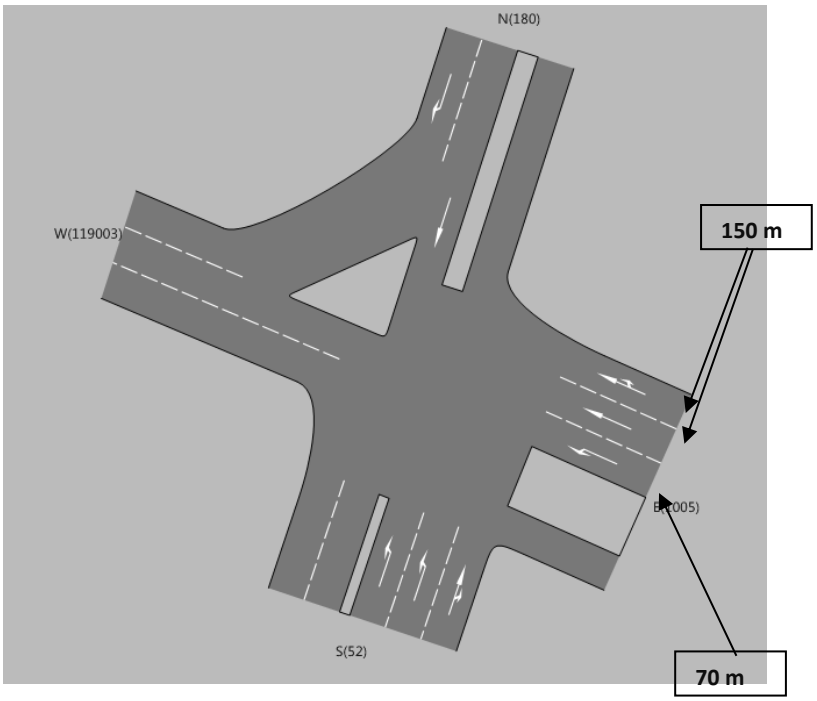
- Dundurn and York
  - Added two short lanes (100m) at intersection for westbound left/through movements
  - Added one short lane (100m) at intersection for eastbound through movement
  - Added one short lane (100m) to accommodate northbound right turn along York
- Locke and York
  - Westbound left turn has been banned
  - Three lanes for all approaches along York 100 metres in length (east and westbound)
- A new traffic signal at Britannia/Parkdale with two lanes on the west leg
- York Boulevard (between Dundurn and Queen) now three lanes for each direction (bike lane to be relocated)
- Dundurn Street between York Blvd and King St changed to operate as two lanes southbound and one lane northbound;
- New layout of the intersection at King St and Dundurn St:
  - One slip lane for the southbound right turn and one lane for southbound through;
  - Two lanes westbound through (added one lane of 150 meters) and one additional lane for westbound left turn and U-turn (70 meters);
  - A total of three lanes exiting westbound
  - This results in property impacts on the north-west and south-east corner

The following figures show the two intersections as coded in VISUM and the length of each proposed additional lane.

**Proposed layout for Dundurn/York intersection**



**Proposed layout for King/Dundurn intersection**




## Overview of VISUM model results

With the introduction of the LRT, there is a change in the traffic patterns in the network. Due to a reduction of capacity on King Street, some westbound traffic has diverted onto parallel routes such as Aberdeen Ave, Wilson St, Cannon St and Barton St. With King Street converted to two-way in many sections, there has been a switch of eastbound traffic using Main St in the downtown core onto King Street.

In terms of north-south traffic, a number of movements onto and across the LRT alignment are limited and so north-south traffic on these routes is reduced and is funnelled to the intersections where the crossing of the LRT alignment is permitted. Consequently, there are intersections along the LRT alignment that end up with an improved level of service and traffic volumes are reduced and conflicted turns are removed. This is offset by the intersections where delays are increased where they have limited opportunity to cross the alignment.

Work has been undertaken to improve the network operation and mitigate the impacts on traffic operation while still maintaining an appropriate level of priority for the LRT. The following mitigations have been applied to intersections within the network: -

- Traffic signal operations
- Timing allocation
- Staging changes
- Dedicated turn phases
- Signal cycle times
- Intersection layout
- Turning lane reallocation
- Addition of turning lanes
- Addition of a dedicated slip lane
- Turn movement bans

The mitigations have been discussed and agreed with the City of Hamilton. The mitigation will be further developed through the PSOS and detailed design.

There is also possibly further scope to limit the intersection changes required, by making use of the City's on-street adaptive traffic signalling technology. This allows traffic signal timings to be interactively changed during the peak hour in order to respond to real time traffic conditions and potentially limit the physical intervention required.

In conclusion, peak hour/period traffic congestion will increase as traffic is forecast to grow into the future. This will occur with or without the LRT. Once the LRT is introduced, traffic patterns will adjust to reflect the changed capacity on certain routes and while some movements will see an increase in journey time and delays, the network will continue to function. Modifications have been identified to mitigate the impact of the LRT both on the immediate corridor and in the wider area of the network. These changes are assumed to be an integral part of the project operation. The BAU model for this work has been developed to allow comparison of the future sceanrios, but it shoukd be noted that full signal optimization was limited to the LRT scenario only.

The modelling work undertaken for the EA/TPAP amendment process has shown that the LRT can be accommodated within the Hamilton network and that solutions have been developed to mitigate the identified traffic impacts. As the design continues to be refined through the PSOS, City/Metrolinx and consulting team staff will continue to review the timing and precise details of the mitigation measures and design and implementation requirements.

# 1 Introduction

## Project Background

1.1 In May 2015 $1 billion funding was announced for the Hamilton LRT project. The project that had previously received TPAP approval has been reconfigured with its eastern terminus now being at Queenston Traffic Circle (replacing Eastgate Square), and with a new section of alignment on James Street linking West Harbour GO Station or the Waterfront.

1.2 Over the last 12 months the design of the LRT alignment along these revised routes, and their stop locations have been the subject of a detailed review. This has resulted in a re-configured alignment with twin LRT tracks running in the centre of the road. Many LRT stops have also been redesigned, with platforms staggered either side of main intersections. Known as 'far-side' stops- the platforms are placed at the far-side of intersections- they maximize passenger catchments, and allow left-turning and u-turning traffic movements to also be accommodated.

1.3 The updates to the LRT route(s) and alignment have also created changes to the surrounding road network- some minor intersections have had turning movement restrictions introduced- to improve priority for the LRT and realize journey time and service reliability benefits. Along much of the LRT route on King Street single lane, two-way traffic movements and access have been introduced, and the LRT has also been complemented by a review of local transit (bus) services, removing duplicate services and amending services to feed into new transfer facilities at McMaster University, MacNab, and Queenston.

1.4 All of these changes result in the need to update the TPAP approval for the LRT project. This includes long term ridership forecasting, and an assessment of traffic impacts, along with consideration of other environmental factors. This report documents the work undertaken to develop the VISUM model to produce ridership forecasts and traffic volumes.

1.5 Common with other modern urban style LRT projects, and following the approach used for the original Hamilton LRT TPAP- the assessment of ridership and traffic uses a set of computer models to understand the benefits and impacts of the proposed LRT project. The results go through a process of testing, modification, iteration and refinement to achieve a balance of competitive LRT performance and efficient traffic operation. This process is on-going as part of the updated TPAP process and is due to be completed in early 2017, alongside the development of project details for the Reference Concept Design (RCD) and procurement documentation (Project Specific Output Specification- PSOS).

## Report Structure

1.6 Following this introductory section, the report is structured as follows: -

- Chapter 2: Overall Modelling Process
- Chapter 3: Wider Area Impacts Process
- Chapter 4: VISUM 2031 BAU Model
- Chapter 5: VISUM 2031 LRT Model
- Chapter 6: Conclusions

# 2 Overall Modelling Process

## Modelling Suite

1.7 A series of models have been built in EMME, VISUM and VISSIM to provide tools to examine LRT ridership, and traffic impacts. These help inform the design and operation of the LRT system and the wider highway and local transit network. This section of the report provides an overview of each of those models and their specific purpose within the modelling suite.

1.1 The methodology builds on the approach developed to support the business case and traffic impact assessment for the previous B-Line project that received TPAP approval. The updated approach makes best use of available models and data, providing consistency with wider Transportation Master Plan (TMP) activities, and also uses updated versions of software packages to examine area-wide and local traffic impacts.

1.2 The figure below shows the different models used to analyse the project.

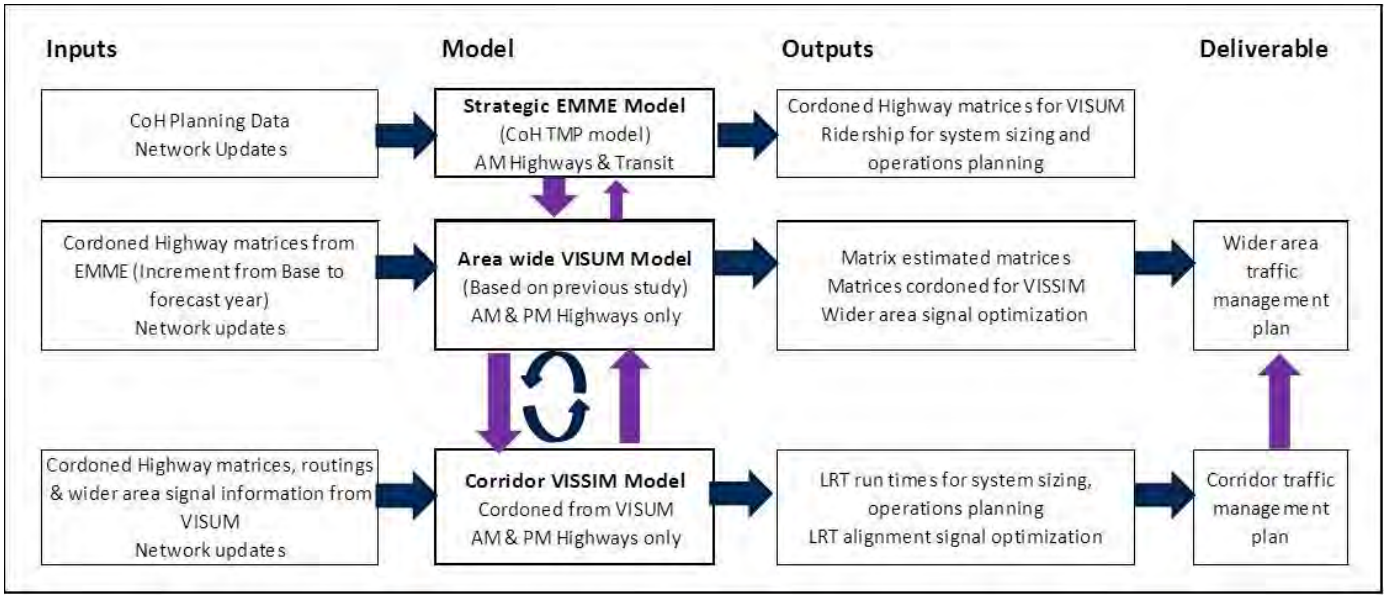
**Figure 2.1: Modelling Geographic Overview**

- Regional level modelling – EMME
  - Covers the geographic area of Hamilton and beyond
  - Consistent with the models used for the Hamilton Transportation Masterplan (TMP)
  - Includes information on both Transit and Highways
  - Source of LRT Ridership forecasts
  - Provides Information on traffic patterns for more detailed modelling (inputs to VISUM model)

- Hamilton Area model - VISUM
  - Traffic demand based on regional information (EMME model outputs) and local context
  - Able to look at the changes in traffic network flows in the Hamilton area
  - Identify issues, develop measures to limit the impacts and test these measures
  - Incorporates detailed signal timing and road capacity information

- LRT Corridor model - VISSIM
  - Models how the LRT and traffic will interact on the corridor
  - Used to understand the measures required for LRT priority
  - Provides more detailed information on LRT runtimes

**Figure 2.2: Model Structure**




## EMME

1.8 The existing City of Hamilton EMME model has been updated based on 2011 TTS data as part of the Transportation Master Plan (TMP) process. This model is used for transit ridership forecasting and it provides cordoned (prior) highway matrices for the VISUM model.

1.9 All transit network analysis is undertaken in EMME including wider area bus network changes and GO Rail (where services fall within the modelled time period.

1.10 The current forecast year for the EMME model is 2031 and this will be used for the traffic impacts work. An EMME model has been generated for the forecast year of 2041, but this will not be used as part of the traffic forecasting work.

## VISUM

1.11 The VISUM model development is documented in the VISUM Base Model report. 2011 was selected as the base year for the model, as that is the latest version of the EMME model held by the client, which provided the cordoned highway matrices for the VISUM model. It is also the most recent year for TTS data which is a primary source of information for EMME model calibration.

1.12 This report documents the development of the VISUM future year models. The future year matrices have been derived by applying the cordoned EMME incremental change between 2011 and 2031. This model will be used to provide traffic information to VISSIM (cordoned demand).

1.13 The PM VISUM model covers the same geographic scope as the AM model. The matrices are based on transposed matrices from the AM period with appropriate adjustments, based on the available PM traffic data.

1.14 For offline signal optimization a separate but linked package called VISTRO was used. This was used as the very final step in the process, to additionally optimize the operation of offline signals. Note that this was only undertaken for the LRT scenario. The revised signal timings were imported back into VISUM for the final assignment and outputs.

## VISSIM

1.15 The model is a cordoned version of the AM VISUM model and the geographic scope covers the LRT alignment only. It includes the AM and PM peak hours only as well as ramp up and ramp down periods. The traffic assignment for this will be directly obtained from the AM VISUM model.

1.16 This model is used to understand in more detail the impacts of the LRT on traffic flow, allows the calculation of LRT runtimes and the production of video clips showing LRT/intersection operation. For the 'with LRT' scenario, information will be fed back to VISUM on the corridor operation. The model includes Transit Signal Priority (TSP) and/or pre-emption priority on the LRT alignment, so will provide detailed analysis of intersection operation and LRT run times.

1.17 The PM VISSIM Model is identical to the AM model, except with PM traffic signal data, PM bus data and assignment from the PM VISUM model.

1.18 The following traffic models for base and future years (2031) have been developed:

- Regional AM EMME model for transit and highways (using the TMP study model as the basis);
- Area wide AM VISUM model for highways;
- Area wide PM VISUM model for highways;
- Corridor AM VISSIM model; and
- Corridor PM VISSIM model.

1.19 This combination of models allows the development of ridership forecasts, provides an understanding of the traffic impacts along the LRT corridor and gives the ability to produce VISSIM

videos showing traffic and LRT operation on the LRT corridor, and the basis for developing an area traffic management plan.

# 3 Wider Area Traffic Impacts Process

## Overview

3.1 Developing the wider area traffic impact mitigations is a multi-step process. Prior to understanding the impacts, the introduction of the LRT causes, it is important to understand the evolution of the background traffic and non LRT related network changes.

3.2 Once the demand for each of the scenarios had been established, traffic was assigned into the different scenarios. Intersections with high delays and queuing were examined in detail and adjustments made in order to reduce the queuing and delays and improve network operation. This process was iterative with flows being assigned and changes made and then flows being assigned again. Quite often reducing delays in one location caused traffic re-routing and impacted on other intersections which then required mitigation.

3.3 Initial work was undertaken in the 'without LRT' BAU scenario and those changes were implemented within the 'With LRT' scenario before the optimisation was undertaken in that scenario. Two designs were tested in the model – the version presented at the Public Information Centres in September 2016, as well as the design tested and documented in this report from December 2016.

3.4 In each instance, a range of different interventions were considered and these are set out below. Some are minor changes, while some intersections require more significant measures in order to operate at an acceptable level.

- Traffic signal operations
- Timing allocation
- Staging changes
- Dedicated turn phases
- Signal cycle times
- Intersection layout
- Turning lane reallocation
- Addition of turning lanes
- Addition of a dedicated slip lane
- Turn movement bans

3.5 One of the considerations when prioritising the mitigation of intersections was the Level of Service (LoS) output from the VISUM model. The link LoS output from EMME has been used as part of the TMP process for reporting network operation, but within VISUM, detailed intersection LoS can be reviewed rather than just an average value on the links. Currently the City standard is for LoS D or above, but this standard can be relaxed on specific intersection movements and when it only occurs for short periods of time, for example within the peak of the peak hour.

3.6 Within the VISUM model, the detail of the intersections within the network is included allowing the examination of turning lanes, queue storage and traffic signal timings as well as the level of service on particular turns, intersections and links.

3.7 Between the base model year of 2011 and the traffic impacts forecast year of 2031, there is forecast to be a significant amount of background traffic growth. The tables below illustrate the changes in the planning data inputs into the model between 2011 and 2031. Population and employment growth leads to an increased number of trips (both auto and transit) within the network and congestion is expected to increase. Planning Data was provided by the City of Hamilton.

**Table 3.1: Planning Data Increases between 2011 and 2031**

| Year | Description | Value | Change from 2011 | Change (%) from 2011 | Change from 2031 | Change (%) from 2031 |
|---|---|---|---|---|---|---|
| 2011 | Population | 531,057 | - | - | - | - |
| 2011 | Employment | 233,896 | - | - | - | - |
| 2031 | Population | 659,748 | 128,691 | 24% | - | - |
| 2031 | Employment | 300,972 | 67,076 | 29% | - | - |

## Network Updates

3.8 A number of updates were required due to changes implemented between the 2011 Base Model and the current 2015/2016 situation, as well as committed improvements between the present day and the forecast years. There were a significant number of changes within the BAU network relating to two-way conversions and the implementation of bike lanes proposed by the City as part of the TMP.

3.9 Limited information was available on intersection layouts and traffic signal operation; so appropriate assumptions have been made. When modelling projects such as the introduction of an LRT, it is important to have a robust BAU model. It needs to contain all committed projects so that the network operation prior to the introduction of the project can be well understood and the underlying assumptions are realistic.

3.10 The key changes made between the 2011 and 2031 models were as follows: -

- Wentworth 2-way from Delaware to Barton
- Hughson 2-way from Barton to Wilson
- Gage - 1 lane reduction from Industrial to Cumberland
- Victoria 2-way from Burlington to Ferrie
- Cannon – 1 lane reduction
- York – 1 lane reduction from Dundurn to Queen
- MacNab – bus only lane from King to Main

3.11 The VISUM model is a highway only model, so transit coding is not captured, however highways impacts related to transit priority and the coding of the LRT scenario are reflected and based on the current version of the design.

3.12 Further detail on the network changes that have been made are detailed in the following chapters however it should be noted that there are a number of changes within Hamilton which cause changes in the traffic operation between 2011 and 2031. These changes required additional work to lane allocations and traffic signal operation within the 2031 BAU model in order to get traffic flowing in the BAU scenario.

## Challenges for the Revised EMME and VISUM Models

3.13 The planning data mentioned above, feeds into the EMME model in the form of revised trip matrices. The EMME is a link based regional model which is good tool for understanding high level traffic impacts; however, like all link based models, it does not fully reflect the impact of congestion in a signalized network, which is the key reason why VISUM and VISSIM models are required for this project. The EMME model is assigned and traffic is routed based on the revised network coding. 2031 Business as Usual matrices are cordoned for the VISUM models which take account of the larger traffic volumes and revised network.

3.14 Work has been required to reconfigure traffic signal staging and timings to accommodate both the network changes and the forecast growth. The EMME cordoned matrices initially produced demand that could not be fully accommodated within the VISUM network and additional effort was required to develop a strategy to produce a traffic assignment that was able to converge within VISUM. Further detail on the matrix development and refinement is provided in the following chapters.

3.15 In addition to producing cordoned flows from the 2031 EMME BAU model, the LRT designs were coded into the EMME model and assignment run. This allowed the traffic diversion caused by the highway network changes made for the LRT (e.g. removal of traffic lanes and turn bans etc.) to be determined. This model was also used to produce cordoned matrices for use in the 2031 LRT model.

# 4 VISUM 2031 BAU Model

## Network Development

4.1 The basis of the 2031 Business as Usual (BAU) network was the 2011 Base calibrated VISUM network. Updates were then made to the model network based on changes between 2011 and the present day as well as committed network changes between now and 2031. The details of the changes made are summarized below. The list has a range of changes including two-way conversions on Wentworth Street, Victoria Avenue, Hughson Street, Caroline Street and the implementation of cycle lanes on York Boulevard and Cannon Street.

**Table 4.1: Road Network Changes (BAU Scenario)**

| Street | Direction | From | To | Changes |
|---|---|---|---|---|
| Wentworth | NB | Delaware | Barton | Converted to two way from Delaware to Barton |
| Wentworth | SB | Barton | Cannon | Changed lanes from 3 to 2 from Barton to Delaware |
| Hughson | NB | Wilson | Barton | Changed lanes from 2 to 1 from Wilson to Barton |
| Hughson | SB | Barton | Wilson | Converted to two way from Barton to Wilson |
| Gage | NB | Cumberland | Industrial | Changed lanes from 2 to 1 from Cumberland to Industrial |
| Gage | SB | Industrial | Cumberland | Changed lanes from 2 to 1 from Industrial to Burlington |
| Locke | NB | Main | King | Changed lanes from 2 to 1 from Main to King |
| Victoria | NB | Claremont | Main | Changed lanes from 5 to 4 from Claremont to Main |
| Victoria | NB | Main | Cannon | Changed lanes from 4 to 3 from Main to Cannon |
| Victoria | NB | Cannon | Burlington | Changed lanes from 3 to 2 from Cannon to Burlington |
| Victoria | SB | Burlington | Ferrie | Converted to two way from Burlington to Ferrie |
| Cannon | EB | Melrose | Kenilworth | Changed lanes from 2 to 1 from Melrose to Kenilworth |
| Cannon | WB | Kenilworth | Melrose | Changed lanes from 2 to 1 from Kenilworth to Melrose |
| Cannon | WB | Sherman | Victoria | Changed lanes from 3 to 2 from Sherman to Sanford |
| MacNab | SB | King | Main | Added bus-only lanes from King to Main |
| MacNab | NB | Main | King | Changed lanes from 2 to 1 from Main to King |
| York | WB | Queen | Dundurn | Changed lanes from 3 to 2 from Queen to Dundurn |
| York | EB | Dundurn | Queen | Changed lanes from 3 to 2 from Dundurn to Queen |

4.2 As mentioned previously, the changes made to the network between 2011 and the 2031 BAU network are reasonably significant which means that changes are also required for the traffic signal coding. There was very little information provided on future traffic signal changes that accompanied the network changes, so changes were made on professional judgement and informed by details of intersection layouts that were provided by the City.

## Matrix Development

4.3 The Hamilton AM EMME model was cordoned as per the figure overleaf for the Base (2011), 2031 BAU and 2031 LRT scenarios. The EMME model which was developed by the Transportation Masterplan (TMP) team is for the AM peak period of 6am to 9am. Within the VISUM model, the AM peak hour was defined as 8.00 to 9.00. A factor of 0.43 was used to convert the EMME peak period cordon matrix to a peak hour matrix. This factor was developed as part of the 2010 study based on count data and established previously as the standard factor to convert EMME peak period to peak hour flows. A cordon file was developed in order to extract an appropriate matrix from EMME.

4.4 The EMME base model was cordoned to create 'Prior' matrices for cars and trucks. Matrix estimation was then run in VISUM, which had the effect of reducing matrix totals significantly from 49,050 to 40,760; a reduction of approximately 17%. This reduction was based on traffic count information within the Hamilton area (for more details on this procedure, see VISUM model Calibration Report).

4.5 The VISUM matrices for BAU and LRT scenarios were created by taking a combination of the VISUM base final calibrated matrix and a comparison of zone total differences between the EMME BAU to EMME base, and the EMME LRT to EMME base. The following formulae were used to calculate the VISUM origin and destination totals:

**VISUM 2031 BAU = VISUM Base + difference (EMME 2031 BAU and EMME Base)**

**VISUM 2031 LRT = VISUM Base + difference (EMME 2031 LRT and EMME Base)**

4.6 These formulae help ensure that only the absolute increase (or decrease) in EMME origin/destination totals are applied to the VISUM calibrated base matrix. Once the VISUM OD totals for BAU and LRT had been determined, a furnessing procedure was applied to obtain the VISUM BAU and LRT matrices.

**Figure 4.1: EMME cordon Area for VISUM**

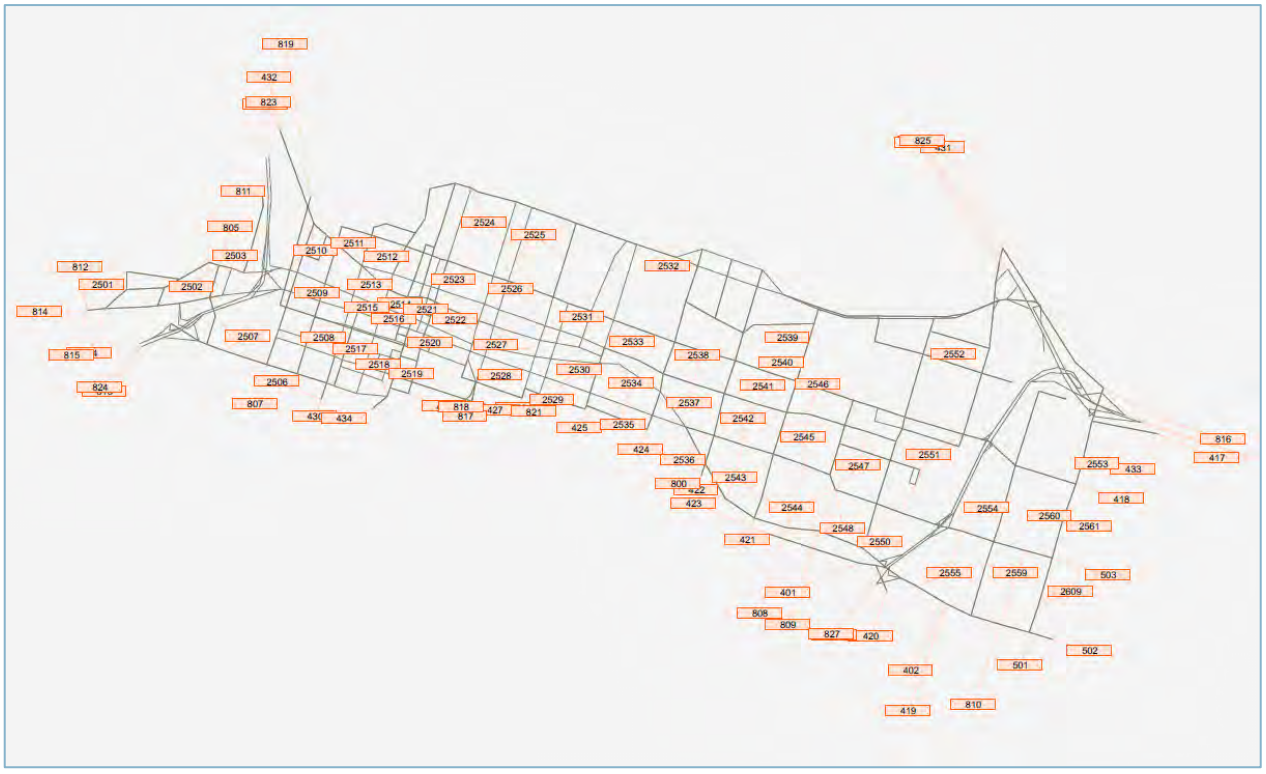



**Table 4.2: EMME and VISUM Matrix Totals**

| Matrix | Car | Truck | Total | Increment from Base |
|---|---|---|---|---|
| AM EMME Base (2011) | - | - | 49,050 | |
| AM EMME BAU (2031) | - | - | 58,600 | 9,550 |
| AM EMME LRT(2031) | - | - | 57,220 | 8,170 |
| | | | | |
| AM VISUM Base (Final, 2011) | 38,790 | 1,980 | 40,760 | |
| AM VISUM BAU (2031) | 47,580 | 2,600 | 50,310 | 9,550 |
| AM VISUM LRT (2031) | 46,250 | 2,520 | 48,920 | 8,160 |
| | | | | |
| PM VISUM Base (Final, 2011) | 45,430 | 1,200 | 46,630 | |
| PM VISUM BAU (2031) | 56,180 | 1,570 | 57,750 | 11,120 |
| PM VISUM LRT (2031) | 54,870 | 1,500 | 56,370 | 9,740 |

### Matrix Adjustments

4.7 Feedback received as part of the model review process highlighted a concern around the traffic volumes on Highway 403, on the Red Hill Valley Parkway and on the Queen Elizabeth Way (QEW). This issue had arisen due to the furnessing process undertaken for the calibration – there had been a lack of peak hour count data available for these routes. Upon review it was determined

that it was through traffic on these routes that was omitted and so this was added as an additional through flow on the two routes.

4.8 Data from EMME was utilised for a section on Highway 403 with an available AM peak count, South of Aberdeen Avenue: the difference between the count and the amount of demand on that section in the Base 2011 scenario has been added as through traffic. Similarly, after having calculated an AM hourly traffic value starting from an available daily count along the Red Hill Valley Parkway (South of King) using a factor of 10 for AADT to AM peak hour, the through traffic along this Highway has been updated. Along the QEW, a total of 2,000 additional vehicles for each direction was assumed. For PM peak the same values but with opposed directions have been used. The following table show demand adjustments.

**Table 4.3: Highways Traffic adjustments**

| | | AM | | PM | |
|---|---|---|---|---|---|
| | | SB | NB | SB | NB |
| **HGW 403 (South of Aberdeen)** | EMME | 2,400 | 3,700 | 3,700 | 2,400 |
| | Base 2011 | 700 | 1,300 | 1,700 | 1,100 |
| | ***to add*** | ***1,700*** | ***2,400*** | ***2,000*** | ***1,300*** |
| **RHVP (South of King)** | Counts | 2,200 | 3,800 | 3,800 | 2,200 |
| | Base 2011 | 1,300 | 2,200 | 2,500 | 1,800 |
| | ***to add*** | ***900*** | ***1,600*** | ***1,300*** | ***400*** |

4.9 The values reported in the table, calculated for Base 2011 scenario, have been added onto the future scenarios as well (2031 BAU and 2031 LRT).

**Peak Spreading Adjustment**

4.10 When the matrices above were run with the VISUM model, there was an issue with the network being able to accommodate the forecast traffic volumes. Despite significant attempts it was not possible to get all of the traffic into the network without the network essentially locking up and experiencing significant queuing in both the Business as Usual and with LRT networks. As the primary purpose of the study is to understand the impact following the introduction of the LRT, it was required to have an operational network to do that.

4.11 It is a commonly observed and acknowledged phenomenon that as networks become congested over time, that travellers begin to change their time of travel in order to complete their journey within a less congested network. This is known as peak spreading, where essentially trips that would ideally travel in the peak are moved to adjacent time periods and this essentially reduces the peak hour demand.

4.12 The forecast year for this assessment is 2031 and between the base 2011 model and the future forecast year, significant demand is expected to be added to the network – in actuality more demand than the network can cope with. In order to get to an operational BAU network it was decided to remove 10% of the demand from the matrix, on the basis that once the network

becomes that congested the additional demand would be moved to an adjacent time period. The following table shows the final BAU and LRT matrix totals currently used.

**Table 4.4: VISUM Matrix Totals after peak spreading adjustment (Note excludes Highway Uplift)**

| Matrix | Car | Truck | Total | Increment from Base |
|---|---|---|---|---|
| AM VISUM BAU | 42,820 | 2,580 | 45,400 | 4,640 |
| AM VISUM LRT | 41,630 | 2,520 | 44,150 | 3,390 |
| PM VISUM BAU | 50,560 | 1,570 | 52,130 | 5,500 |
| PM VISUM LRT | 49,380 | 1,500 | 50,880 | 4,250 |

4.13 This process resulted in BAU and LRT networks that still experienced significant levels of congestion, but that were still able to operate. This allowed the networks to be developed to maximise the level of demand they could cope with and allow the assessment of the network changes and impacts caused by the LRT.

4.14 Details on the operation and performance of the BAU and LRT networks are documented in the sections following this.

## BAU Network Operation

4.15 Using the matrices developed above, traffic was assigned to the revised VISUM network. As the configuration and operation of a number of intersections had changed since the 2011 version, additional time and effort was spent to ensure that traffic operated satisfactorily within the BAU network for both the AM and PM periods. Note that full signal optimization was not undertaken for this scenario.

4.16 Work has been undertaken to improve the flow of traffic within the BAU network and improve traffic operation to accommodate the increased traffic and the two-way conversions. The table below sets out the changes required at specific intersections in order to keep the network moving.

**Table 4.5: Table of Mitigation Measures in 2031 AM BAU model**

| Intersection | Signals | Details |
|---|---|---|
| James and King (South) | SBRT and WBT | More green to SBRT and WBT |
| James and Main | EBT | More green to EBT |
| Main and Queen | EBT and SBT | More green to EBT and SBT |
| Queenston and RHVP West | EBT, WBT and RHVP | More green to EBT/WBT and RHVP |
| King and Parkdale | WBT, EBT and NBT | More green to WBT/EBT and NBT |
| King and RHVP West Ramp | | More green to NBT/EBT/SBT/WBT |
| Barton and Woodward | | More green to NBT/SBT and EBT/WBT |
| Barton and RHVP West | WBT | More green to WBT |
| Barton and Nash | SBT and NBLT | More green to SBT and NBLT |
| Cannon and Queen/ York | SBT, EBT and WBT | More green to SBT and less green to EBT/WBT |
| Cannon and Gage | WBT | Slight increase green to WBT |
| Burlington and Wentworth | NBT, EBT and WBT | More green to NBT and less green to EBT/WBT |

| Intersection | Signals | Details |
|---|---|---|
| Main and Wentworth | | Added one lane at Wentworth<br>Added one lane for NB on the south approach (from 1 approach to 2). |
| King and Main East | All inbound links | Improved signal plan (cycle length to 120 sec, more green time to WBT) |
| Cannon and Queen/York | WBLT | The optimized signal plan does not include a protected period for WBLT. |
| Cannon and Victoria | | Added one lane at Victoria south approach, (from 3 approaches to 4) |
| Locke and York | New signal plan | WBLT has been banned and an optimized signal plan has been developed without protected WBLT. |
| Dundurn and Lamoreaux (ped) | Cycle length | This is a pedestrian recall signal: we used a longer fixed cycle length, supposing one pedestrian every 180 sec |

**Table 4.6: Table of Mitigation Measures in PM BAU model**

| Intersection | Signals | Details |
|---|---|---|
| Main and Queen | EBT | More green to EBT |
| Main and Wellington | EBT | More green to EBT |
| Queenston and RHVP West | RHVP, EBT and WBT | More green to RHVP less green to EBT/WBT |
| King and RHVP West Ramp | | More green to NBT/SBT and less green to EBT/WBT (-7 sec) |
| Barton and RHVP West | SBT, EBT and WBT | More green to SBT and less green to EBT/WBT |
| Cannon and Queen/ York | SBT, EBT and WBT | More green to SBT and less green to EBT/WBT |
| Cannon and Gage | WBT | More green to WBT |
| Aberdeen and Queen | NB | More green to NBLT |
| Burlington and Wentworth | NBT, EBT and WBT | More green to WB/EB and NBT |
| King and Main East | EBT | Cycle length to 120 sec, more green percentage to EBT |
| Queenston and RHVP West | WB/EB | More green to WB/EB |
| King and Parkdale | WB/EB | More green to WB/EB |
| King and RHVP West Ramp | WB/EB | SBT lane shared with SBRT  More green to WB/EB |
| King and Nash | WB/EB | More green to WB/EB |
| Barton and RHVP West | WB/EB | More green to WB/EB |
| Main and Wentworth | | Added one lane at Wentworth for NB on the south approach (from 1 approach to 2). |
| Cannon and Victoria | | Added one lane at Victoria south approach, (from 3 approaches to 4) |
| Locke and York | new signals plan | WBLT has been banned and a new signs plan has been developed without protected WBLT. |
| James and Main | | EBRT lane shared with EBT |

4.17 The measures implemented above have not completely offset the congestion caused by the increased traffic volumes and revised network coding. The plots below show the traffic flows within the networks following the mitigation measures.

**Figure 4.2: 2031 AM BAU Volumes**

**Figure 4.3: 2031 PM BAU Volumes**

4.18 For urban models, with a high level of detail, such those implemented in VISUM, a commonly used measure of auto network performance is a 'Level of Service' (LoS) grading, that is based on a letter system which ranges from LoS A to F (with A having the shortest amount of delay).

4.19 The table below illustrates the intersections within the AM and PM models that operate at a Level of Service of D or below and experience a drop of two or more levels between 2011 and 2031 BAU. Note that the BAU scenario is for high level reference only as this scenario does not have full signal optimization in place.

4.20 These are the intersections where the focus of the effort has been directed. The LoS for all intersections is shown in the figures that follow the tables. Note that currently within the City of Hamilton, an acceptable Level of Service is considered to be D or above.

**Table 4.7: Intersection Level of Service 2031 AM BAU**

| Name | AM Base | AM BAU |
|---|---|---|
| Main and Dundurn | C | F |
| Main and Bay | C | F |
| Main and John | C | E |
| Main and Sherman | B | E |
| Queenston and Reid | B | E |
| King and Dundurn | C | E |
| King and Walnut | B | F |
| King & Ottawa | C | E |
| King and Parkdale | C | F |
| Barton and Bay | C | E |
| Barton and Victoria | C | F |
| Barton and Woodward | B | E |
| Cannon and Sherman | C | E |
| Wilson and Wellington | C | E |
| Main and Queenston | D | F |
| Barton and MacNab | B | F |
| Centennial and Arrowsmith | B | E |
| Dundurn and Charlton | C | E |
| Burlington and Victoria | B | E |
| Burlington and Wentworth | C | E |
| Burlington and Ottawa | B | F |
| Ottawa and Industrial | B | F |
| Ottawa and Beach | A | E |
| Depew and Industrial | B | E |

**Table 4.8: Intersection Level of Service 2031 PM BAU**

| Name | PM Base | PM BAU |
|---|---|---|
| James and Cannon | C | F |
| Main and Wellington | C | E |
| Main and Sherman | C | F |
| King and Main East | B | E |
| Main and Ottawa | B | E |

| Name | PM Base | PM BAU |
|---|---|---|
| King and Dundurn | D | F |
| King and Queen | C | E |
| King and Walnut | C | F |
| King & Ottawa | C | F |
| Barton and Smith (ped) | A | F |
| Cannon and Victoria | B | E |
| Cannon and Sherman | C | E |
| Cannon and Gage | C | E |
| York and Locke | B | E |
| Barton and MacNab | A | F |
| Centennial and Arrowsmith | B | F |
| Dundurn and Aberdeen | D | F |
| Dundurn and Charlton | A | F |
| John and Guise | A | F |
| Burlington and Wentworth | C | F |
| Burlington and Gage | B | E |
| Burlington and Ottawa | C | E |
| Ottawa and Industrial | C | F |
| Kenilworth and McAnulty | B | E |
| Sherman and Delaware | A | E |

4.21 It is important to note that as the node LoS is calculated across all of the turn movements at an intersection (Potentially 16 moves across a 4 arm intersection), it can be impacted by one turn with a very large delay, or a number of turns with smaller increases in delay. More detailed information on an individual turn basis has been reviewed with City staff to ensure they are comfortable with the operation and proposed mitigation measures.

4.22 It should also be noted that the LoS output from the VISUM model is not directly comparable with the LoS output from the EMME model. EMME calculates Link LoS based on the traffic volume over the traffic capacity (V/C ratio) while in VISUM it is based on actual delay values. Due to this, the VISUM reported LoS are likely to be lower than the equivalent LoS in EMME.

4.23 Within the tables, there are a number of corridors where more than one intersection is listed e.g. Barton, Burlington, Cannon, Dundurn, Main and King. It may be that further optimization is possible, but the focus of the project is the operation of the network following the implementation of LRT. While there are still considerable impacts observed within the network, the models indicate that the traffic does keep flowing, albeit with an increased level of delay. This BAU network, which is operational, provides a basis for comparison against the network following the implementation of LRT.

4.24 The plots which follow set out the node LoS of all the intersections where the model calculates the delays (signalized, yield, roundabout), the link LoS (based on the average delay experienced by vehicles exiting each link) and the queuing within the network. It is important to note that the following figures are extracted from the model after having applied all the mitigation measures set out above. These changes have been implemented to get the network operational, ensuring that all the demand could enter into it, however despite this, queues remain.

**Figure 4.4: 2031 AM BAU Network – Intersection Levels of Service**

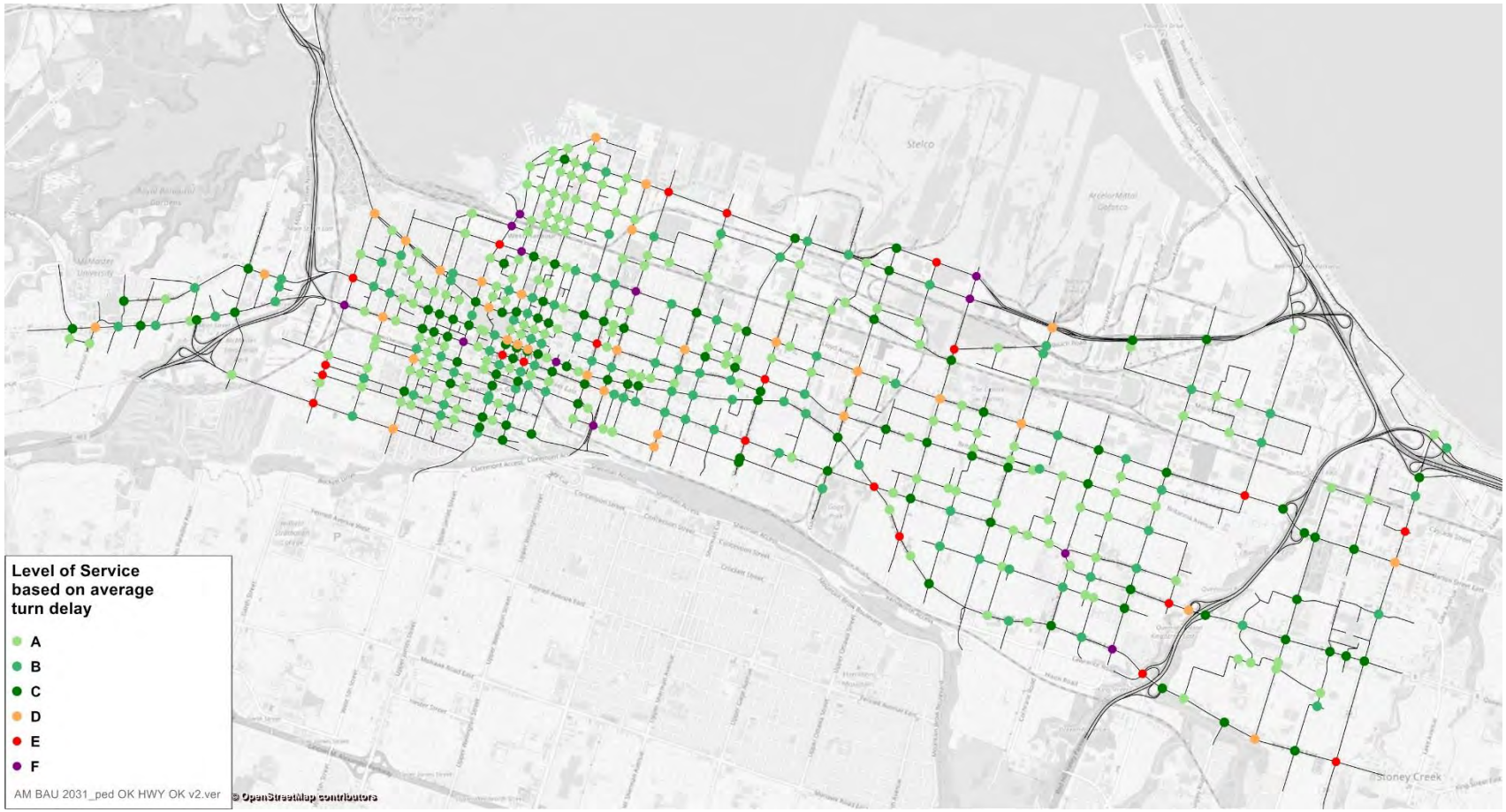


**Figure 4.5: 2031 PM BAU Network – Intersection Levels of Service**

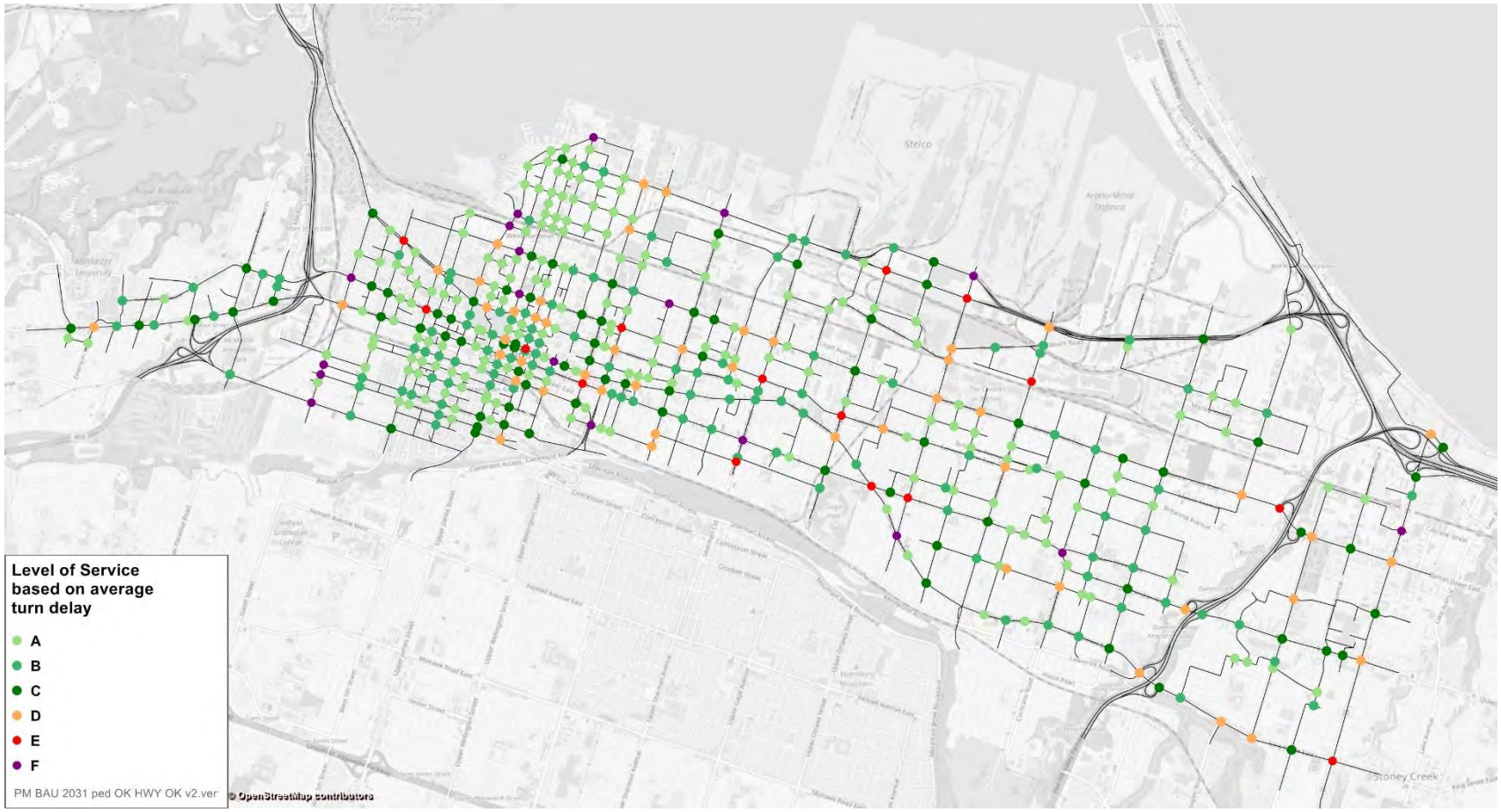


**Figure 4.6: 2031 AM BAU Network – Link Levels of Service**

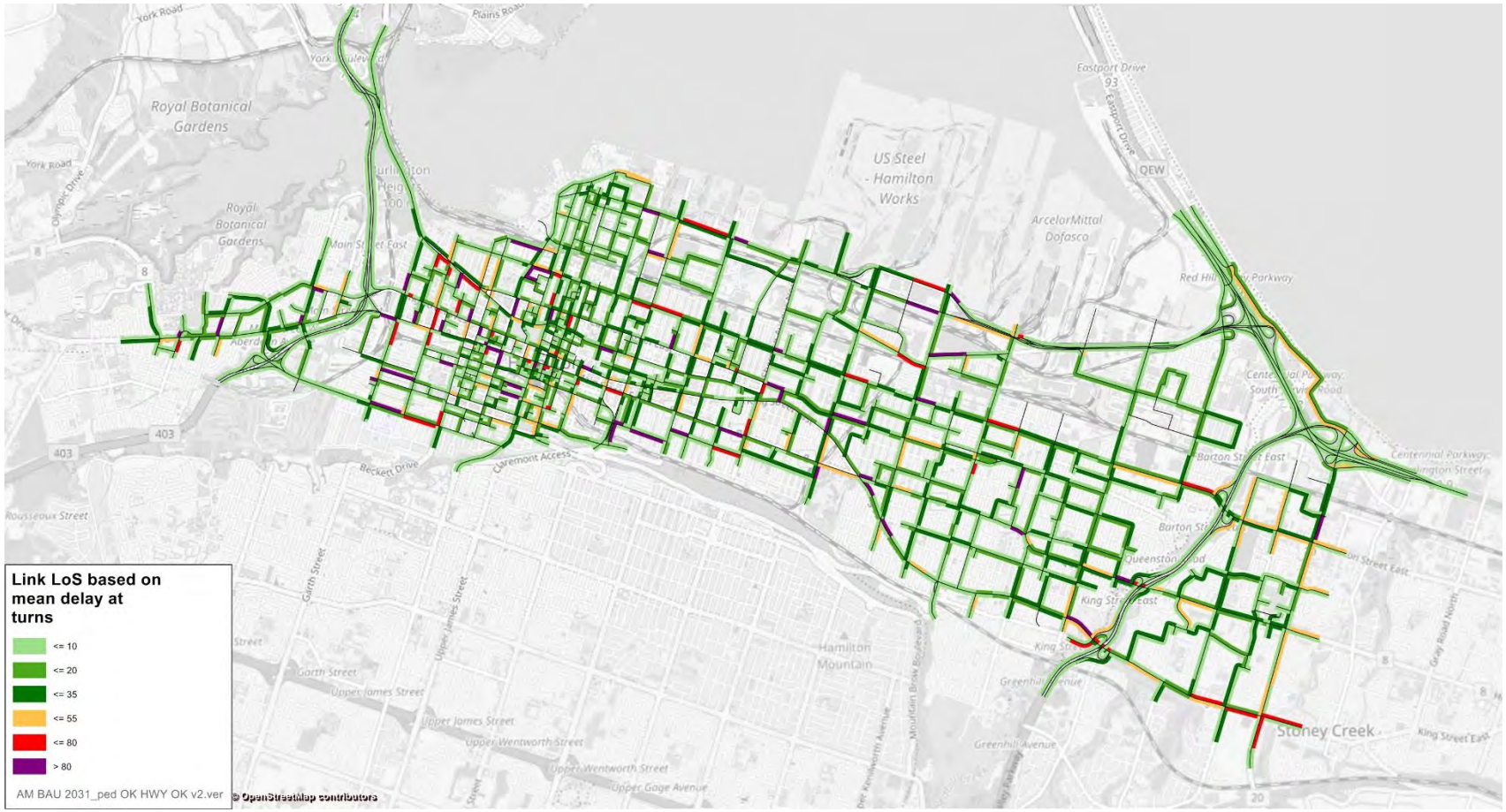


**Figure 4.7: 2031 PM BAU Network – Link Levels of Service**

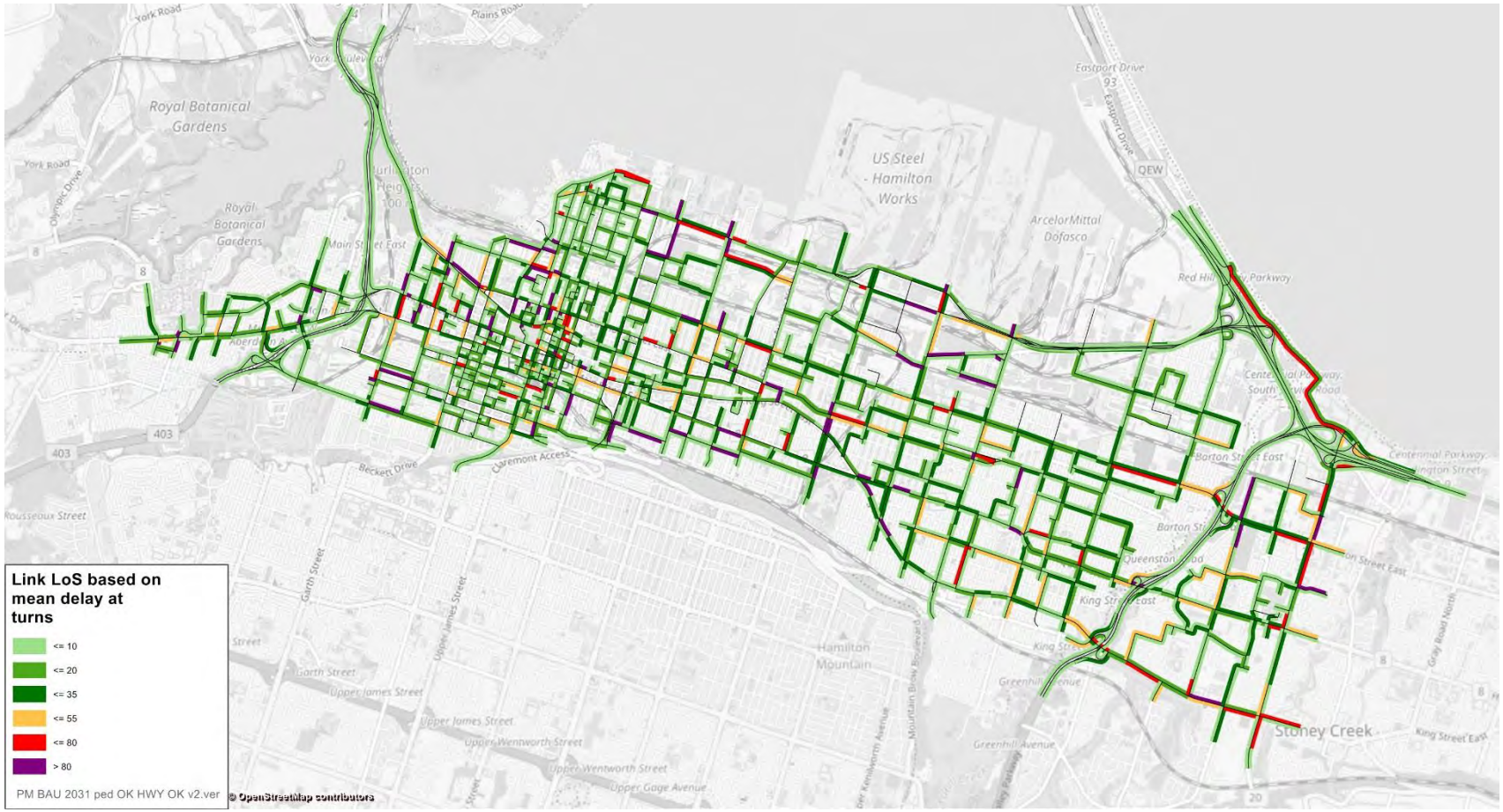


**Figure 4.8: 2031 AM BAU Network – Queuing**

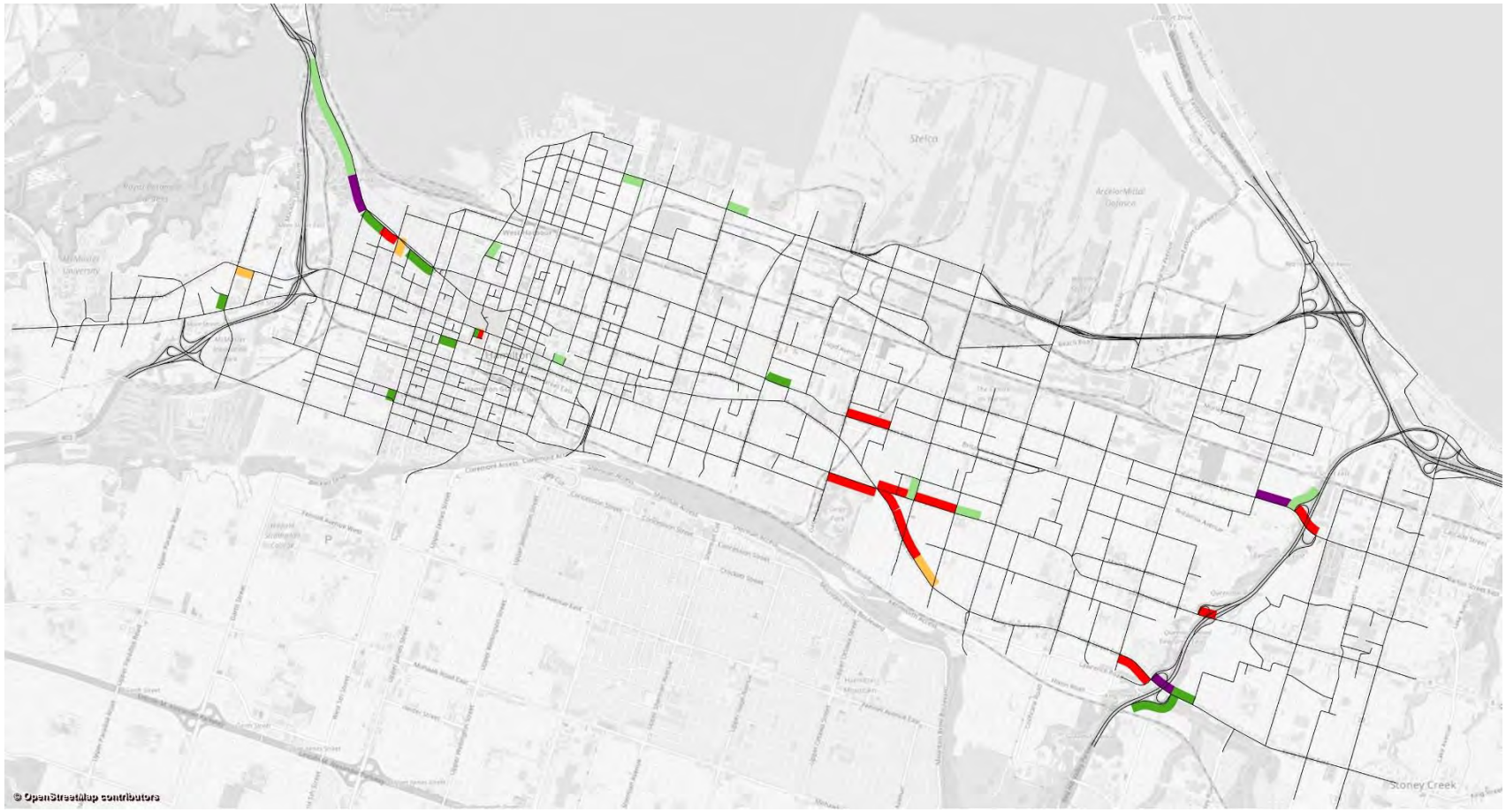


**Figure 4.9: 2031 PM BAU Network – Queuing**

## Comparison of 2031 BAU and 2011 VISUM Base Models

4.25 A comparison was made of the VISUM 2031 BAU network against the 2011 network for the AM peak. Figure 4.10 shows the difference in volumes between the two networks

**Figure 4.10: 2031 BAU Volumes vs 2011 base volumes**


4.26 In the difference plot, red bars show where there is increased traffic between 2011 and 2031 and green bars show where there is a decrease. This plot shows that there is an increase in traffic throughout the network between 2011 and 2031. Most of the few small green bars are due to the capacity reductions for the introduction of bike lanes and two-way conversions. This confirms that the increased traffic volumes are able to enter and flow within the network.

The figures on the following pages show the number of levels of change in the LoS grade between the 2011 networks and the 2031 networks. It can be seen that the change is significant and is widespread across the network. As mentioned previously, it should be noted that the signals in the BAU models have not been fully optimized. This should be considered when reviewing the comparisons between the BAU and LRT models.

**Figure 4.11: Node Level of Service - AM BAU 2031 vs AM Base 2011**

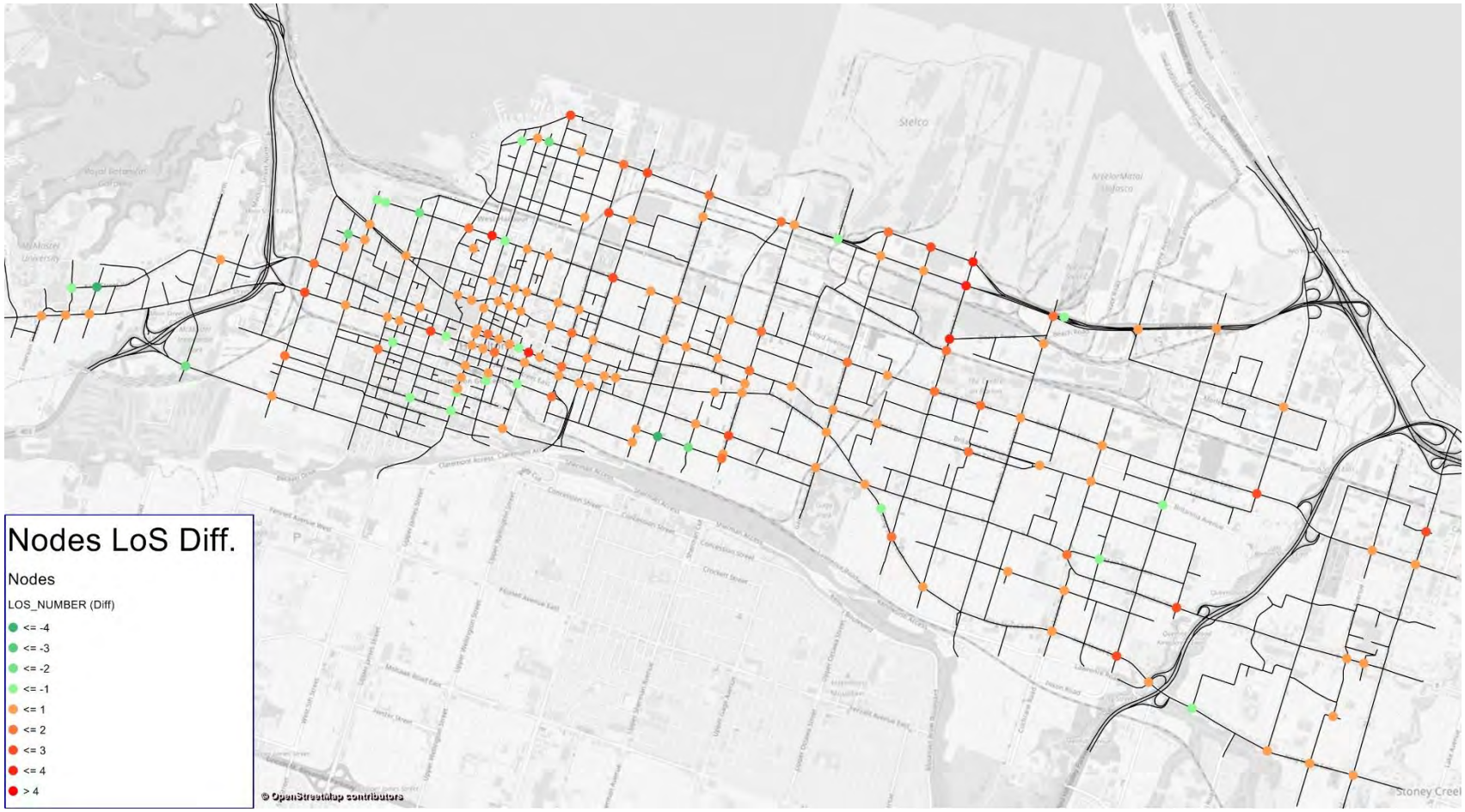


**Figure 4.12: Node Level of Service - PM BAU 2031 vs PM Base 2011**

# 5 VISUM 2031 LRT Model

## Network Development

5.1 The basis of the 2031 LRT network was the 2031 Business as Usual (BAU) VISUM network. Updates were then made to the network based on the latest version of the LRT design. The details of the changes made (before optimization) are set out below. These changes reduced highway capacity and changed permitted turns at intersections in order to accommodate the LRT.

5.2 The VISUM coding was made in accordance with the AECOM drawings which were provided in November 2016. The main principles of the scheme, in terms of LRT operation are as follows:

- The LRT B-Line Alignment is along Main Street (Cootes to Macklin), King Street (Dundurn to Main/King intersection) and Main St (from Main/King intersection to Queenston.
- The LRT A-Line James Street alignment runs from the James St South intersection to Burlington Street.

5.3 LRT is centre running along:

- Main Street (from Dalewood to Paradise);
- King Street (from Dundurn to Queen);
- King Street (from Hess to James);
- King Street (from John to Catharine);
- King Street (from Wellington to Main);
- Main Street (from King to Queenston);

5.4 LRT is side running along:

- Main Street (from Emerson to Dalewood);
- Main Street (from Paradise to Macklin);
- King Street (from Queen to Hess)- note traffic is westbound only in this section;
- King Street (from James to John) – note traffic is westbound only in this section;
- King Street (from Catherine to Wellington) – note traffic is eastbound only in this section

5.5 LRT is street-running and non-segregated on James Street from the Rebecca Street (south) intersection to Burlington Street. South of Rebecca Street, the LRT alignment is segregated to the MacNab Terminus Station (located to the west side of James Street, North of King Street).

**Table 5.1: Road Network Changes With LRT Scenario – in addition to BAU Changes**

| Street | Direction | From | To | Changes |
|---|---|---|---|---|
| Main | WB | Haddon | Cootes | Changed lanes from 3 to 2 |
| Main | WB | Strathearne | King | Changed lanes from 2 to 1 |
| Main | EB | King | Strathearne | Changed lanes from 2 to 1 |
| King | EB | Dundurn | Queen | Converted to two way from Dundurn to Queen (1 lane) |
| King | EB | Hess | James | Converted to two way from Hess to James (1 lane) |
| King | EB | Catharine | Wellington | Change direction (1 lane EB) |
| King | EB | Wellington | Main | Converted to two way from Wellington to Main (1 lane) |
| King | WB | Main | West | Changed lanes from 4 to 1 |
| King | WB | West | Wellington | Changed lanes from 4 to 2 |
| King | WB | Wellington | Catharine | Removed auto link from Wellington to Catharine |
| King | WB | Catharine | James | Changed lanes from 3 to 1 |
| King | WB | James | MacNab | Changed lanes from 3 to 1 |
| King | WB | MacNab | Bay | Changed lanes from 4 to 2 |
| King | WB | Bay | Locke | Changed lanes from 4 to 1 |
| King | WB | Locke | Dundirn | Changed lanes from 5 to 1 |
| King | WB | Dundurn | Breadalbane | Changed lanes from 5 to 3 |

5.6 The signal coding along the LRT alignment was developed following the principles set out in the tables below. For each intersection, the design features and the LRT signal priority type have been highlighted; either they operate as Transit Signal Priority (TSP) or as a signal pre-empt.

**Table 5.2: B-Line Traffic Signal Assumptions and Design Features**

| Intersection | Intersection Design Features | LRT Priority Type | LRT Runs with… |
|---|---|---|---|
| Main / Emerson | WBR signal head for LRT | TSP | WBT+EBT |
| Main/ Bowman | All existing turns allowed | TSP | WBT+EBT |
| Main / Dalewood | All existing turns allowed. WB Stop line set approximately 60m back | Pre-empt | Dedicated timing period |
| Main/ Haddon | All existing turns allowed | | |
| Main / Cline | Right in/ Right out only (no signals) | - | - |
| Main / 403 Ramp | All existing turns allowed | TSP | WBT+EBT |
| Main / Paisley | SBLT ban, EBLT ban | TSP | WBT+EBT |
| Main / Longwood | Centre platform on west side. Pedestrian split phases on east/west crosswalks | TSP | WBT+EBT |
| Main/ Paradise | Signals added | TSP | WBT+EBT |
| Main / Macklin | - | Pre-empt | Dedicated timing period |
| King / Dundurn | SBLT ban, NBRT introduced<br>3 lanes on east arm (WBL, WBT, WBT)<br>3 lanes on south arm (NBL, NBL, NBT)<br>2 lanes on north arm (SBR, SBT) | TSP | Dummy EB |

| Intersection | Intersection Design Features | LRT Priority Type | LRT Runs with… |
|---|---|---|---|
| King / Strathcona | EB introduced, SBRT only, NBRT only, EBLT ban, WBLT ban | TSP | WBT+EBT |
| King / Locke | No NBRT. EBLT introduced | Pre-empt | Dedicated timing period |
| King / Queen | EB introduced<br>Centre platform on west side. Pedestrian split phases on west crosswalk | Pre-empt | Dedicated timing period |
| King / Hess | NBRT only | TSP | WBT |
| King / Bay | EBT, EBLT and EBU introduced, WBU introduced, NBRT introduced | TSP | WBT+EBT |
| King / Summers | EB introduced, Car park exit is NBRT only | TSP | WBT+EBT |
| King / MacNab | EB introduced, EBLT ban, NBRT introduced | TSP | WBT+EBT |
| King / James | WBLT ban, NBLT ban | TSP | WBT+EBT |
| King / Hughson | Pedestrian crossing on west side | TSP | WBT+EBT |
| King / John | SBLT ban. NBRT introduced | TSP | WB |
| King / Catherine | No WB approach, SBLT introduced, EBRT and EBT introduced | TSP | EB |
| King/ Mary | EBT introduced. North link blocked up, No WB.<br>Centre platform on east side. Pedestrian split phases on east crosswalk | TSP | EB |
| King/ Walnut | EBT and EBRT introduced. North link blocked up, No WB, NBRT only | TSP | EB |
| King / Ferguson | EBT and EBRT introduced. North link blocked up, No WB | TSP | EB |
| King / Wellington | EBT and EBRT introduced. No WBT, WBU introduced. SBLT introduced, no SBRT<br>Centre platform on east side. Pedestrian split phases on east crosswalk | TSP | EB |
| King / West | EB introduced (EBLT ban), SBRT only, NBRT only.<br>Pedestrian crossing on west side only | TSP | Dedicated timing period |
| King / Victoria | EB introduced (EBLT allowed, EBRT ban) | Pre-empt | Dedicated timing period |
| King / Tisdale | EB introduced, NBRT only, SBRT only, EBLT ban, WBLT ban | TSP | WBT+EBT |
| King / Wentworth | EB introduced. All movements allowed. WBU and EBU introduced.<br>Centre WB platform on west side. Centre EB platform on east side<br>Pedestrian split phases on west/east crosswalks | TSP | WBT+EBT |
| King / Holton | EBT and EBRT introduced, NBRT only | TSP | WBT+EBT |

| Intersection | Intersection Design Features | LRT Priority Type | LRT Runs with… |
|---|---|---|---|
| King / Sherman | EB introduced, All moves all approaches, WBU and EBU introduced<br>Centre platform on east side. Pedestrian split phases on west/east crosswalk<br>Pedestrian split phases on west/east crosswalks | TSP | WBT+EBT |
| King / Melrose | EB introduced (all moves)<br>Centre platform on east side. Pedestrian split phases on east crosswalk | Pre-empt | Dedicated timing period |
| King / Leinster | EB introduced<br>Pedestrian crossing introduced to east side of Scott Park station | TSP | WBT |
| King / Gage | EB introduced. All movements allowed. WBU and EBU introduced | TSP | WBT+EBT |
| King / East Bend Avenue | LRT tunnel<br>Pedestrian crossing introduced | TSP | WBT+EBT |
| King/ Belview | EB introduced. Pedestrian crossing introduced | TSP | WBT+EBT |
| King / Main | Changes to intersection format. No signal for LRT<br>Pedestrian crossing across Main St to east side of Gage Park station | - | - |
| Main / Rosslyn | New link from King Street (East) | TSP | WBT+EBT |
| Main / Ottawa | All moves all approaches, WBU and EBU introduced<br>Centre platform on west side. Pedestrian split phases on west/east crosswalk | TSP | WBT+EBT |
| Main / Graham | SBRT and NBRT only, no EBLT or WBLT | TSP | WBT+EBT |
| Main / Kenilworth | All moves all approaches, WBU and EBU introduced<br>Centre platform on west side. Pedestrian split phases on west/east crosswalk | TSP | WBT+EBT |
| Main / Cope | SBRT only, EBLT banned | TSP | WBT+EBT |
| Main / Strathearne | Existing Roundabout converted to Signals | Pre-empt | EBRT |

**Table 5.3: A-Line Traffic Signal Assumptions and Design Features**

| Intersection | Intersection Design Features | LRT Priority Type | LRT Runs with… |
|---|---|---|---|
| James / King | No WBLT, No NBLT | TSP | With NBT+SBT |
| James / King William | Reduced capacity<br>SB LRT segregated<br>NB LRT merges with general traffic north of intersection | TSP | With NBT+SBT |
| James / Rebecca | Reduced capacity on N+S LRT mixed lane | TSP | With NBT+SBT |
| James / Wilson | Reduced capacity on N+S LRT mixed lane | TSP | With NBT+SBT |

| | | | |
|---|---|---|---|
| James / Cannon | Reduced capacity on N+S LRT mixed lane | TSP | With NBT+SBT |
| James / Barton | Reduced capacity on N+S LRT mixed lane | TSP | With NBT+SBT |
| James / Harbour | Reduced capacity on N+S LRT mixed lane | TSP | With NBT+SBT |
| James / Burlingon | West approach is EB only | TSP | With NBT+SBT |

5.7 The key changes to traffic circulation in the B-Line LRT corridor are set out below.

- Near the western terminus, from the McMaster stop east of Cootes Drive, to Dalewood Avenue, the LRT will operate on the north side of the street, in both directions. The existing turning movements will be maintained throughout this section of the corridor.
- East of Haddon Avenue, the centre left-turn lane will be eliminated and unsignalized intersections will be limited to right-in / right-out movements only, similar to the 2011 TPAP design.
- In the vicinity of the Highway 403 crossing, the existing one-way circulation (westbound on King Street West and Paradise Road South; eastbound on Main Street West) is retained.
- King Street, west of Dundurn, remains one-way westbound.
- East of Dundurn, King Street will be generally one lane in each direction, with centre-running LRT, with the following exceptions:
- From Queen Street to Hess Street: westbound only, with the LRT on the south side
- From Catharine Street to Wellington Street: eastbound only, with the LRT on the north side
- From the Delta to Queenston Traffic Circle, Main Street East will operate with one lane in each direction and centre-running LRT.
- The change in lane configurations introduces a variety of new intersection configurations along King Street between Dundurn and the Delta and on Main Street East from the Delta to the Queenston Traffic Circle
- Introducing eastbound traffic on King Street allows the opportunity for new southbound left turns and northbound right turns from perpendicular streets and eastbound left turns from King Street. Left turns across the LRT tracks are limited to key signalized intersections. Left turns from King Street are only permitted where separate left turn lanes can be accommodated.

**Permitted and Prohibited Turning Movements**

5.8 With the introduction of LRT and the associated changes to traffic circulation, there will be changes to the turning movements which are permitted along the B-Line route, particularly where these movements cross the LRT tracks. These changes are required both to facilitate the smooth reliable running of the LRT system, with the appropriate level of priority at signalized intersections, and on safety grounds.

5.9 Where the LRT tracks run adjacent to traffic lanes (whether on the side of road or a central alignment) the layout is such that the direction of travel on the LRT lane is the same as in the adjacent traffic lane. This arrangement minimizes the total road width required, and avoids the situation where drivers can be presented with an oncoming LRV approaching on the ‘wrong’ side. Similarly, pedestrians crossing the road are presented with vehicles in the closest lane(s) approaching from the left, and in the far lane(s) approaching from the right, in the conventional manner.

5.10 With this layout, drivers wishing to turn left (or U-turn) across the LRT tracks will have a clear view of an oncoming LRV (on the track further to their left). However, they may not be aware of a LRV approaching from behind on their left-hand side. In order to minimize the risk of accidents, it is necessary to prohibit uncontrolled left turns and U-turns across the LRT tracks. This applies both to the central running LRT tracks on two-way roads, and on streets where the LRT tracks are on the left-hand side of the one-way traffic lanes.

5.11 Right turns into and out of side roads (which do not cross the LRT tracks) are not affected and will continue to operate as at present. Thus, many side streets along the centre-running sections of the route and on the non-LRT side of the side- running sections will, in future, operate as right-in/right-out only.

5.12 Left turns and U-turns will be permitted at signalized intersections. However, over much of the B-Line route there is insufficient space for dedicated lanes for left-turning vehicles (turning across the LRT tracks), in addition to the lanes for ahead and right-turning traffic. Hence, the left turners will use a lane marked for ahead and left-turning traffic. This in turn means that left turns can take place at any time in the traffic stage, so a separate LRT-only stage is needed for LRV movements. Accordingly, existing two-stage intersections will operate with three stages in those cycles when an LRV movement occurs. This will reduce the intersection capacity, in addition to the capacity reduction arising from the reduction in the number of traffic lanes. In response to this, some drivers of motorized vehicles are expected to either change their routing to alternative routes or, if convenient, change their travel to LRT instead of private car. It is important to note that while the traffic capacity of the corridor will be reduced, the people carrying capacity of the corridor will be increased by introducing the LRT service.

5.13 Left turns out from or into a side street, across the LRT tracks at unsignalized intersections, will not be permitted. In some cases, traffic may be able to take advantage of a pedestrian crossing signal to make these moves, where permitted by the design.

## LRT Network Operation

5.14 Due to the reduction in both link capacity and in particular capacity at intersections, significant work was needed in order to get the traffic flowing adequately within the LRT scenario. The LRT design limits turning movements across the alignment, funnelling demand to the specified crossing points.

5.15 The volume plots show a revised traffic pattern with a significant reduction in demand on King Street Westbound, while there is new traffic eastbound on King Street where the new traffic lane is introduced.

5.16 Traffic decreases on some perpendicular routes because of restrictions on crossing the LRT alignment which results in the banning of some movements e.g. only right in and right out movements are permitted at certain intersections. These north south movements are then consolidated at crossing points where the demand on other north south routes is increased.

5.17 Routes parallel to the LRT alignment see a traffic increase as traffic diverts off the more capacity restrained LRT alignment. As would be expected, the main challenges are at intersections.

5.18 Work has been undertaken as part as an iterative process to mitigate the congestion and delays of traffic within the network. This is a time consuming and iterative process where 'fixing' an issue at one intersection pushes the traffic elsewhere within the network and it generates a new and different problem elsewhere.

5.19 Ultimately the network is not at a point where the impact is limited to a number of constrained points in the network. In order to get to this stage, a number of mitigations were required, some having more impact than others. These are set out in the table below.

**Table 5.4: Network Changes required to accommodate LRT**

| Intersection | Signals | Changes |
|---|---|---|
| James and Main | Signal Timing | Higher green time to EBT |
| Main and Emerson | Signal Timing | Higher green time to EBT, WBT and EBLT |
| Main and Dalewood | Signal Timing | Higher green time to EB/WB |
| Main and Hwy 403 | Signal Timing | Higher green time to EB/WB |
| Main and Longwood | Signal Timing | Higher green time to NBT |
| Main and Queen | Signal Timing | Higher green time to EB |
| Queenston and RHVP West | Signal Timing | Higher green time to EBT, WBT |
| King and Strathcona | Signal Timing | Higher green time to EB/WB |
| King and Parkdale | Signal Timing | Higher green time to EB/WB |
| King and RHVP West Ramp | Signal Timing | Higher green time to EB/WB |
| Barton and Ottawa | Signal Timing | Higher green time to EBT/WBT |
| Barton and Kenilworth | Signal Timing | Higher green time to WBT |
| Barton and Woodward | Signal Timing | Higher green time to EB/WB |
| Barton and RHVP West | Signal Timing | Higher green time to EB/WB |
| Barton and Nash | Signal Timing | Higher green time to NBLT, lower to SBT |
| Cannon and Queen/ York | Signal Timing | Higher green time to EBT/WBT;<br>3 lanes on EB approach (York) |
| Cannon and Gage | Signal Timing | Higher green time to WBT |
| Cannon and Kenilworth | Signal Timing | Higher green time to NBT |
| Barons and Cannon | Signal Timing | Higher green time to WBT |
| Dundurn and York | Signal Timing | Added two pocket lanes for WBLT and WBT (100 m); added one pocket lane for EBT (100 m) and an additional lane (100 m) to accommodate NBRT vehicles along York. Higher green time to WBLT, WBT, NBLT; lower green time to EBT |
| Locke and York | Signal Timing | Banned WBLT, higher green time to EB/WB;<br>3 lanes for all approaches along York (EB and WB, additional lanes of 100 m). |
| Main and Queenston | Cycle length | From 90 to 105 |
| Dundurn and Lamoreaux (ped) | Cycle length | From 90 to 300, pedestrian recall |
| Depew and Industrial | Signal Timing | Lower green time to SB |

| Intersection | Signals | Changes |
|---|---|---|
| Cannon and Sherman | | WB approach: right lane shared for WBT and WBRT movements. |
| Barton Street | | Between Lottridge and Barnsdale (currently operates with one lane) requires a capacity increase by removing the temporary obstacles. |

5.20 In addition to the changes above there were very significant changes required along Dundurn Street North, in the section between York Blvd and King St. These include:

- New layout of the intersection of York Blvd and Dundurn St:
  - 3 lanes eastbound through (added one lane of 100 meters) and 1 lane eastbound right turn;
  - 2 lanes westbound left turn and 2 lanes westbound through (added 1 lane for WBT and 1 for WBLT, 100 meters long).
- Dundurn Street between York Blvd and King St changed to operate as 2 lanes southbound and 1 lane northbound;
- New layout of the intersection between King St and Dundurn St:
  - 1 slip lane for the southbound right turn and 1 lane for southbound through;
  - 2 lanes westbound through (added 1 lane of 150 meters) and 1 additional lane for westbound left turn and U-turn (70 meters);
  - a total of 3 lanes exiting westbound.

5.21 The following figures show the two intersections as coded in VISUM and the length of each proposed additional lane.

**Figure 5.1: Proposed layout for Dundurn/York intersection**

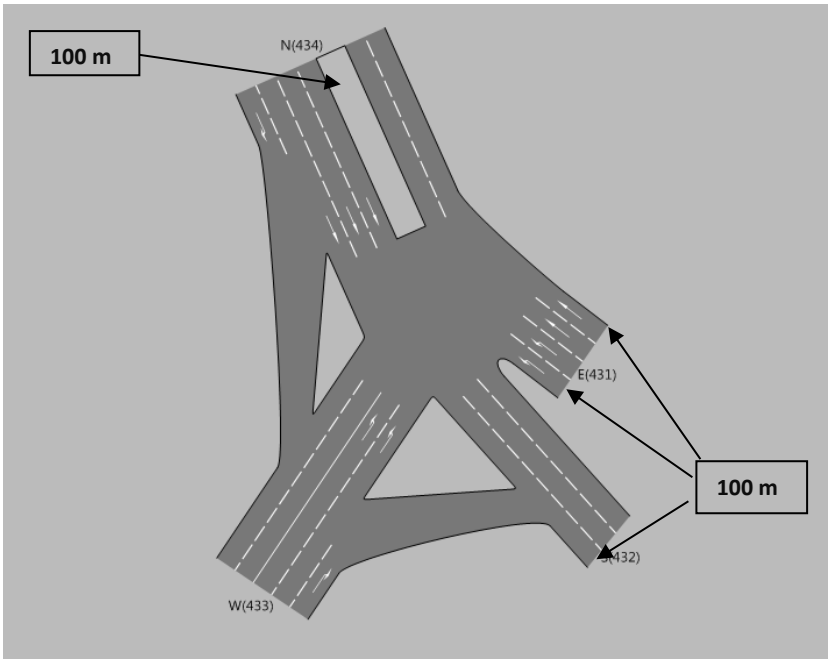
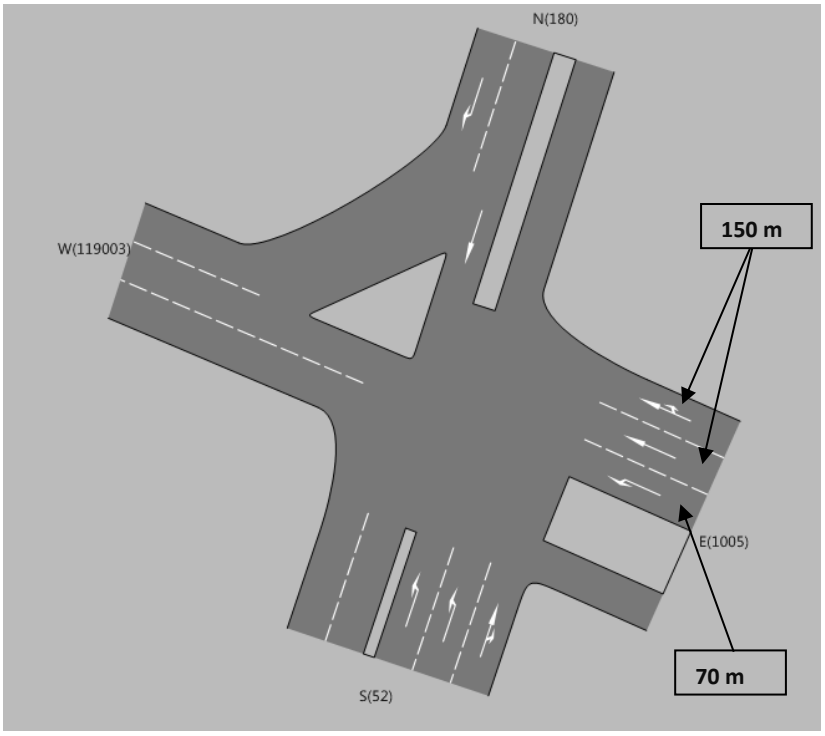


**Figure 5.2: Proposed layout for King/Dundurn intersection**




## VISTRO Optimization

5.22 The final step in the network optimization process for the offline traffic signals was the use of VISTRO. Online signals have previously been optimised within the VISSIM model. VISTRO is a separate but related package to VISUM. Traffic flows and initial traffic signal timings are taken from VISUM and input to VISTRO. Network characteristics such as intersection geometry, travel demand, turning movement volumes and signal timing data are transferred to VISTRO with each model. Based on the flow patterns VISTRO optimizes the timings at a route level. These optimized timings are then taken back into VISUM and used in the assignment to produce the final outputs.

5.23 This was used as the very final step in the process, as there is a limit to the changes that are made in VISTRO, to it is important to have established a sensible traffic pattern before it is used (otherwise it may optimize volumes where you do not want them.)

5.24 In addition to the VISTRO changes, some additional changes were made within VISUM to rectify some local issues.

- AM
  - Added a EBLT protected phase at York/Locke
- PM
  - Added additional green time for SBT at John/King
  - Less green time for NBT and more green for WBT at York/Locke

5.25 Overall the VISTRO process reduced delays throughout the network. There were a limited number of locations where the delays increased and/or the LoS reduced – these were at locations where

corridors had been optimized and increased traffic had been facilitated, but the potential 'entry' and 'exit' points to these corridors are slight bottle necks.

5.26 All of the plots below utilise the signal timings from the VISTRO process. It should be noted that the VISTRO optimization process was not undertaken for the BAU models.

**Figure 5.3: 2031 AM LRT Volumes**

**Figure 5.4: 2031 PM LRT Volumes**

Despite the mitigations set out previously, there are still intersections which show a decreased level of service. These are set out in the tables below. The plots on the following pages show node LoS across the network for all the calculated intersections. It should be noted that the BAU models have not been fully signal optimized. This should be considered when reviewing the comparisons between the BAU and LRT models.

**Table 5.5: Intersection Level of Service 2031 AM LRT (with at least a -2 decrease LRT-BAU)**

| Name | AM Base | AM BAU | AM LRT |
|---|---|---|---|
| James and Cannon | C | D | F |
| Wilson/ York and James | C | C | F |
| James and King | C | D | F |
| Main and Ottawa | C | C | E |
| King and Strathcona | B | B | E |
| King and Locke | B | B | E |
| King and Bay | C | C | E |
| King and Wentworth | B | B | E |
| King and Sherman | B | C | E |
| Gage and King | B | C | E |
| Barton and Smith (ped) | A | B | E |
| Cannon and Wentworth | C | D | F |
| Cannon and Kenilworth | C | C | E |
| Barons and Cannon | A | B | F |
| Hunter and John and GO Station | B | C | E |
| John and Guise | A | D | F |
| Burlington and Sherman | A | B | E |
| Wentworth and Brant | A | B | F |
| Queen and Bold | B | D | F |
| Young and John | B | B | F |
| Sherman and Maplewood | B | C | E |

**Table 5.6: Intersection Level of Service 2031 PM LRT (with at least a -2 decrease LRT-BAU)**

| Name | PM Base | PM BAU | PM LRT |
|---|---|---|---|
| James and King | B | D | F |
| King and Strathcona | C | C | F |
| King and Locke | B | C | E |
| King and Wentworth | B | C | E |
| King and Sherman | B | B | E |
| Cannon and Wentworth | B | D | F |
| Hunter and John and GO Station | C | D | F |
| Ottawa and Beach | A | D | F |

**Figure 5.5: 2031 AM LRT Network – Intersection Levels of Service**

**Figure 5.6: 2031 PM LRT Network – Intersection Levels of Service**

## Comparison of 2031 LRT and 2031 BAU Models

5.27 The figure below shows the differences in assigned traffic volumes between the 2031 LRT VISUM network and the 2031 BAU network. The thickness of the red band represents an increase in traffic in the LRT scenario compared to the BAU, whilst the green bands represent the additional traffic in the BAU compared to the LRT scenario.

**Figure 5.7: 2031 AM LRT Volumes vs 2031 AM BAU volumes**


**Figure 5.8: 2031 PM LRT Volumes vs 2031 PM BAU volumes**

5.28 The large green bands in the downtown core represent the large decrease in traffic volumes on King Street westbound, which is attributed to a reduction in lane capacity in many sections (in most sections, the reduction is from 3 lanes to 1 lane). The same effect is produced along Main Street West in both the directions, where the allocation of the LRT alignment at the center of the carriageway has as a consequence the reduction of capacity along the corridor.

5.29 Due to the reduction of capacity on King Street, some westbound traffic has diverted onto parallel routes such as Aberdeen Av, Hunter St, Wilson St, Cannon St and Barton St. With King Street converted to two-way in many sections, there has been a switch of eastbound traffic using Main St in the downtown core onto King Street.

5.30 In the AM difference plot there is a drop in flow on Highway 403, primarily in northbound and southbound trips coming from King Street. This is related to the constraints in the network around King / Dundurn and York / Dundurn.

5.31 Restricted capacity in those locations cause bottlenecks within the network. As set out earlier in the chapter, mitigations have been discussed with City staff and Metrolinx and these are presented above. These mitigations still however result in queuing within the network as set out in figures 5.11 and 5.12 and leads to a reduction in vehicles completing their journey within the modelled time period.

5.32 Alternatives investigated, but not taken forward which would improve network operation were the addition of another southbound right turn lane at Dundurn/King (a second slip lane). Another option that was tested was the LRT centre running between Dundurn and Queen. This improves operation as it creates two lanes for westbound traffic. The mitigations taken forward represent a trade-off in traffic operation, LRT operation, pedestrian and cycle movements and the requirement for land/property take.

5.33 The PM plots also show less traffic accessing Downtown via York Boulevard, instead accessing via Main Street. This is due to the reduction of capacity for EBT traffic at York/Dundurn intersection (less green time) to accommodate an increased westbound traffic using the path York/Dundurn. As both the base volumes, as well as the traffic increase are greater in the PM peak, there is a greater diversion observed within the PM plots.

5.34 Further plots showing the link LoS (based on the average delay experienced by vehicles exiting each link) and queuing – after having included all the mitigations above – are set out below. They also illustrate that there are greater impacts under these metrics in the PM networks with increased queuing and a greater number of links with a lower level of service.

5.35 This diversion of traffic and the resulting patterns create congestion in several areas:

- Main Street West segment
  - While the number of westbound lanes can be reduced from three to two, maintaining three eastbound traffic lanes results in traffic volumes within the capacity of the roadway and the intersections.
- King / Dundurn
  - The diversion pattern shown in Figures 5.7 and 5.8 results in considerable pressure on the route from the parallel streets back to the intersection of King Street with Dundurn Street to access Hwy 403 and King Street West. While some of the diverted traffic uses

York Street to and from the east, and some uses Aberdeen Street to and from the west, a considerable amount of traffic still seeks a path to King Street to access Hwy 403 and west Hamilton.

- Downtown and International Village
  - Intersections through the Downtown and the International Village see a reduction in the overall intersection level of service with increased congestion. Due to volume reduction on certain traffic movements some intersection level of services are improved.
- Delta Area
  - The convergence of Main Street East and King Street East at the Delta results in considerable congestion in both the BAU and LRT scenarios.

5.36 Traffic diverting away from the roads/links with reduced capacity and restricted turns following the introduction of the LRT is pushing traffic elsewhere in the network. In the case of the intersections above it can be a single arm that is experiencing delay, or even a single movement.

The plots below hone in on the changes between the BAU and LRT networks. LoS is usually displayed in categories from A to F, but in the case of the plots below the difference in levels is displayed and so is a numeric value. It should be noted that the BAU models have not been fully signal optimized. This should be considered when reviewing the comparisons between the BAU and LRT models.

5.37 As mentioned previously, the LoS outputs from VISUM are much more detailed and likely to show significantly more congestion that those from the EMME modelling that are used to report for the Transportation Masterplan work.

5.38 It can be seen that there are intersections which move to a higher level of service as well as those that have a reduced level of service. The intersections with a higher level of service are generally changed due to changed traffic patterns and demands – often a left turn movement led to delays at an intersection, but with the LRT some of these movements have been removed and so the LoS is increased.

5.39 In other intersections there is additional traffic being funnelled to the key crossing points of the LRT alignment, and as a consequence delays are increased in those locations.

5.40 Overall, work has been undertaken to improve the flow of traffic within the LRT network and improve traffic operation to accommodate the increased traffic and the new network operating scheme. There are still significant intersection delays occurring within the network but traffic does still flow. It should be remembered that even without the LRT the future year network is congested.

5.41 The greatest impact on traffic operations is on the west side of the network, due to the reduction of capacity on the westbound section of King Street, Downtown to Dundurn Street. This results in a reassignment of traffic onto the York Boulevard westbound link, and the subsequent southbound route along Dundurn Street North, to reach the King Street/Dundurn Street intersection. The primary destination zones for this traffic are the University area and the residential areas to the west, such as Dundas and Greensville, as well as Highway 403 westbound. A portion of traffic bound for Highway 403 eastbound will divert to the York Boulevard access, moderating the increase in this pattern.

5.42 In terms of overall net effects, the implementation of the B-Line LRT can be accommodated by the existing road network, albeit with a general reduction in performance for other motorized road users. This is offset by the increase in people carrying capacity on the corridor and the introduction of some offline intersection and link improvements.

**Figure 5.9: 2031 AM LRT Network – Link Levels of Service**

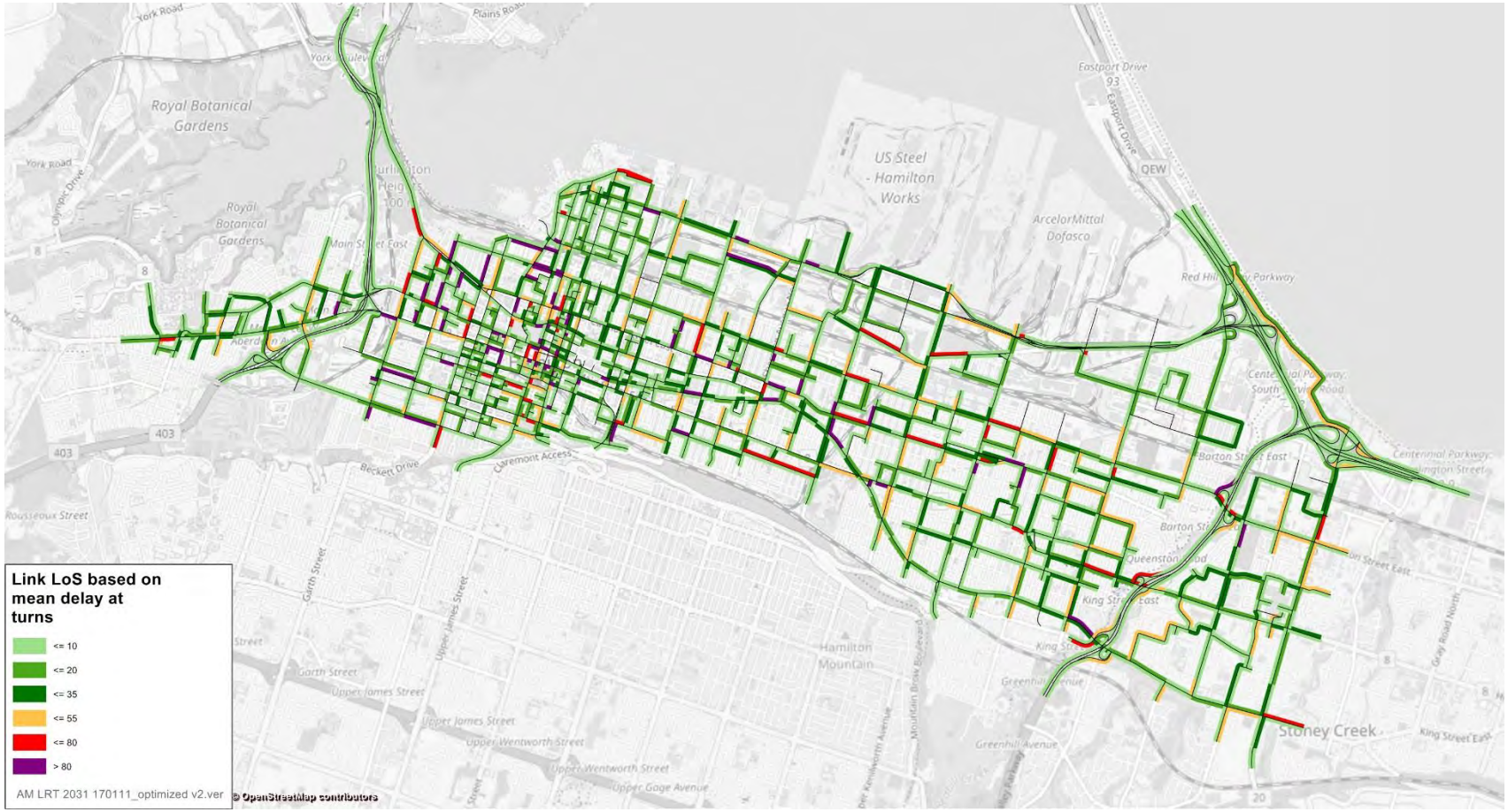


**Figure 5.10: 2031 PM LRT Network – Link Levels of Service**

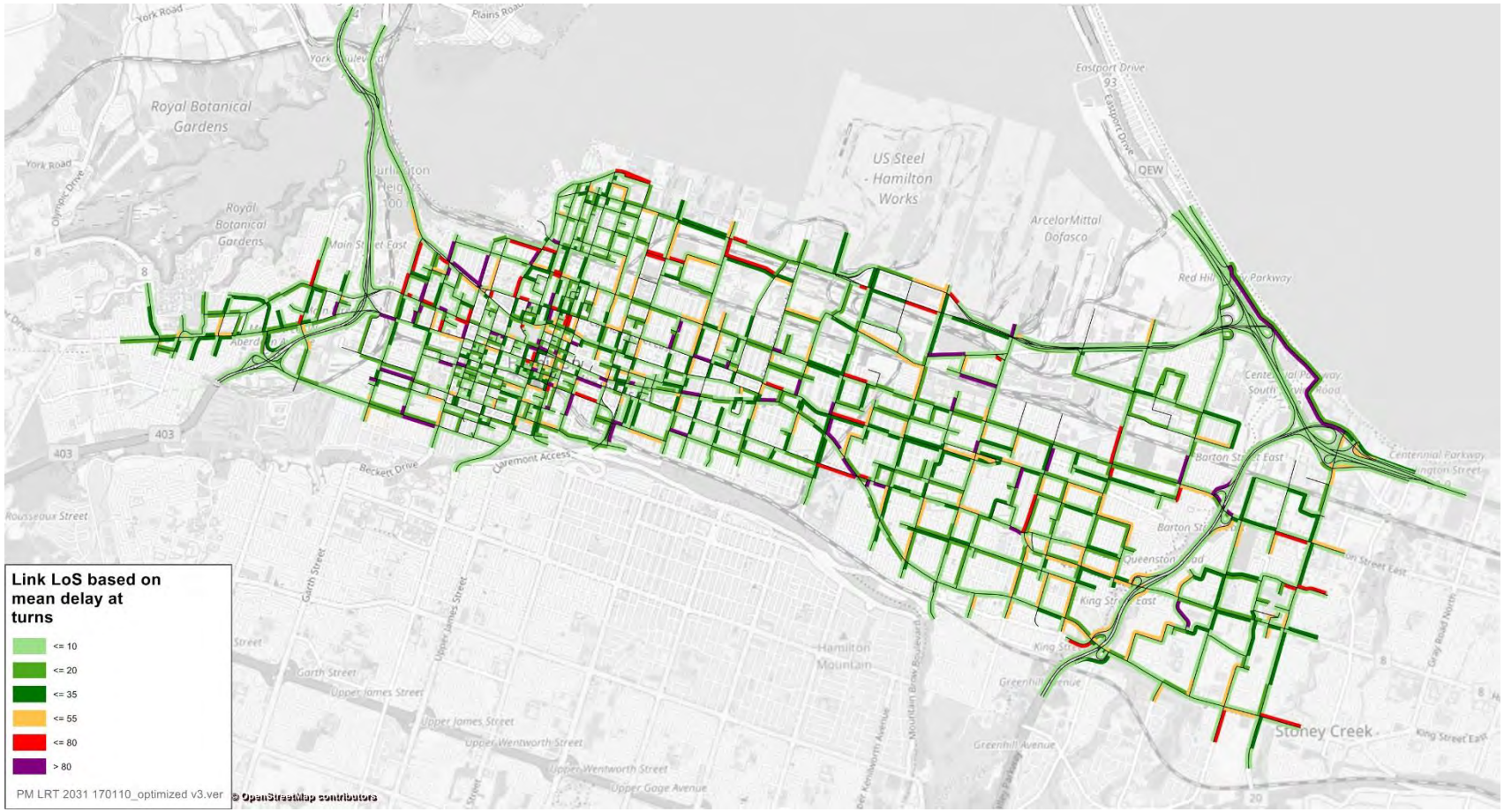


**Figure 5.11: 2031 AM LRT Network – Queuing**

**Figure 5.12: 2031 PM LRT Network – Queuing**

**Figure 5.13 Node Level of Service - AM LRT vs AM BAU**

**Figure 5.14 Node Level of Service - PM LRT vs PM BAU**

# 6 Conclusions

6.1 The work undertaken to model the traffic impacts in the Hamilton area has shown that going into the future the road network will become more congested, driven by growth in the population and employment in the region.

6.2 Future plans for changes to the road network to improve bike facilities and convert a number of streets from one-way to two-way will change traffic patterns and this combined with the forecast traffic growth will lead to changes in the levels of service of intersection, with more intersections operating at a level of service of D or below.

6.3 As part of this, it has been assumed that a certain amount of peak spreading will occur within the Hamilton catchment – as traffic grows, a percentage of the new trips will be expected to shift their journey slightly outside the peak hour as the road network approaches capacity.

6.4 When the LRT is introduced, while it will provide another transport choice and greater people moving capacity, it will lead to changes in the auto network and the capacity of certain links and intersections. Auto vehicle capacity along the LRT corridor will be reduced, causing traffic to divert to alternative parallel routes. Turning movements onto and across the corridor are limited to a number of key intersections which places additional demand at these locations.

6.5 Work has been undertaken to understand the wider area traffic impacts of the LRT introduction and to mitigate these impacts to an appropriate level to ensure that traffic within the network can keep flowing. In order to mitigate for any the impacts of the Hamilton LRT scheme on the surrounding highway network, the following measures to improve traffic operation were tested and implemented to ensure that impacts are kept to a minimum.

- Traffic Signal Timing Optimization
- Changes to traffic signal staging
- Changes to lane allocations at intersections for different turning movements
- Provision of dedicated left turn lanes
- Provision of right turn slip lanes
- Turn bans (primarily U-turn and left turns).

6.6 Where possible, the mitigations undertaken were implemented with an eye to preserving LRT priority and limiting the potential impact on LRT run time along the corridors. It is possible that certain measures could be beneficial for traffic (and congestion), but to the detriment of LRT operation and runtimes. Where possible the potential impact on properties has also been kept to minimum – another trade -off between traffic operation and wider knock-on impacts.

6.7 The outcome of the Wider Area Traffic Impacts work is a series of changes to the traffic signal operation and intersection design both on and off the corridor. While these changes have not eliminated the impacts of the LRT on traffic operation, they have reduced them to an acceptable level and ensured that the road network will continue to function.

6.8 It should also be noted that just as is undertaken in the network today, smaller changes can be implemented to alleviate any issues during the implementation process, the network will not remain static between now and the introduction of the LRT.

6.9 The traffic volumes that have been tested here are for 2031, yet the planned opening day is sooner. The with and without LRT scenarios have been compared to determine the 'diverted' traffic, yet some of this traffic does not in reality exist on the network today – as it joins the network, the LRT will already be in place and the 'diversion' route will simply be the route, and the 'extended' travel time will simply be the travel time.

6.10 The LRT will not arrive overnight – people will gradually have time to adapt and change their traffic patterns. It has been shown that often during the construction phase of projects such as this, people start searching for short term alternatives and their diversion occurs then as the system is built, rather than a big bang on the opening day.

6.11 This technical analysis has shown that in 2031 with or without the LRT the network will experience greater congestion than today. With the implementation of LRT there will be greater constraints on road network capacity and traffic patterns will be forced to change. Congestion will worsen, but the network will still be able to operate, and have in addition the people carrying capacity of the LRT network.

6.12 The modelling work undertaken for the EA/TPAP amendment process has shown that the LRT can be accommodated within the Hamilton network and that solutions have been developed to mitigate the identified traffic impacts and potential delays to LRT. As the design continues to be refined through the PSOS, City/Metrolinx and consulting team staff will continue to review the design and implementation requirements.

# A Model Traffic Volume Plots

## 2031 BAU Auto Network Coding

**Table A.1: Road Network Changes (BAU Scenario)**

| Street | Direction | From | To | Changes |
|---|---|---|---|---|
| Wentworth | NB | Cannon | Barton | Converted to two way from Cannon to Barton |
| Wentworth | NB | Wilson | Cannon | Converted to two way from Wilson to Cannon |
| Wentworth | NB | King William | Wilson | Converted to two way from King William to Wilson |
| Wentworth | NB | King | King William | Converted to two way from King to King William |
| Wentworth | NB | Main | King | Converted to two way from Main to King |
| Wentworth | NB | Delaware | Main | Converted to two way from Delaware to Main |
| Wentworth | SB | Barton | Cannon | Changed lanes from 3 to 2 from Barton to Cannon |
| Wentworth | SB | Cannon | Wilson | Changed lanes from 3 to 2 from Cannon to Wilson |
| Wentworth | SB | Wilson | King William | Changed lanes from 3 to 2 from Wilson to King William |
| Wentworth | SB | King William | King | Changed lanes from 3 to 2 from King William to King |
| Wentworth | SB | King | Main | Changed lanes from 3 to 2 from King to Main |
| Wentworth | SB | Main | Delaware | Changed lanes from 3 to 2 from Main to Delaware |
| Hughson | NB | Wilson | Cannon | Changed lanes from 2 to 1 from Wilson to Cannon |
| Hughson | NB | Cannon | Robert | Changed lanes from 2 to 1 from Cannon to Robert |
| Hughson | NB | Robert | Barton | Changed lanes from 2 to 1 from Robert to Barton |
| Hughson | SB | Cannon | Wilson | Converted to two way from Cannon to Wilson |
| Hughson | SB | Robert | Cannon | Converted to two way from Robert to Cannon |
| Hughson | SB | Barton | Robert | Converted to two way from Barton to Robert |
| Gage | NB | Cumberland | Maplewood | Changed lanes from 2 to 1 from Cumberland to Maplewood |
| Gage | NB | Maplewood | Main | Changed lanes from 2 to 1 from Maplewood to Main |
| Gage | NB | Main | King | Changed lanes from 2 to 1 from Main to King |
| Gage | NB | King | Cannon | Changed lanes from 2 to 1 from King to Cannon |
| Gage | NB | Cannon | Barton | Changed lanes from 2 to 1 from Cannon to Barton |

| Street | Direction | From | To | Changes |
|---|---|---|---|---|
| Gage | NB | Barton | Beach | Changed lanes from 2 to 1 from Barton to Beach |
| Gage | NB | Beach | Burlington | Changed lanes from 2 to 1 from Beach to Burlington |
| Gage | NB | Burlington | Industrial | Changed lanes from 2 to 1 from Burlington to Industrial |
| Gage | SB | Industrial | Burlington | Changed lanes from 2 to 1 from Industrial to Burlington |
| Gage | SB | Burlington | Beach | Changed lanes from 2 to 1 from Burlington to Beach |
| Gage | SB | Beach | Barton | Changed lanes from 2 to 1 from Beach to Barton |
| Gage | SB | Barton | Cannon | Changed lanes from 2 to 1 from Barton to Cannon |
| Gage | SB | Cannon | King | Changed lanes from 2 to 1 from Cannon to King |
| Gage | SB | King | Main | Changed lanes from 2 to 1 from King to Main |
| Gage | SB | Main | Maplewood | Changed lanes from 2 to 1 from Main to Maplewood |
| Gage | SB | Maplewood | Cumberland | Changed lanes from 2 to 1 from Maplewood to Cumberland |
| Locke | NB | Main | King | Changed lanes from 2 to 1 from Main to King |
| Victoria | NB | Barton | Birge | Changed lanes from 3 to 2 from Barton to Birge |
| Victoria | NB | Birge | Burlington | Changed lanes from 3 to 2 from Birge to Burlington |
| Victoria | SB | Burlington | Sawyer | Converted to two way from Burlington to Sawyer (Birge in EMME model as Sawyer is not modelled) |
| Victoria | NB | Claremont | Hunter | Changed lanes from 5 to 4 from Claremont to Hunter |
| Victoria | NB | Hunter | Main | Changed lanes from 5 to 4 from Hunter to Main |
| Victoria | NB | Main | King | Changed lanes from 4 to 3 from Main to King |
| Victoria | NB | King | King William | Changed lanes from 4 to 3 from King to King William |
| Victoria | NB | King William | Wilson | Changed lanes from 4 to 3 from King William to Wilson |
| Victoria | NB | Wilson | Cannon | Changed lanes from 4 to 3 from Wilson to Cannon |
| Victoria | NB | Cannon | Barton | Changed lanes from 3 to 2 from Cannon to Barton |
| Victoria | NB | Sawyer | Burlington | Changed lanes from 3 to 2 from Sawyer to Burlington (Birge to Burlington in EMME model as Sawyer is not in the model) |
| Cannon | EB | Melrose | Gage | Changed lanes from 2 to 1 from Melrose to Gage |
| Cannon | EB | Gage | Belmont | Changed lanes from 2 to 1 from Gage to Belmont |
| Cannon | EB | Belmont | Ottawa | Changed lanes from 2 to 1 from Belmont to Ottawa |
| Cannon | EB | Ottawa | Frederick | Changed lanes from 2 to 1 from Ottawa to Frederick |
| Cannon | EB | Frederick | Kenilworth | Changed lanes from 2 to 1 from Frederick to Kenilworth |
| Cannon | WB | Kenilworth | Frederick | Changed lanes from 2 to 1 from Kenilworth to Frederick |
| Cannon | WB | Frederick | Ottawa | Changed lanes from 2 to 1 from Frederick to Ottawa |
| Cannon | WB | Ottawa | Belmont | Changed lanes from 2 to 1 from Ottawa to Belmont |
| Cannon | WB | Belmont | Gage | Changed lanes from 2 to 1 from Belmont to Gage |
| Cannon | WB | Gage | Melrose | Changed lanes from 2 to 1 from Gage to Melrose |
| MacNab | SB | King | Main | Added bus-only lanes from King to Main |
| MacNab | NB | Main | King | Added bus-only lanes from Main to King |

# 2031 LRT Auto Network Coding

**Table A.2: Road Network Changes (With LRT Scenario)**

| Street | Direction | From | To | Changes |
|---|---|---|---|---|
| Main | EB | Leland | Emerson | Changed lanes from 3 to 2 from Leland to Emerson |
| Main | EB | Emerson | Gary | Changed lanes from 3 to 2 from Emerson to Gary |
| Main | EB | Gary | Cline | Changed lanes from 3 to 2 from Gary to Cline |
| Main | EB | Cline | Newton | Changed lanes from 3 to 2 from Cline to Newton |
| Main | EB | Newton | Longwood | Changed lanes from 3 to 2 from Newton to Longwood |
| Main | EB | Longwood | Paradise | Changed lanes from 3 to 2 from Longwood to Paradise |
| Main | EB | Paradise | Macklin | Changed lanes from 5 to 2 from Paradise to Macklin |
| Main | EB | Macklin | Frid | Changed lanes from 5 to 3 from Macklin to Frid |
| Main | EB | Kensington | Ottawa | Changed lanes from 2 to 1 from Kensington to Ottawa |
| Main | EB | Ottawa | Graham | Changed lanes from 2 to 1 from Ottawa to Graham |
| Main | EB | Graham | Kenilworth | Changed lanes from 2 to 1 from Graham to Kenilworth |
| Main | EB | Kenilworth | Tragina | Changed lanes from 2 to 1 from Kenilworth to Tragina |
| Main | EB | Tragina | Strathearne | Changed lanes from 2 to 1 from Tragina to Strathearne |
| Main | EB | Strathearne | Rosewood | Changed lanes from 2 to 1 from Strathearne to Rosewood |
| Main | WB | Strathearne | Tragina | Changed lanes from 2 to 1 from Strathearne to Tragina |
| Main | WB | Tragina | Kenilworth | Changed lanes from 2 to 1 from Tragina to Kenilworth |
| Main | WB | Kenilworth | Graham | Changed lanes from 2 to 1 from Kenilworth to Graham |
| Main | WB | Graham | Ottawa | Changed lanes from 2 to 1 from Graham to Ottawa |
| Main | WB | Ottawa | Kensington | Changed lanes from 2 to 1 from Ottawa to Kensington |
| Main | WB | Gary | Emerson | Changed lanes from 3 to 2 from Gary to Emerson |
| Main | WB | Emerson | Leland | Changed lanes from 3 to 2 from Emerson to Leland |
| King | EB | Dundurn | New | Converted to two way from Dundurn to New |
| King | EB | New | Locke | Converted to two way from New to Locke |
| King | EB | Locke | Pearl | Converted to two way from Locke to Pearl |
| King | EB | Pearl | Queen | Converted to two way from Pearl to Queen |
| King | EB | Queen | Hess | Added new walk link from Queen to Hess |
| King | EB | Hess | Bay | Converted to two way from from Hess to Bay |
| King | EB | Bay | Summers | Converted to two way from Bay to Summers |
| King | EB | Summers | MacNab | Converted to two way from Summers to MacNab |
| King | EB | MacNab | James | Converted to two way from MacNab to James |
| King | EB | John | Catharine | Converted to two way from John to Catharine |
| King | EB | Catharine | Mary | Converted to two way from Catharine to Mary |
| King | EB | Mary | Walnut | Converted to two way from Mary to Walnut |
| King | EB | Walnut | Wellington | Converted to two way from Walnut to Wellington |
| King | EB | Wellington | West Ave | Converted to two way from Wellington to West Ave |
| King | EB | West Ave | Victoria | Converted to two way from West Ave to Victoria |

| Street | Direction | From | To | Changes |
|---|---|---|---|---|
| Street | Direction | From | To | Changes |
| King | EB | Victoria | East Ave | Converted to two way from Victoria to East Ave |
| King | EB | East Ave | Wentworth | Converted to two way from East Ave to Wentworth |
| King | EB | Wentworth | Sanford | Converted to two way from Wentworth to Sanford |
| King | EB | Sanford | Stirton | Converted to two way from Sanford to Stirton |
| King | EB | Stirton | Sherman | Converted to two way from Stirton to Sherman |
| King | EB | Sherman | Barnesdale | Converted to two way from Sherman to Barnesdale |
| King | EB | Barnesdale | Gage | Converted to two way from Barnesdale to Gage |
| King | EB | Gage | Hilda | Converted to two way from Gage to Hilda |
| King | EB | Hilda | Kensington | Converted to two way from Hilda to Kensington |
| King | WB | Kensington | Hilda | Changed lanes from 4 to 1 from Kensington to Hilda |
| King | WB | Hilda | Gage | Changed lanes from 4 to 1 from Hilda to Gage |
| King | WB | Gage | Barnesdale | Changed lanes from 4 to 1 from Gage to Barnesdale |
| King | WB | Barnesdale | Sherman | Changed lanes from 4 to 1 from Barnesdale to Sherman |
| King | WB | Sherman | Stirton | Changed lanes from 4 to 1 from Sherman to Stirton |
| King | WB | Stirton | Sanford | Changed lanes from 4 to 1 from Stirton to Sanford |
| King | WB | Sanford | Wentworth | Changed lanes from 4 to 1 from Sanford to Wentworth |
| King | WB | Wentworth | East Ave | Changed lanes from 4 to 1 from Wentworth to East Ave |
| King | WB | East Ave | Victoria | Changed lanes from 4 to 2 from East Ave to Victoria |
| King | WB | Victoria | West Ave | Changed lanes from 4 to 1 from Victoria to West Ave |
| King | WB | West Ave | Wellington | Changed lanes from 4 to 2 from West Ave to Wellington |
| King | WB | Wellington | Walnut | Removed auto link from Wellington to Walnut |
| King | WB | Walnut | Mary | Removed auto link from Walnut to Mary |
| King | WB | Mary | Catharine | Removed auto link from Mary to Catharine |
| King | WB | Catharine | John | Changed lanes from 3 to 1 from Catharine to John |
| King | WB | John | Hughson | Changed lanes from 4 to 1 from John to Hughson |
| King | WB | Hughson | James | Changed lanes from 4 to 1 from Hughson to James |
| King | WB | James | MacNab | Changed lanes from 4 to 1 from James to MacNab |
| King | WB | MacNab | Summers | Changed lanes from 4 to 2 from MacNab to Summers |
| King | WB | Summers | Bay | Changed lanes from 4 to 2 from Summers to Bay |
| King | WB | Bay | Hess | Changed lanes from 4 to 1 from Bay to Hess |
| King | WB | Hess | Queen | Changed lanes from 4 to 1 from Hess to Queen |
| King | WB | Queen | Pearl | Changed lanes from 4 to 1 from Queen to Pearl |
| King | WB | Pearl | Locke | Changed lanes from 4 to 1 from Pearl to Locke |
| King | WB | Locke | New | Changed lanes from 5 to 1 from Locke to New |
| King | WB | New | Dundurn | Changed lanes from 5 to 1 from New to Dundurn |
| King | WB | Dundurn | Breadalbane | Changed lanes from 5 to 2 from Dundurn to Breadalbane |
| Wentworth | NB | Cannon | Barton | Converted to two way from Cannon to Barton |

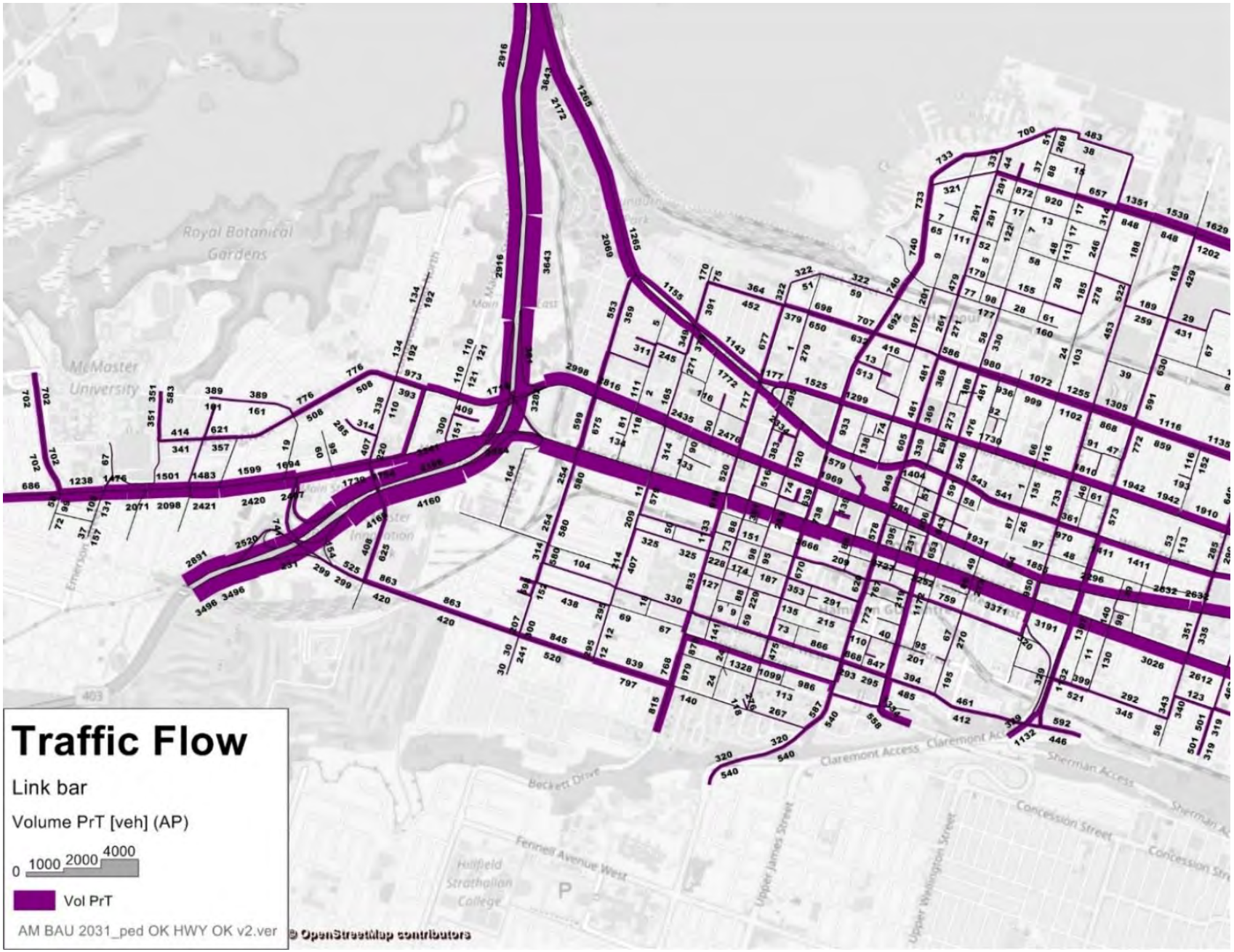
| Street | Direction | From | To | Changes |
|---|---|---|---|---|
| Wentworth | NB | Wilson | Cannon | Converted to two way from Wilson to Cannon |
| Street | Direction | From | To | Changes |
| Wentworth | NB | King William | Wilson | Converted to two way from King William to Wilson |
| Wentworth | NB | King | King William | Converted to two way from King to King William |
| Wentworth | NB | Main | King | Converted to two way from Main to King |
| Wentworth | NB | Delaware | Main | Converted to two way from Delaware to Main |
| Wentworth | SB | Barton | Cannon | Changed lanes from 3 to 2 from Barton to Cannon |
| Wentworth | SB | Cannon | Wilson | Changed lanes from 3 to 2 from Cannon to Wilson |
| Wentworth | SB | Wilson | King William | Changed lanes from 3 to 2 from Wilson to King William |
| Wentworth | SB | King William | King | Changed lanes from 3 to 2 from King William to King |
| Wentworth | SB | King | Main | Changed lanes from 3 to 2 from King to Main |
| Wentworth | SB | Main | Delaware | Changed lanes from 3 to 2 from Main to Delaware |
| Victoria | NB | Barton | Birge | Changed lanes from 3 to 2 from Barton to Birge |
| Victoria | NB | Birge | Burlington | Changed lanes from 3 to 2 from Birge to Burlington |
| Victoria | SB | Birge | Barton | Converted to two way from Birge to Barton |
| Victoria | SB | Burlington | Birge | Converted to two way from Burlington to Birge |
| Hughson | NB | Wilson | Cannon | Changed lanes from 2 to 1 from Wilson to Cannon |
| Hughson | NB | Cannon | Robert | Changed lanes from 2 to 1 from Cannon to Robert |
| Hughson | NB | Robert | Barton | Changed lanes from 2 to 1 from Robert to Barton |
| Hughson | SB | Cannon | Wilson | Converted to two way from Cannon to Wilson |
| Hughson | SB | Robert | Cannon | Converted to two way from Robert to Cannon |
| Hughson | SB | Barton | Robert | Converted to two way from Barton to Robert |
| Gage | NB | Cumberland | Maplewood | Changed lanes from 2 to 1 from Cumberland to Maplewood |
| Gage | NB | Maplewood | Main | Changed lanes from 2 to 1 from Maplewood to Main |
| Gage | NB | Main | King | Changed lanes from 2 to 1 from Main to King |
| Gage | NB | King | Cannon | Changed lanes from 2 to 1 from King to Cannon |
| Gage | NB | Cannon | Barton | Changed lanes from 2 to 1 from Cannon to Barton |
| Gage | NB | Barton | Beach | Changed lanes from 2 to 1 from Barton to Beach |
| Gage | NB | Beach | Burlington | Changed lanes from 2 to 1 from Beach to Burlington |
| Gage | NB | Burlington | Industrial | Changed lanes from 2 to 1 from Burlington to Industrial |
| Gage | SB | Industrial | Burlington | Changed lanes from 2 to 1 from Industrial to Burlington |
| Gage | SB | Burlington | Beach | Changed lanes from 2 to 1 from Burlington to Beach |
| Gage | SB | Beach | Barton | Changed lanes from 2 to 1 from Beach to Barton |
| Gage | SB | Barton | Cannon | Changed lanes from 2 to 1 from Barton to Cannon |
| Gage | SB | Cannon | King | Changed lanes from 2 to 1 from Cannon to King |
| Gage | SB | King | Main | Changed lanes from 2 to 1 from King to Main |
| Gage | SB | Main | Maplewood | Changed lanes from 2 to 1 from Main to Maplewood |
| Gage | SB | Maplewood | Cumberland | Changed lanes from 2 to 1 from Maplewood to Cumberland |

| Street | Direction | From | To | Changes |
|---|---|---|---|---|
| Locke | NB | Main | King | Changed lanes from 2 to 1 from Main to King |
| Victoria | NB | Claremont | Hunter | Changed lanes from 5 to 4 from Claremont to Hunter |
| Street | Direction | From | To | Changes |
| Victoria | NB | Hunter | Main | Changed lanes from 5 to 4 from Hunter to Main |
| Victoria | NB | Main | King | Changed lanes from 4 to 3 from Main to King |
| Victoria | NB | King | King William | Changed lanes from 4 to 3 from King to King William |
| Victoria | NB | King William | Wilson | Changed lanes from 4 to 3 from King William to Wilson |
| Victoria | NB | Wilson | Cannon | Changed lanes from 4 to 3 from Wilson to Cannon |
| Victoria | NB | Cannon | Barton | Changed lanes from 3 to 2 from Cannon to Barton |
| Victoria | NB | Barton | Birge | Changed lanes from 3 to 2 from Barton to Birge |
| Victoria | NB | Birge | Burlington | Changed lanes from 3 to 2 from Birge to Burlington |
| Cannon | EB | Melrose | Gage | Changed lanes from 2 to 1 from Melrose to Gage |
| Cannon | EB | Gage | Belmont | Changed lanes from 2 to 1 from Gage to Belmont |
| Cannon | EB | Belmont | Ottawa | Changed lanes from 2 to 1 from Belmont to Ottawa |
| Cannon | EB | Ottawa | Frederick | Changed lanes from 2 to 1 from Ottawa to Frederick |
| Cannon | EB | Frederick | Kenilworth | Changed lanes from 2 to 1 from Frederick to Kenilworth |
| Cannon | WB | Kenilworth | Frederick | Changed lanes from 2 to 1 from Kenilworth to Frederick |
| Cannon | WB | Frederick | Ottawa | Changed lanes from 2 to 1 from Frederick to Ottawa |
| Cannon | WB | Ottawa | Belmont | Changed lanes from 2 to 1 from Ottawa to Belmont |
| Cannon | WB | Belmont | Gage | Changed lanes from 2 to 1 from Belmont to Gage |
| Cannon | WB | Gage | Melrose | Changed lanes from 2 to 1 from Gage to Melrose |
| MacNab | SB | King | Main | Added bus-only lanes from King to Main |
| MacNab | NB | Main | King | Added bus-only lanes from Main to King |

# B Model Node Level of Service Plots

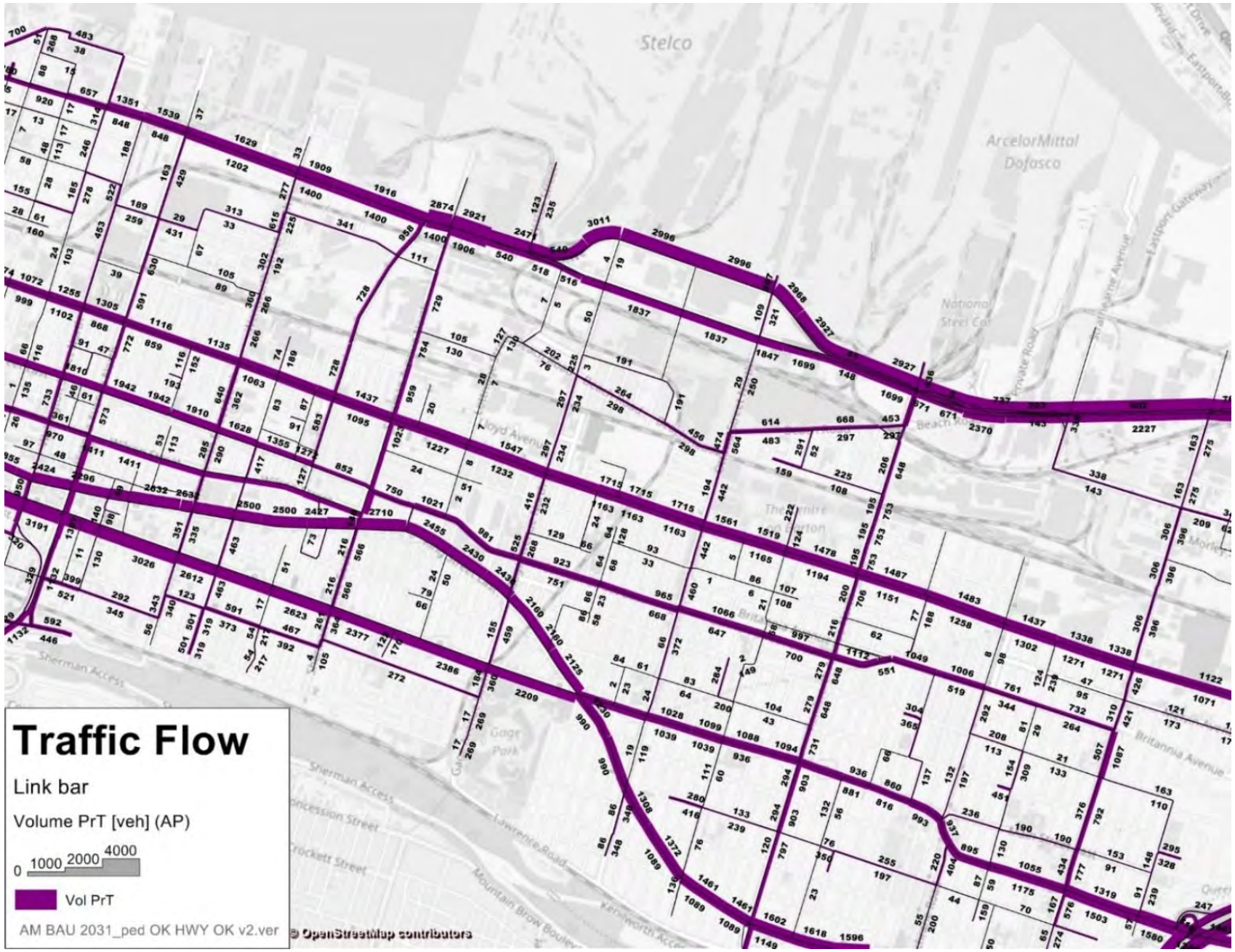
## AM BAU VOLUMES

West



## AM BAU VOLUMES

Central



## AM BAU VOLUMES

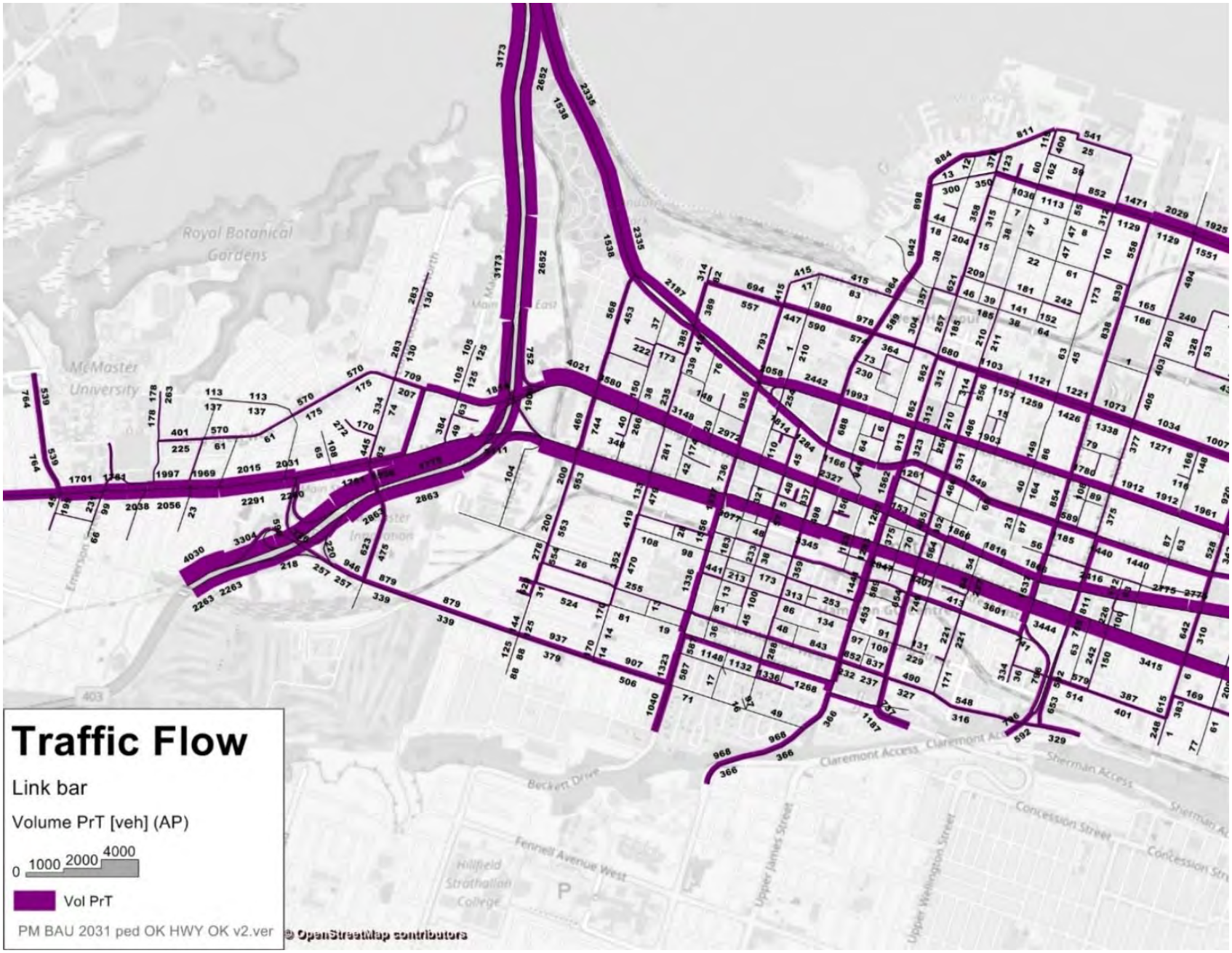
North - East

## AM BAU VOLUMES

South - East

## PM BAU VOLUMES

West



## PM BAU VOLUMES

Central

## PM BAU VOLUMES

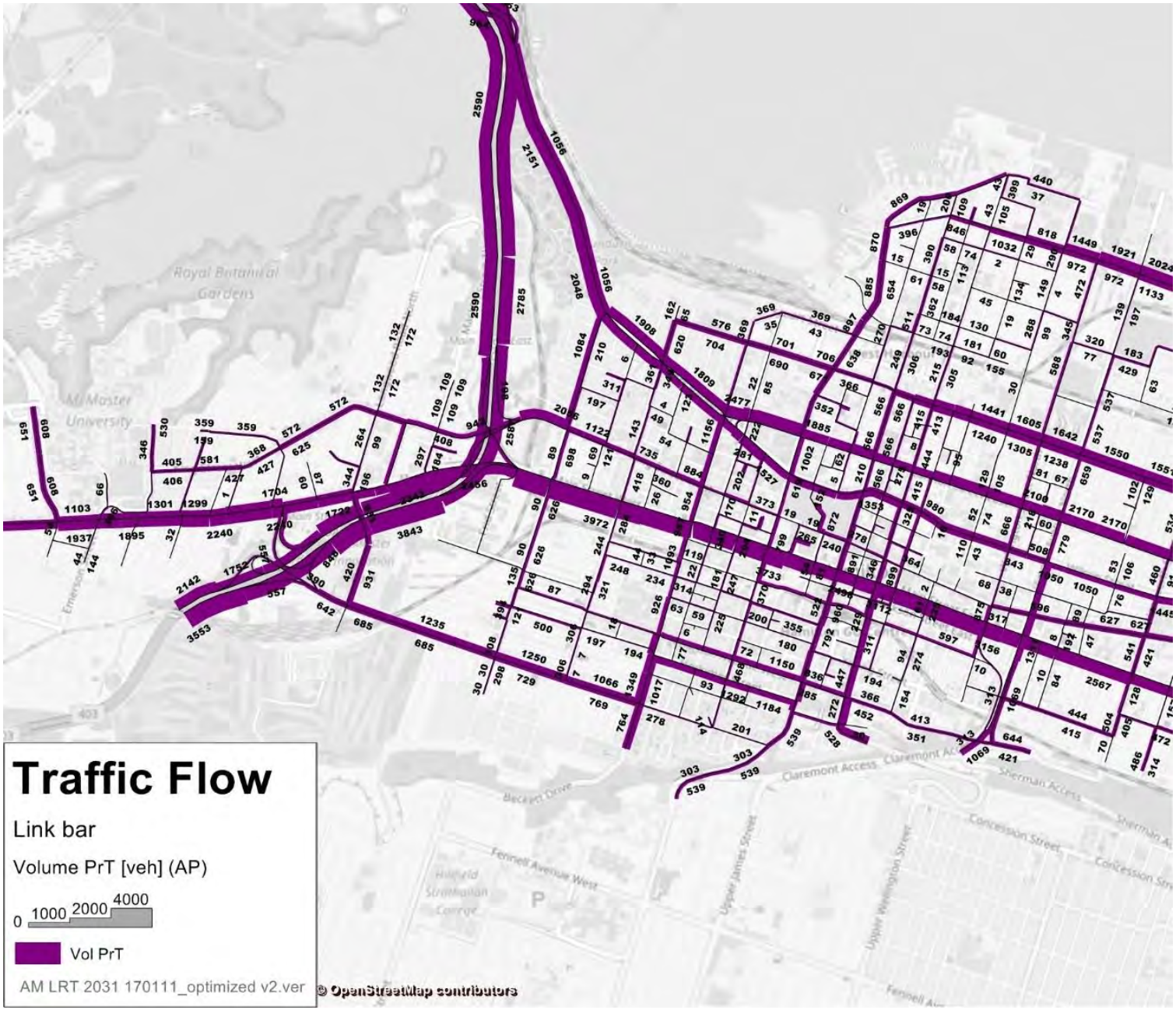
North - East

## PM BAU VOLUMES

Central

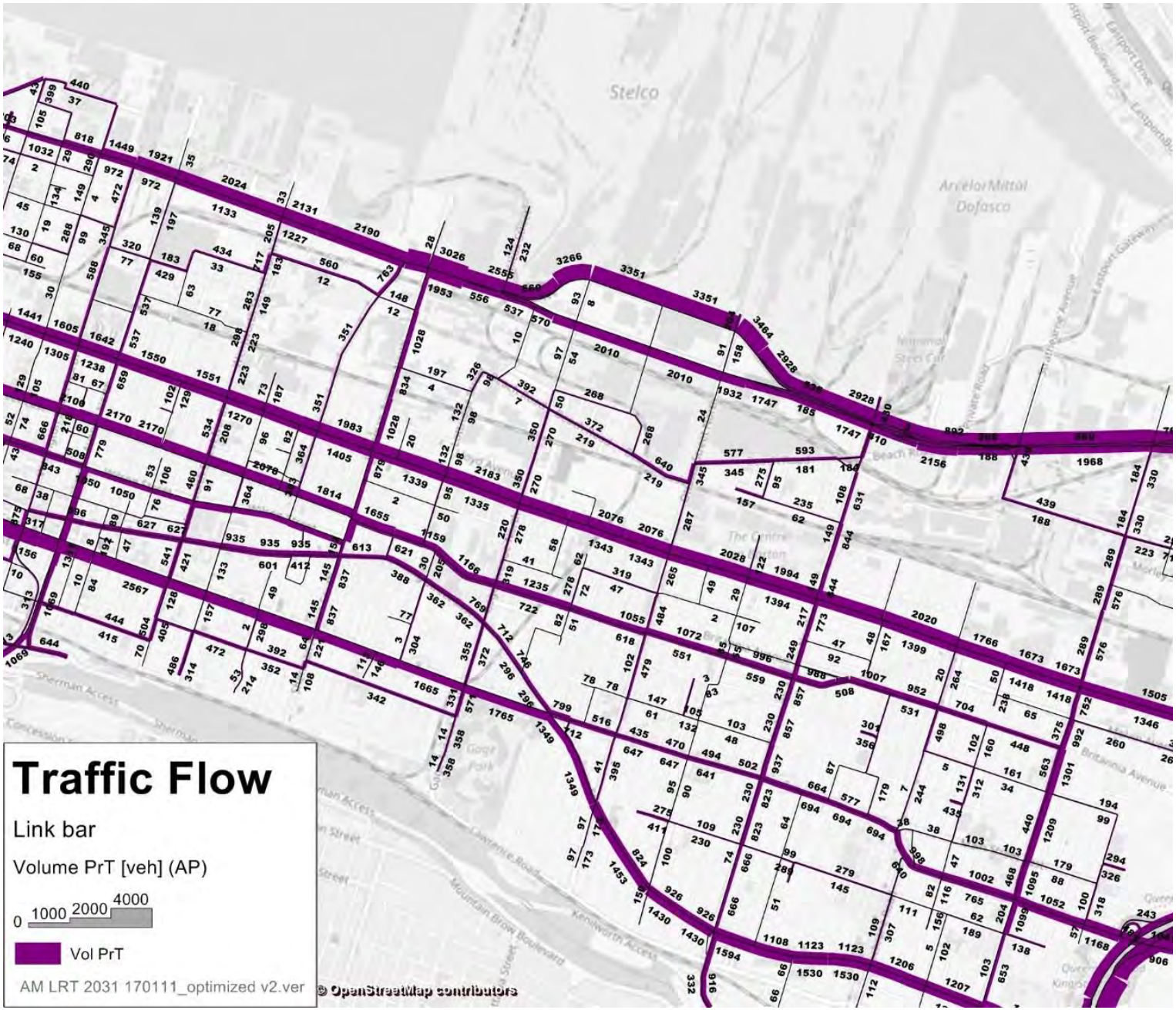
## AM LRT VOLUMES

West



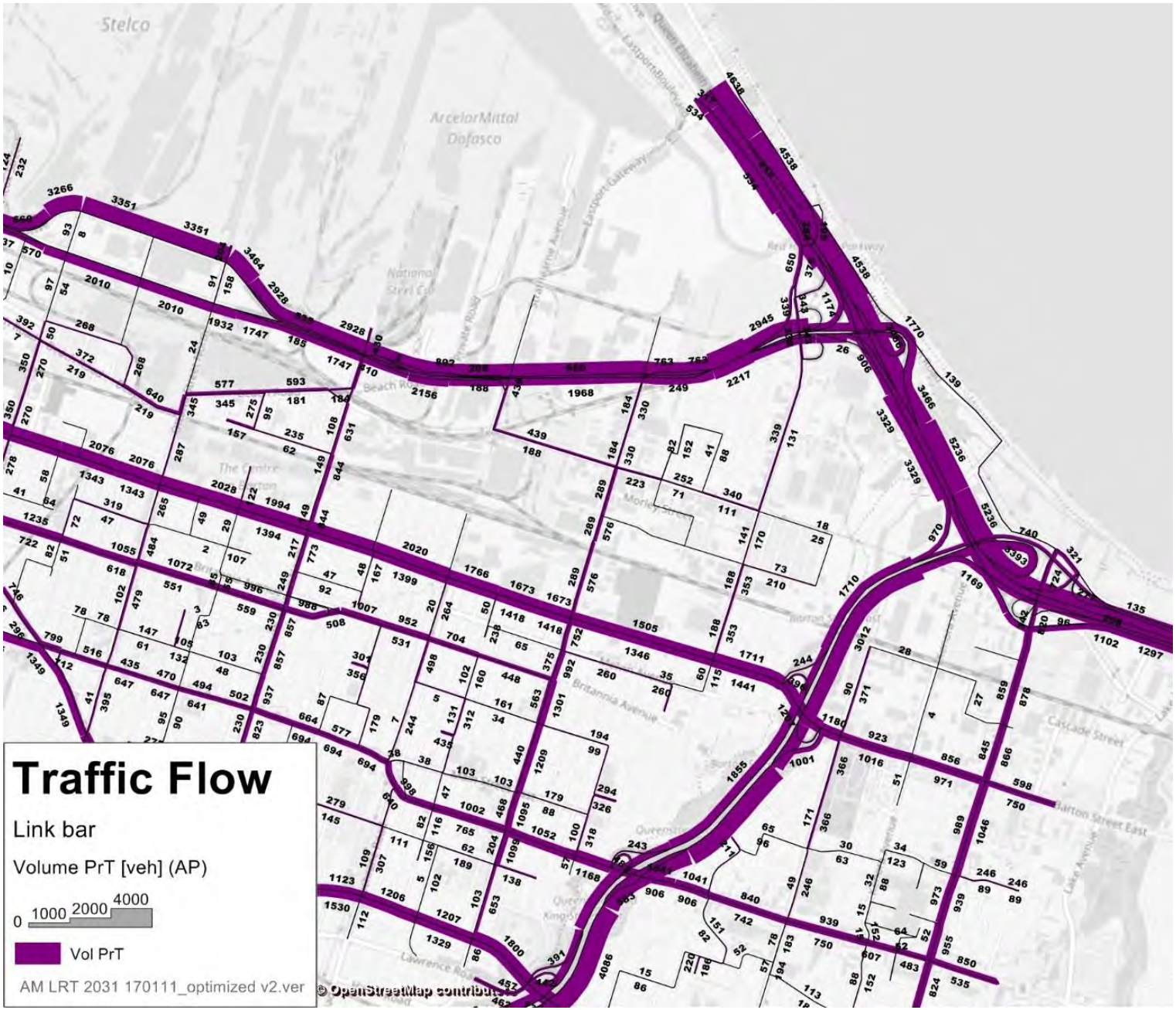
## AM LRT VOLUMES

Central



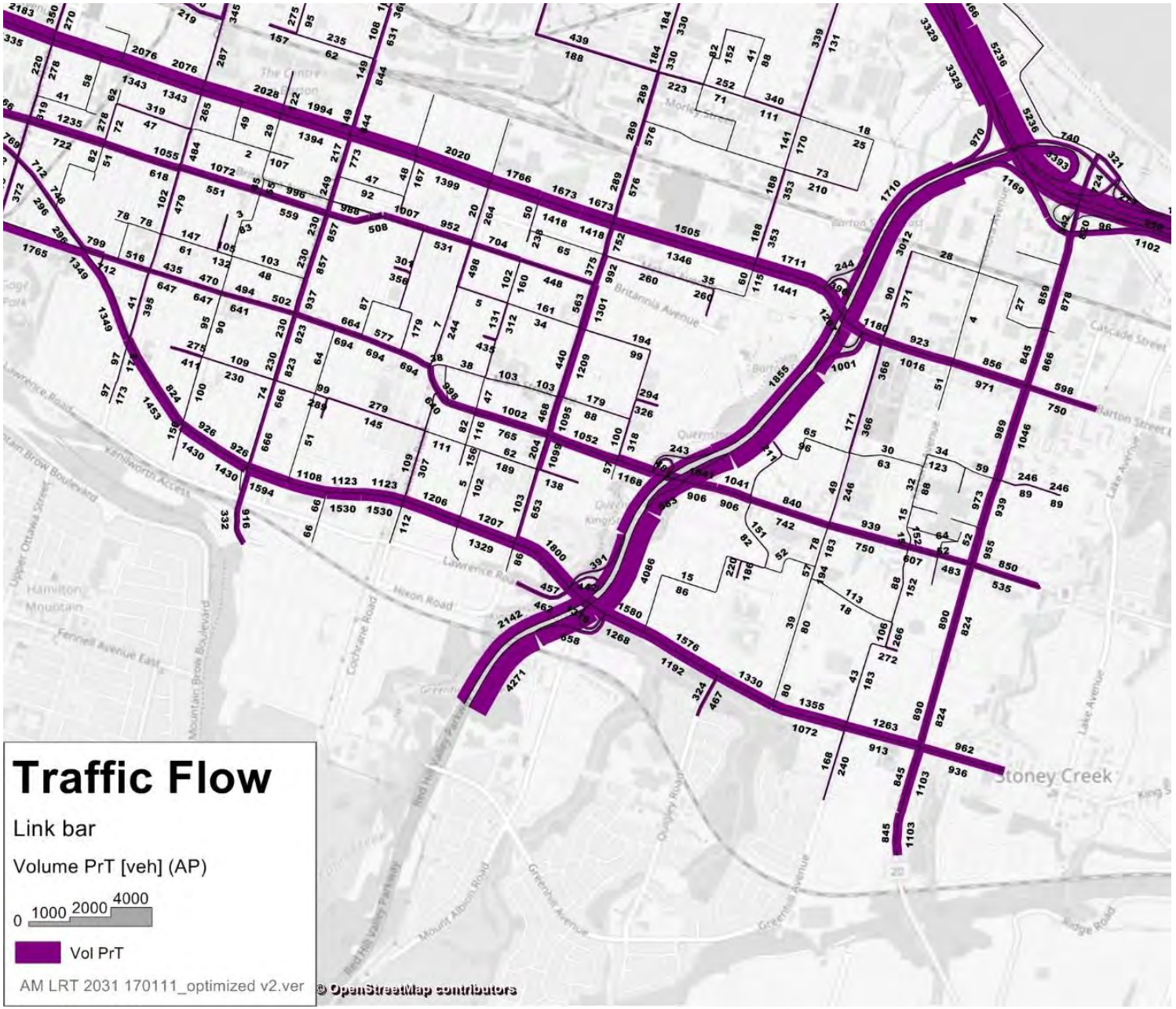
## AM LRT VOLUMES

North - East



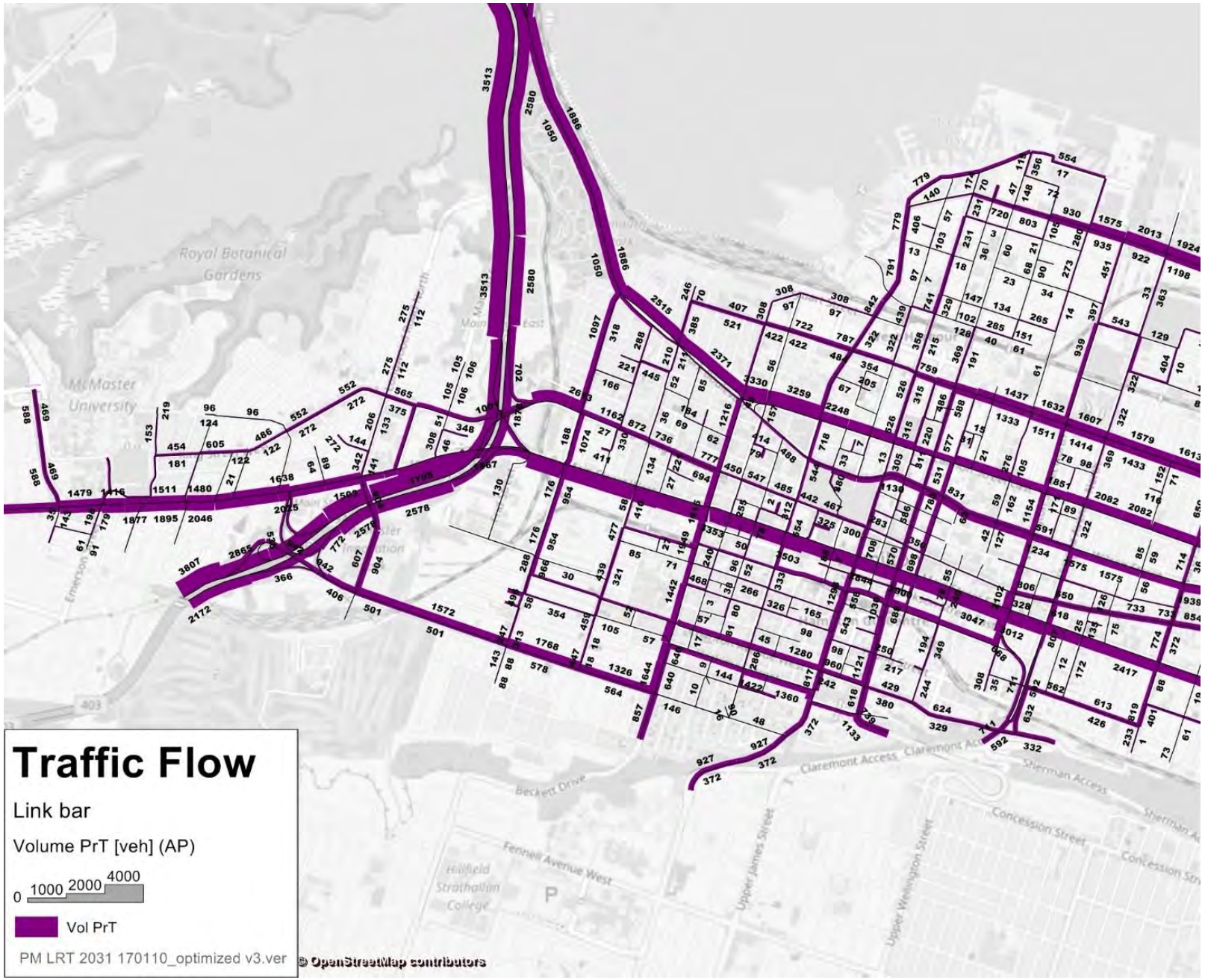
## AM LRT VOLUMES

South - East



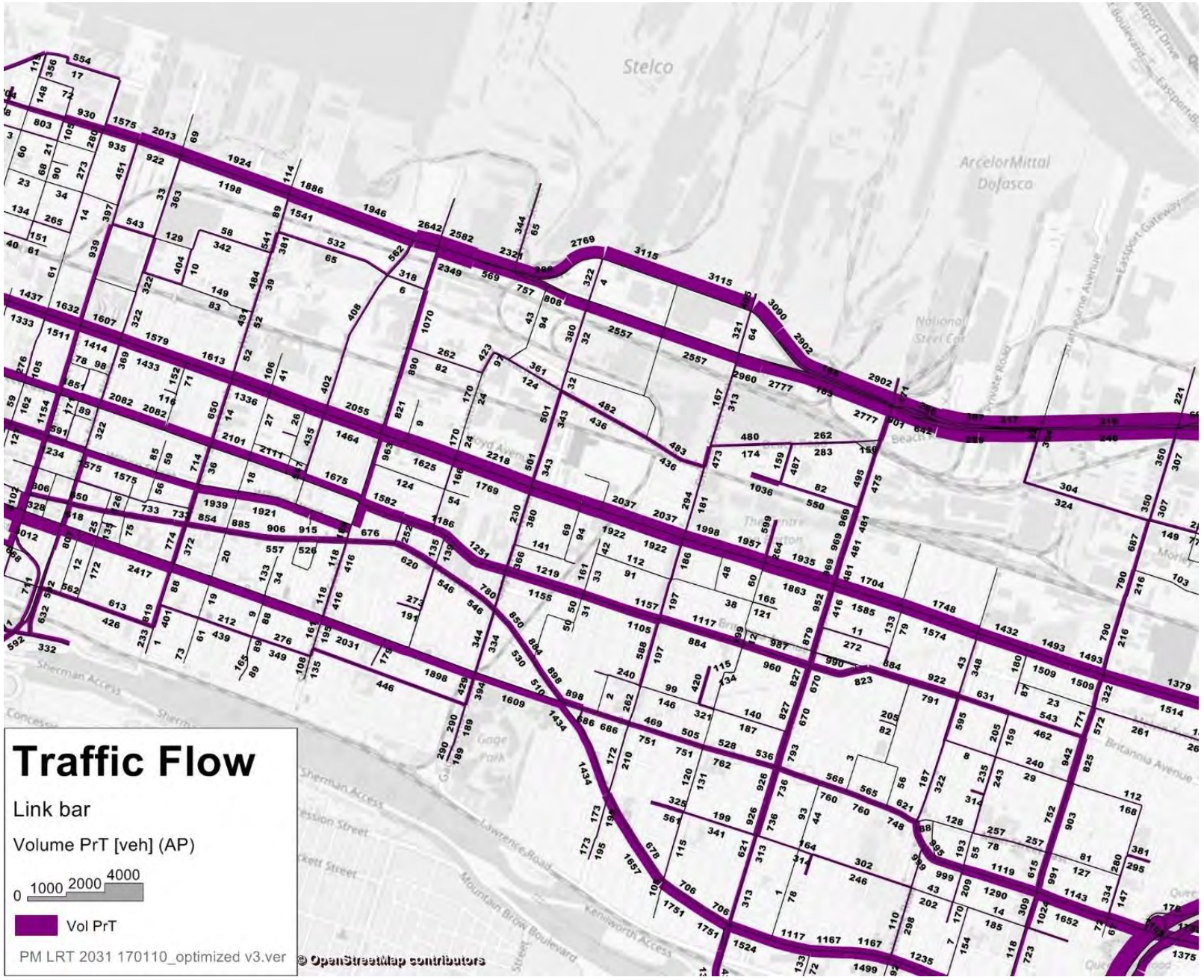
## PM LRT VOLUMES

West



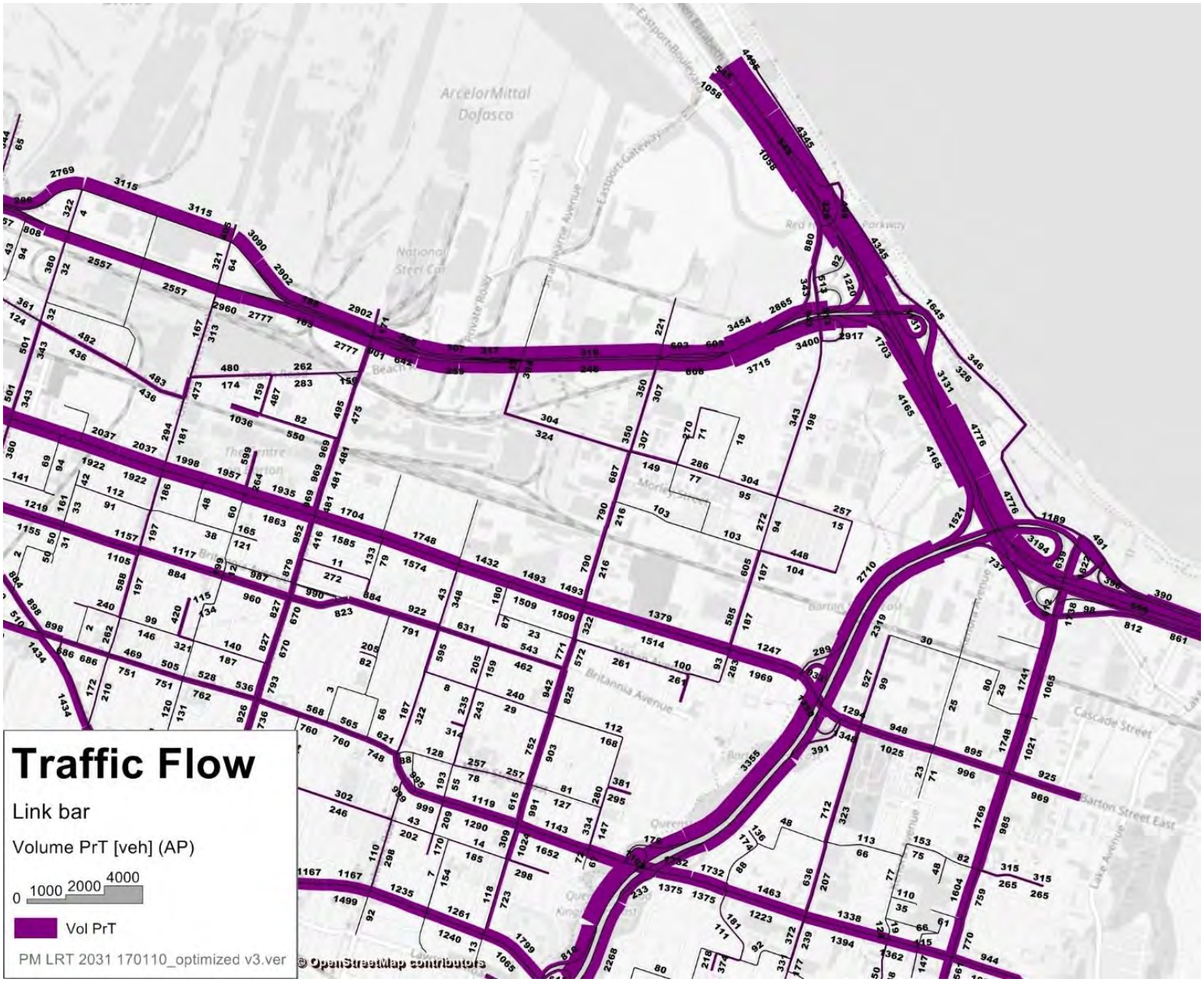
## PM LRT VOLUMES

Central



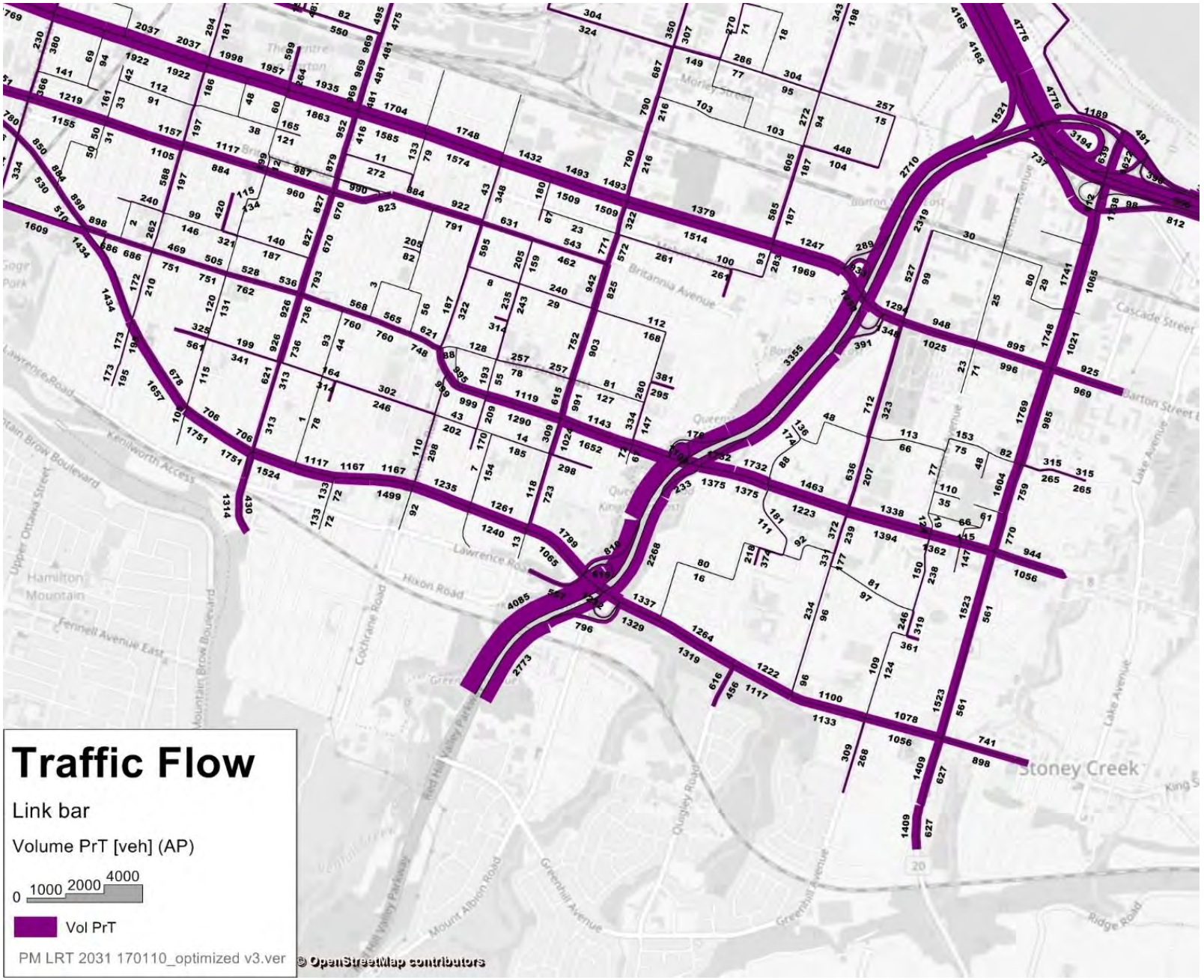
## PM LRT VOLUMES

North - East



## PM LRT VOLUMES

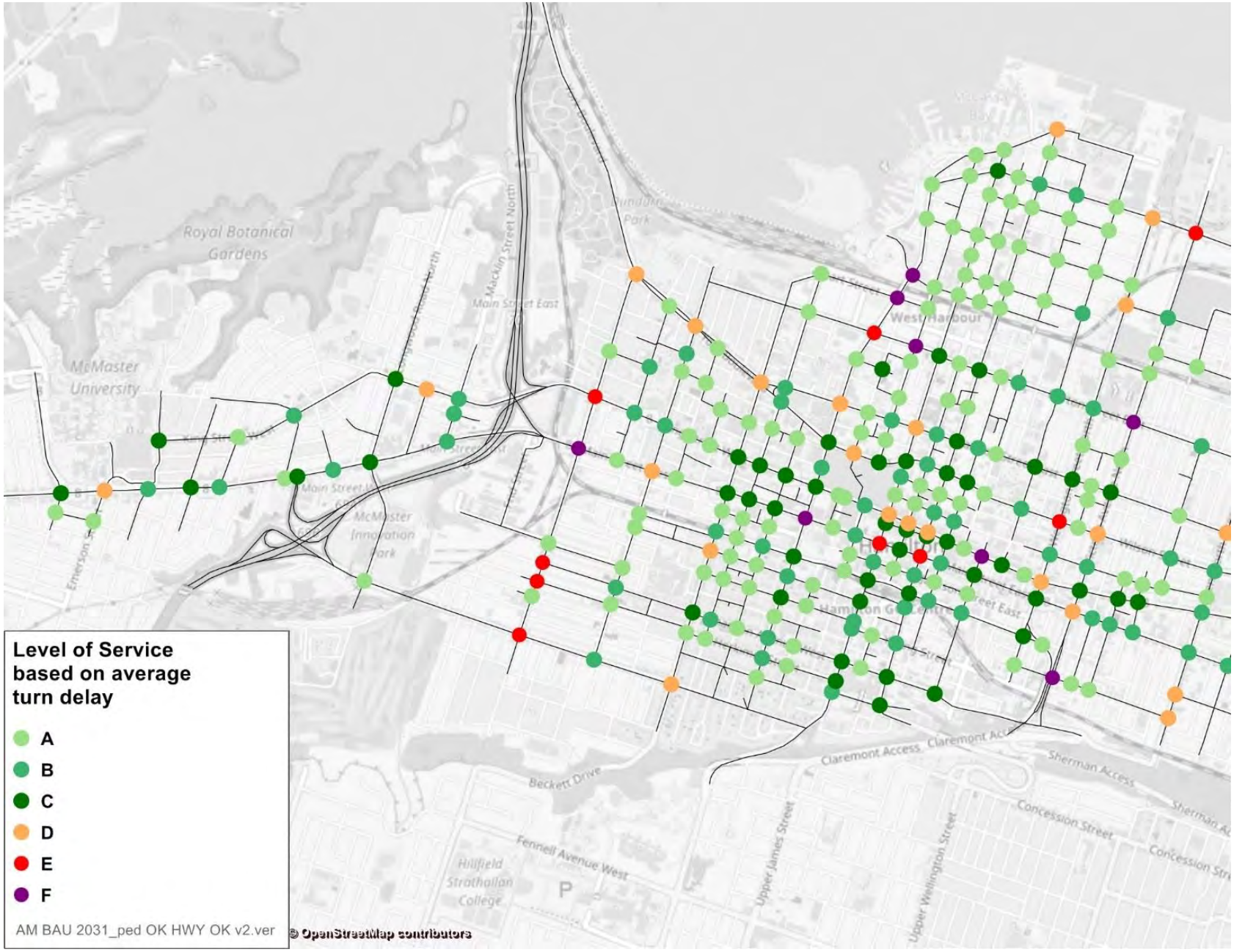
South - East



# C Model Link Level of Service Plots

## AM BAU INTERSECTION LEVELS OF SERVICE

West



## AM BAU INTERSECTION LEVELS OF SERVICE

Central

## AM BAU INTERSECTION LEVELS OF SERVICE

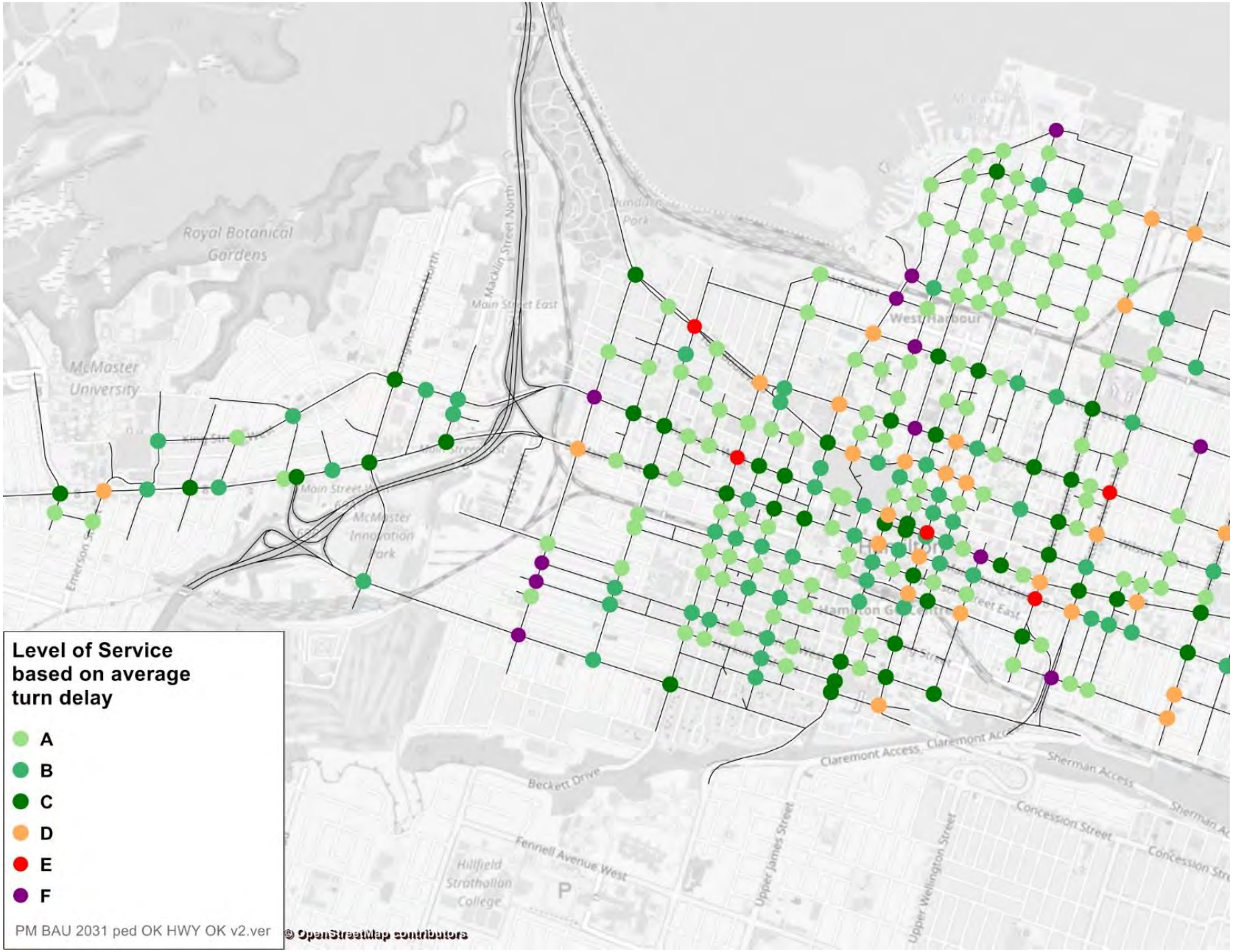
North - East

## AM BAU INTERSECTION LEVELS OF SERVICE

South – East

## PM BAU INTERSECTION LEVELS OF SERVICE

West



## PM BAU INTERSECTION LEVELS OF SERVICE

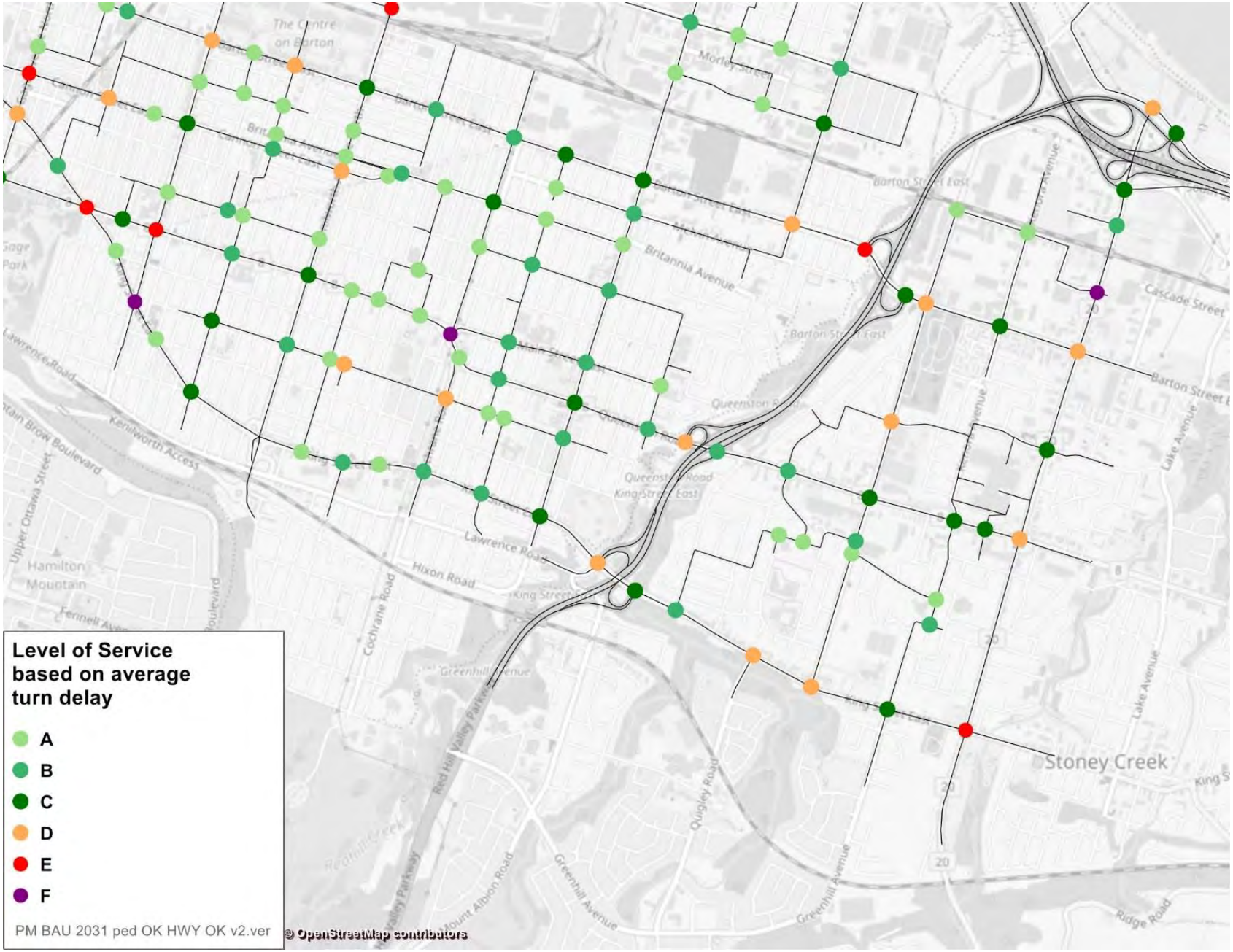
Central

## PM BAU INTERSECTION LEVELS OF SERVICE

North – East

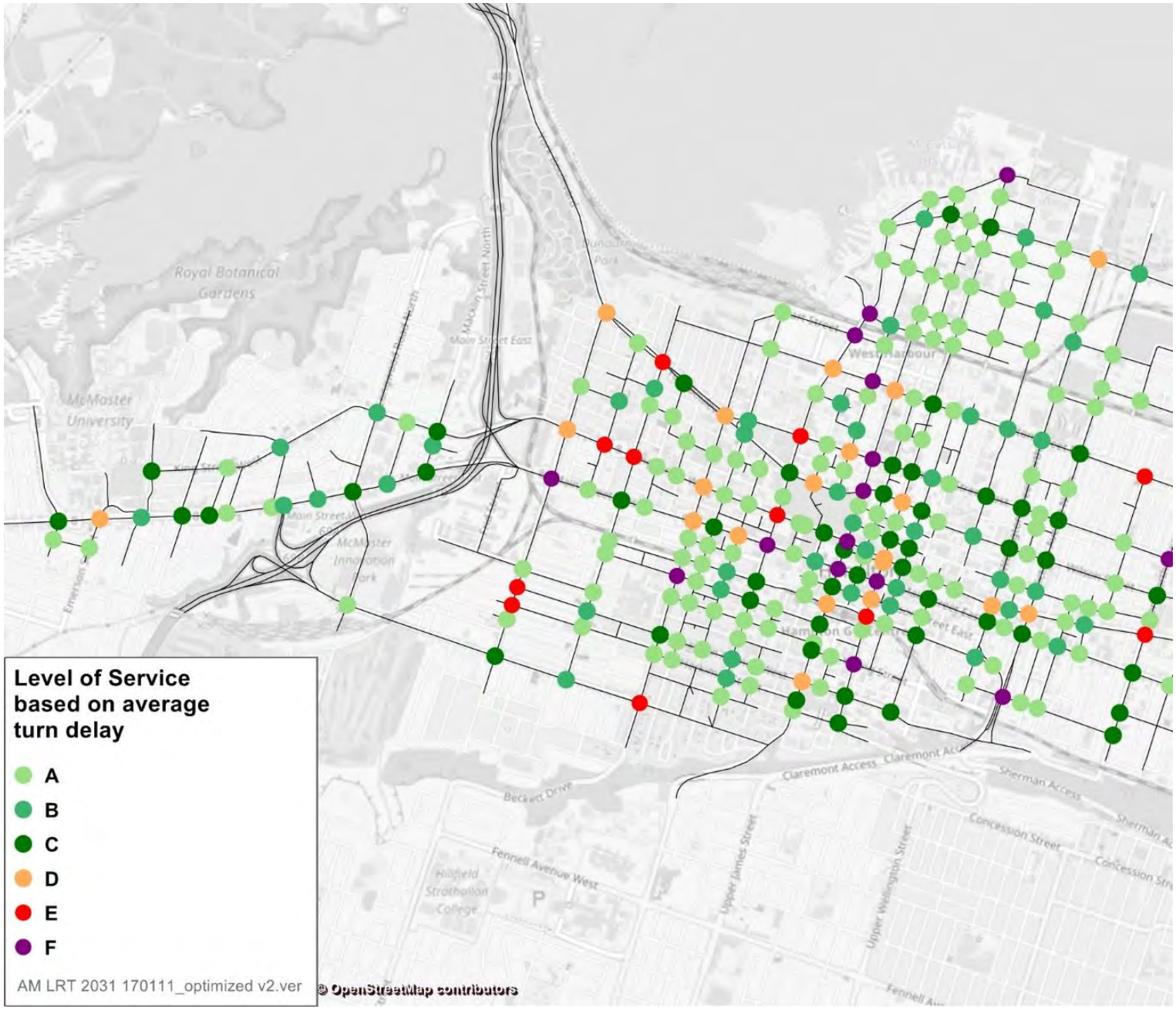
## PM BAU INTERSECTION LEVELS OF SERVICE

South – East



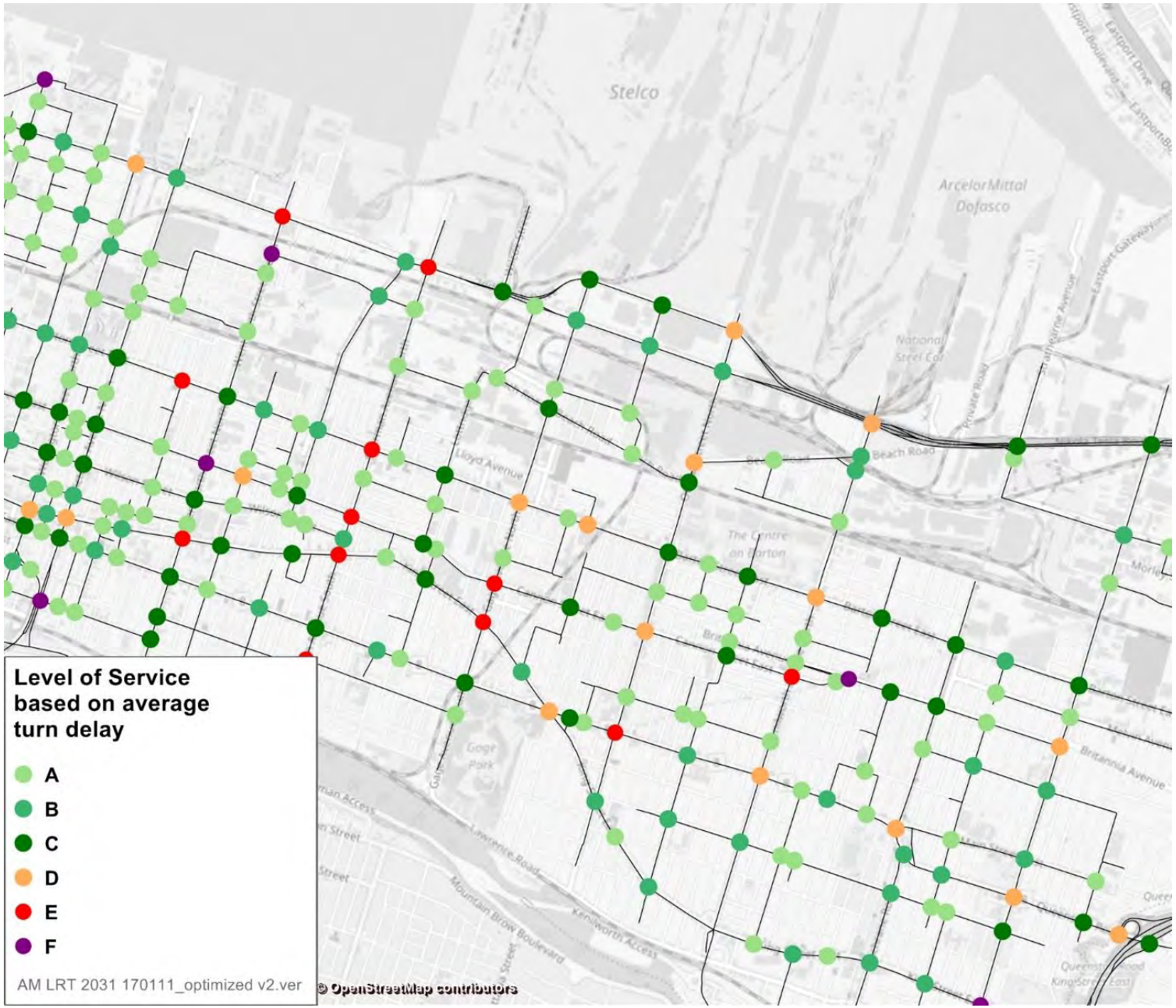
## AM LRT INTERSECTION LEVELS OF SERVICE

West



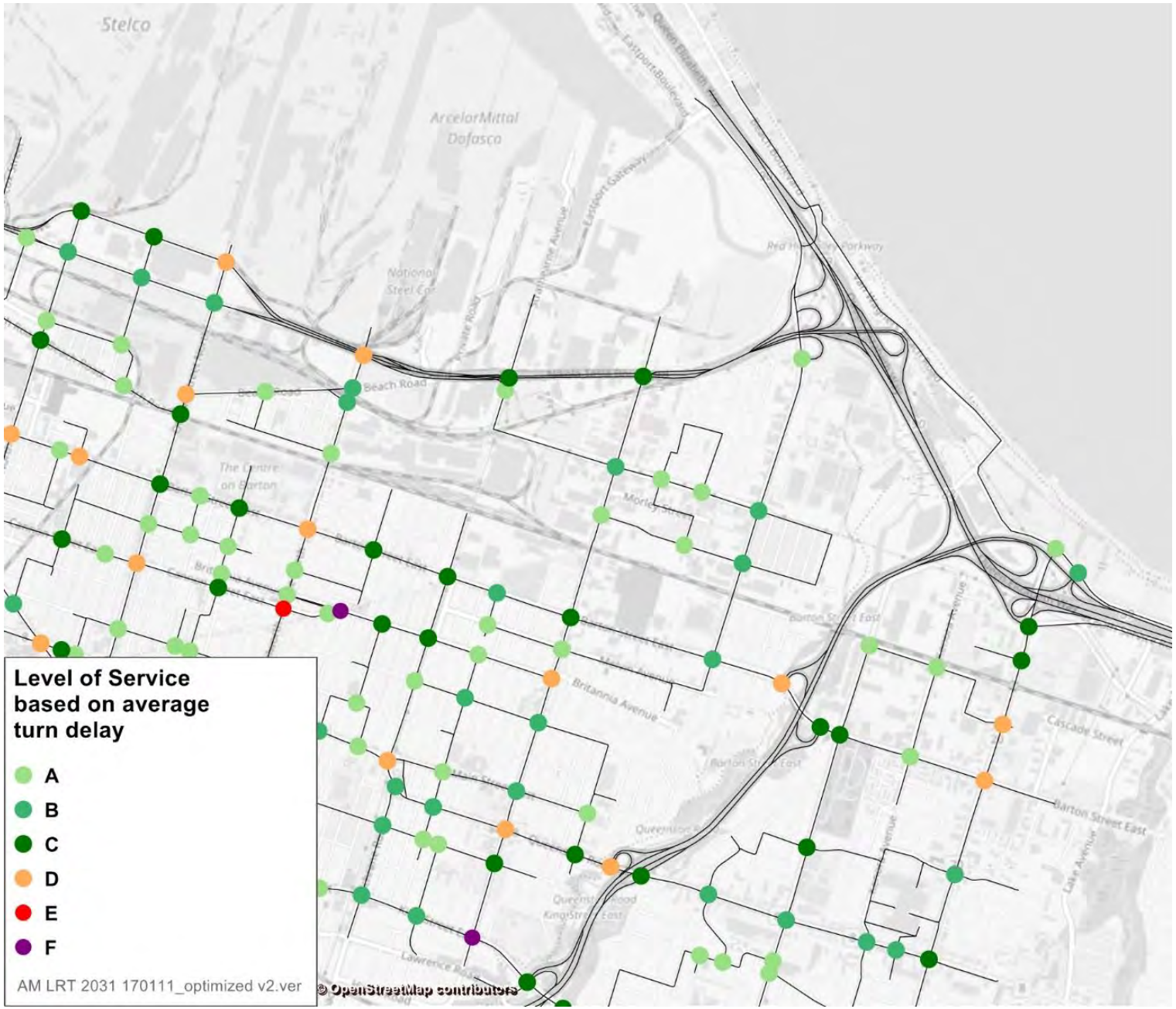
## AM LRT INTERSECTION LEVELS OF SERVICE

Central



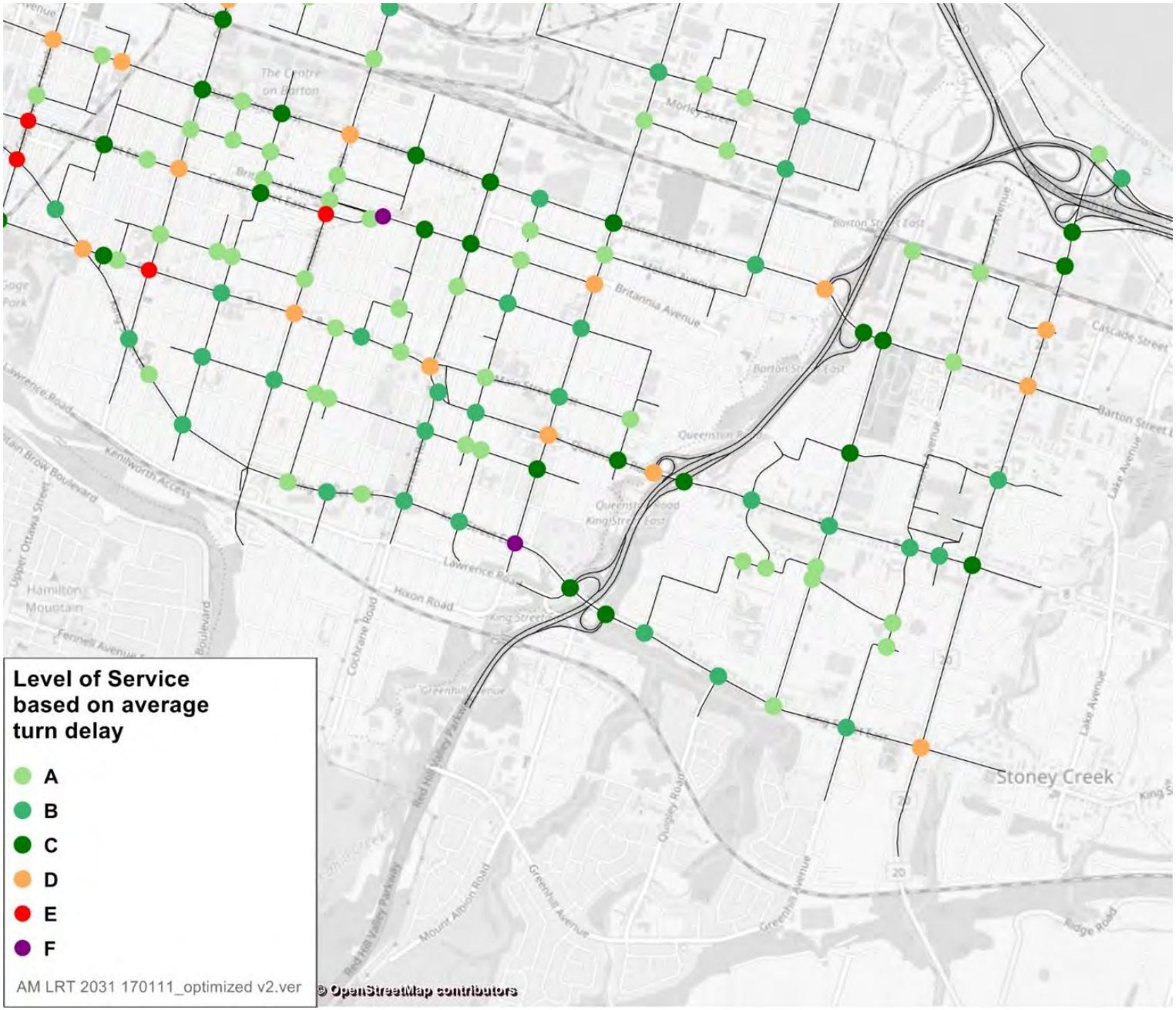
## AM LRT INTERSECTION LEVELS OF SERVICE

North – East



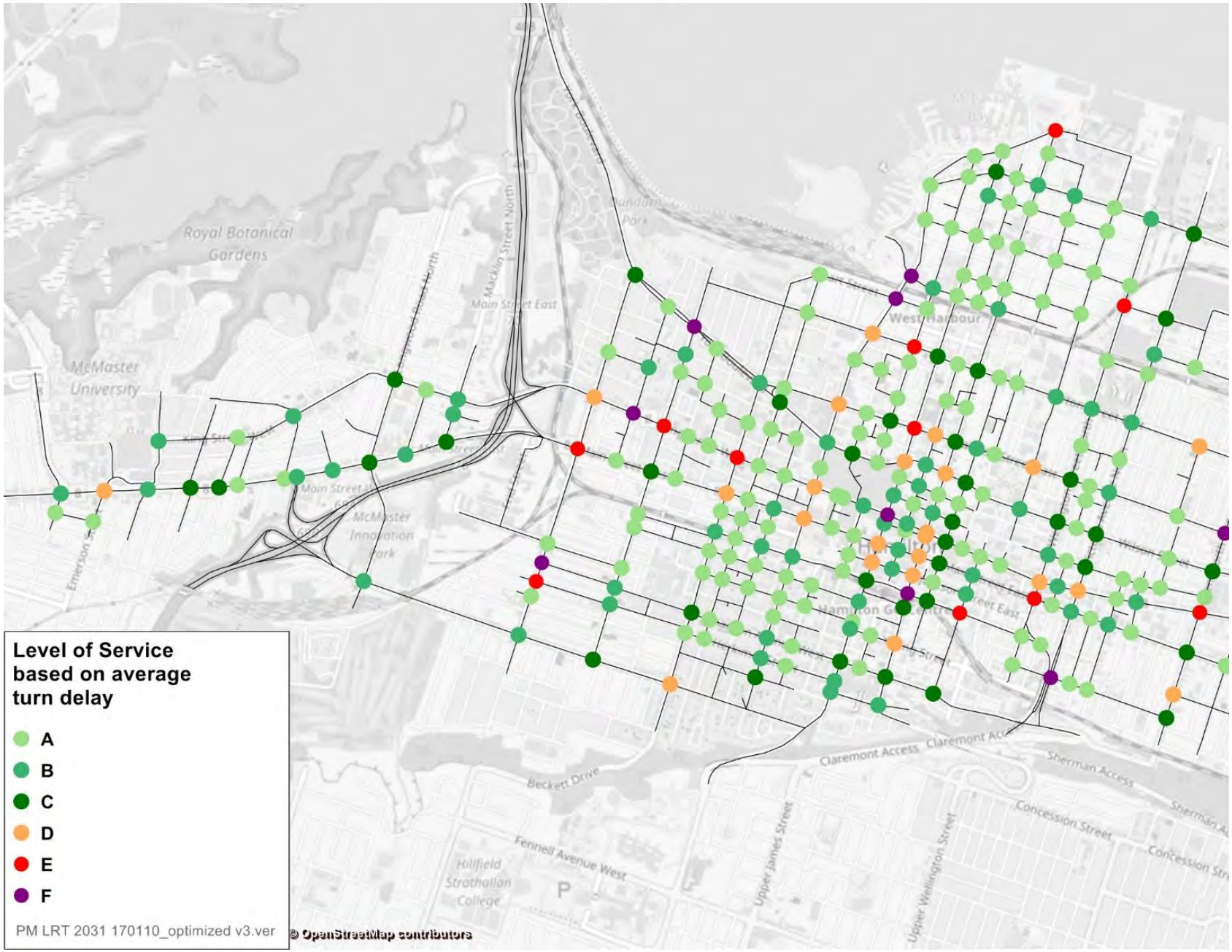
## AM LRT INTERSECTION LEVELS OF SERVICE

South – East



## PM LRT INTERSECTION LEVELS OF SERVICE

West



## PM LRT INTERSECTION LEVELS OF SERVICE

Central

## PM LRT INTERSECTION LEVELS OF SERVICE

North - East

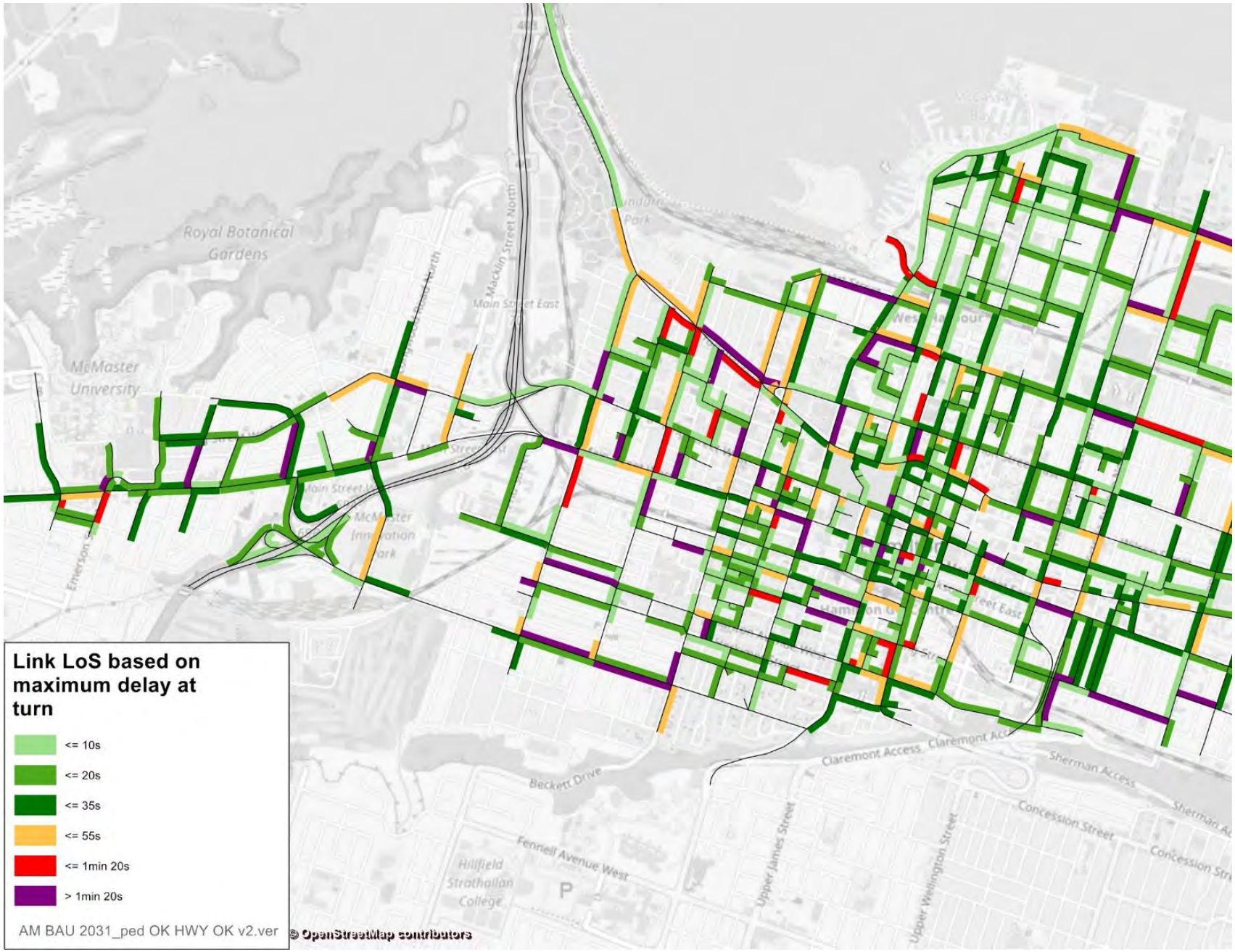
## PM LRT INTERSECTION LEVELS OF SERVICE

South - East

# D Model Link Level of Service Plots

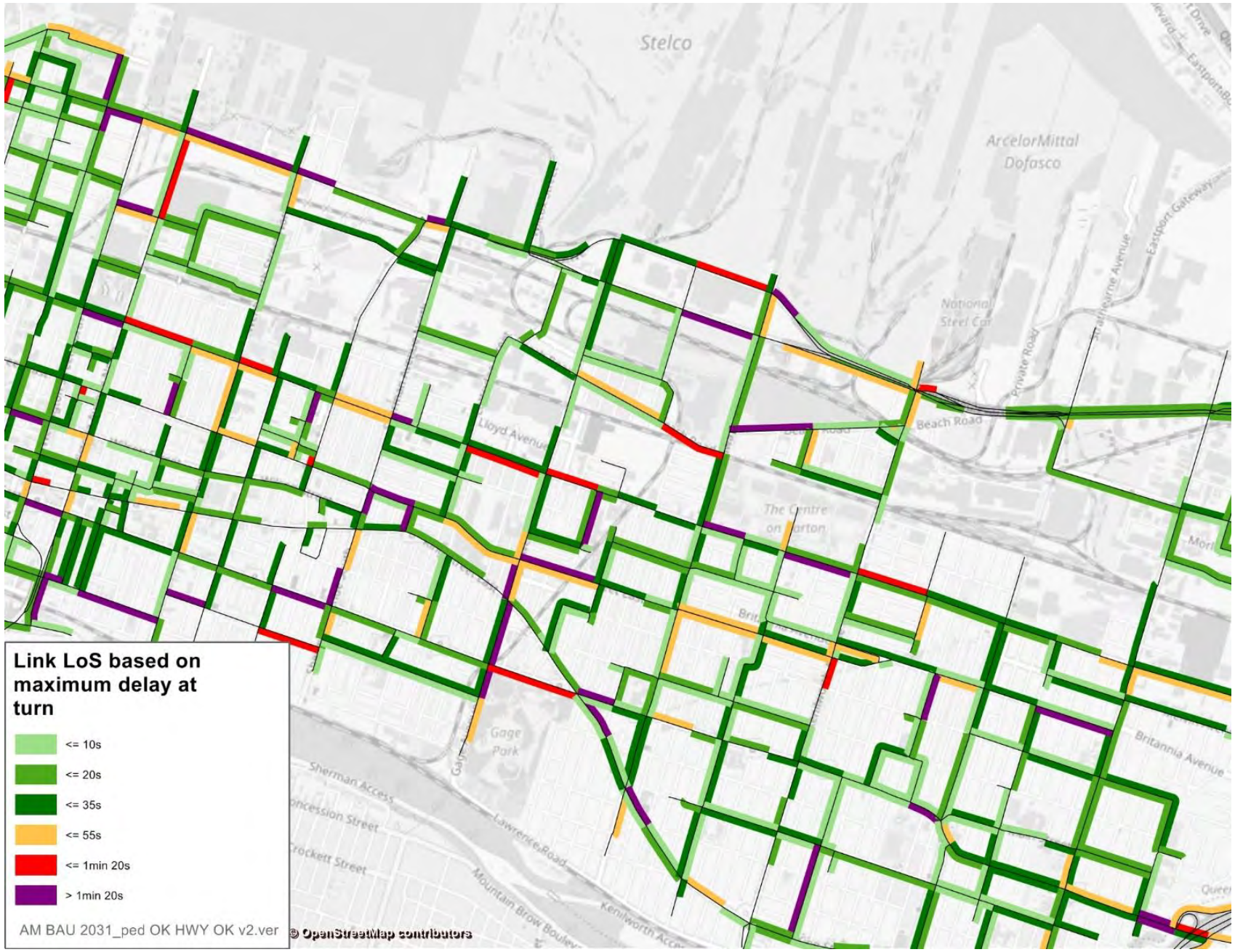
## AM BAU LINK LEVELS OF SERVICE

West



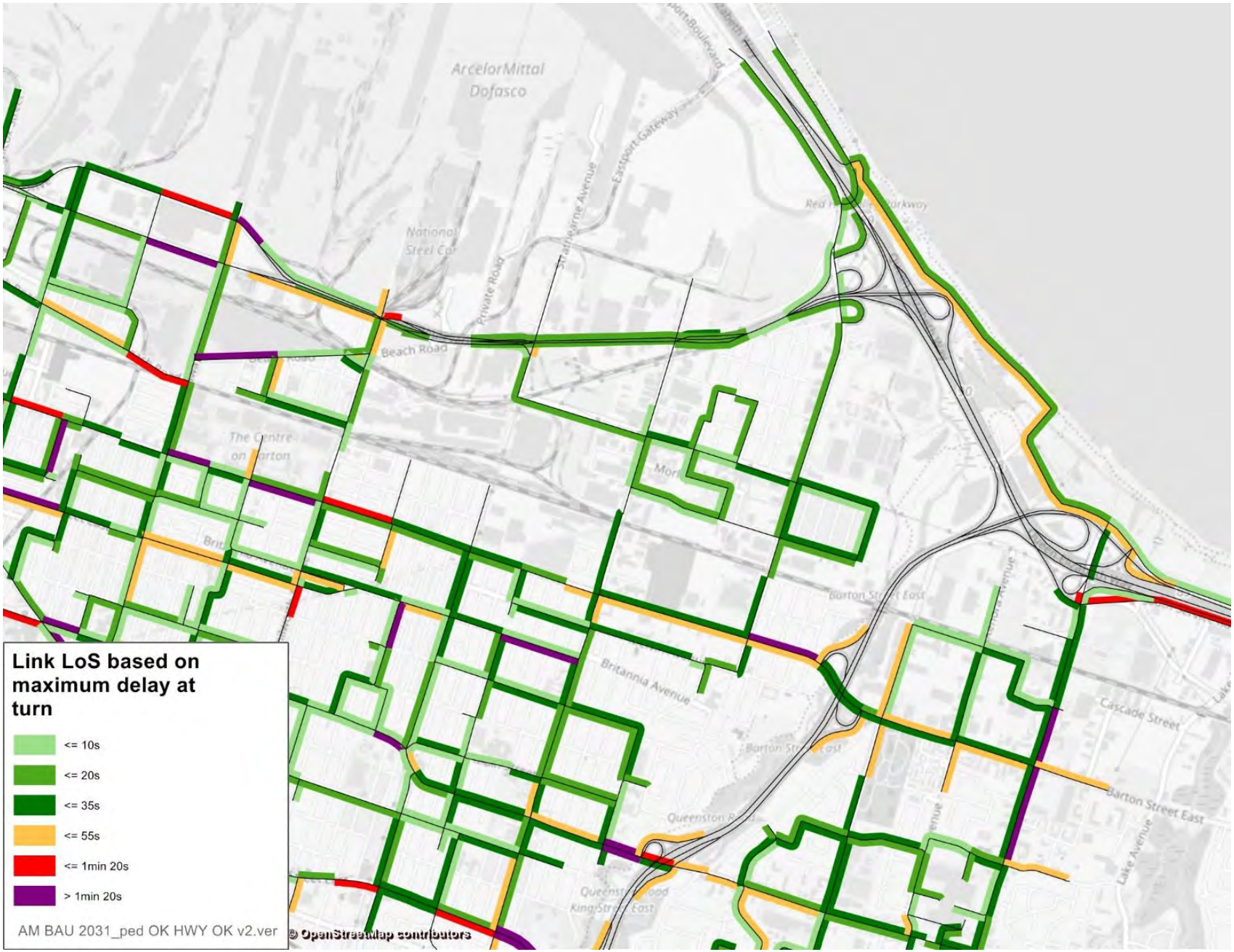
## AM BAU LINK LEVELS OF SERVICE

Central



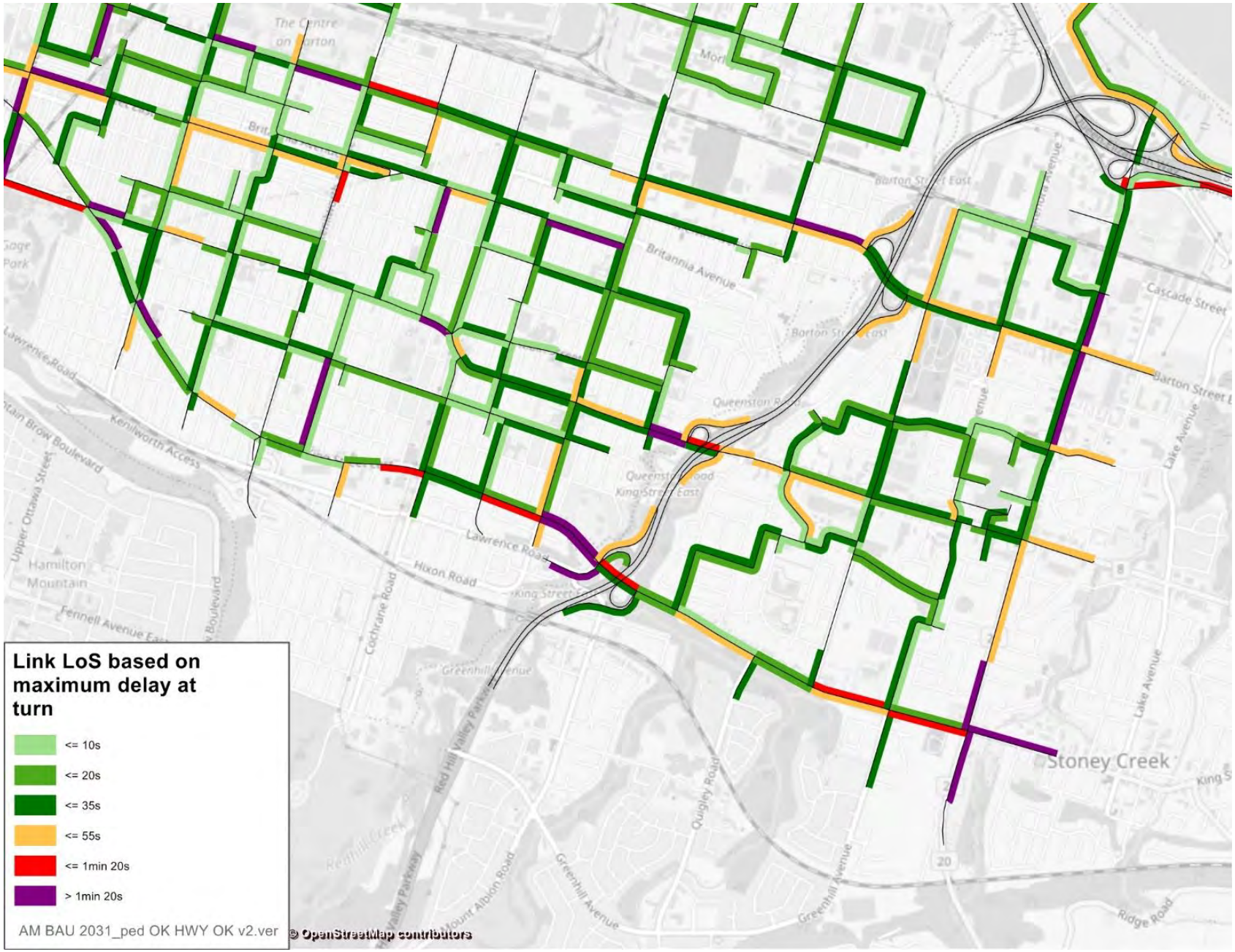
## AM BAU LINK LEVELS OF SERVICE

North - East



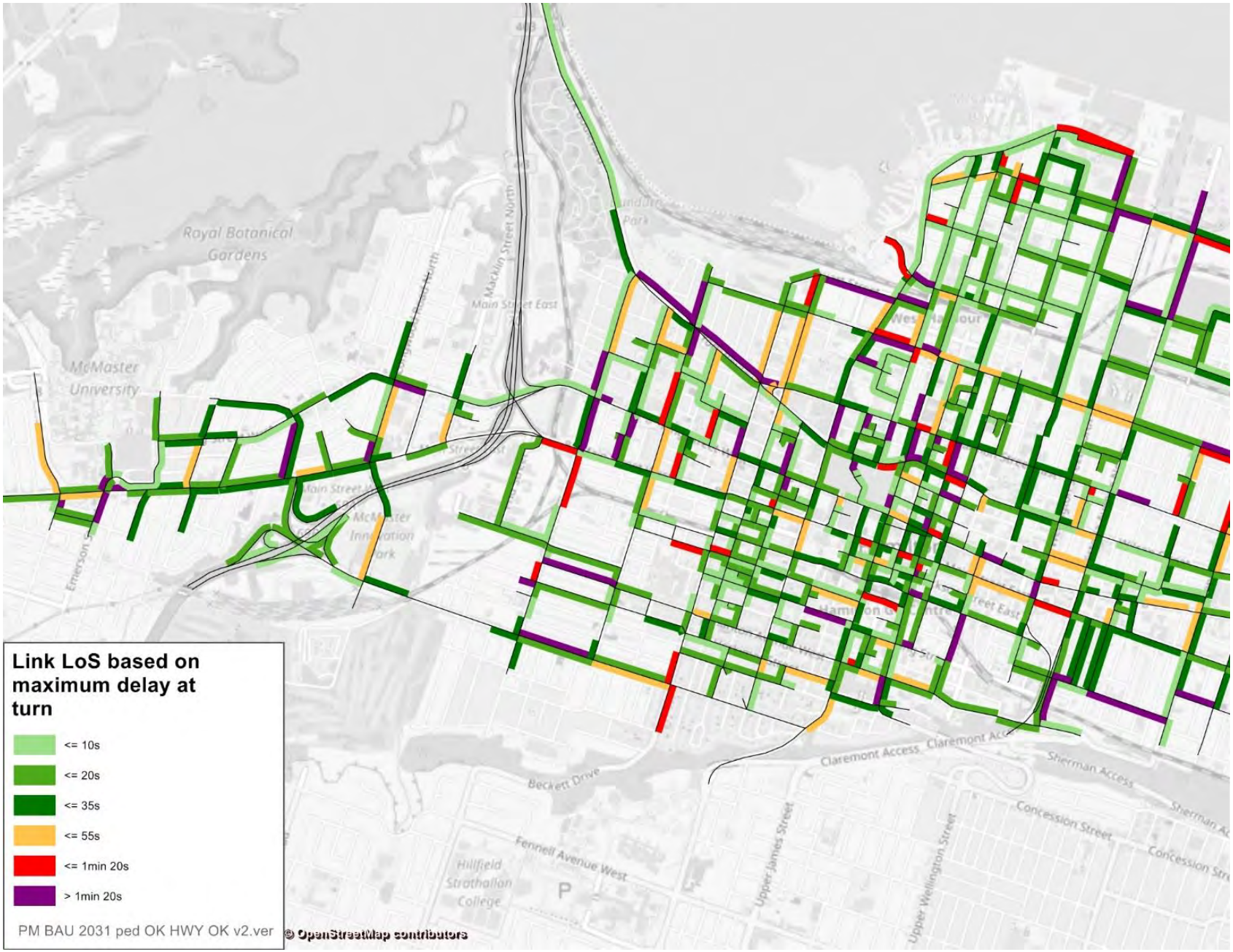
## AM BAU LINK LEVELS OF SERVICE

South - East



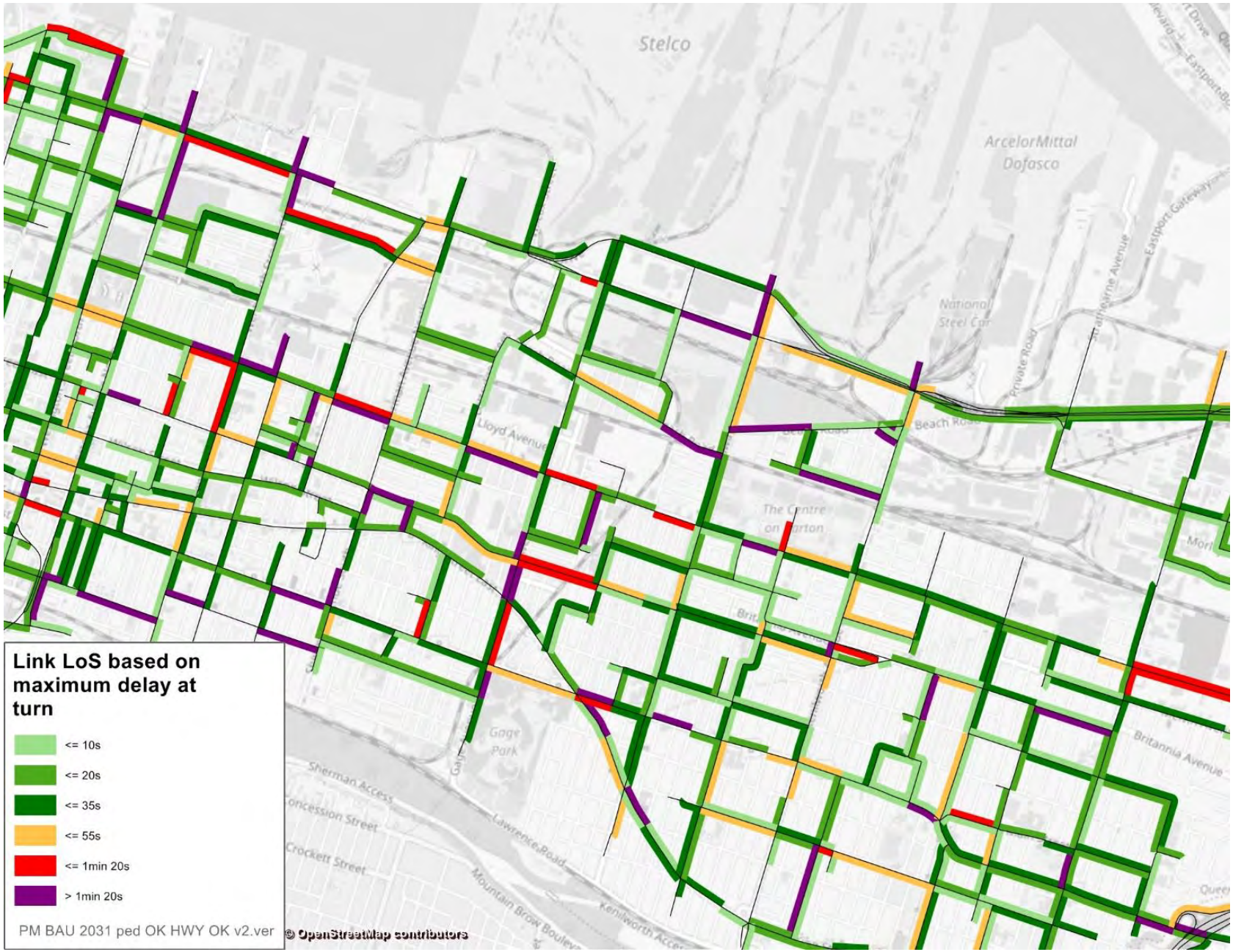
## PM BAU LINK LEVELS OF SERVICE

West



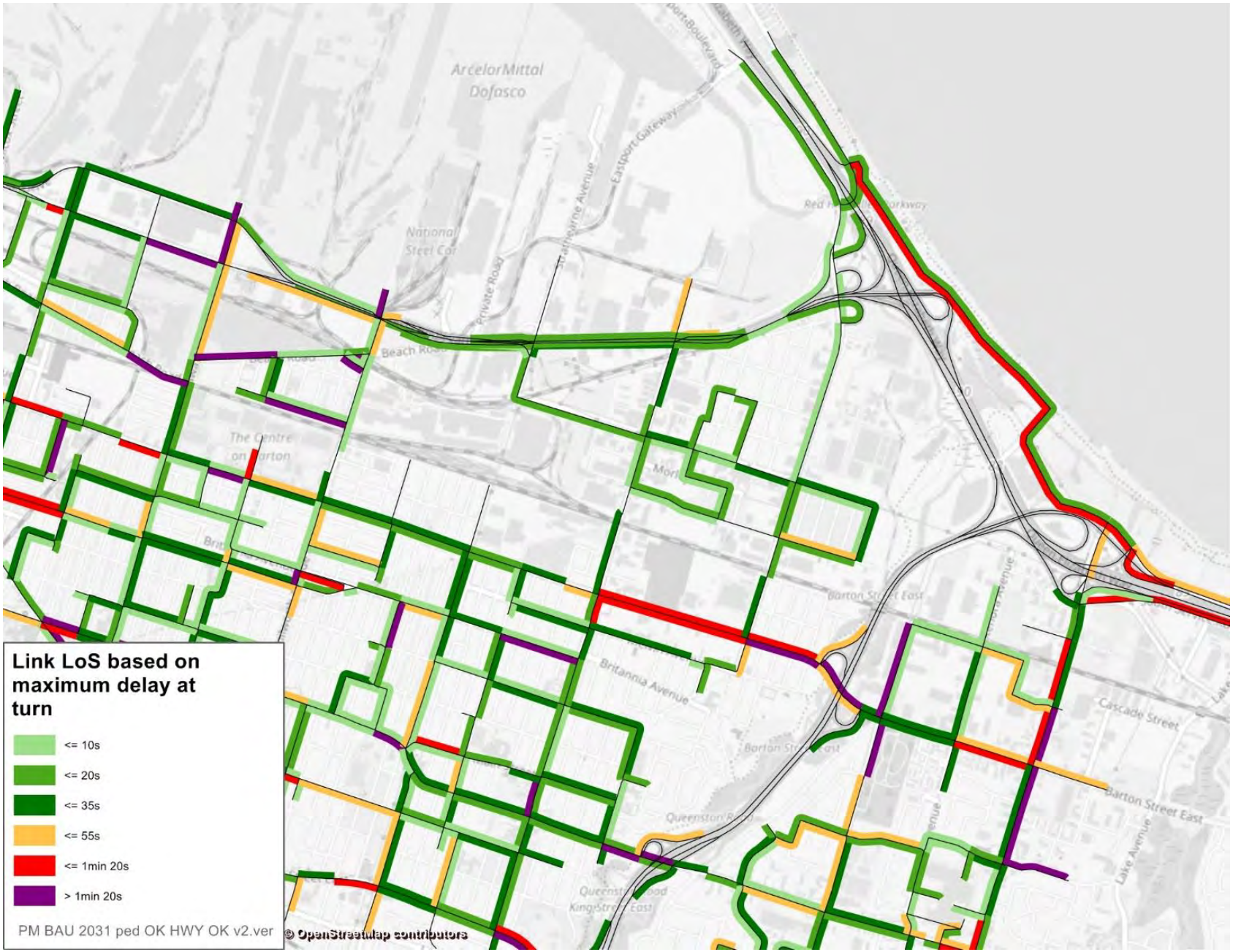
## PM BAU LINK LEVELS OF SERVICE

Central



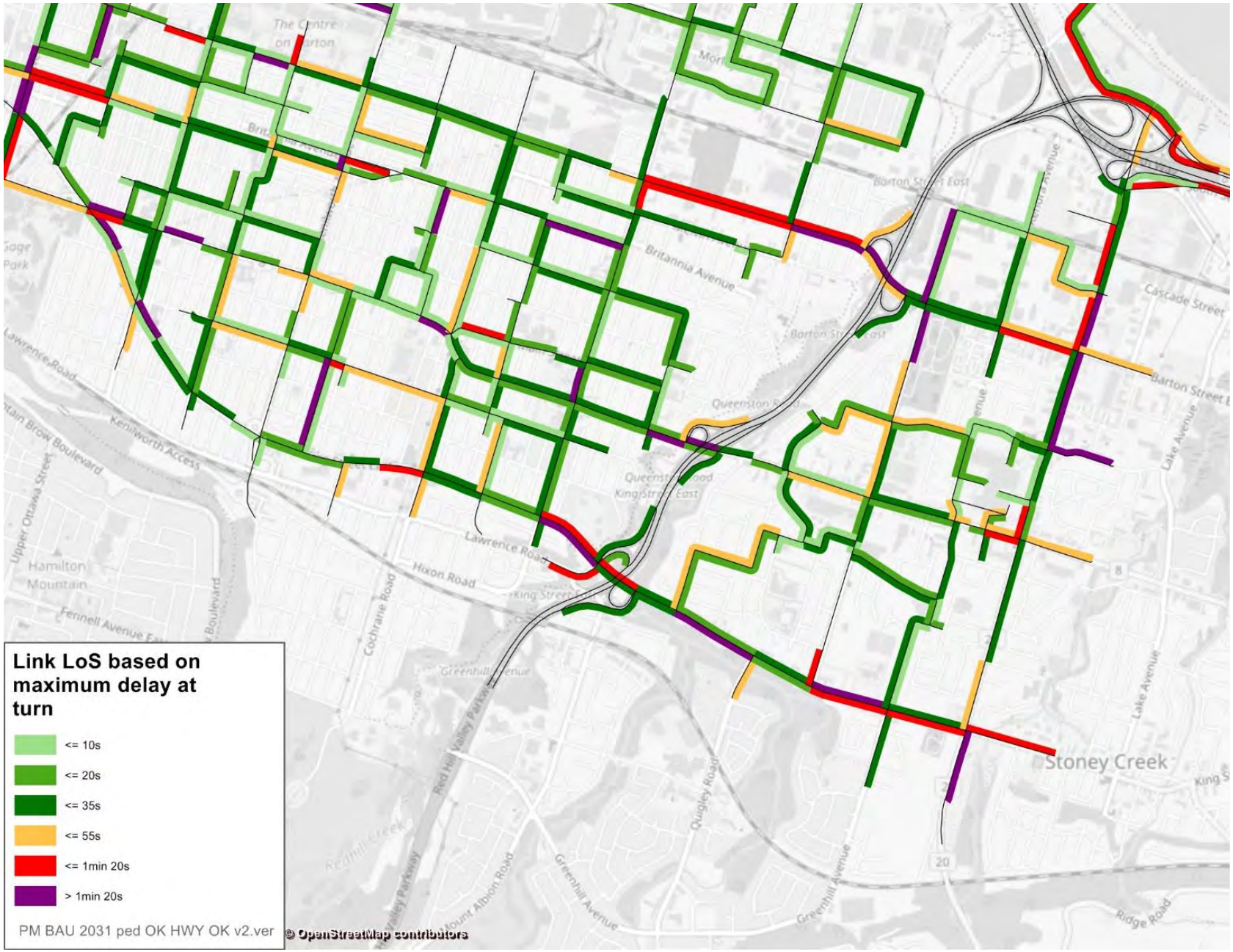
## PM BAU LINK LEVELS OF SERVICE

North - East



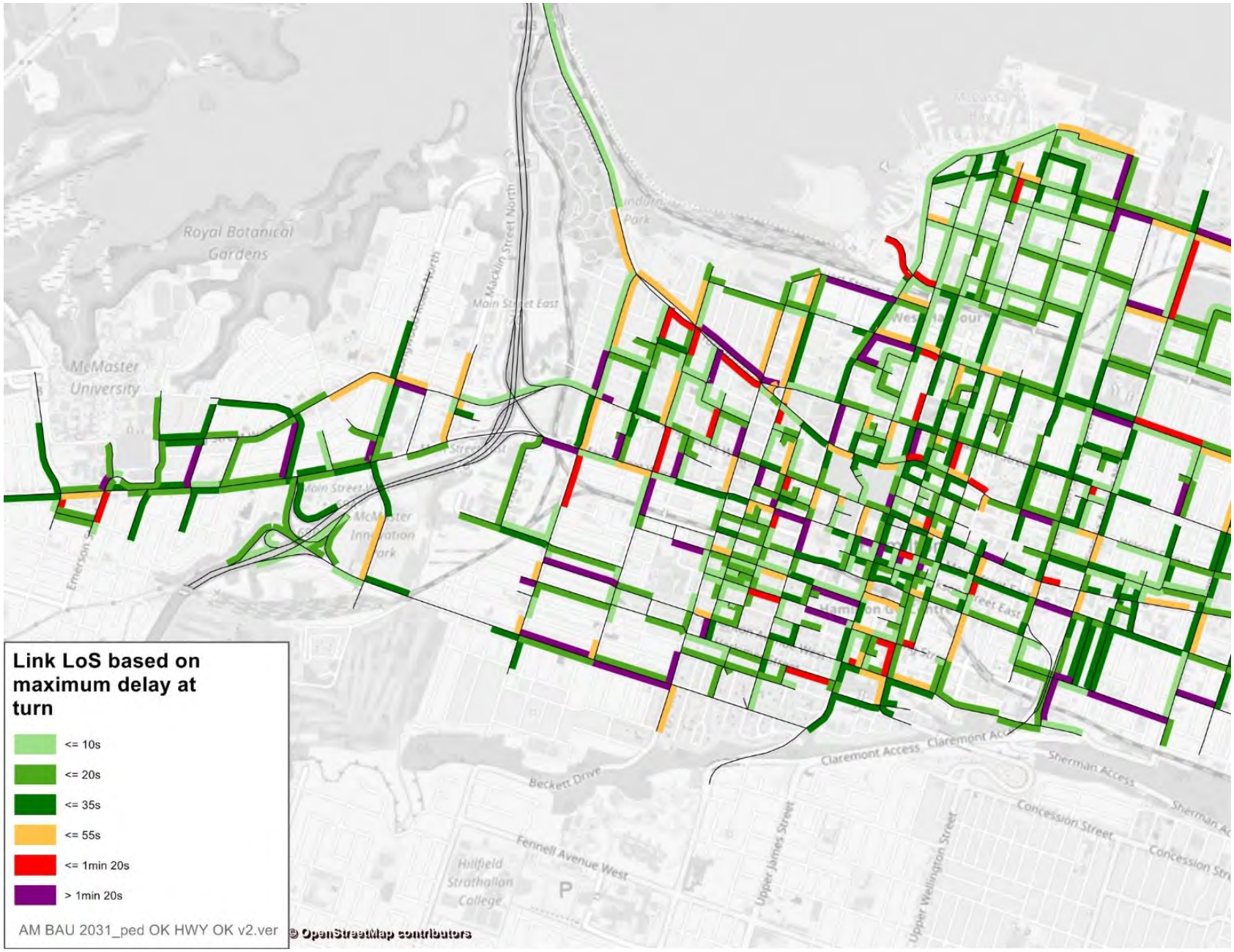
## PM BAU LINK LEVELS OF SERVICE

South - East



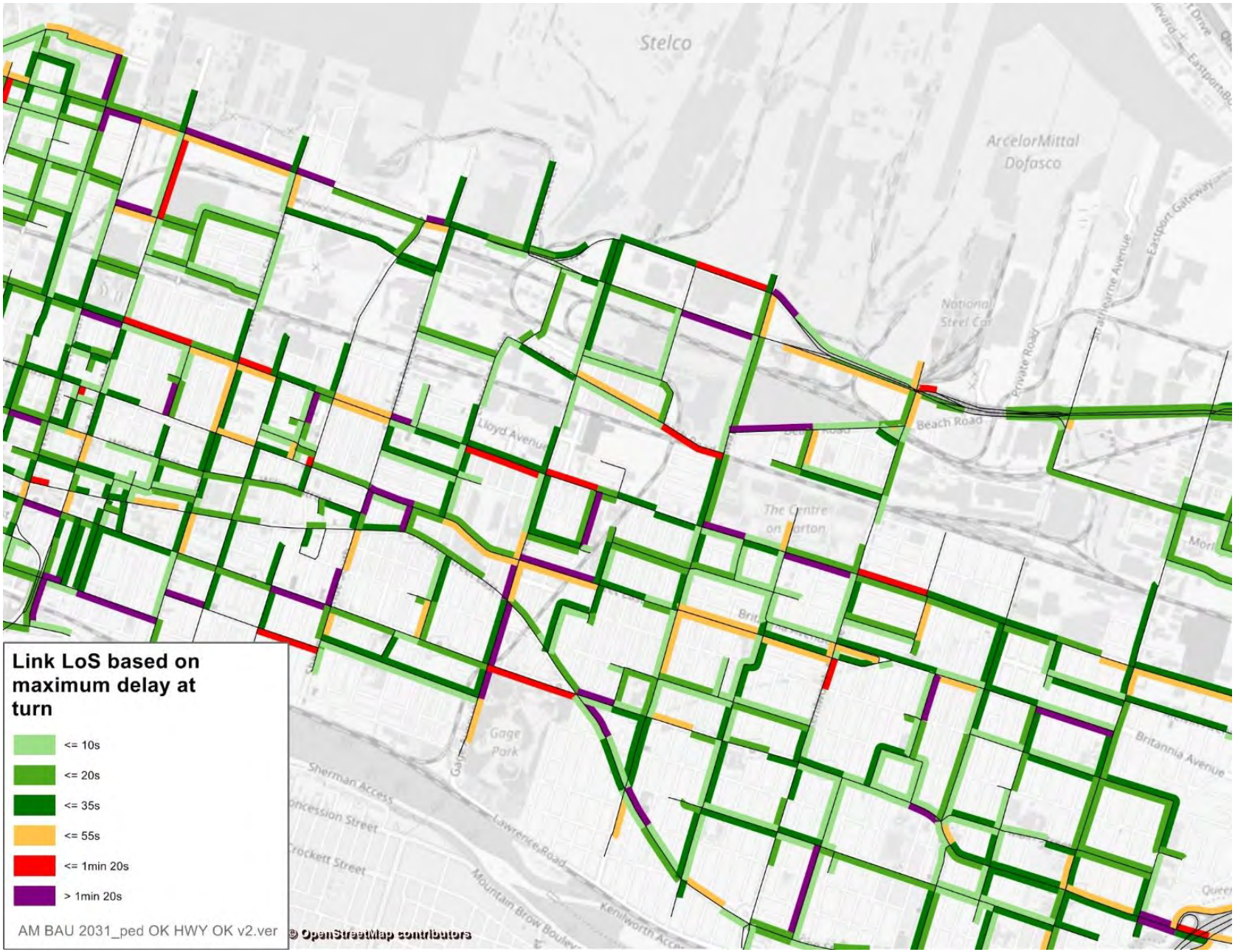
## AM LRT LINK LEVELS OF SERVICE

West



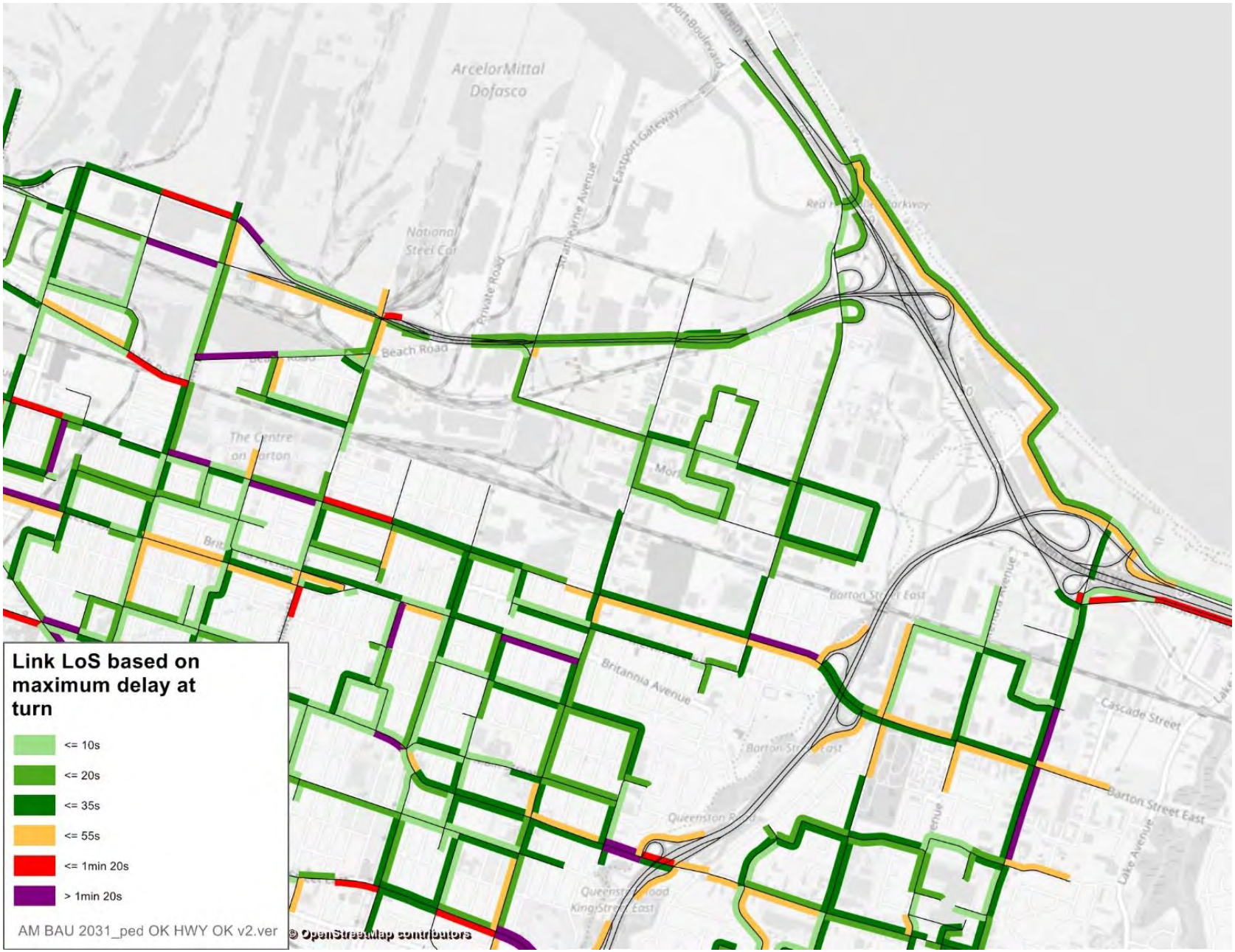
## AM LRT LINK LEVELS OF SERVICE

Central



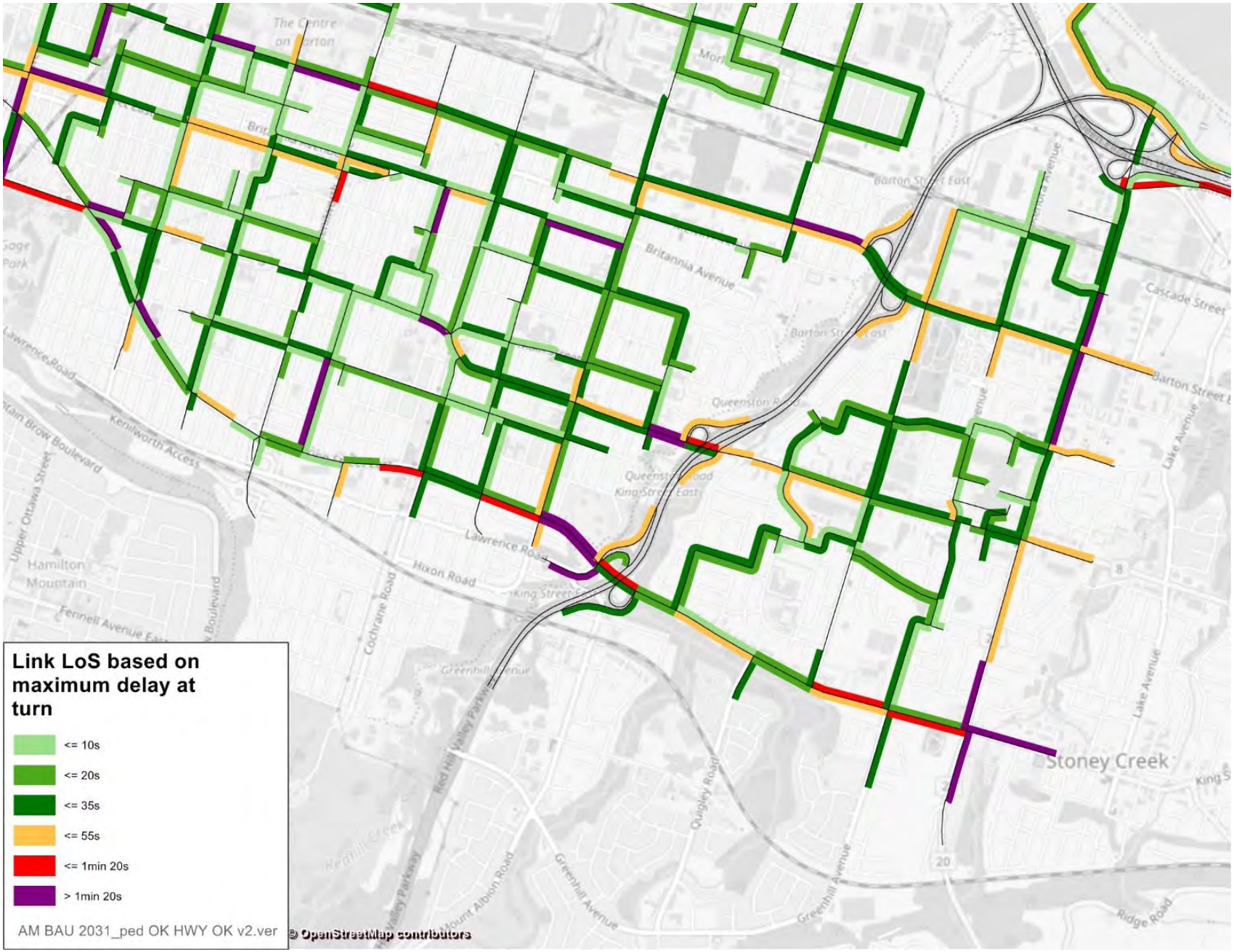
## AM LRT LINK LEVELS OF SERVICE

North - East



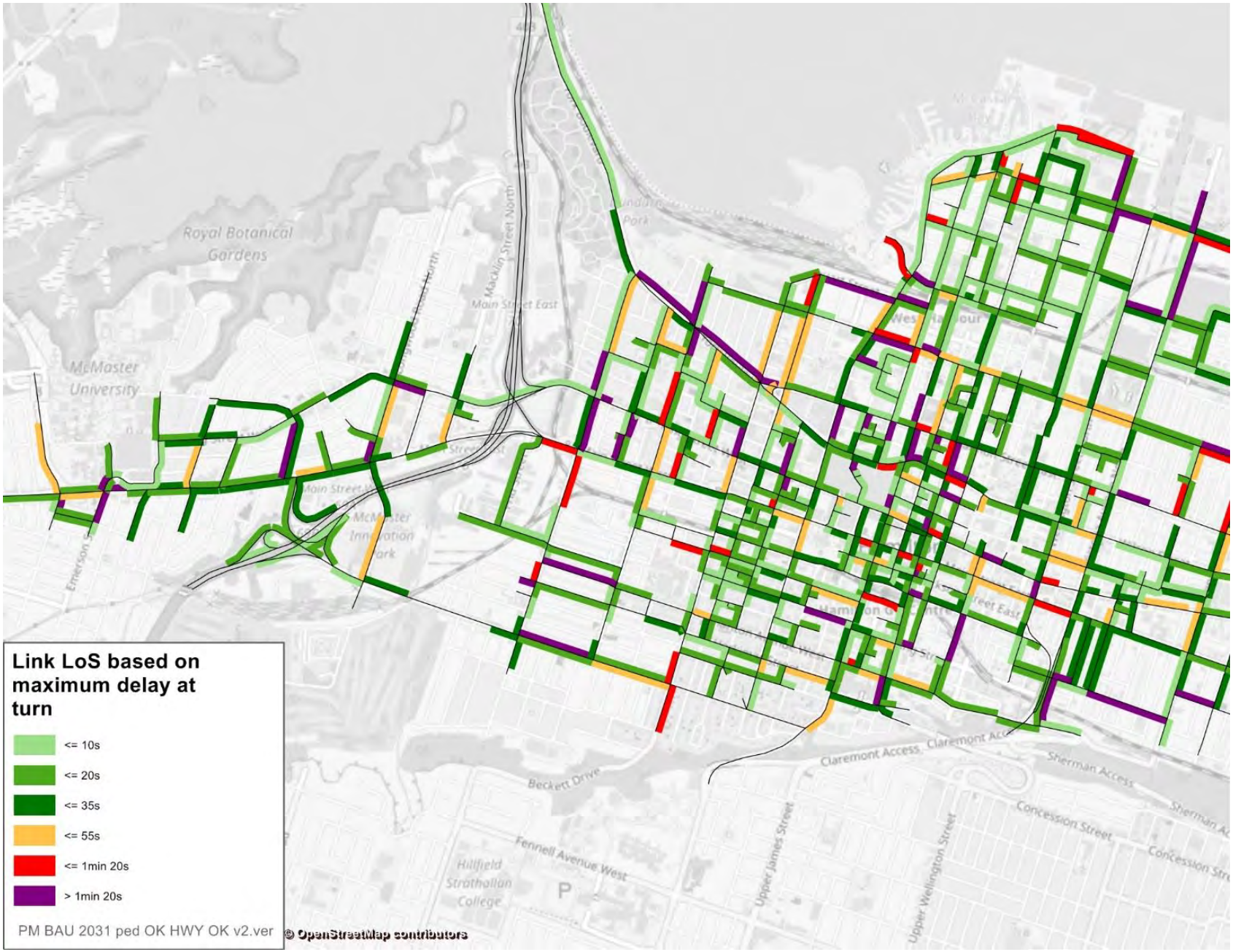
## AM LRT LINK LEVELS OF SERVICE

South – East



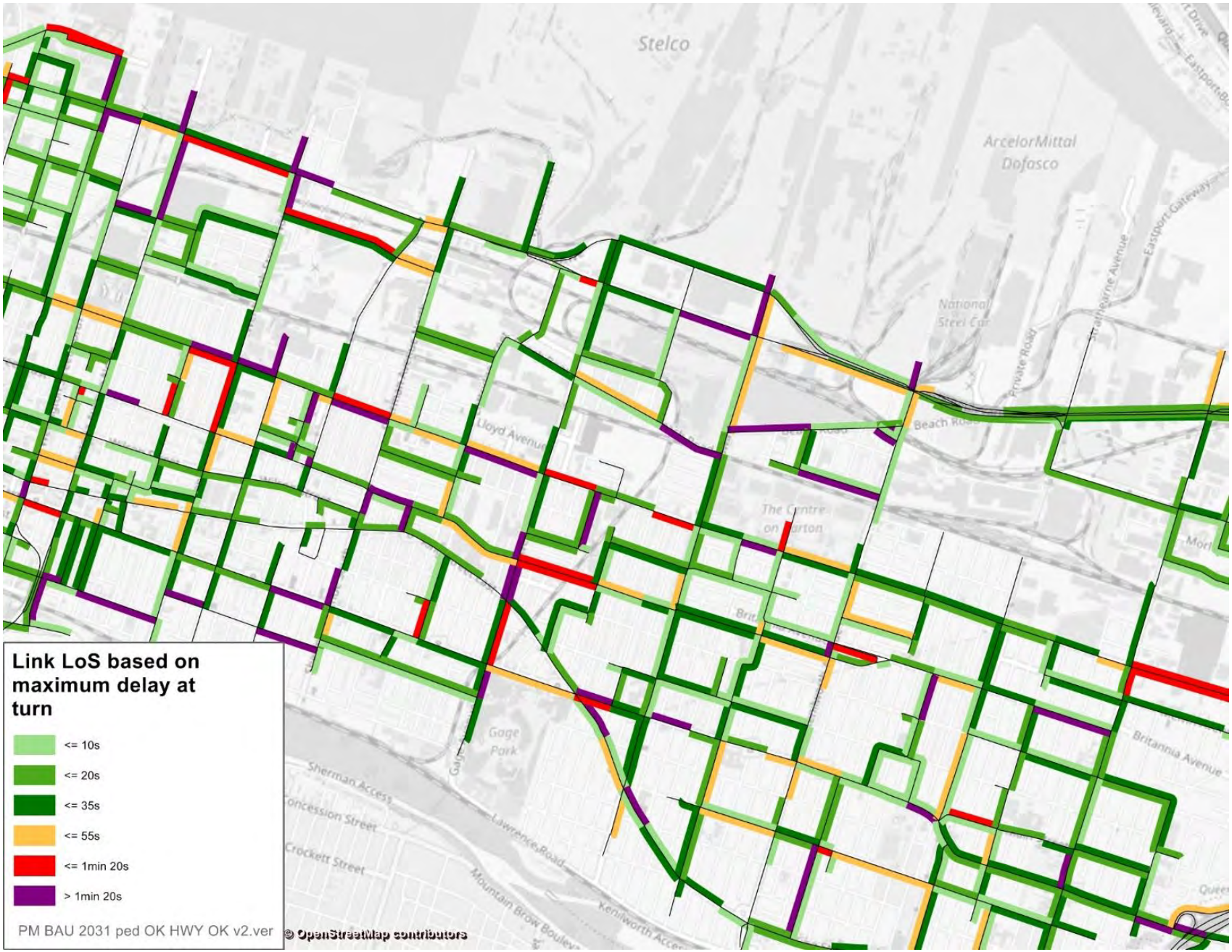
## PM LRT LINK LEVELS OF SERVICE

West



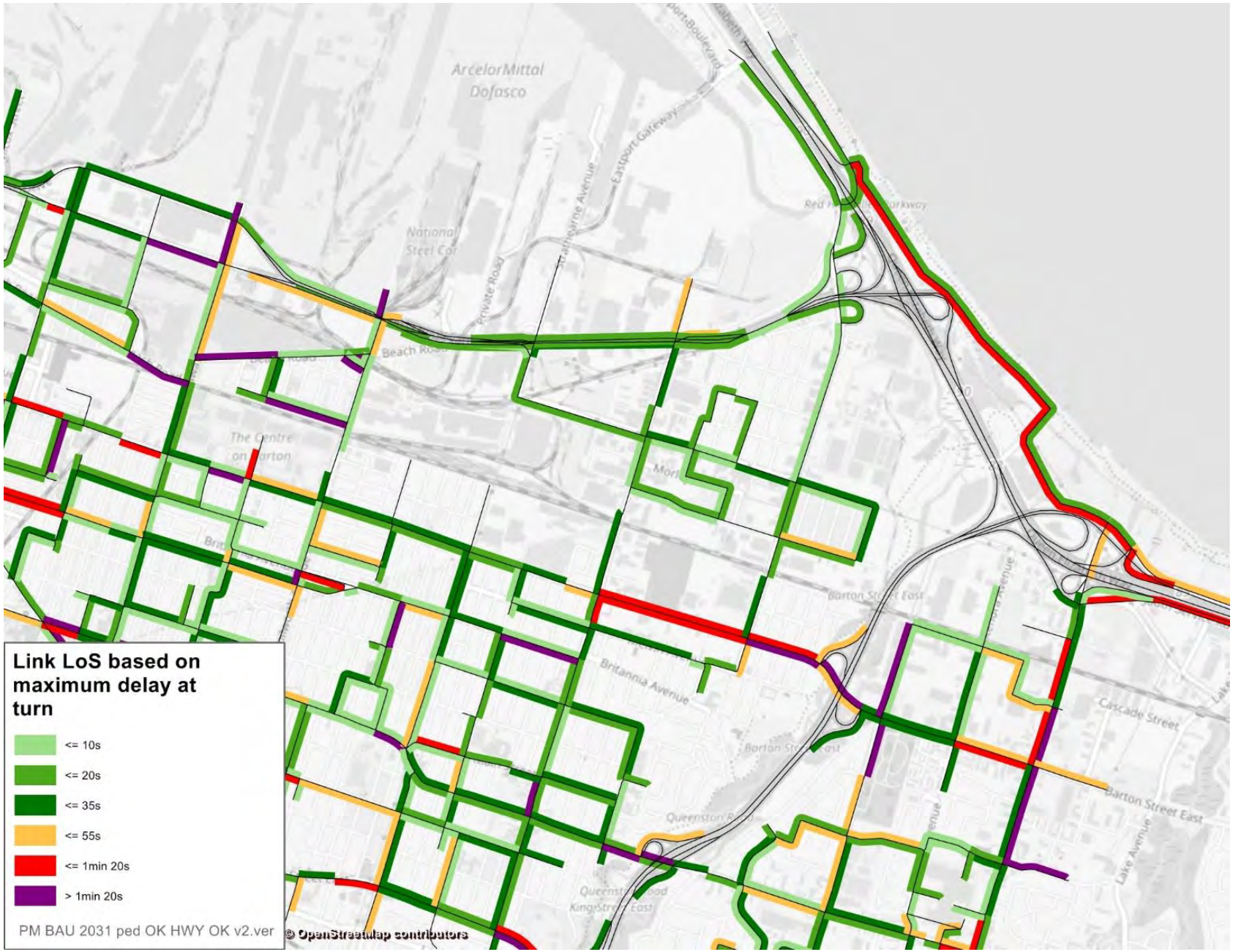
## PM LRT LINK LEVELS OF SERVICE

Central



## PM LRT LINK LEVELS OF SERVICE

North - East



## PM LRT LINK LEVELS OF SERVICE

South - East