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Hamilton Airshed Modelling System: Sub-Regional Analysis

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CITY OF HAMILTON

Acknowledgements

Golder would gratefully like to acknowledge the following contributors to the project:

- Jim Wilkinson, Ph.D.
- Barron Henderson, Ph.D.
- Environment and Climate Change Canada
- Stakeholder Advisory Committee
  - HIEA
  - Public Health
  - Community Stakeholders

Project Objectives

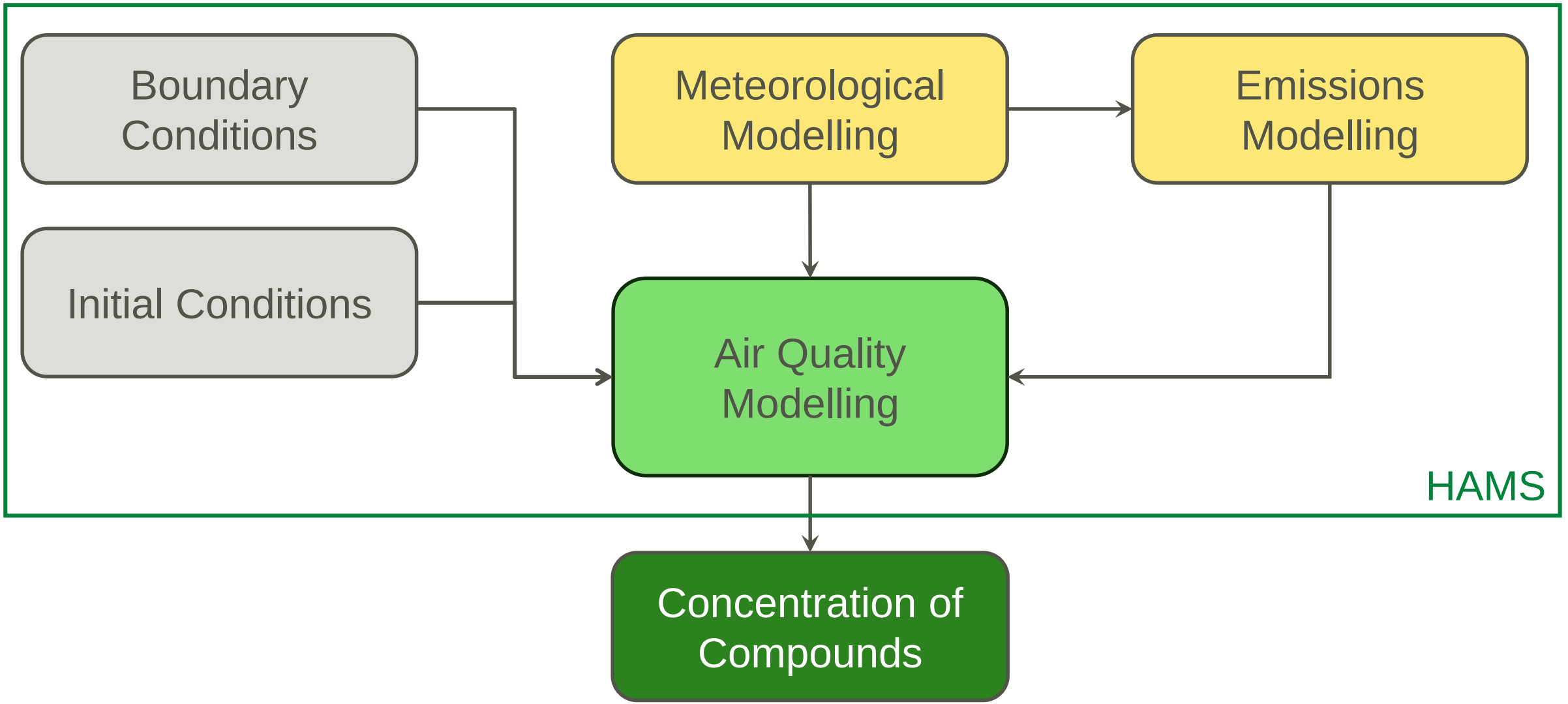
Challenges: The Hamilton Airshed Puzzle

- Who? What? Where? and How much contributes to air quality?
- Are levels different in different parts of the City?
- How much is local?
- What is the influence of the USA or outside geographies on Hamilton?

Solution: Hamilton Airshed Modelling System (HAMS)

- Built on understanding of the current state of the science
- Relies on local data as well as transboundary (e.g. land use, roadways, trains, industry, agriculture)
- Handles complex meteorology (e.g. lake effects and escarpment)
- Considers atmospheric chemistry – important part of the puzzle
- Needs a Big computer

Hamilton Airshed Modelling System



Compounds of Interest

Studied Compounds*	
Acrolein	Ozone
Ammonia	Volatile Organic Carbons
Benzene	Benzo(a)pyrene
Butadiene 1,3	Cadmium
Carbon Monoxide	Chromium (III)
Formaldehyde	Chromium (VI)
Nitrogen Oxides (NO_2 and NO)	Lead
Sulphur Dioxide	Manganese
PM_{10}	Mercury
$PM_{2.5}$	Nickel

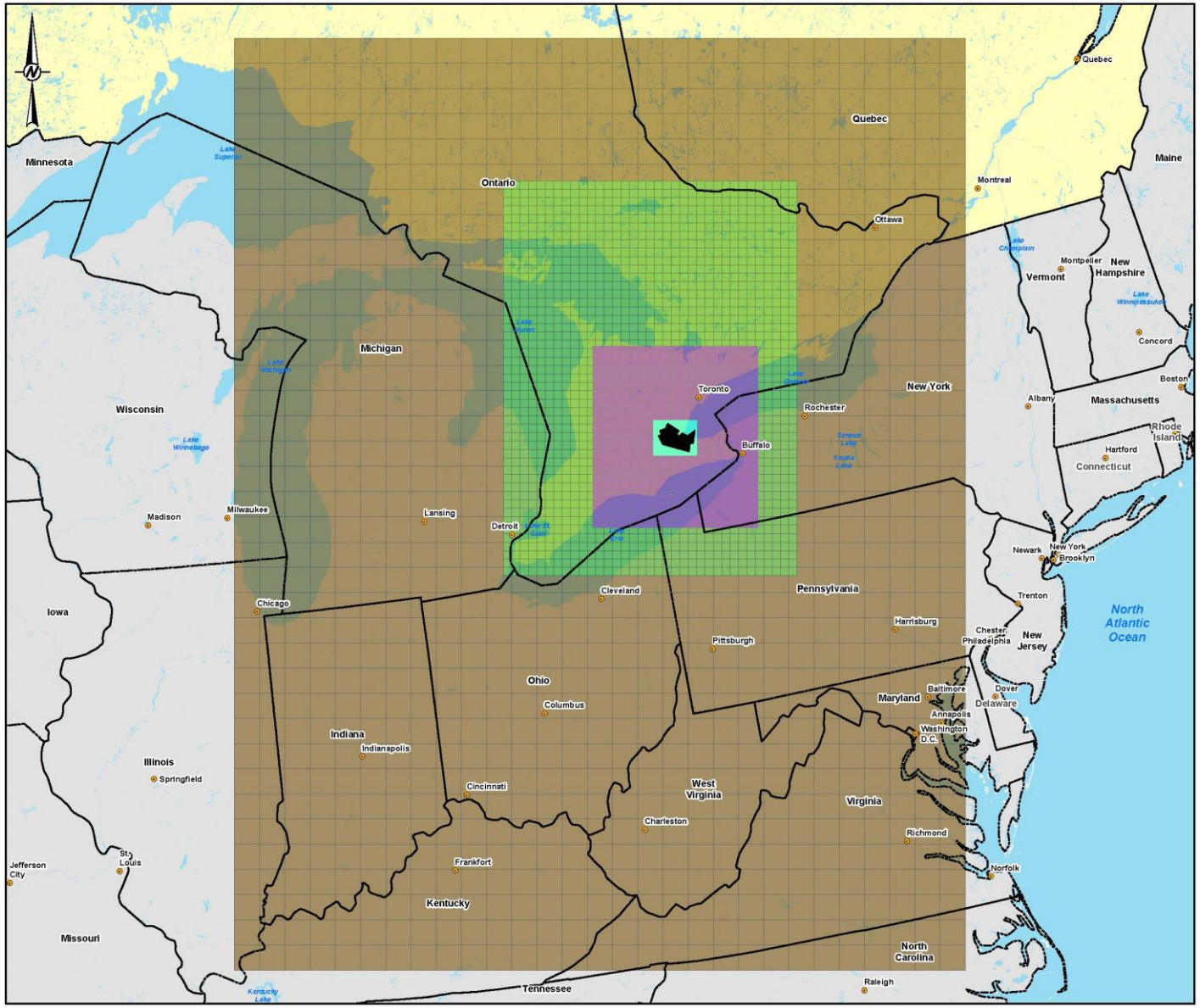
**Please note additional species, including precursors, are available but were not studied*

Presented Compounds*
$PM_{2.5}$
PM_{10}
Nitrogen Oxides
Sulphur Dioxide
Ozone
Benzene
Benzo(a)pyrene

** Selected by the Stakeholder Advisory Committee*

Grid Density: All Tiers

Tier
Tier I (36 km)
Tier II (12 km)
Tier III (3 km)
Tier IV (1.33 km)



Selected Urban Regions

Regions	Influence
IC = industrial core	Industry, port, rail, roads
WL = west lower	Road, non-road
EL = east lower	Industry, road, non-road
WU = west upper	Road
EU = east upper	Road

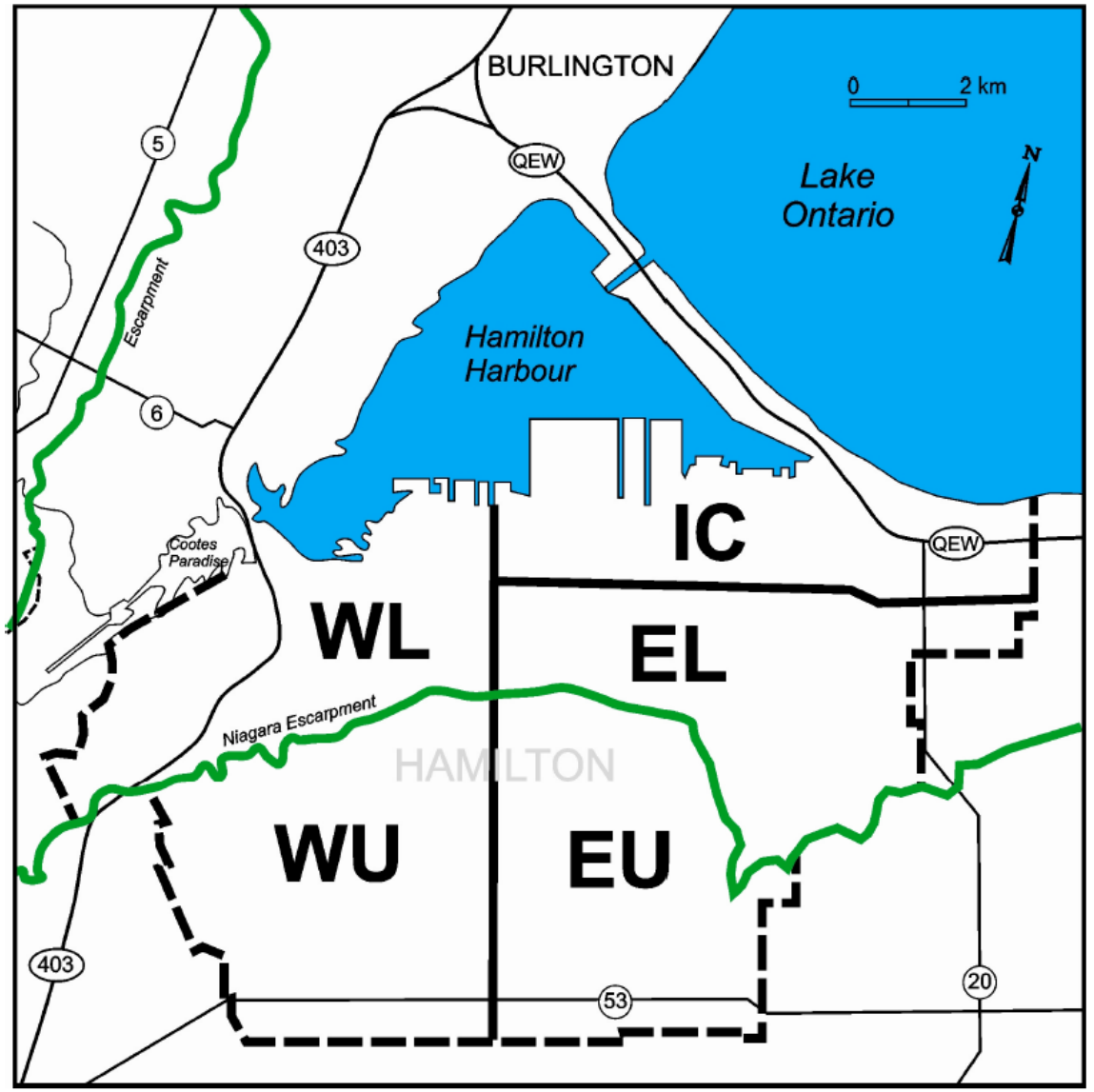


Figure 1 in Radisic,S., Newbold, K. B., Eyles, J. and Williams, A. (2016). Factors influencing health behaviours in response to the air quality health index: a cross-sectional study in Hamilton, Canada. *Environmental Health Review, Volume 59(1), 17-29*. DOI: 10.5864/d2016-002

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Model Verification

Model Verification

MODEL PERFORMANCE EVALUATION SUMMARY

- The results meet published benchmarks which provides confidence in the results of the modelling simulations.
  - Meteorology benchmarks met for temperature, mixing ratio, wind speed and wind direction
  - Particulate matter met performance criteria
    - PM_{10} is under-predicted likely due to unaccounted for fugitive dust source
  - All compounds are predicted within a factor of 2
    - Performing within expectations of the modelling community
  - Transboundary NO_2 emissions are overstated leading to model over-prediction
  - Metrics for benzene and B(a)P could be impacted by lack of observations (compared to other species)
- Hamilton Airshed Modelling System provides conservative and reliable results with a strong degree of confidence

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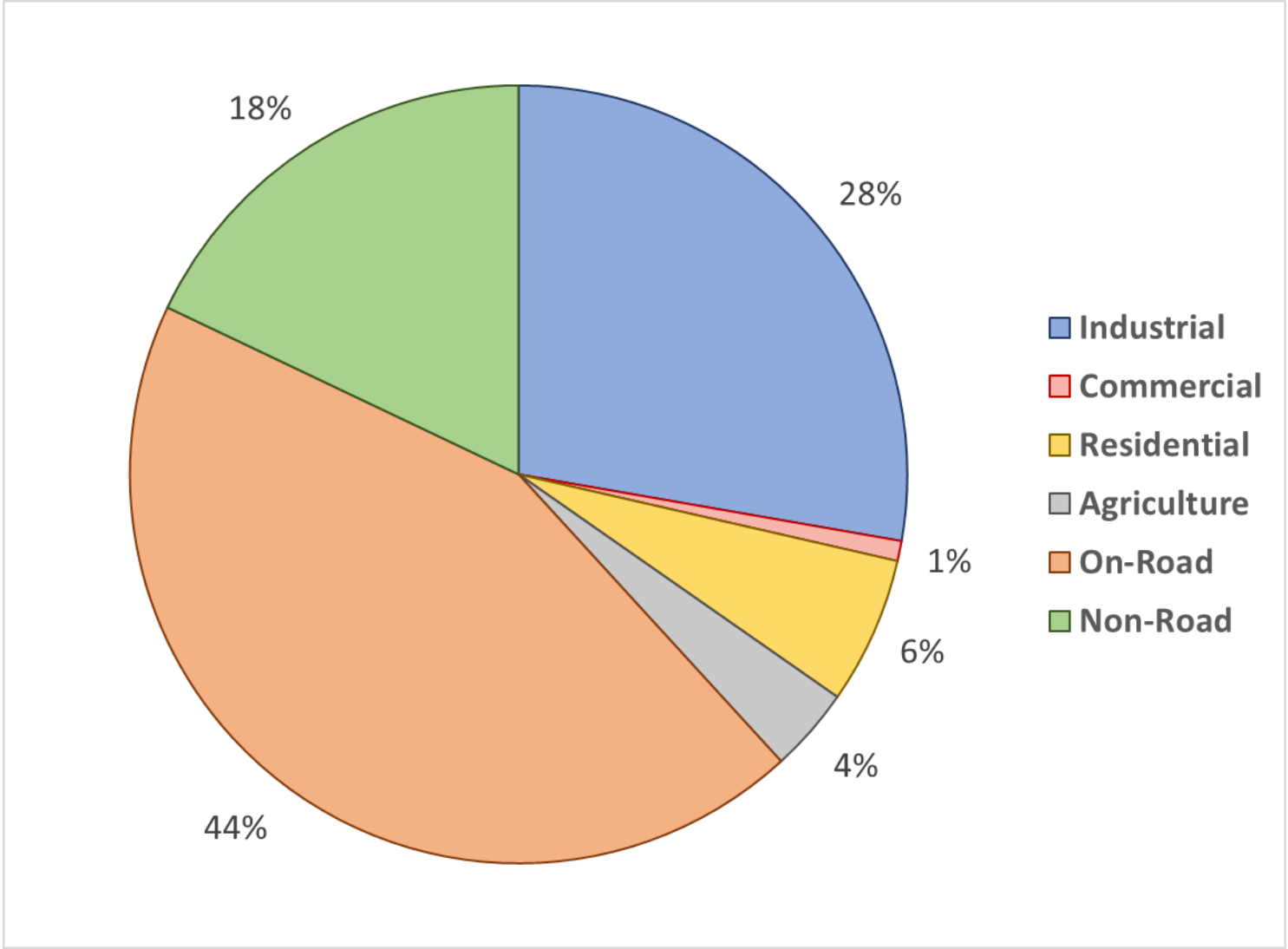
Emissions Inventory Results

Emissions Inventory Sources

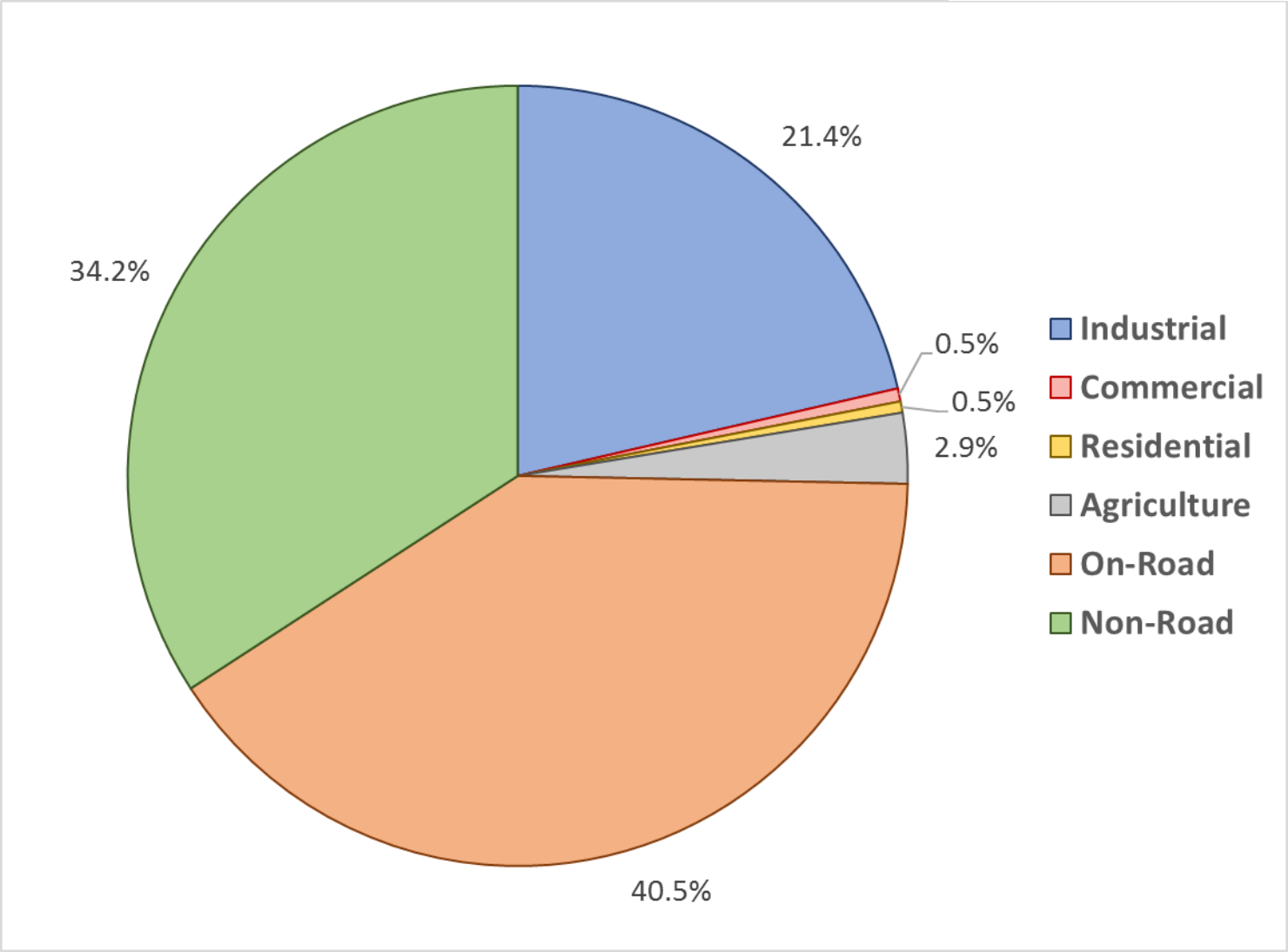
GRIDDED, HOURLY EMISSION ESTIMATES BY TIER

Emission Classification	Type	Definition	Source	
			Tier I	Tiers II – IV
Industrial	Point (all tiers)	Elevated stacks from industrial activities	2006 Canadian National Emissions Inventory (NEI) 2011 US NEI	2012 NPRI, 2011 US NEI
	Area	Industrial activities		2012 NPRI, 2011 US NEI
Commercial	Point (Tier I, US Only)	Natural gas usage, auto-body shops, dry cleaners, commercial solvents		2012, ChemTRAC (scaled by population), 2012 Stats Can population data, 2011 US NEI
	Area			
Residential	Area	Natural gas usage, other residential heating sources		2012 natural gas consumption, 2012 Stats Canada energy use, 2011 US NEI
On-Road	Area	On-road vehicles (trucks, cars, motorcycles)		2012 MOVES, 2012 MTO traffic data, 2011 US NEI
Non-Road	Point (Tier I, US Only)	Airport, marine, rail and lawn mowers,		2006 Canadian NEI, 2012 NRCAN data, 2011 US NEI
	Area			
Biogenic / Agricultural	Area	E.g., natural, farmland	2012 MEGAN, 2006 Canadian NEI, 2011 US NEI	2012 MEGAN, 2012 NONROAD

Total Hamilton Emissions Profile – All Tiers

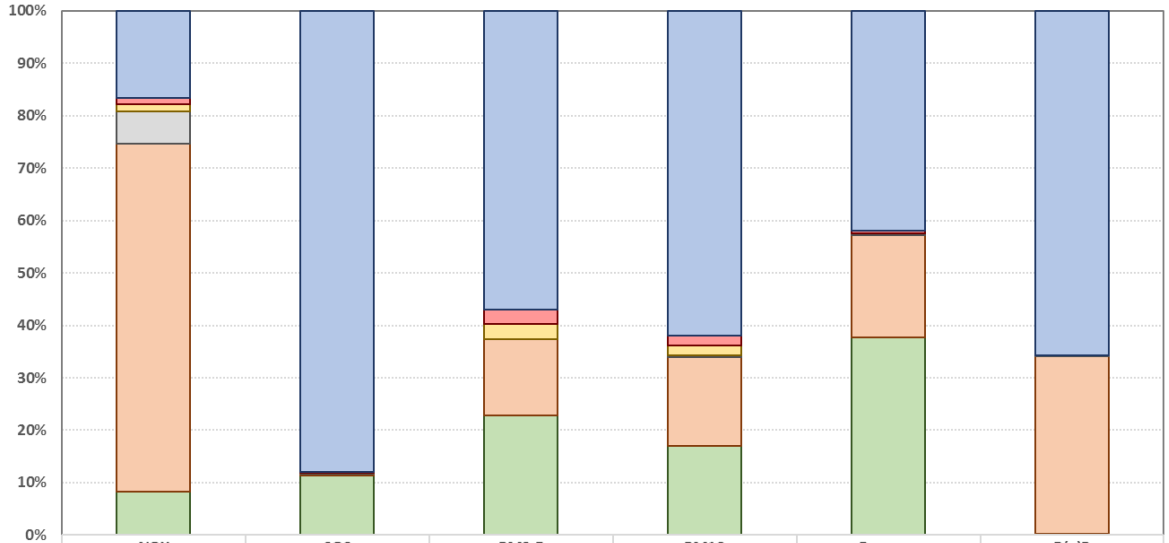


Total Hamilton Emissions Profile – Tier IV



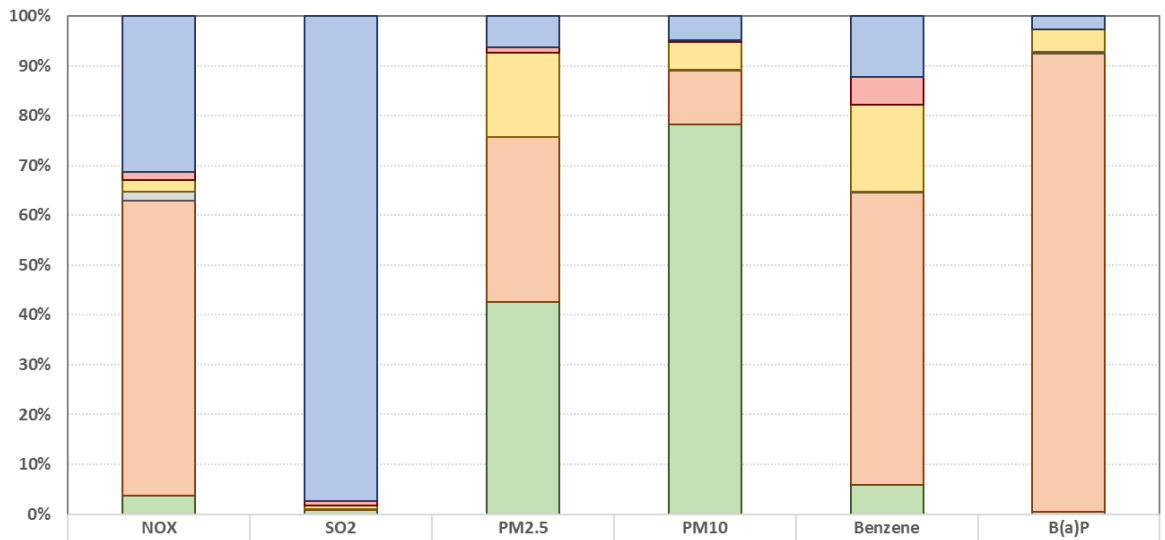
Hamilton & Transboundary Emissions Profiles

HAMILTON EMISSIONS (%)



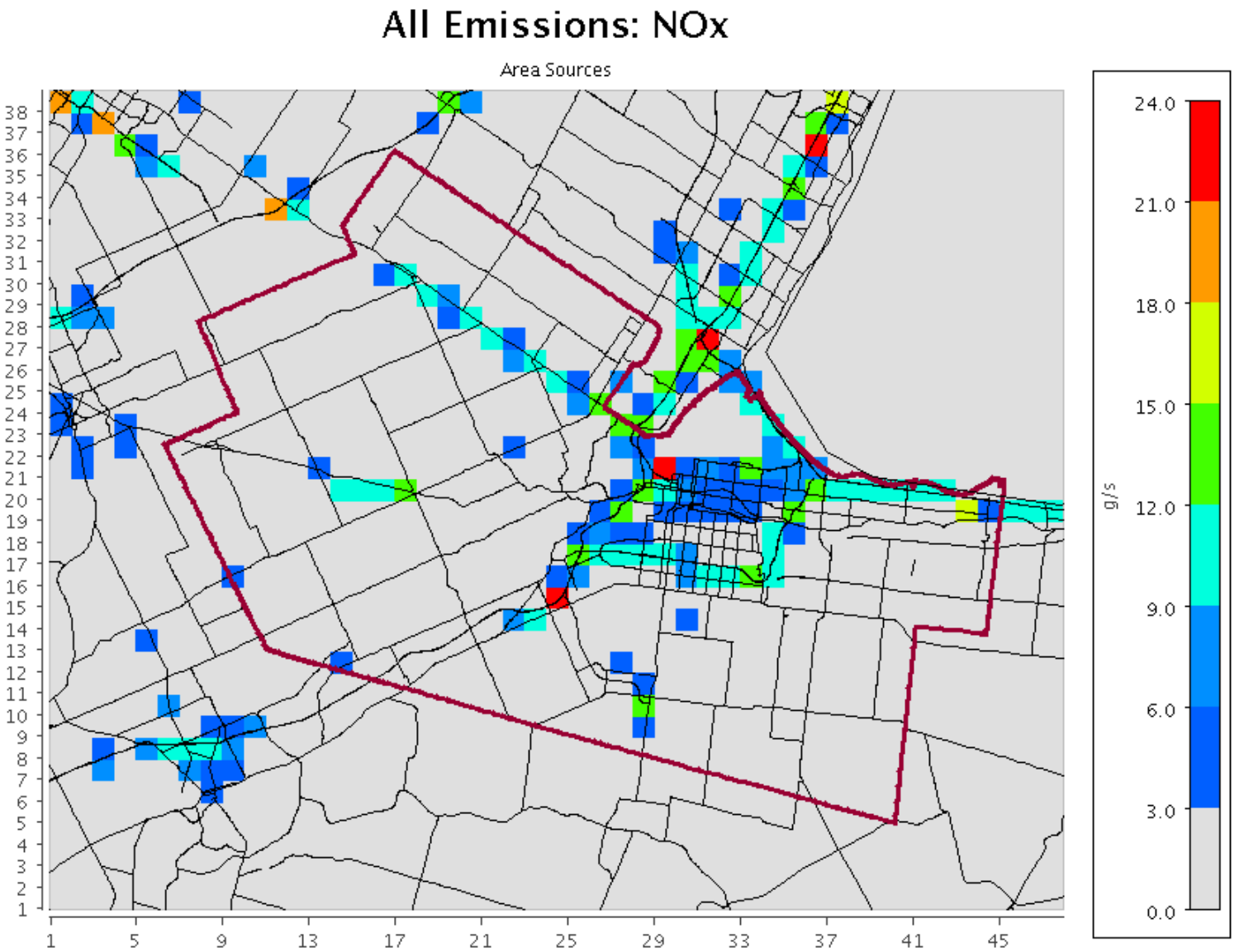
	NOX	SO2	PM2.5	PM10	Benzene	B(a)P
Industrial	16.6%	88.0%	57.0%	61.9%	42.0%	65.7%
Commercial	1.2%	0.02%	2.7%	1.8%	0.5%	0.0%
Residential	1.3%	0.02%	2.9%	2.0%	0.0%	0.0%
Agriculture	6.2%	0.3%	0.0%	0.3%	0.4%	0.2%
On-Road	66.4%	0.4%	14.7%	17.0%	19.4%	33.8%
Non-Road	8.2%	11.3%	22.7%	17.0%	37.7%	0.3%

TRANSBOUNDARY EMISSIONS (%)



	NOX	SO2	PM2.5	PM10	Benzene	B(a)P
Industrial	31.3%	97.3%	6.4%	4.8%	12.2%	2.7%
Commercial	1.7%	1.0%	1.1%	0.5%	5.7%	0.0%
Residential	2.3%	0.7%	16.8%	5.6%	17.5%	4.4%
Agriculture	1.8%	0.0%	0.1%	0.1%	0.1%	0.5%
On-Road	59.1%	0.2%	33.1%	10.9%	58.7%	91.9%
Non-Road	3.7%	0.8%	42.5%	78.2%	5.9%	0.5%

Tier IV: NO_x Emissions



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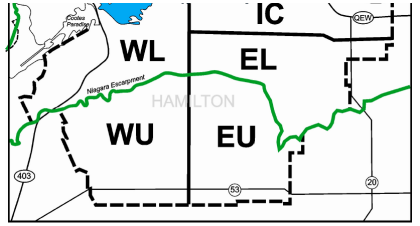
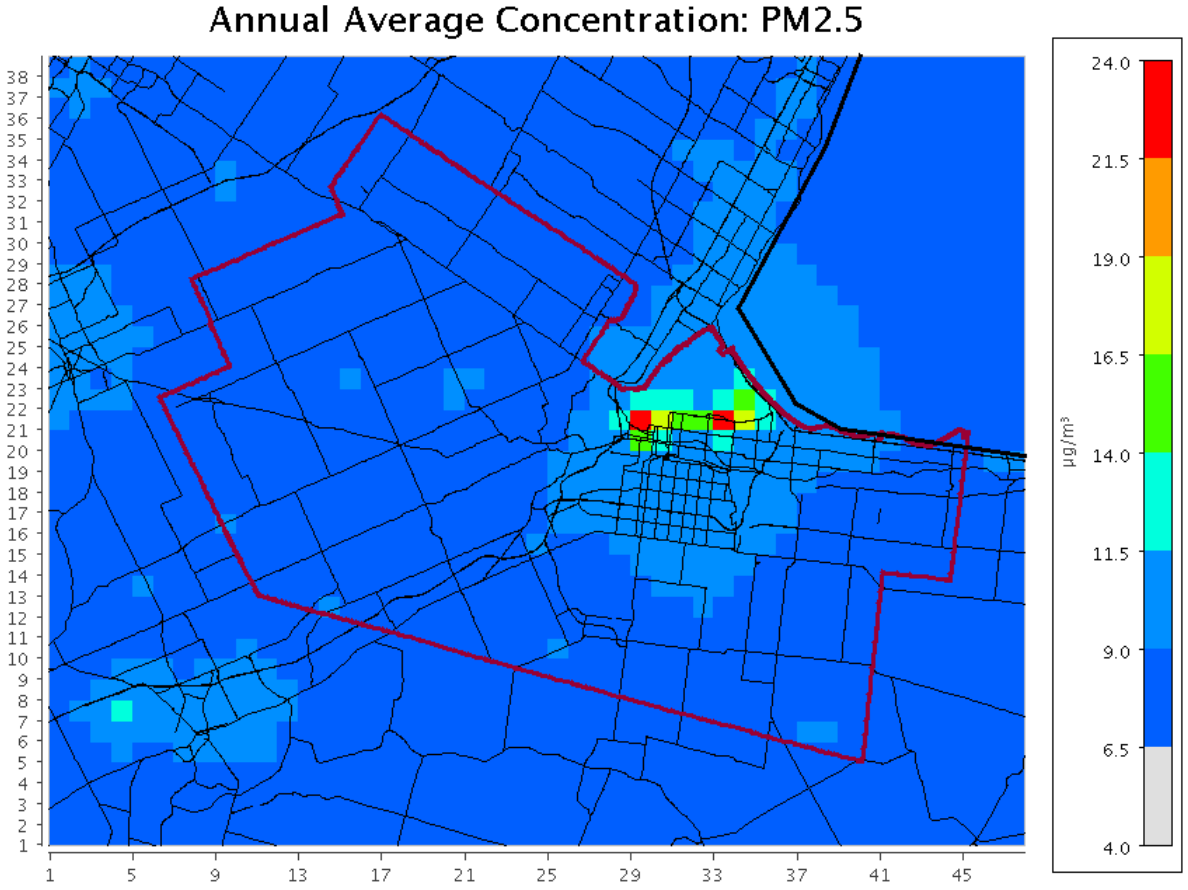
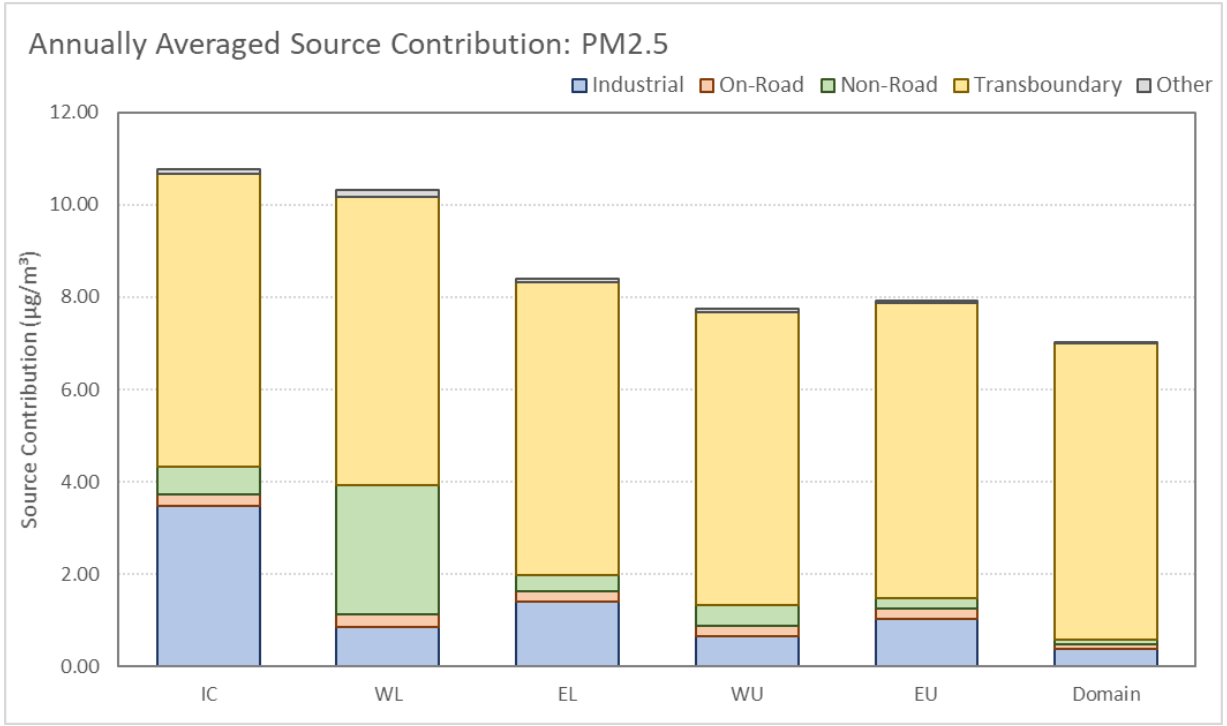
Air Quality Modelling Results: Aerial and Source Apportionment Update

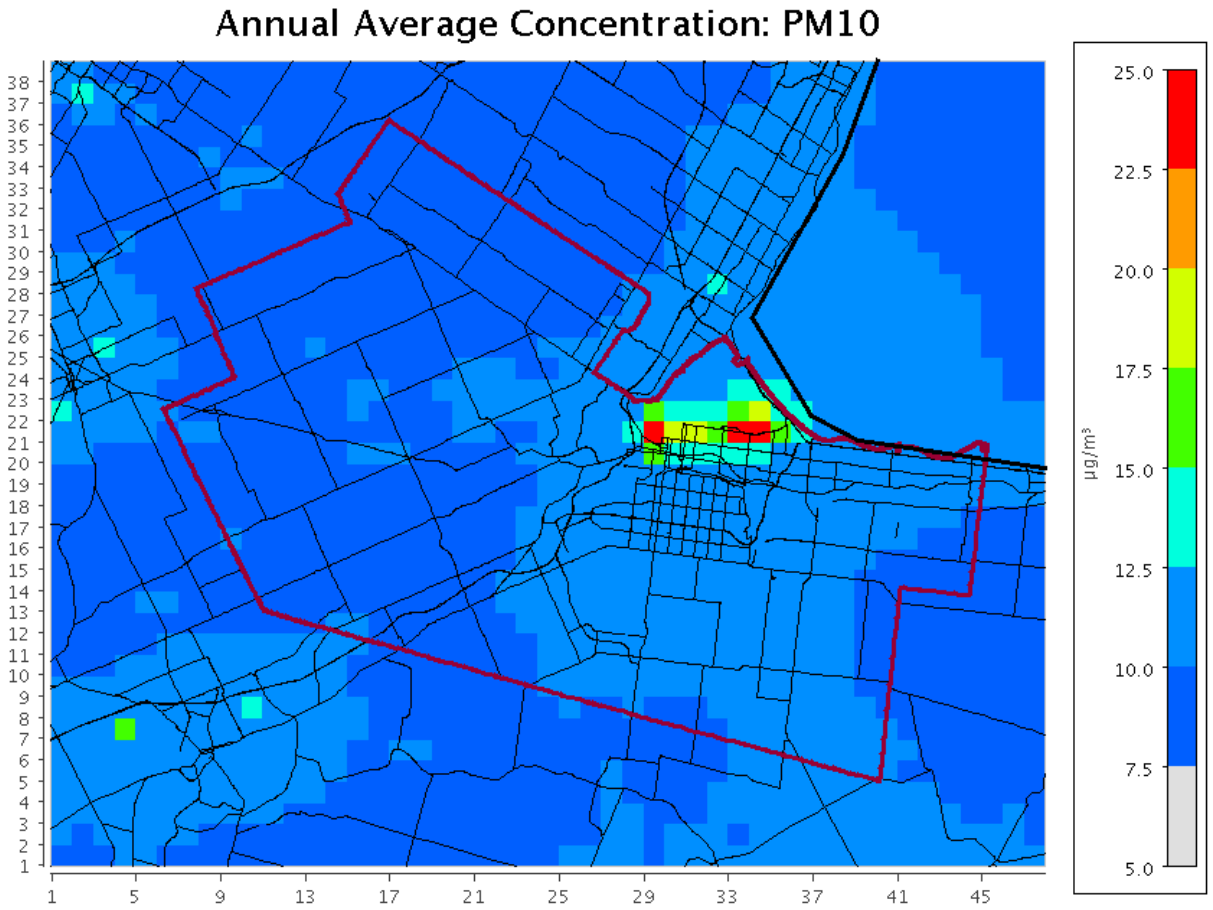
Air Quality Modelling Results: $PM_{2.5}$

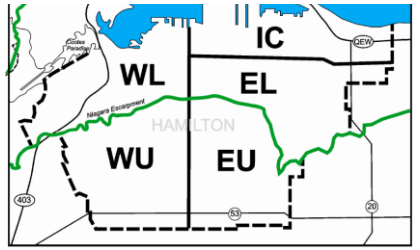


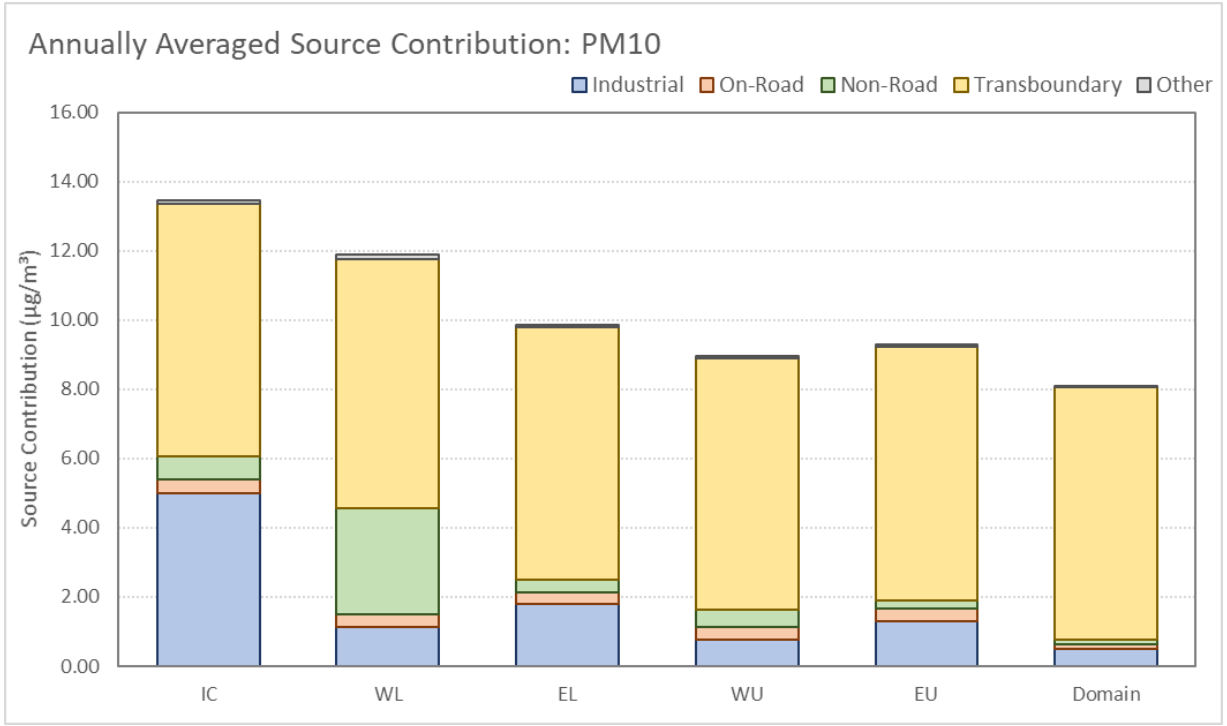




Air Quality Modelling Results: PM_{10}

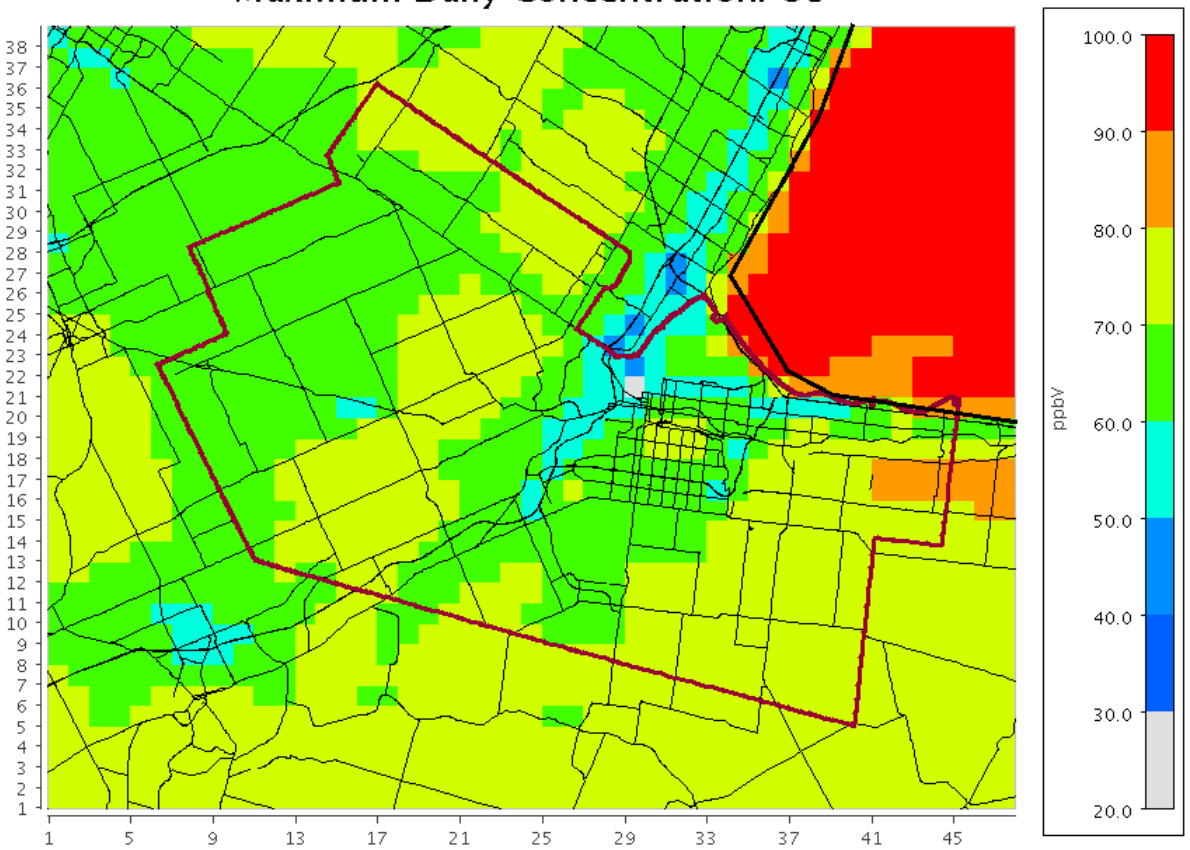




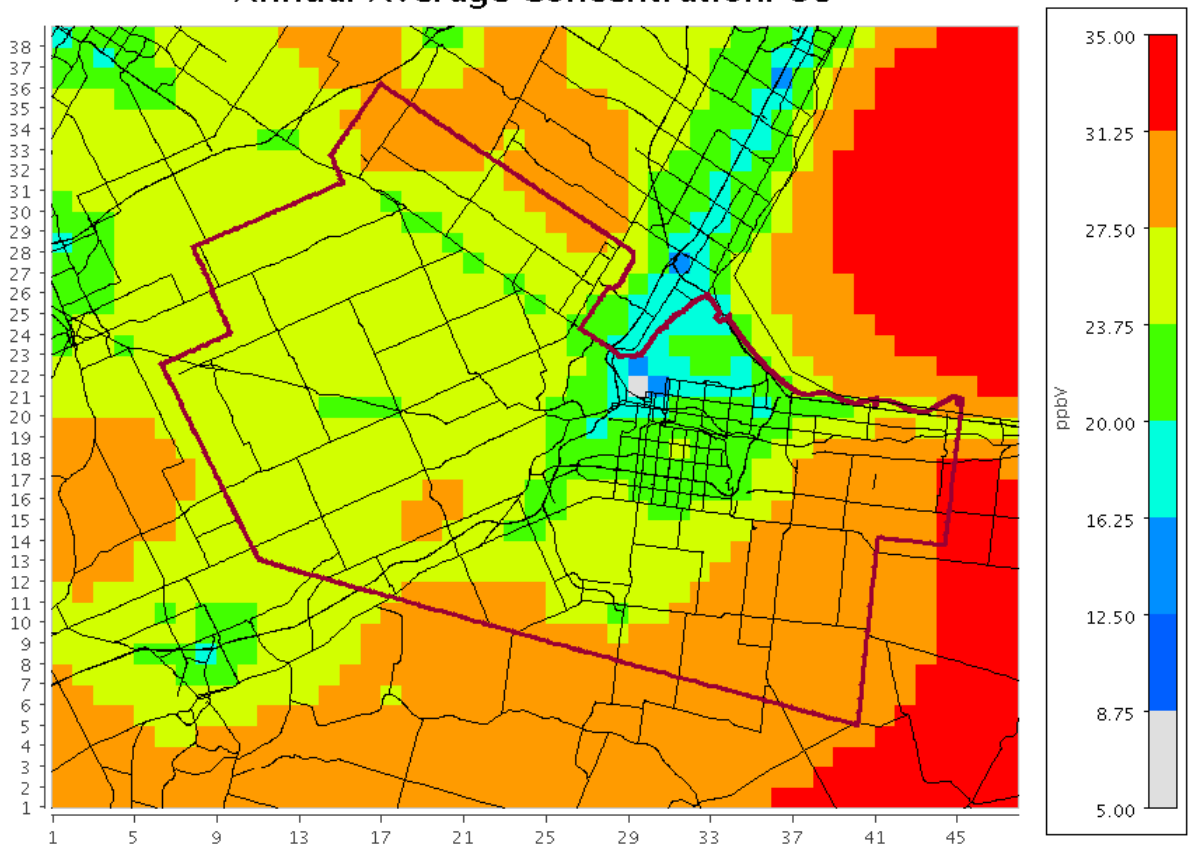


Air Quality Modelling Results: O_3

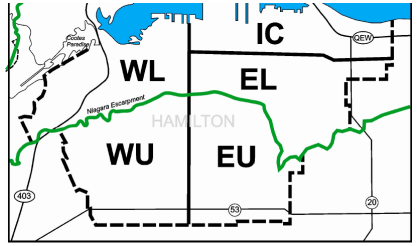
Maximum Daily Concentration: O3

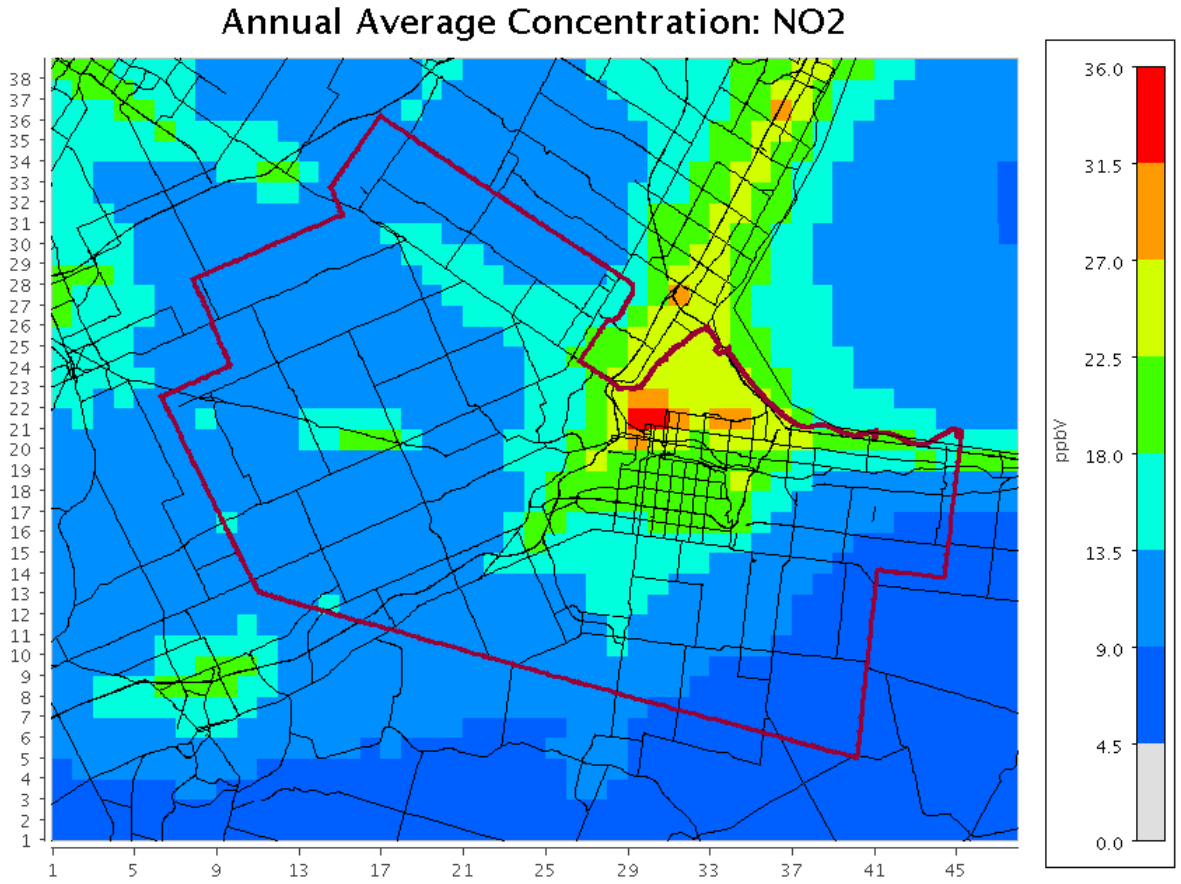


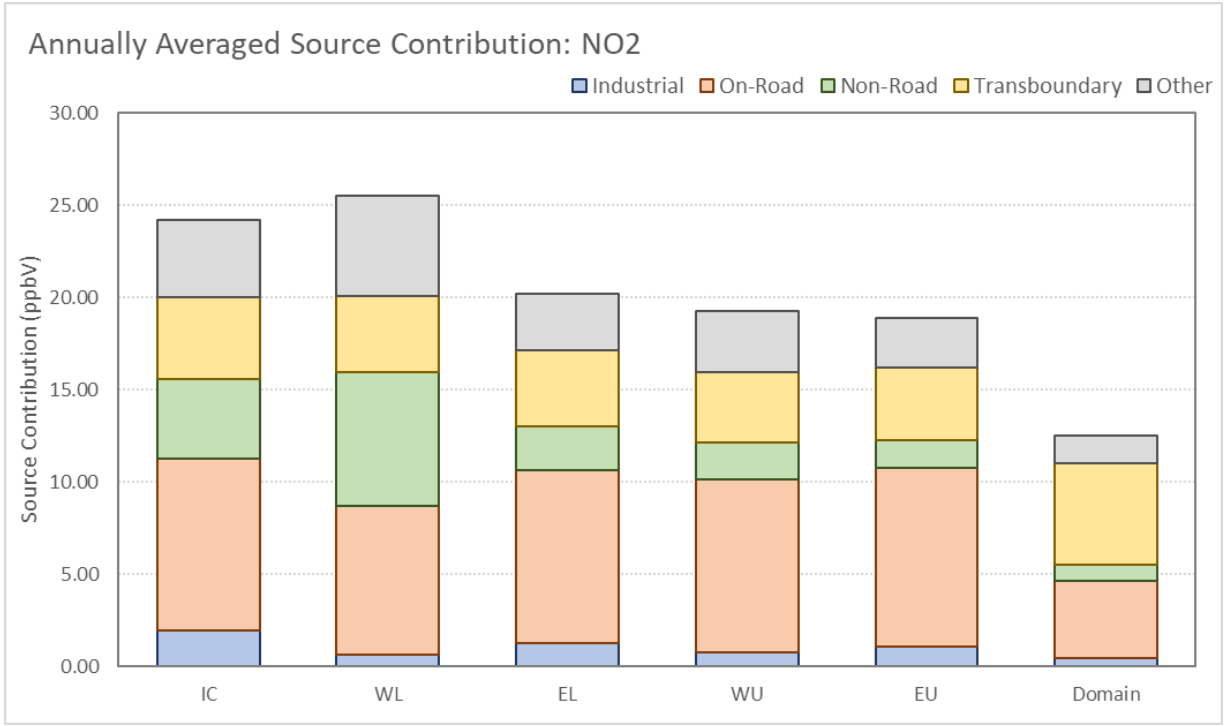
Annual Average Concentration: O3



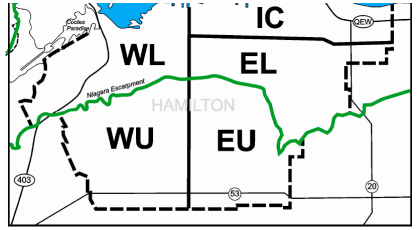
Air Quality Modelling Results: NO_2

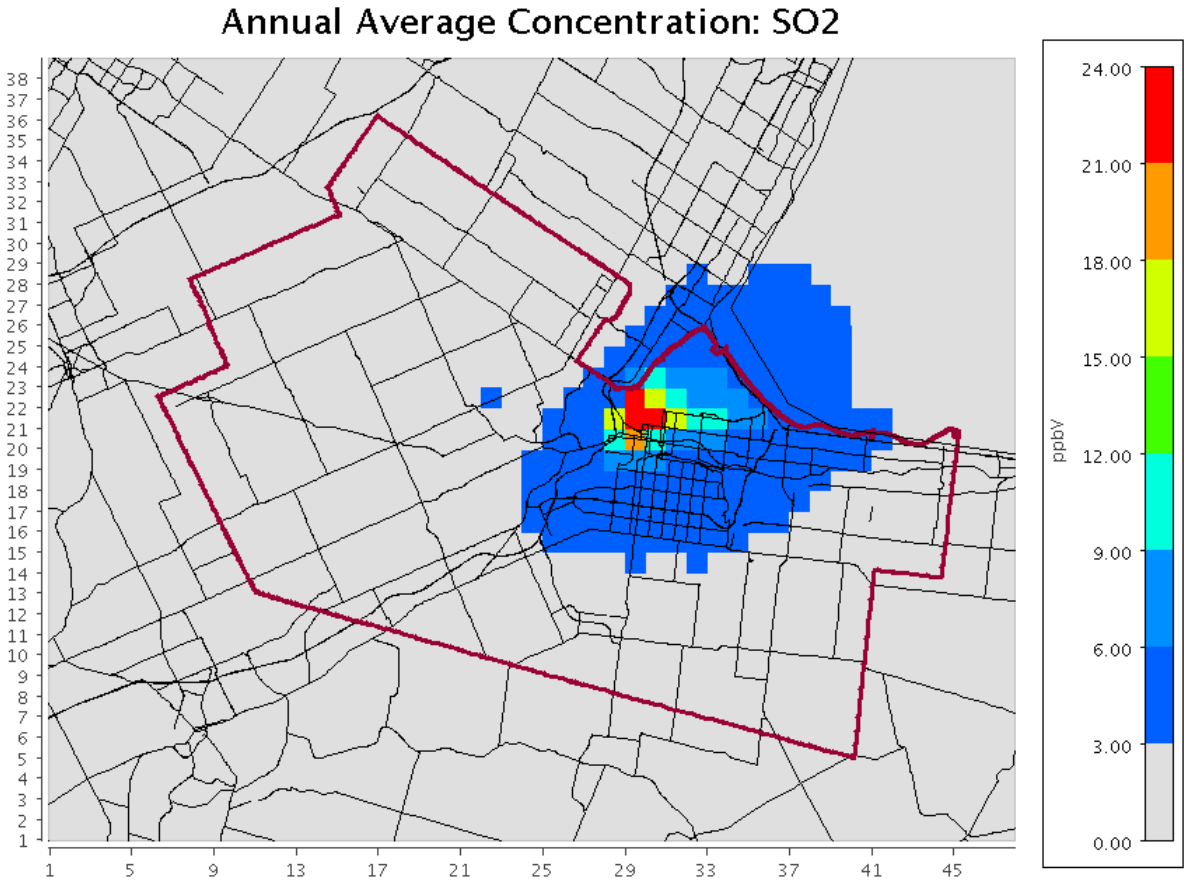


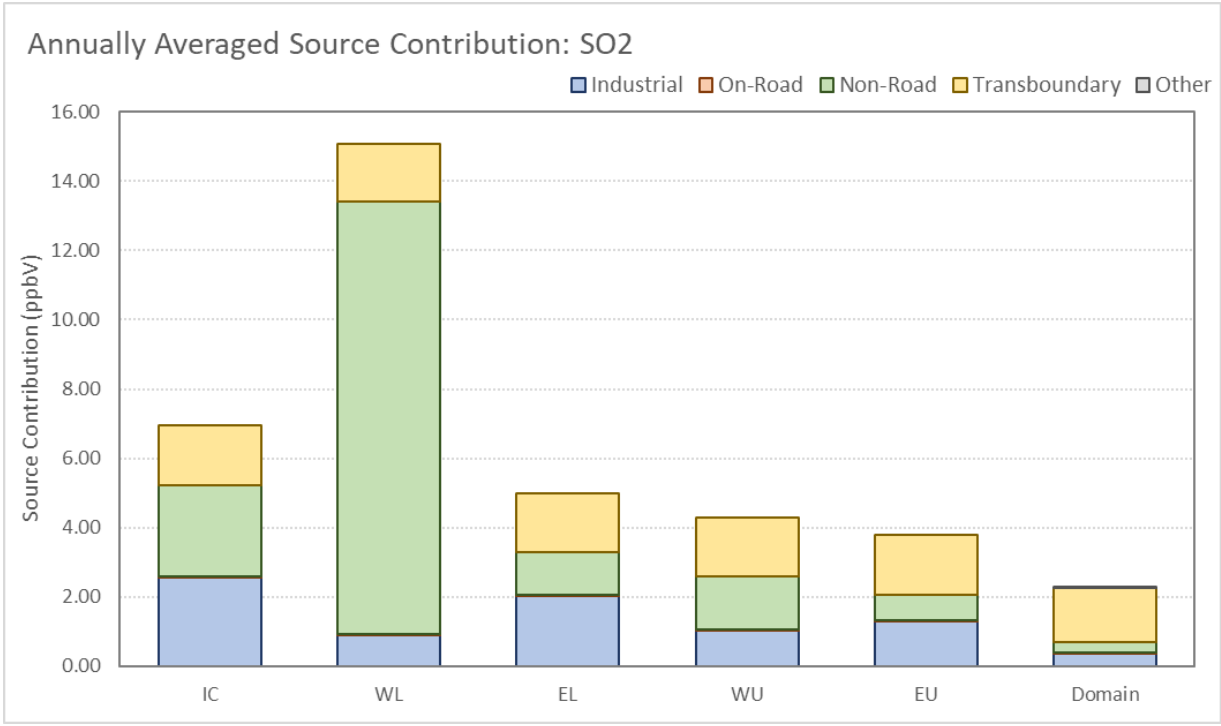




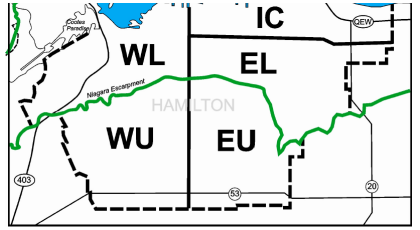
Air Quality Modelling Results: SO_2

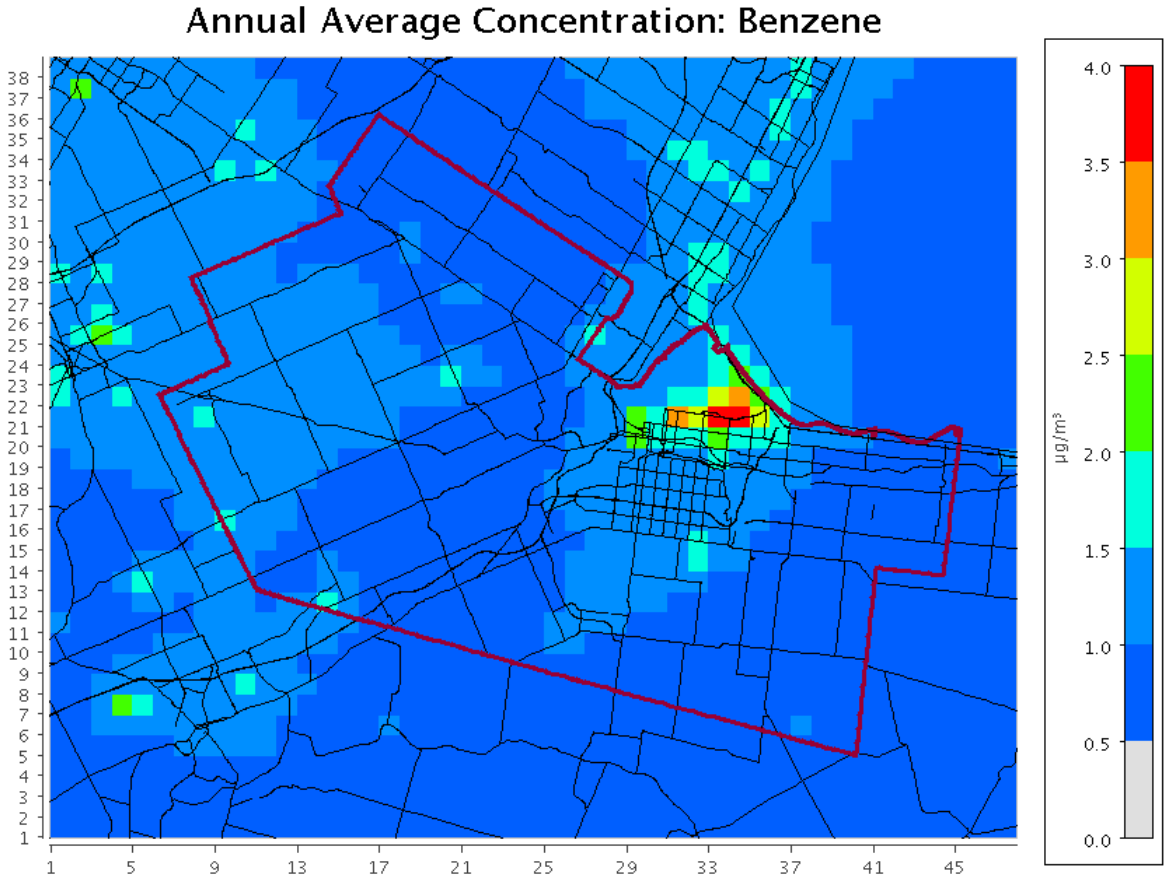


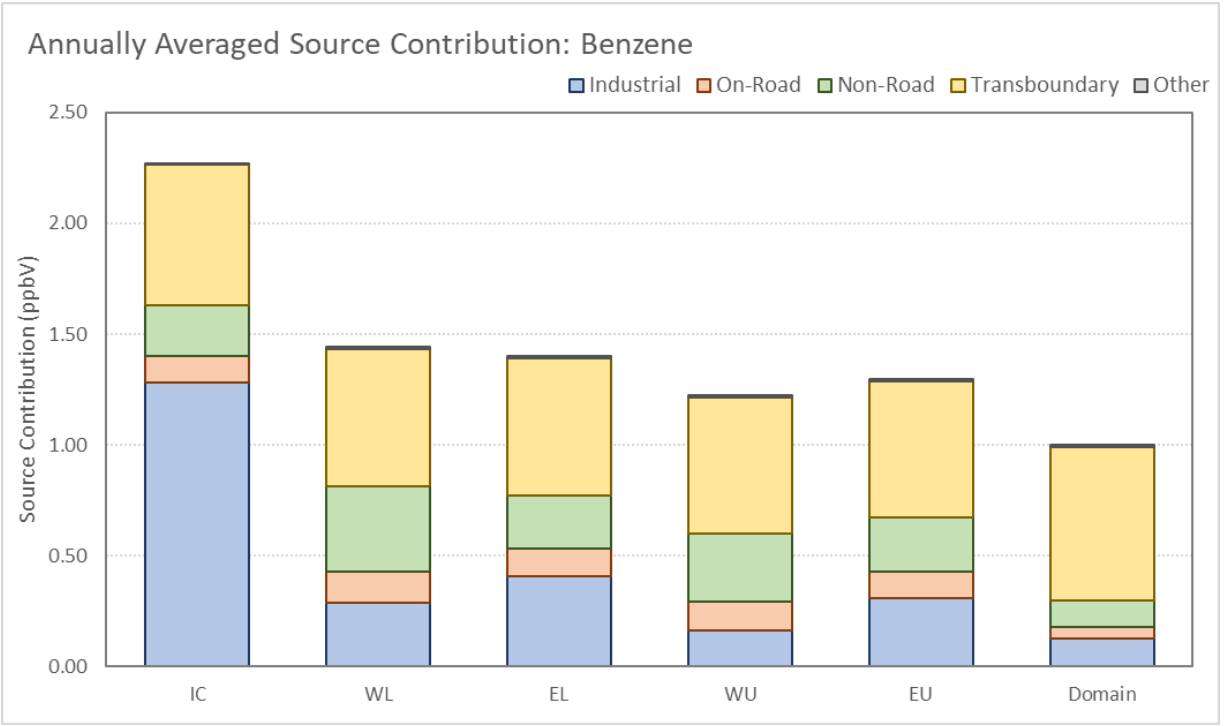




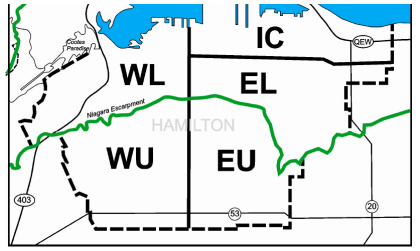
Air Quality Modelling Results: Benzene

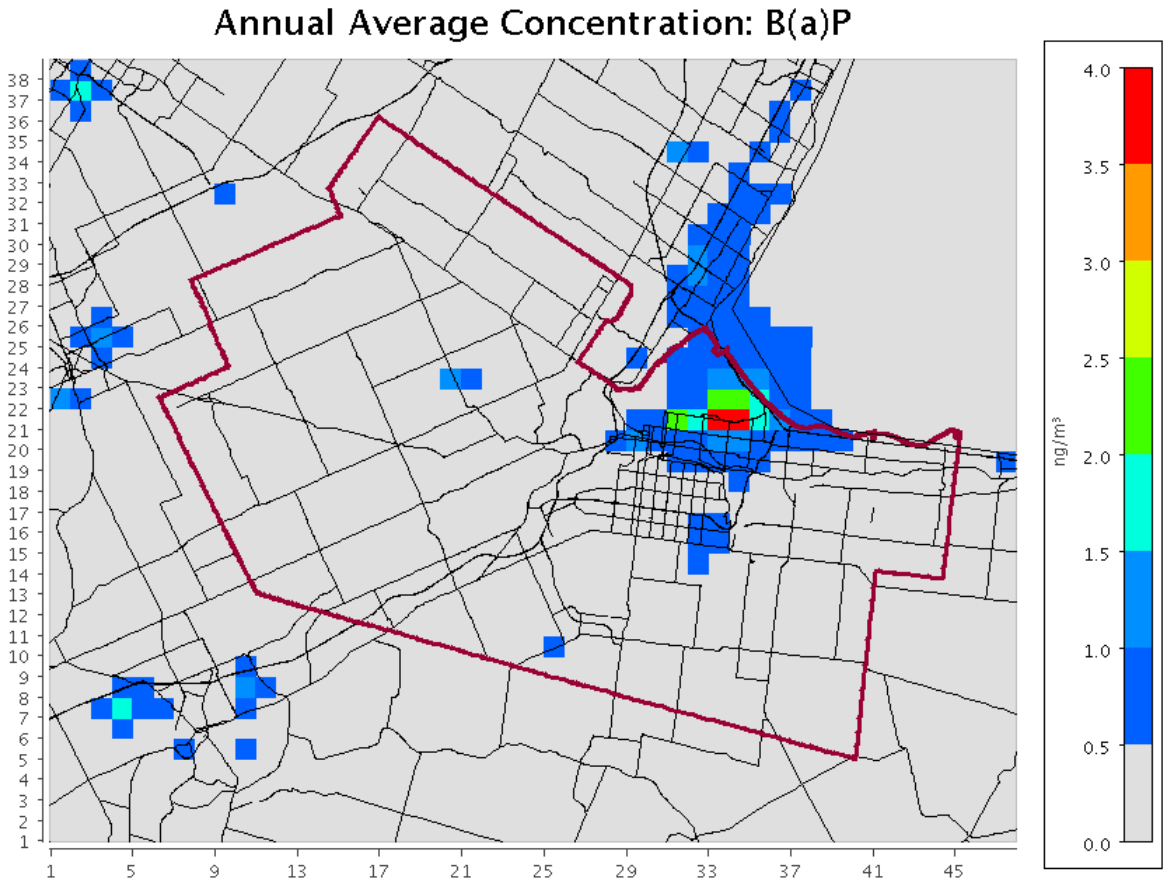


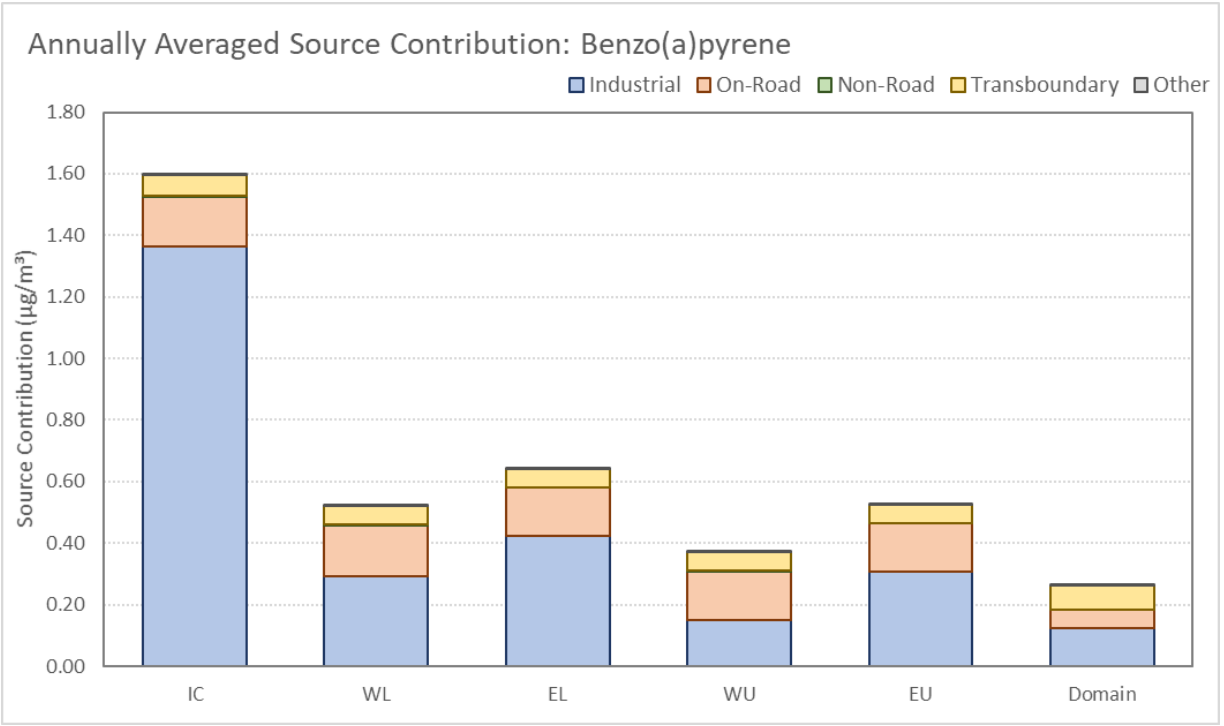




Air Quality Modelling Results: B(a)P







Conclusions

WHAT HAVE WE LEARNED FROM THE HAMILTON AIRSHED MODELLING SYSTEM?

- Source contribution varies according to geographic location (i.e. domain average different from industrial core)
- The industrial core (IC) and western lower (WL) regions consistently experience the highest concentration of pollutants, much higher than the domain average
- Compared to the domain average, transportation related activities are more significant
- Strong transboundary contribution to $PM_{2.5}$ and PM_{10} remains
- On-road NO_2 sources have a higher contribution than other sources but controlling NO_2 locally will impact the ozone concentrations
- Rail emissions dominant contributor to SO_2 levels in WL region
- Outside of IC, industrial contribution to air quality shows a significant drop for benzene and B(a)P

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Thank you.

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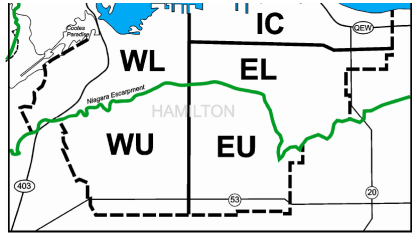
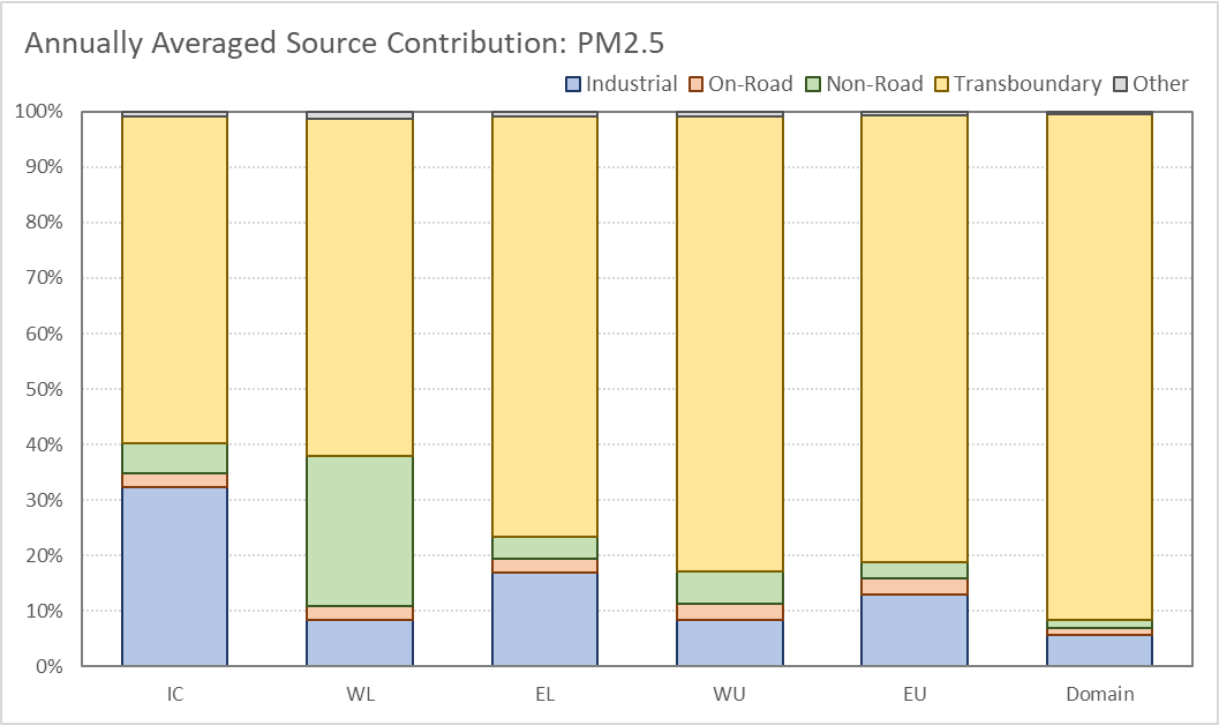
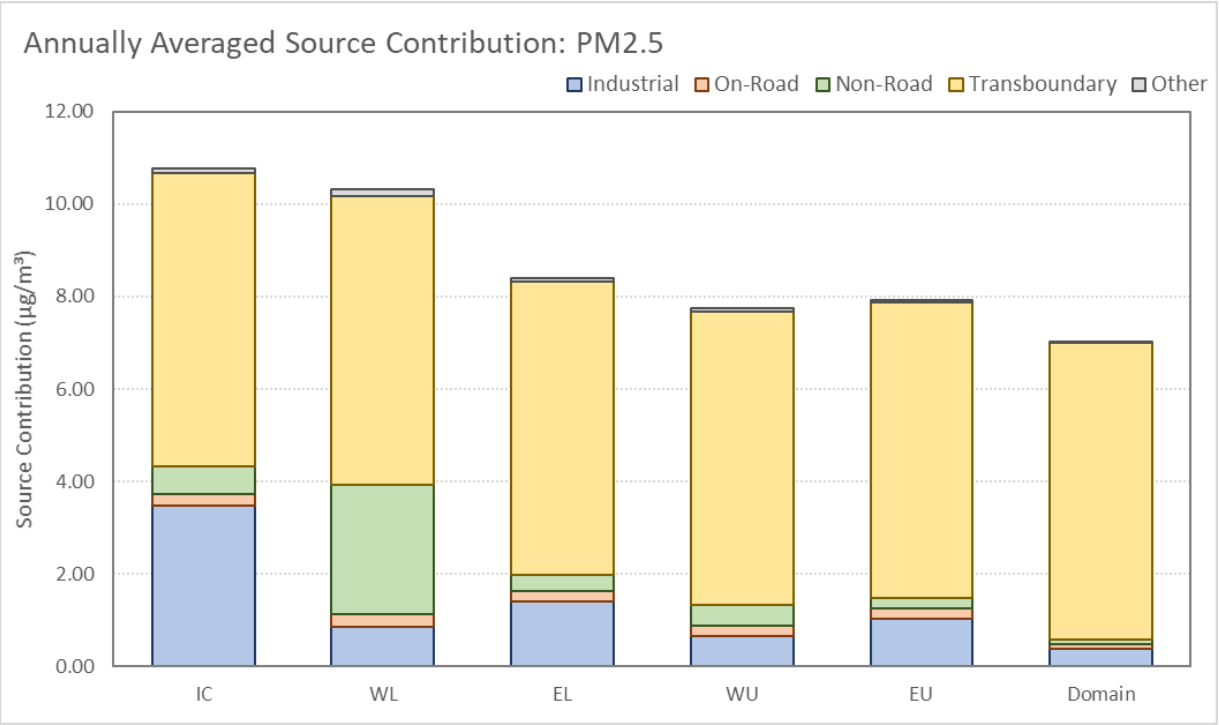
Additional Information:

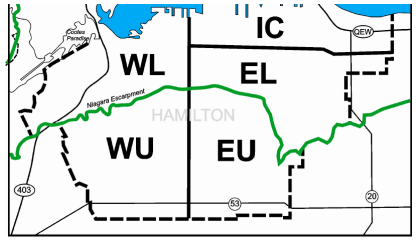
Air Quality Modelling Results: $PM_{2.5}$

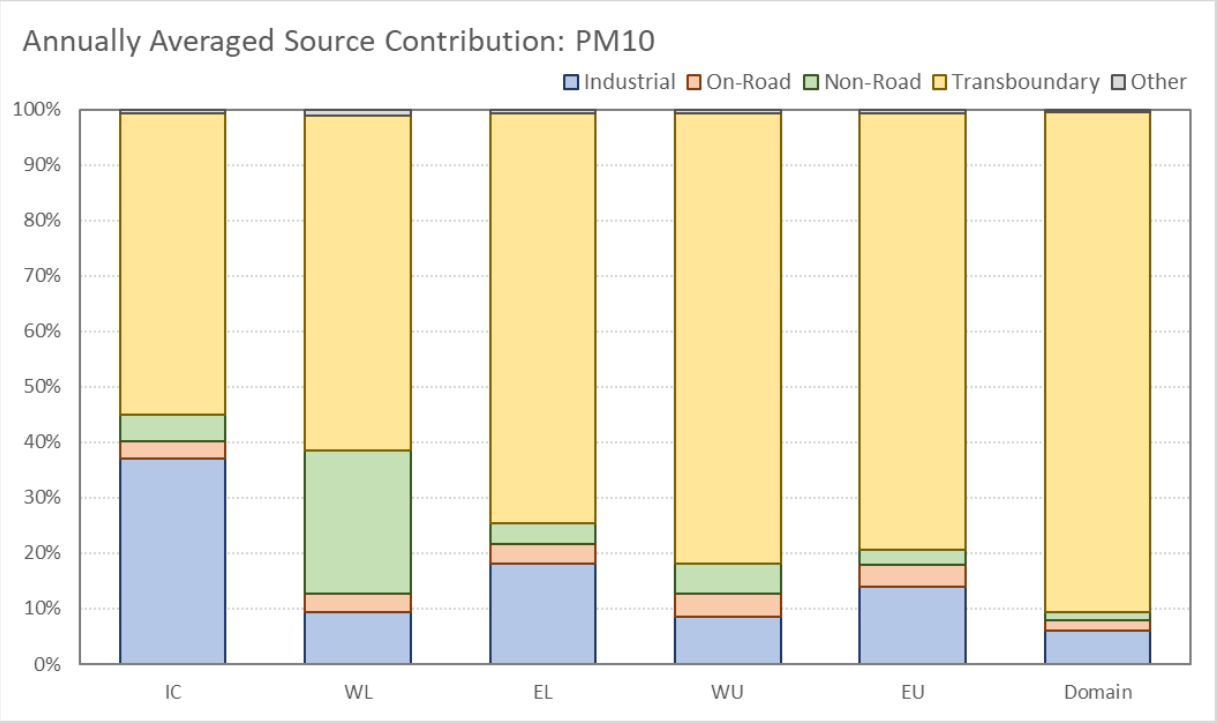


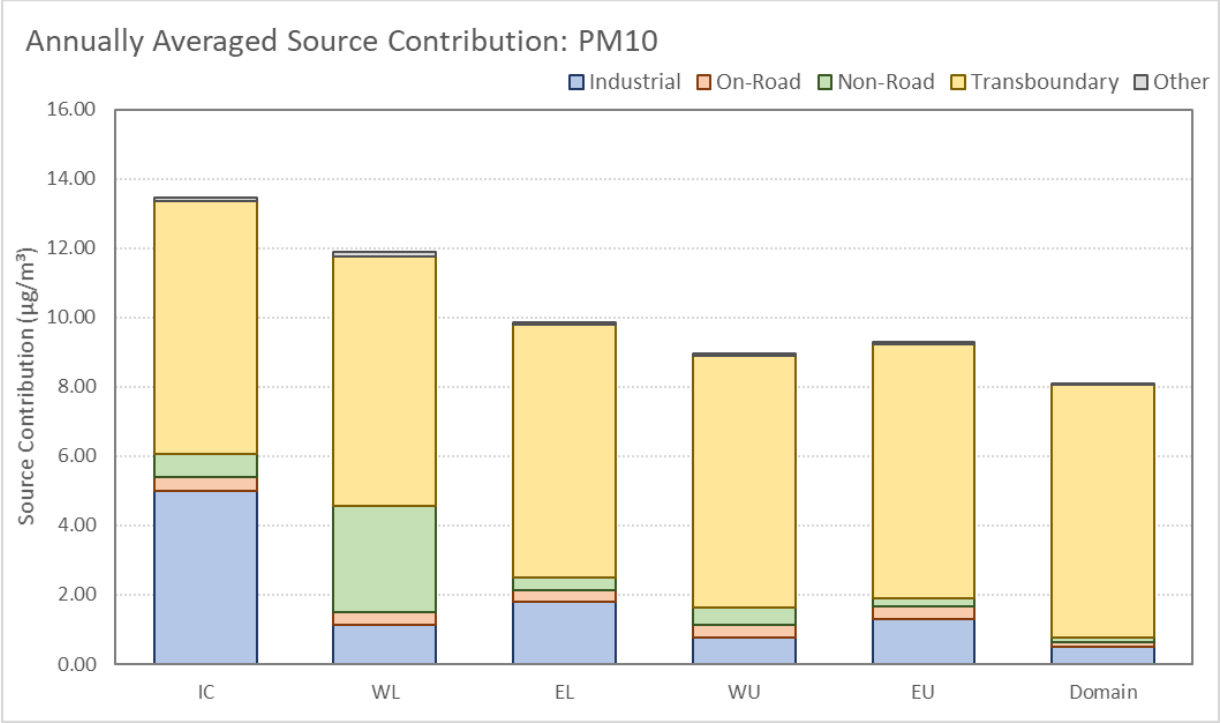




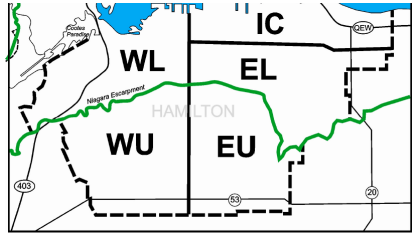
Air Quality Modelling Results: PM_{10}

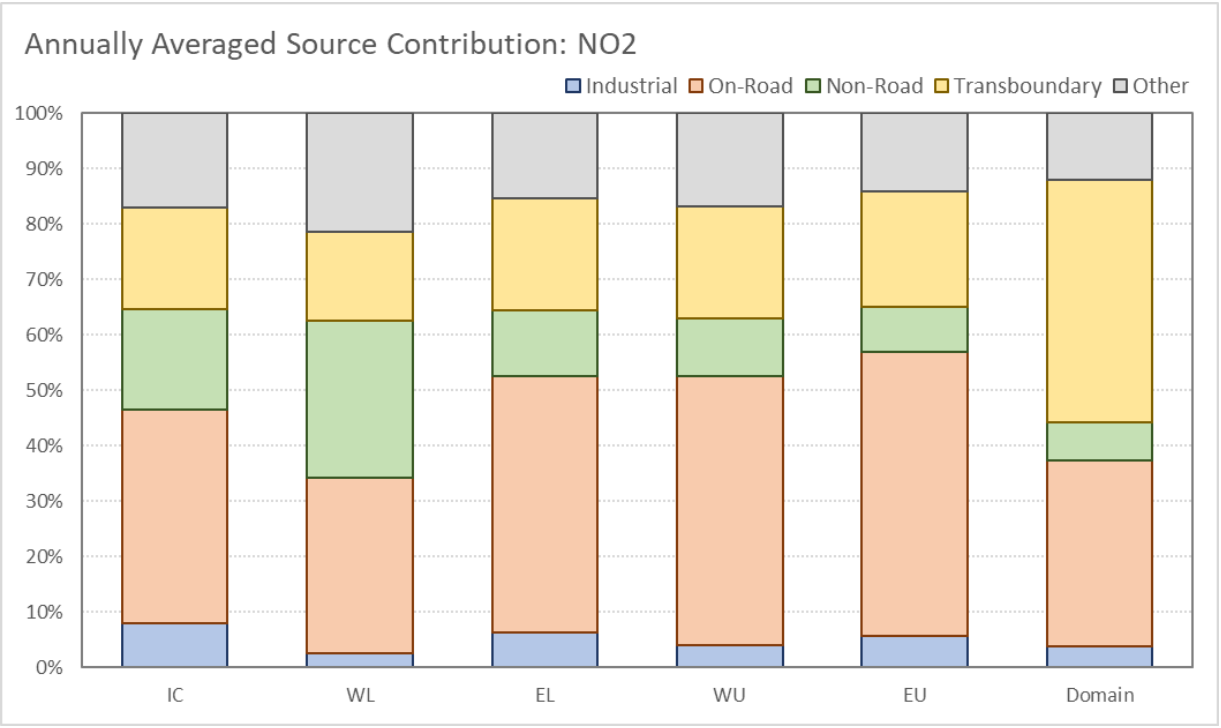


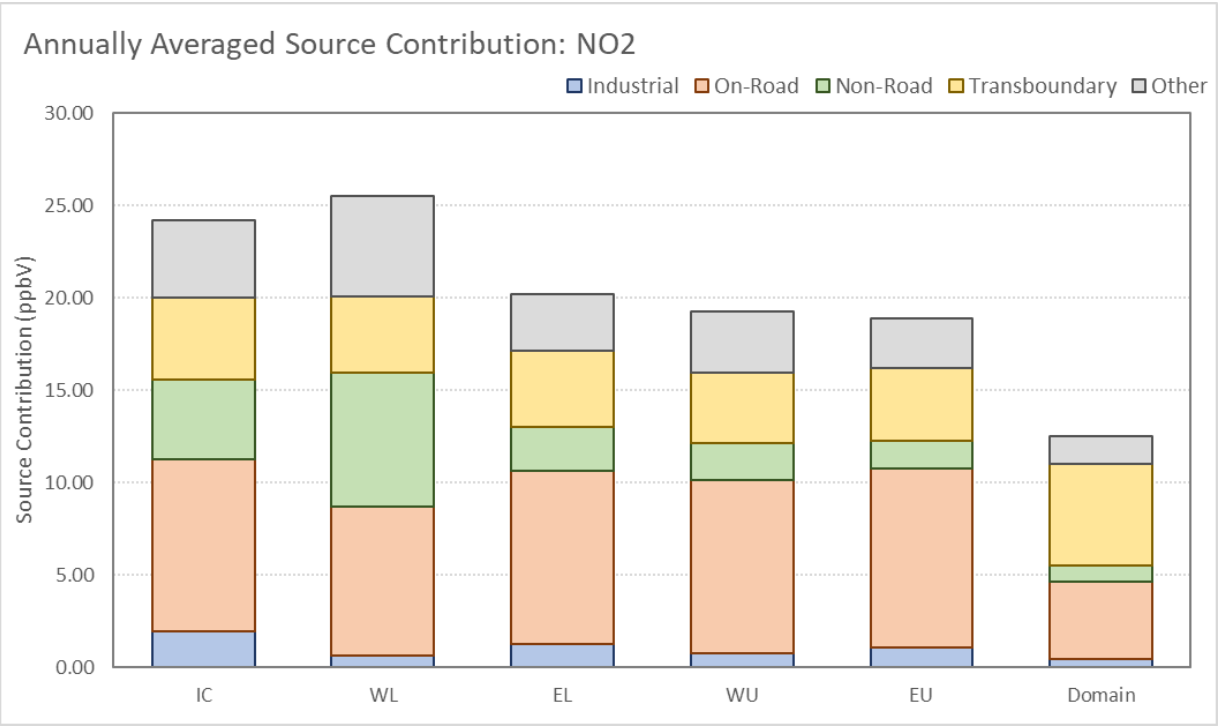




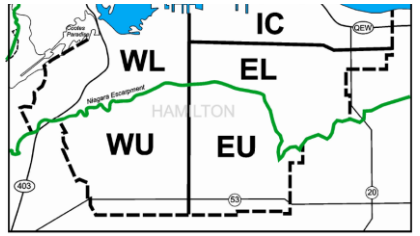
Air Quality Modelling Results: NO_2

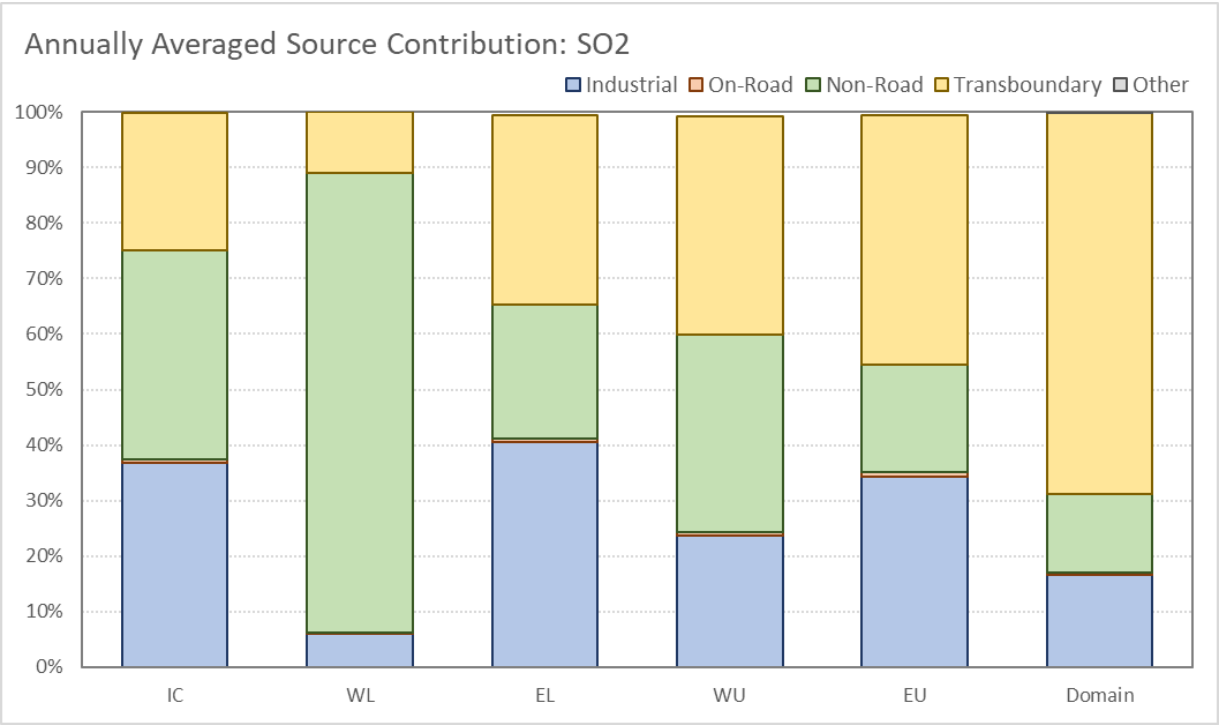


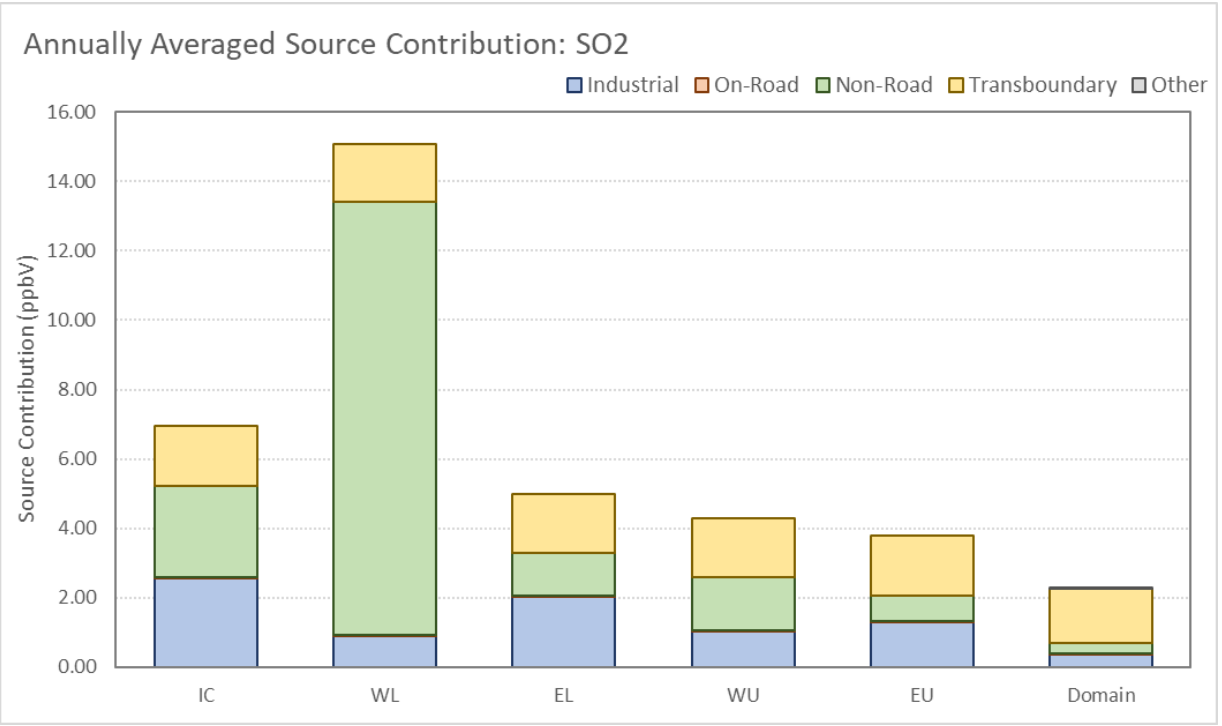




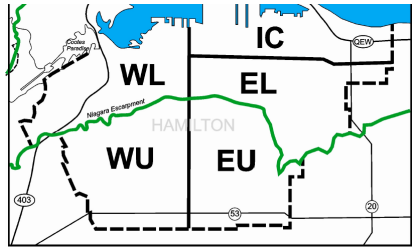
Air Quality Modelling Results: SO_2

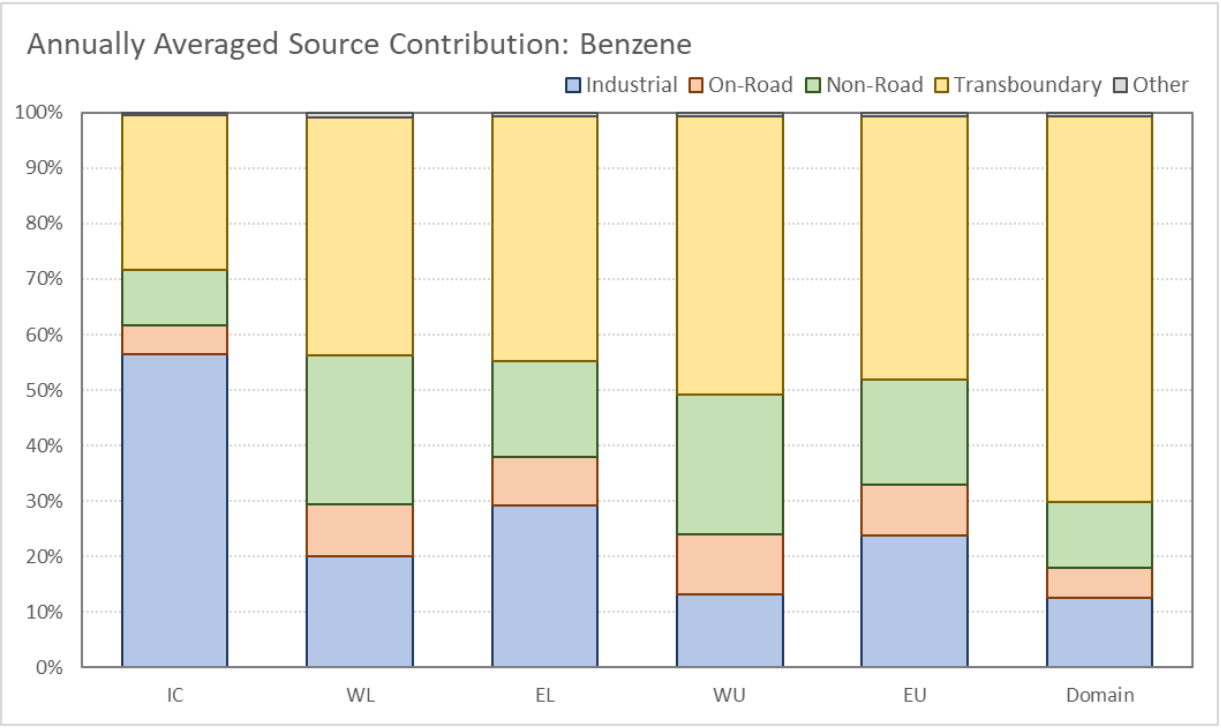


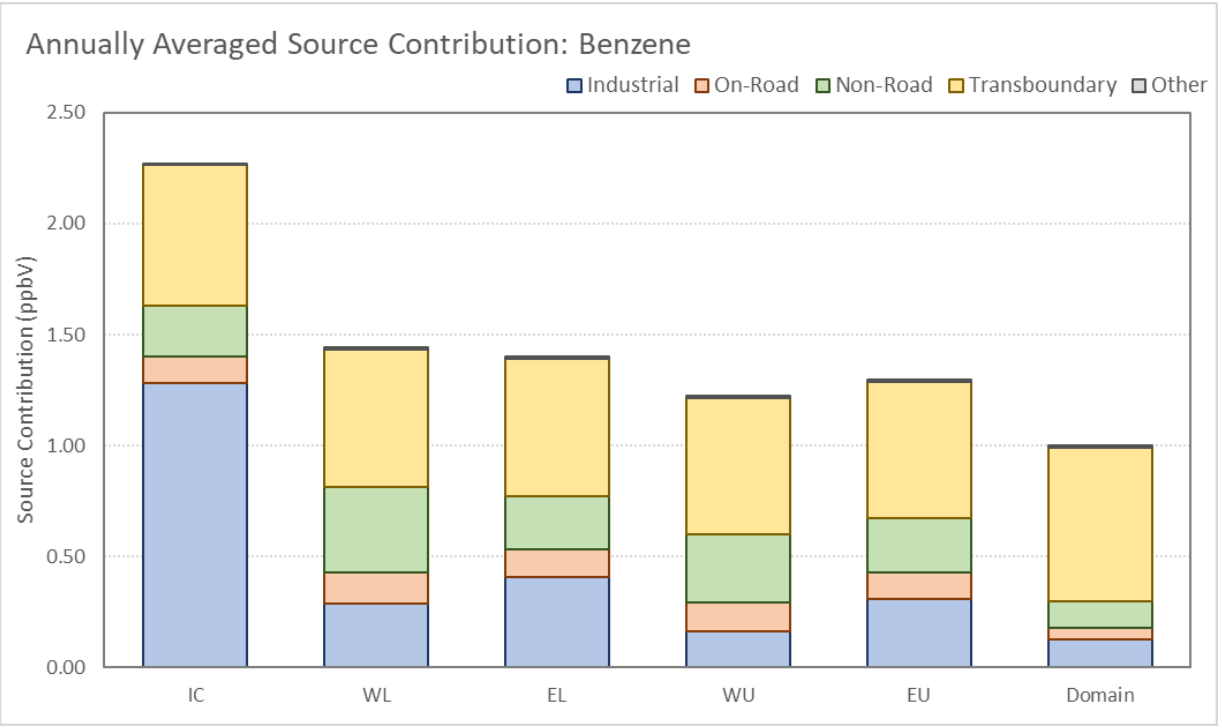




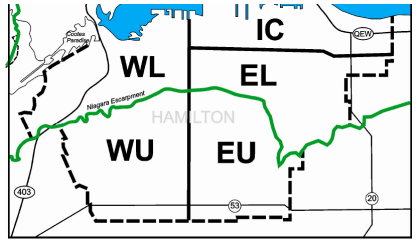
Air Quality Modelling Results: Benzene

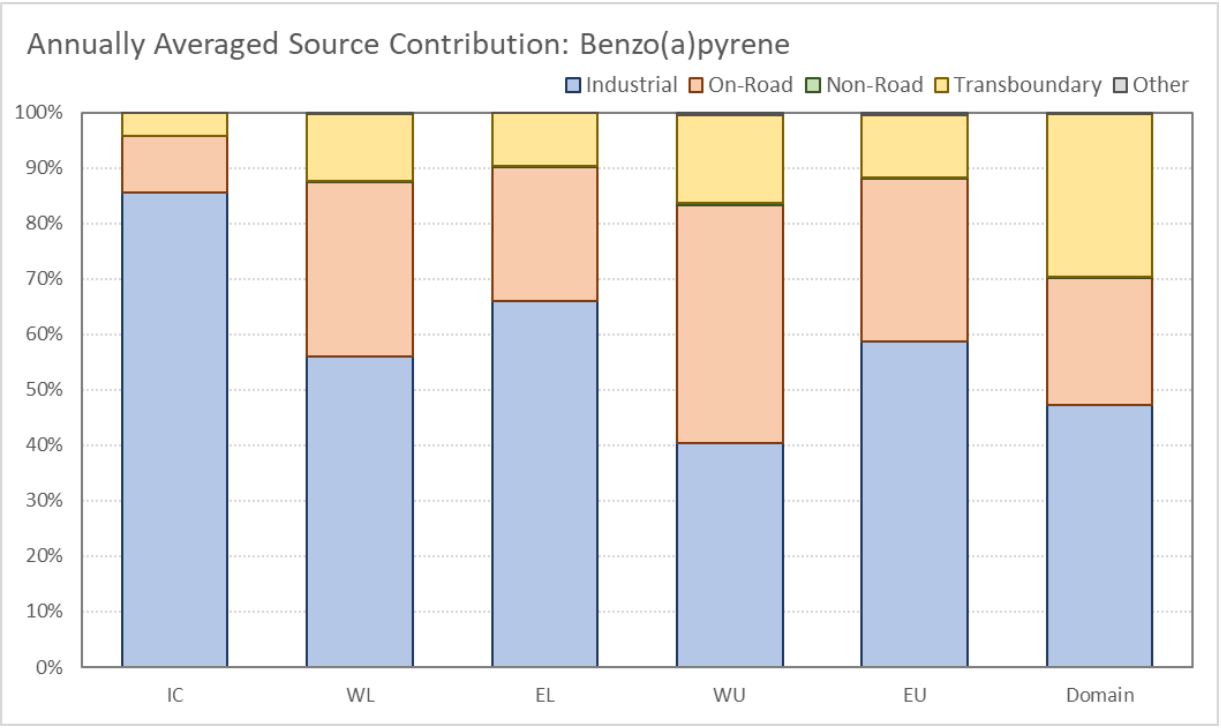


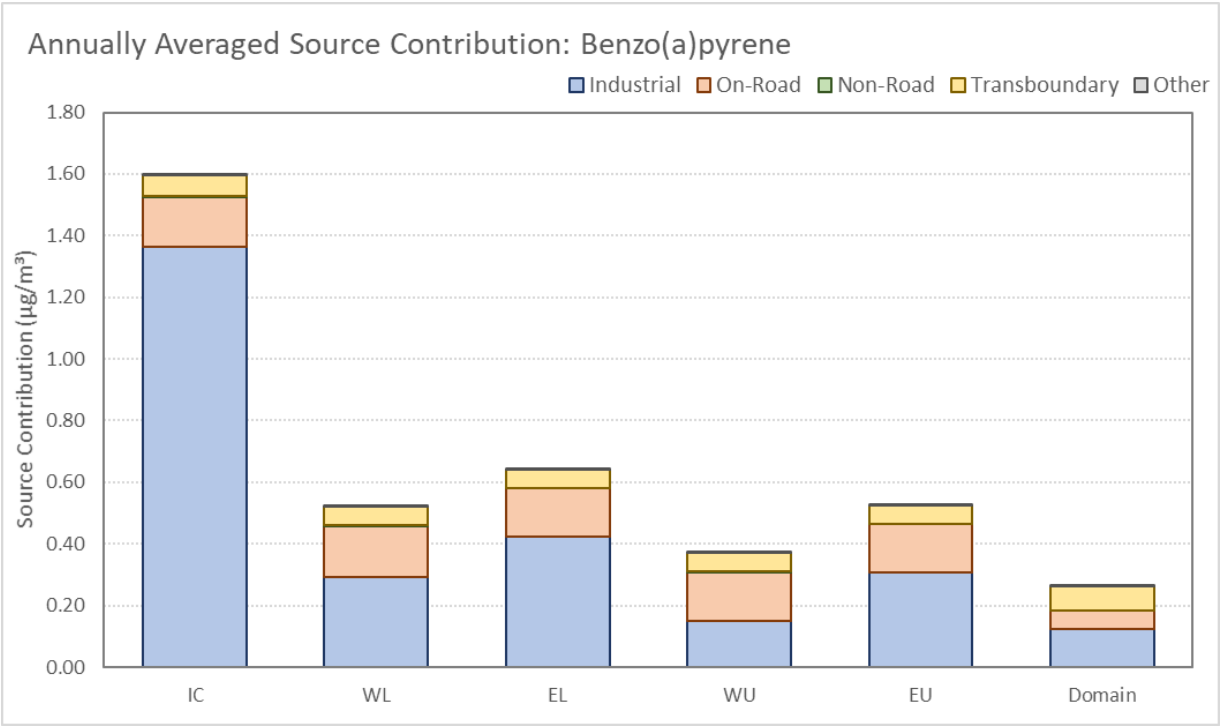




Air Quality Modelling Results: B(a)P

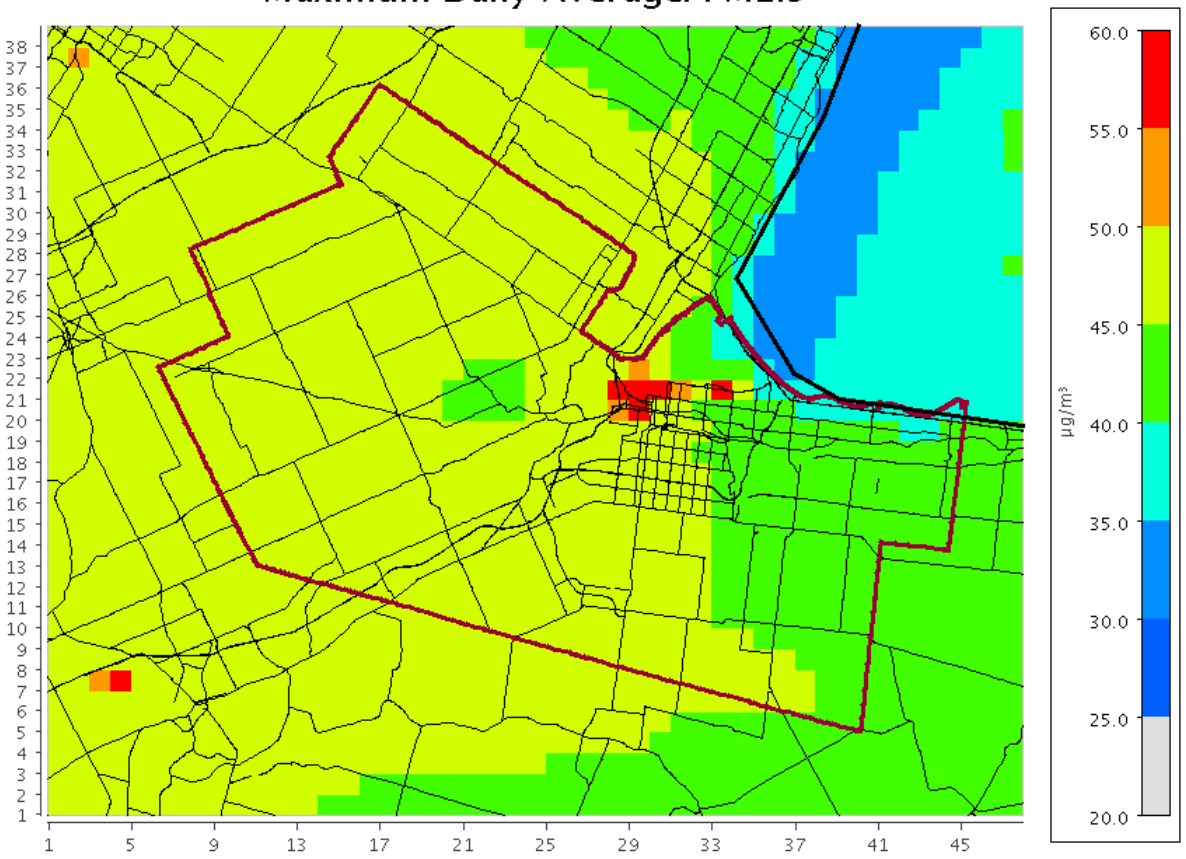




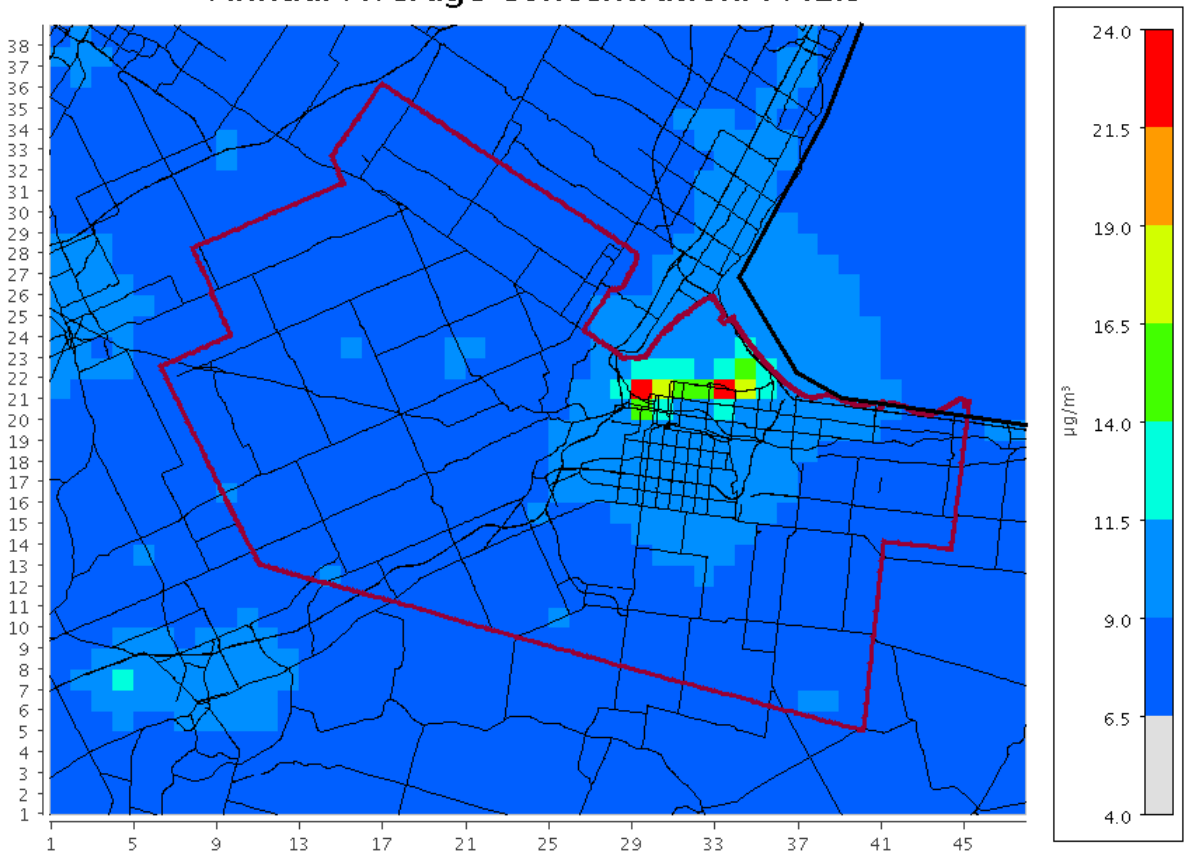


Air Quality Modelling Results: $PM_{2.5}$

Maximum Daily Average: PM2.5

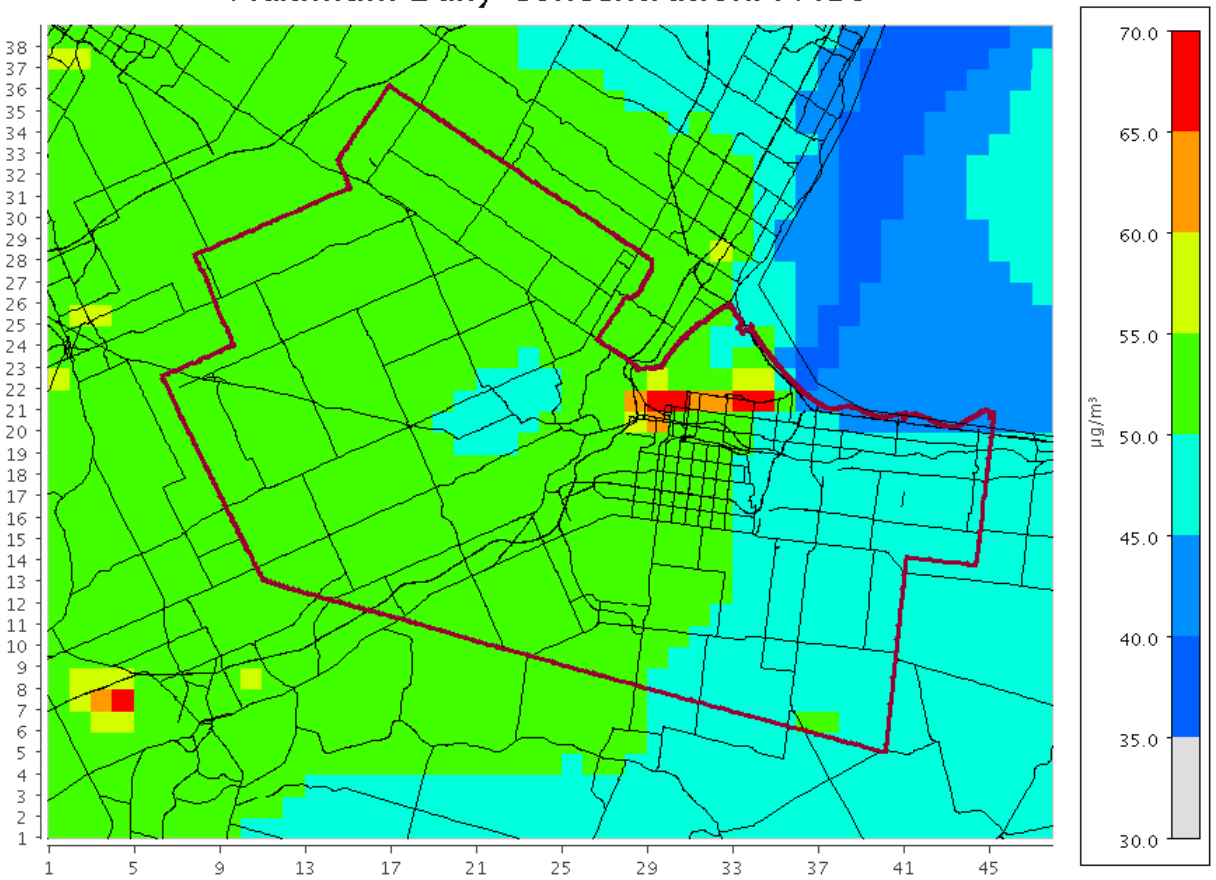


Annual Average Concentration: PM2.5

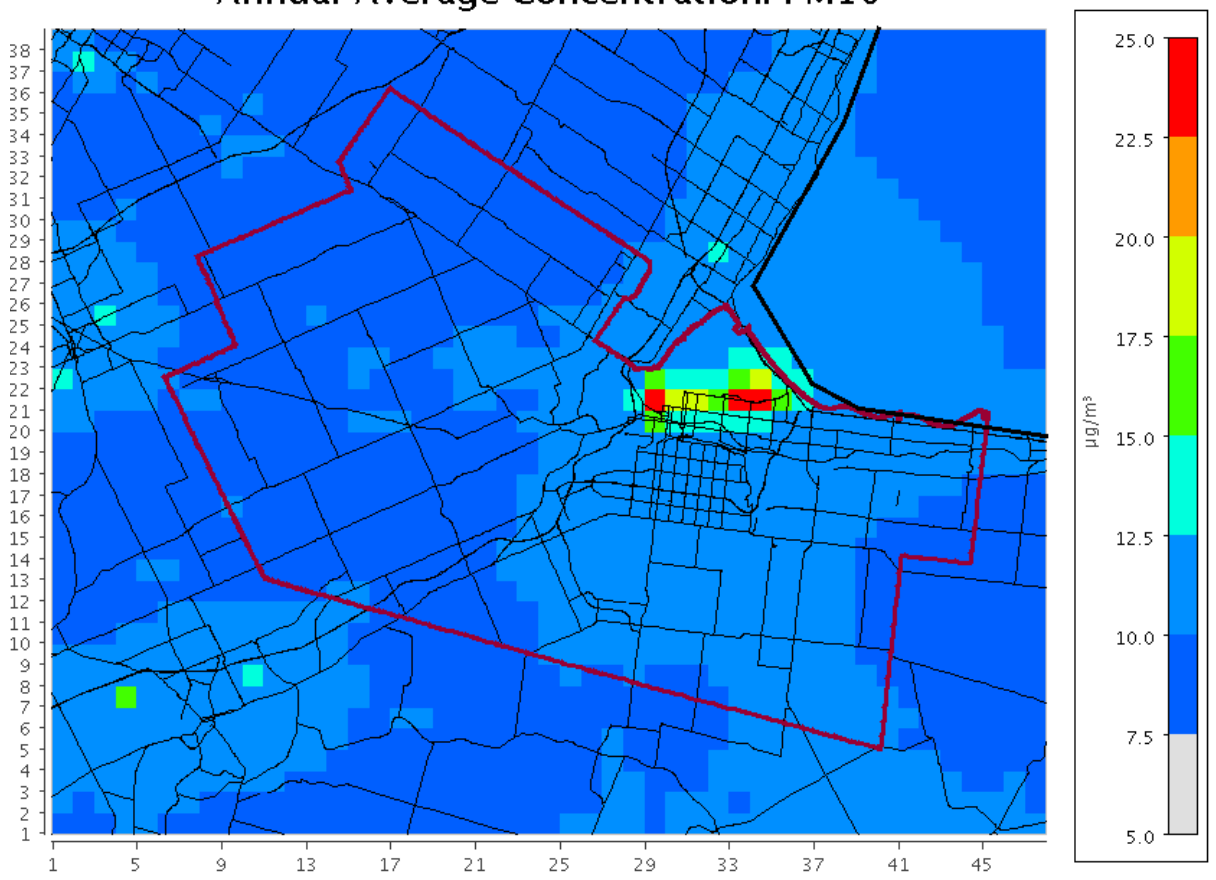


Air Quality Modelling Results: PM_{10}

Maximum Daily Concentration: PM10

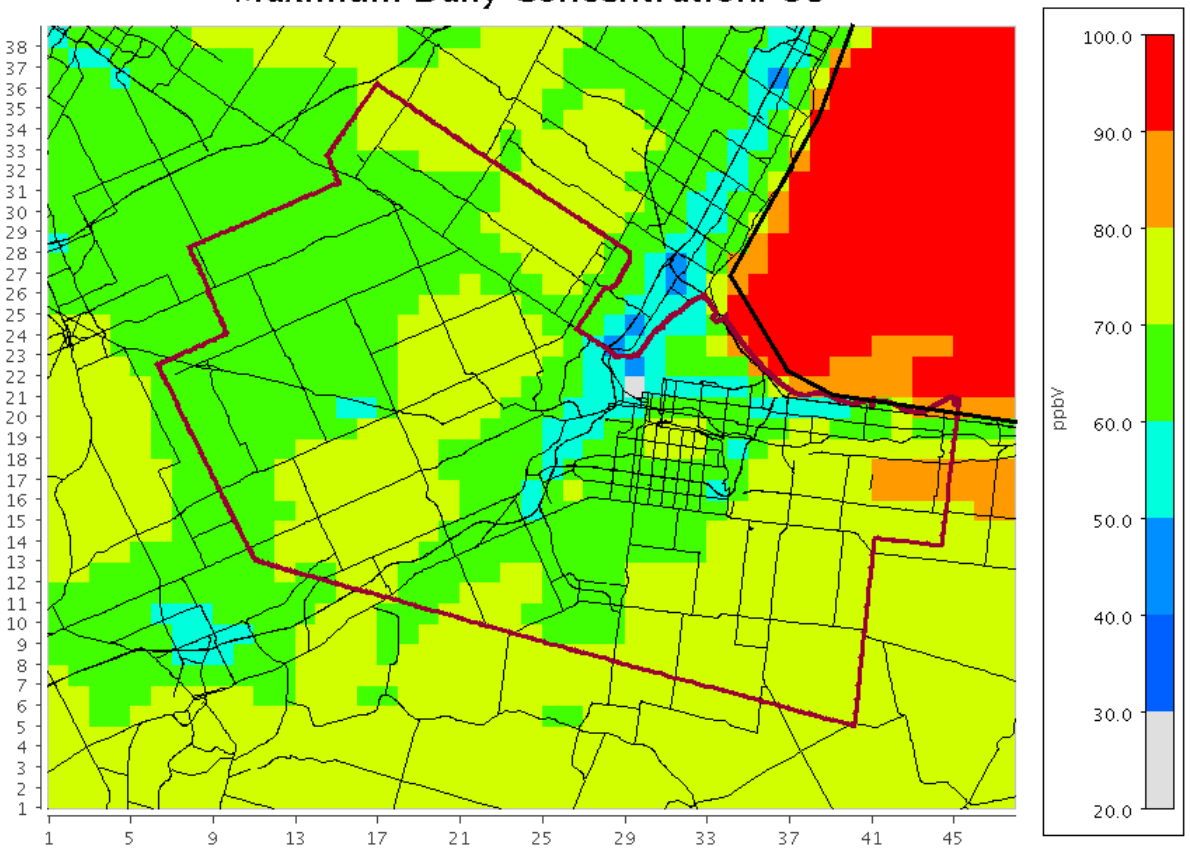


Annual Average Concentration: PM10

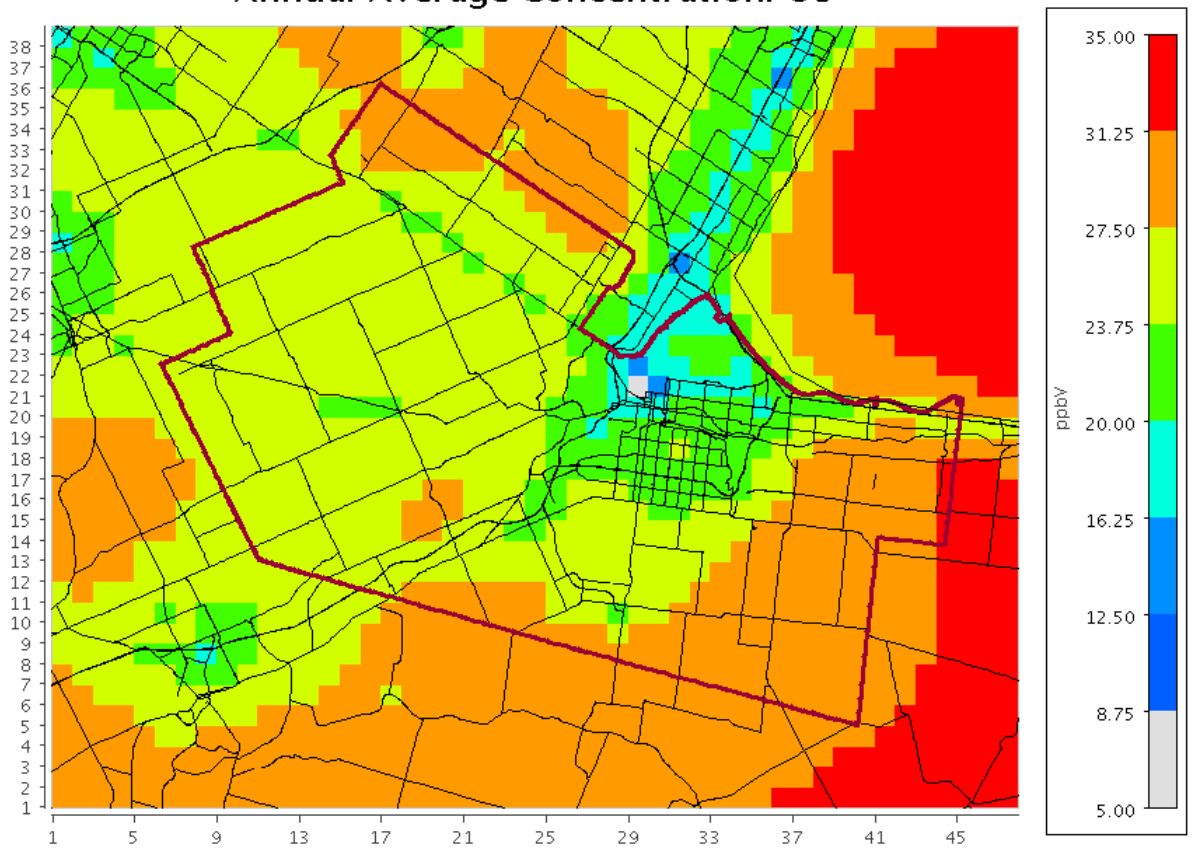


Air Quality Modelling Results: O_3

Maximum Daily Concentration: O3

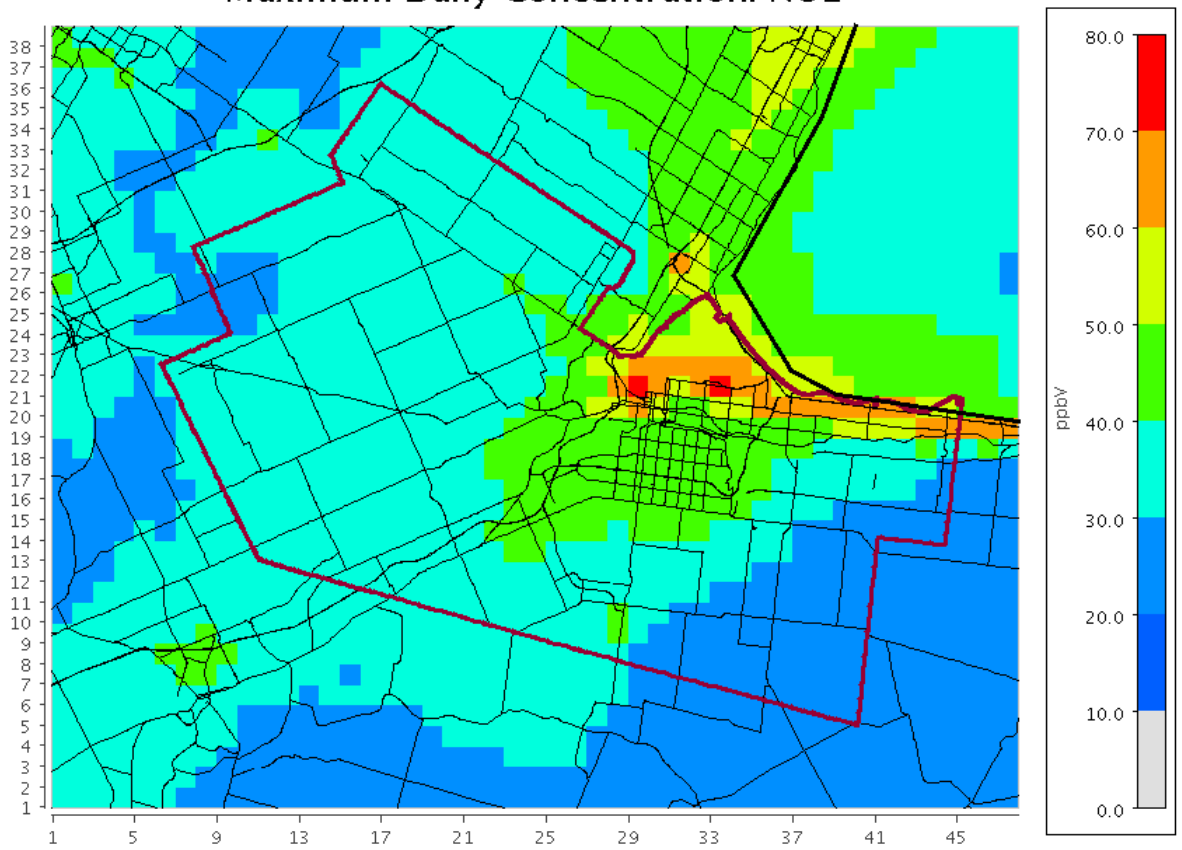


Annual Average Concentration: O3

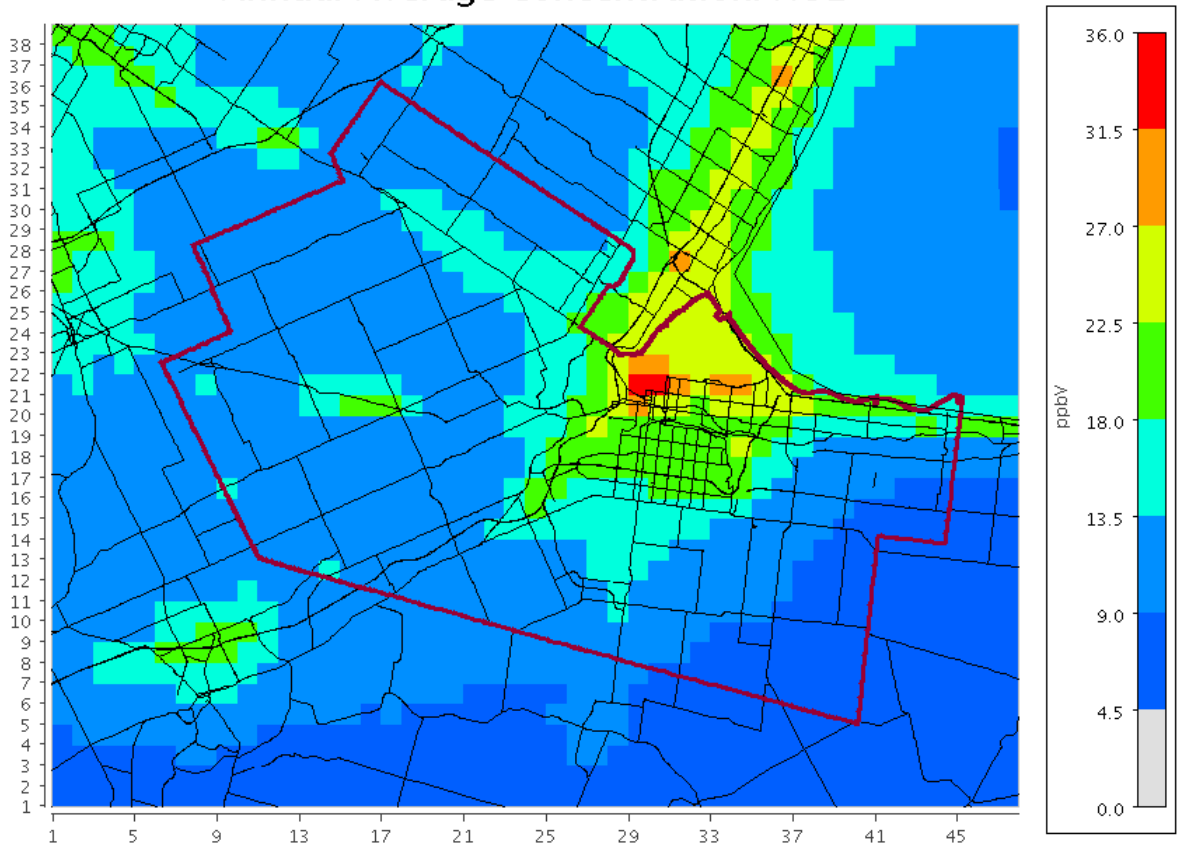


Air Quality Modelling Results: NO_2

Maximum Daily Concentration: NO2

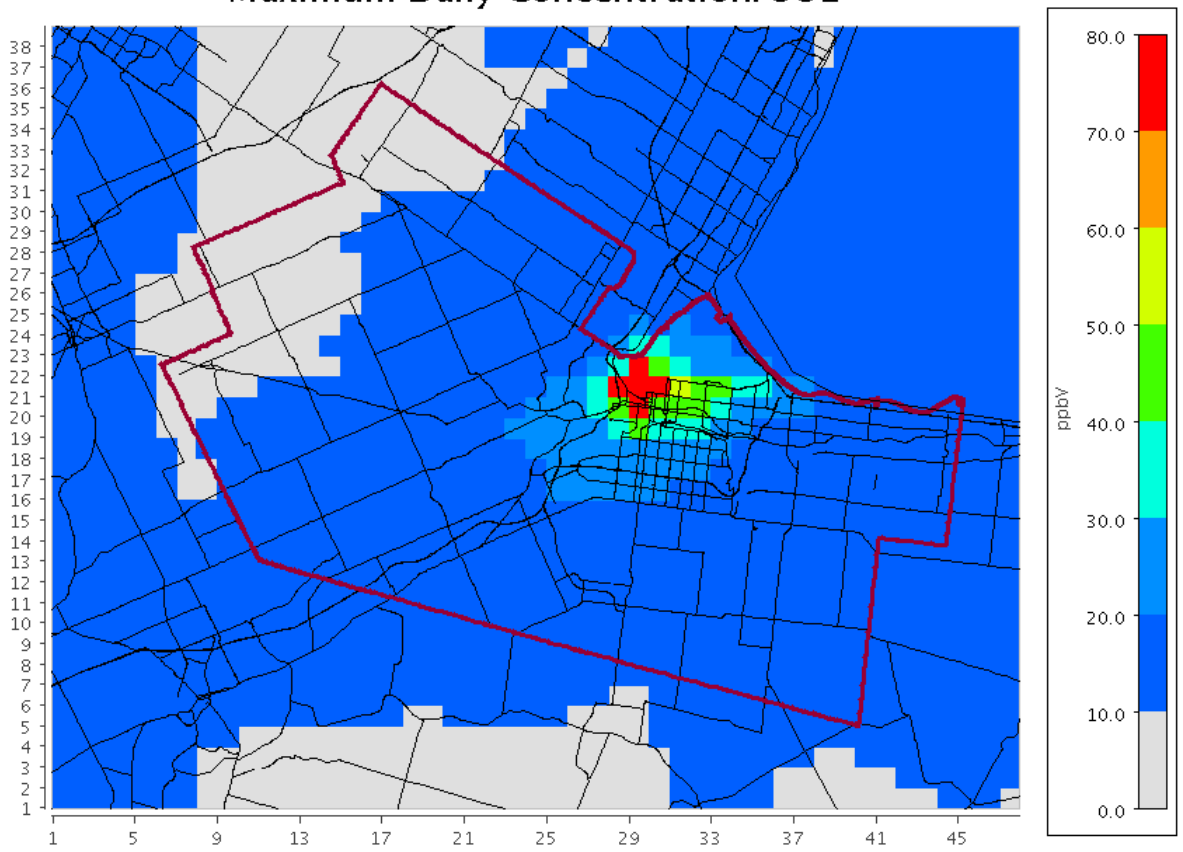


Annual Average Concentration: NO2

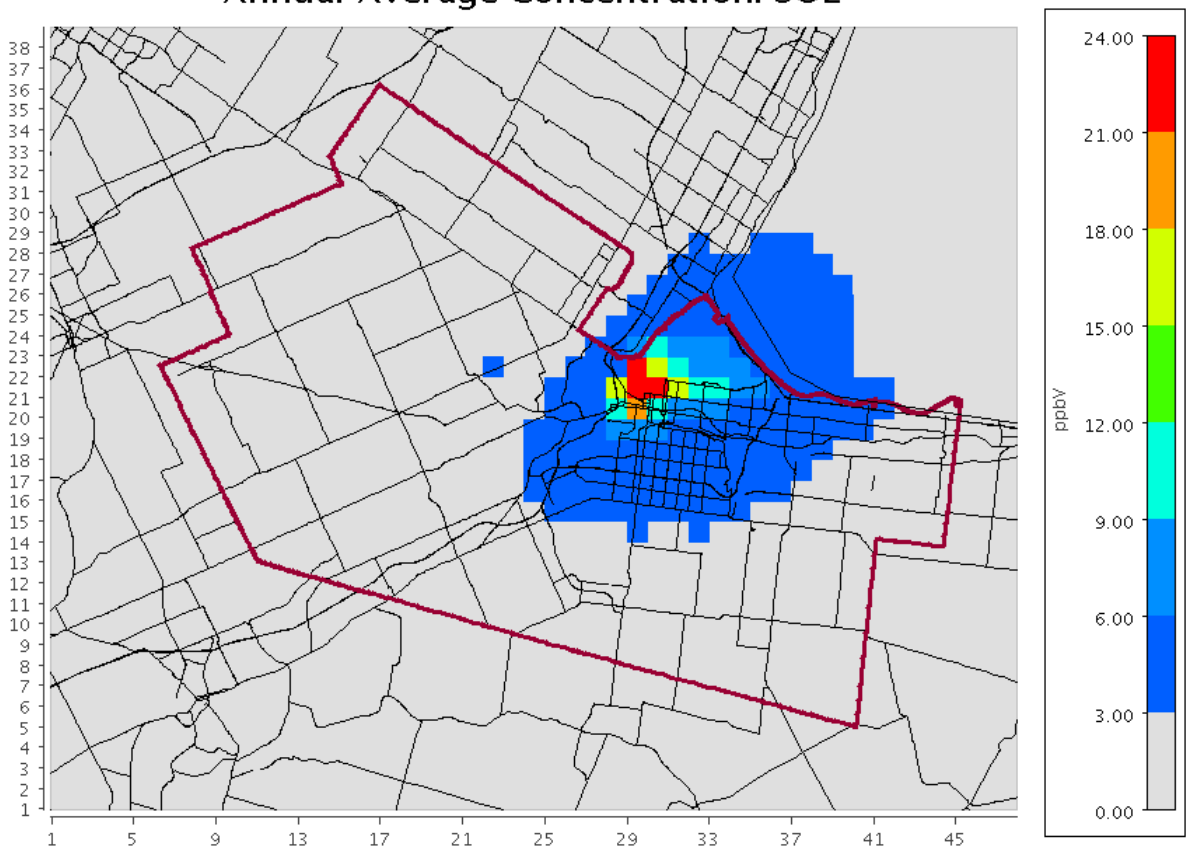


Air Quality Modelling Results: SO_2

Maximum Daily Concentration: SO2

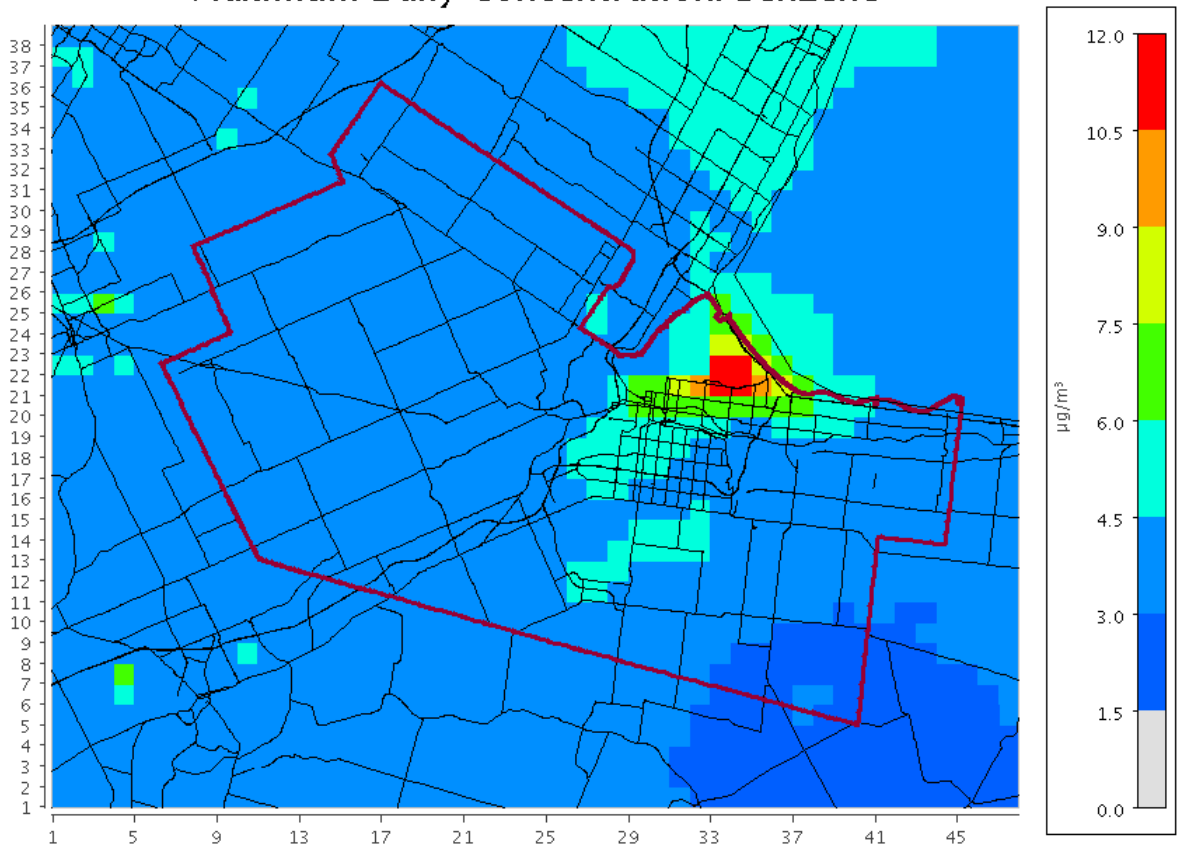


Annual Average Concentration: SO2

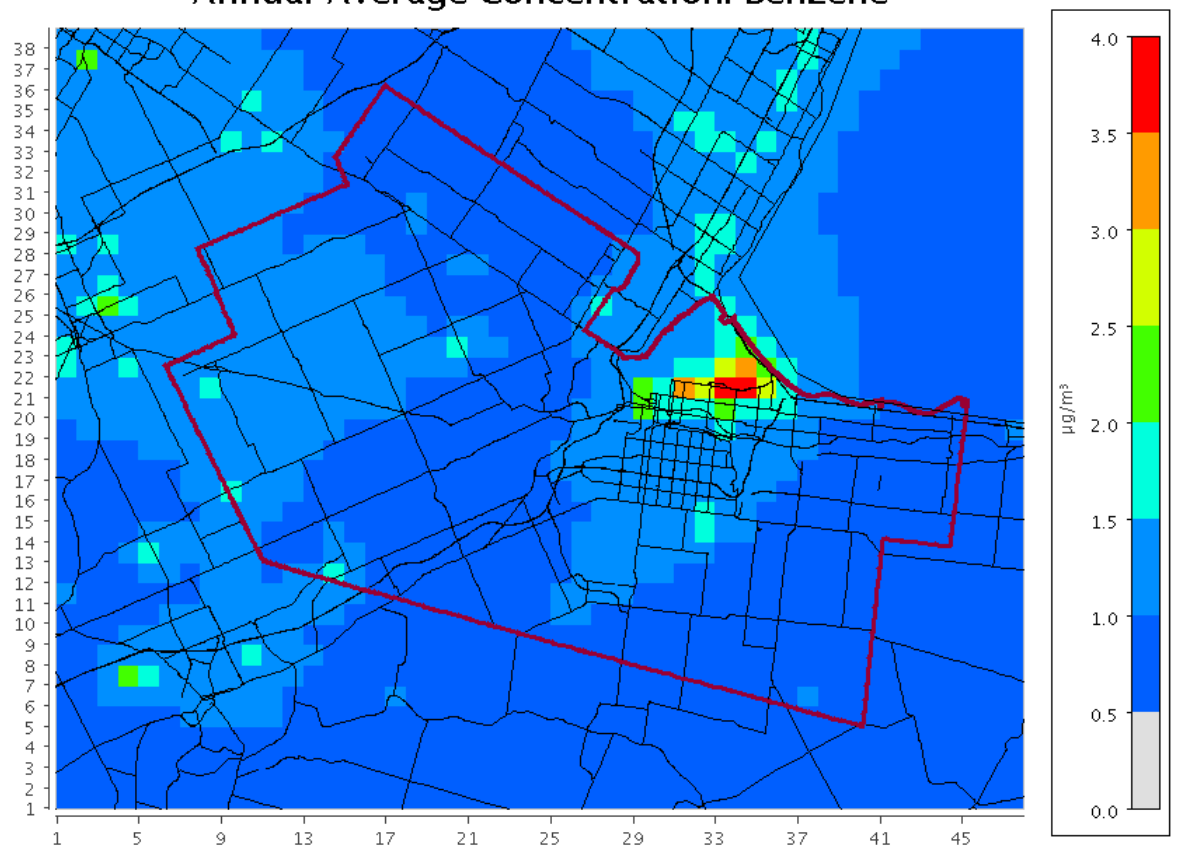


Air Quality Modelling Results: Benzene

Maximum Daily Concentration: Benzene

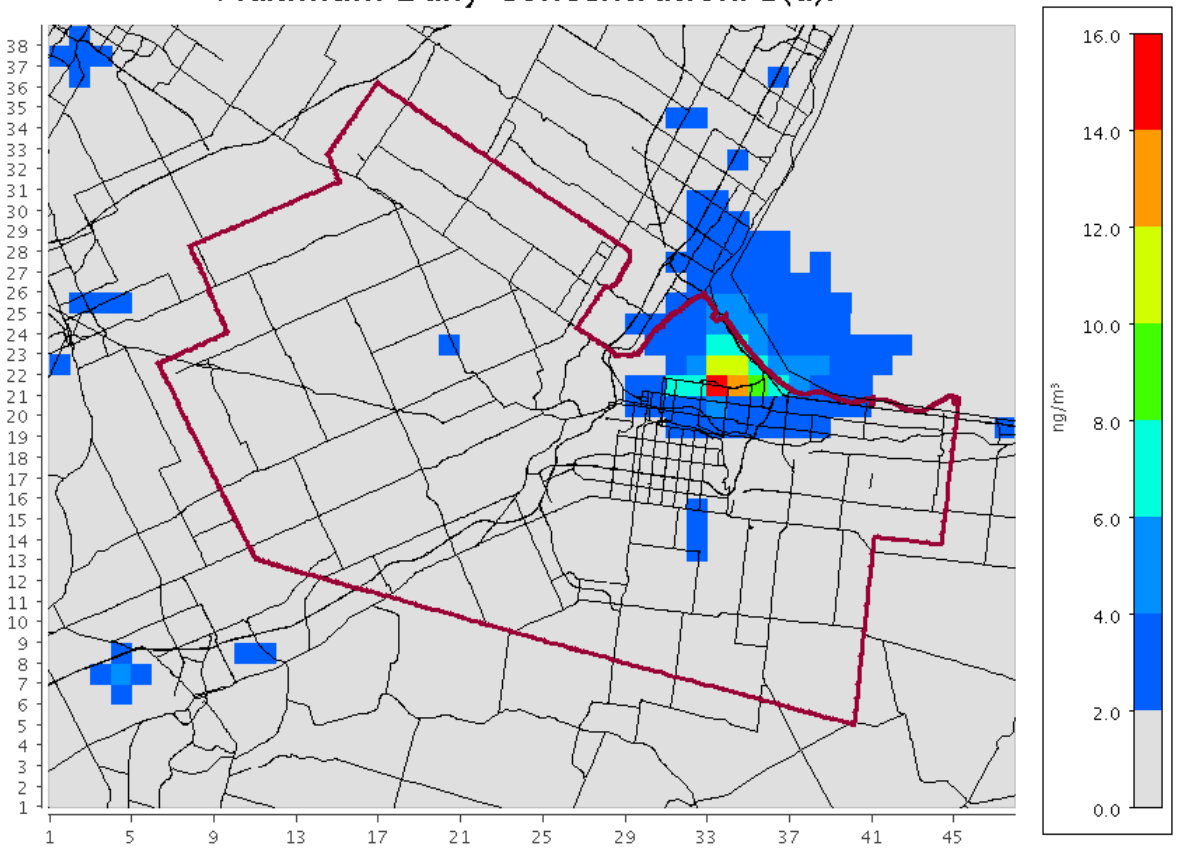


Annual Average Concentration: Benzene

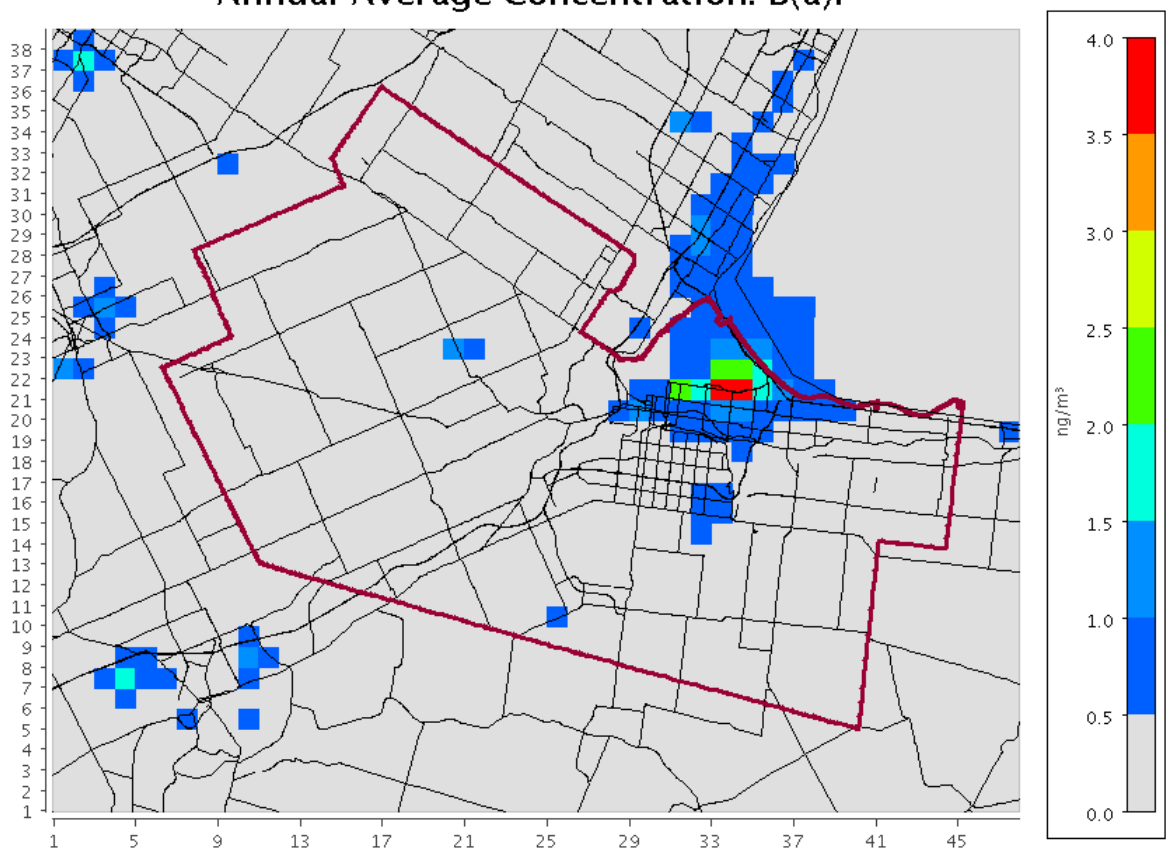


Air Quality Modelling Results: B(a)P

Maximum Daily Concentration: B(a)P



Annual Average Concentration: B(a)P



Results Across Domain: Tier IV

Compounds	Symbol	Units	Annual Average	Maximum Daily
Acrolein	C_3H_4O	ppb	0.0069	0.64
Ammonia	NH_3	ppb	0.12	2.60
Benzene	C_6H_6	µg/m^3	1.00	18.00
1,3 Butadiene	C_4H_6	ppb	0.0088	0.57
Carbon Monoxide	CO	ppb	220	1100
Formaldehyde	CH_2O	ppb	1.40	16
Nitrogen Dioxide	NO_2	ppb	12	110
Particulate Matter less than 10 µm in diameter	PM_{10}	µg/m^3	10	100
Particulate Matter less than 2.5 µm in diameter	$PM_{2.5}$	µg/m^3	8.80	91
Sulphur Dioxide	SO_2	ppb	2.40	200
Volatile Organic Carbons (Anthropogenic/Biogenic)	VOCs	ppbC	130	1500
Ozone	O_3	ppb	27	100
Benzo (a) pyrene	B(a)P	ng/m3	0.27	17
Lead	Pb	µg/m^3	0.0024	0.10
Cadmium	Cd	µg/m^3	0.0031	0.10
Chromium (III)	Cr(III)	µg/m^3	0.00015	0.016
Chromium (VI)	Cr(VI)	µg/m^3	0.000039	0.0082
Nickel	Ni	µg/m^3	0.00028	0.012
Mercury	Hg	ppb	0.00026	0.0063
Manganese	Mn	µg/m^3	0.00093	0.080