City of Hamilton
BOARD OF HEALTH

Meeting #:	18-004
Date:	April 16, 2018
Time:	1:30 p.m.
Location:	Council Chambers, Hamilton City Hall 71 Main Street West

Loren Kolar, Legislative Coordinator (905) 546-2424 ext. 2604

Pages

1. APPROVAL OF AGENDA

   (Added Items, if applicable, will be noted with *)

2. DECLARATIONS OF INTEREST

3. APPROVAL OF MINUTES OF PREVIOUS MEETING

   3.1 March 19, 2018 — 5

4. DELEGATION REQUESTS

5. CONSENT ITEMS

   5.1 Stock Epinephrine Auto Injector Expansion in Restaurants (BOH13040(d)) (City Wide) — 9

   5.2 Public Health Services 2017 Annual Report (BOH18010) (City Wide) — 11

   5.3 Board of Health Self-Evaluation (BOH18011) (City Wide) — 30

   5.4 Reduction of Airborne Particulates in Hamilton (BOH18018) (City Wide) — 40

6. PUBLIC HEARINGS / DELEGATIONS

7. STAFF PRESENTATIONS

   7.1 Hamilton Airshed Modelling System (BOH18016) (City Wide) — 44

8. DISCUSSION ITEMS

9. MOTIONS

10. NOTICES OF MOTION

11. GENERAL INFORMATION / OTHER BUSINESS

Note: Due to bulk, the Guidelines and Protocols attached here as Appendix "A" to "G" will not be included in the print format of the agenda.

Recommendation: Be received.

11.2 Amendments to the Outstanding Business List

11.2.a Items to be marked as completed and removed from the Outstanding Business List:

Item A - Staff to report on Food Waste Management
January 12, 2015
(Addressed under Item 5.3 of the March 19, 2018 meeting)

Item D - Physician Recruitment - Policy respecting managed entry into the Family Health Network or Family Health Organizations - Q code enrolment premiums
May 21, 2015
(Letter sent out October 13, 2017)

Item I - Pilot-Project to Eliminate Sales of Products with Peanuts or Tree Nuts in four City of Hamilton Facilities
June 13, 2016
(Addressed under Item 8.1 at the March 19, 2018 meeting)

Item MM - Amendment to the City of Hamilton's Food Strategy (Revised)
(Addressed under Items 8.1 and 8.2 at the February 22, 2018 meeting)

Item CC - Millgrove Public School respecting a Food Recovery Program from Stores and Farmers for the Benefit of the Food Bank
June 19, 2017
(Addressed under Item 5.3 at the March 19, 2018 meeting)

Item DD - Stock Epinephrine Auto Injector Expansion in Restaurants (BOH13040(c))
June 19, 2017
(Addressed under Item 5.1 of this agenda)

Item EE - Reduction of Airborne Particulate in Hamilton
July 13, 2017
(Addressed under Item 5.4 of this agenda)

11.2.b Due date to be revised:

Item L - Food Strategy Priority Actions 2 &3
August 11, 2016
Due Date: Q4 2018
Revised Due Date: Q1 2019

12. PRIVATE AND CONFIDENTIAL

13. ADJOURNMENT

BOARD OF HEALTH
MINUTES 18-003
1:30 p.m.
Monday, March 19, 2018
Council Chambers
Hamilton City Hall

Present: Mayor F. Eisenberger
Councillors J. Farr, M. Green, S. Merulla, C. Collins, T. Jackson, D. Skelly, T. Whitehead, D. Conley, M. Pearson, B. Johnson, L. Ferguson, A. VanderBeek and J. Partridge

Absent with regrets: Councillor R. Pasuta – City Business

THE FOLLOWING ITEMS WERE REFERRED TO COUNCIL FOR CONSIDERATION:

1. Food Advisory Committee Minutes - January 10, 2018 (Item 5.1)

(Partridge/Collins)
That the Food Advisory Committee Minutes of January 10, 2018, be received.

CARRIED

2. Oral Health (BOH18001) (City Wide) (Item 5.2)

(Merulla/Farr)
That Report BOH18001, respecting Oral Health, be received.

CARRIED

3. Food Waste Reduction (BOH13001(h)/PW18023) (City Wide) (Item 5.3)

(Partridge/VanderBeek)
That Report BOH13001(h)/PW18023, respecting Food Waste Reduction, be received.

CARRIED

4. Infectious Disease and Environmental Health Semi-Annual Report (BOH18004) (City Wide) (Item 5.4)

(Partridge/VanderBeek)
That Report BOH18004, respecting Infectious Disease and Environmental Health, Semi Annual Report, be received.

CARRIED

5. Lyme Disease Risk in Hamilton (BOH18013) (Item 7.1)

(Merulla/Pearson)
That Report BOH18013, respecting Lyme Disease Risk in Hamilton, be received.

CARRIED

6. Feasibility of Peanut Restrictions in City Facilities (BOH16024(a)/HSC18012) (City Wide) (Item 8.1)

(Whitehead/Ferguson)

(a) That signage indicating common allergens (e.g. nuts, dairy) that are contained in the food products available at concessions be posted to educate and assist with food purchase decision making for clientele; and

(b) That the City of Hamilton continue to accommodate individuals based on self-identification.

CARRIED

7. Expanded Use of Naloxone on Hamilton Fire Vehicles (BOH18012) (City Wide) (Item 8.2)

(Jackson/Ferguson)
That the Board of Health approve the expansion of Naloxone use by the Hamilton Fire Department to include the administering of intranasal Naloxone to members of the public to help reverse the effects of opioid overdoses.

CARRIED

8. Correspondence from the Assistant Deputy Minister of Health and Long-Term Care respecting Ontario Public Health Standards – Implementation Work Plan Updates (Item 11.1)

(Skelly/Partridge)
That the correspondence from the Assistant Deputy Minister of Health and Long-Term Care respecting Ontario Public Health Standards – Implementation Work Plan, be received.

CARRIED

9. Correspondence from the Assistant Deputy Minister of Health and Long-Term Care respecting Ontario Public Health Standards: Requirements for Programs, Services, and Accountability Updates (Item 11.2)

(Skelly/Whitehead)
That the correspondence from the Assistant Deputy Minister of Health and Long-Term Care respecting Ontario Public Health Standards: Requirements for Programs, Services, and Accountability, be received.

CARRIED

FOR INFORMATION:

Mayor Eisenberger recognized Susan Harding-Cruz, Program Manager, for 31 years of service in Public Health Services. Ms. Harding-Cruz will be retiring on May 31, 2018.

(a) CHANGES TO THE AGENDA (Item 1)

The Clerk advised the Board that there were no changes to the agenda.

(B. Johnson/Conley)
That the agenda for the March 19, 2018 Board of Health be approved, as presented.

CARRIED

(b) DECLARATIONS OF INTEREST (Item 2)

None.

(c) APPROVAL OF MINUTES OF PREVIOUS MEETING (Item 3)

(i) February 22, 2018 (Item 3.1)

(Skelly/Jackson)
That the Minutes of the February 22, 2018 meeting of the Board of Health be received, as presented.

CARRIED

(d) PRESENTATION (Item 7)

(i) Lyme Disease Risk in Hamilton (BOH18013) (Item 7.1)

Susan Harding-Cruz, Program Manager, Vector Born Diseases, addressed the Board with an overview of Report BOH18013 respecting Lyme Disease Risk in Hamilton, with the aid of a PowerPoint presentation. A copy of the presentation has been included in the official record.

(Merulla/Collins)
WHEREAS, the tick population is rapidly growing in the City of Hamilton;

WHEREAS, the City of Hamilton has been deemed to be a high-risk area for tick population;

WHEREAS, Provincial legislation prevents public pesticide use to control the tick population; and

WHEREAS, the producers of the tick pesticide do not consider Ontario a viable market

THEREFORE BE IT RESOLVED:

That Public Health staff be directed to investigate the pros and cons of using pesticides to control the tick population.

CARRIED

(Merulla/Pearson)
That the presentation respecting Lyme Disease Risk in Hamilton (BOH18013), be received.

CARRIED

For further disposition of this matter, refer to Item 5.

The presentation is available at www.hamilton.ca

(e) ADJOURNMENT (Item 13)

(Skelly/Merulla)
That, there being no further business, the Board of Health be adjourned at 2:29 p.m.

CARRIED

Respectfully submitted,

Mayor F. Eisenberger
Chair, Board of Health

Loren Kolar
Legislative Coordinator
Office of the City Clerk

Hamilton

INFORMATION REPORT

TO:	Mayor and Members Board of Health
COMMITTEE DATE:	April 16, 2018
SUBJECT/REPORT NO:	Stock Epinephrine Auto Injector Expansion in Restaurants (BOH13040(d)) (City Wide) (Outstanding Business List Item)
WARD(S) AFFECTED:	City Wide
PREPARED BY:	Dr. Ninh Tran (905) 546-2424, Ext. 7113
SUBMITTED BY: **SIGNATURE:**	Ninh Tran, M.D., MSc, CCFP, FRCPC Associate Medical Officer of Health, Public Health Services - Office of the Medical Officer of Health Healthy and Safe Communities Department

Council Direction:

At its meeting of June 19, 2017, the Board of Health directed staff to explore options for identifying restaurants that are participating in the Stock Epinephrine Auto Injector Program to the public.

Information:

On June 19, 2017, the Board of Health accepted the recommendations presented with Report (BOH13040(c)), including:

> "That a volunteer-based stock Epinephrine Auto Injector Program be developed and implemented to facilitate the access to and training on the use of stock epinephrine auto-injectors by up to 50 restaurants in the City of Hamilton under the following conditions:"

One of the conditions was:

> "That a minimum of six participants, representing six different restaurant chains, be registered with interest gauged by an online survey developed by McMaster University;"

This Information Report details the response to the Board of Health's consequent direction "that staff explore options for identifying restaurants that are participating in the

Stock Epinephrine Auto Injector Program to the public"; this item can now be removed from the Outstanding Business List.

The following methods will be used to promote and identify restaurants:

1) General promotion. A media release will be developed and sent out with a link to McMaster's online survey for restaurant owners/operators to complete. The online survey will provide information on the pilot, including a backgrounder, general expectations, ask questions and provide a mechanism for restaurants to self-identify and leave their name and contact information for follow-up.

2) Targeted promotion. The City has a list of approximately 2000 restaurants, including their name and contact information.

   a) Email: Though this would be a quick and free method of promoting the program and to include the link to the online survey, less than 1% of restaurants provide an email address.

   b) Phone: Phone numbers are provided for almost all of the 2000 restaurants. A representative of Food Allergy Canada as well as volunteer citizen(s) will be calling a select sample of these restaurants to promote the program.

Promoting the program through regular mail was also considered, but would cost approximately $2200 for 1-way postage alone for all restaurants and over $4000 in postage alone if return envelopes with stamp were also provided. It would also require staffing time as well as paper and printing costs. Given that the BOH accepted moving forward with the program on the condition/assumption of no net cost to the City, this option is not being pursued.

Work is underway developing and preparing for the program. Drafts of the Memorandum of Understanding (MOU) have been developed and are currently undergoing reviews by the respective organizations. Preliminary work on the online survey, training materials, exploration of appropriate training site locations and informal promotion of the program is underway. This will be finalized once the final MOU's have been approved by all parties involved.

Appendices and Schedules Attached:

Not Applicable.

Hamilton

INFORMATION REPORT

TO:	Mayor and Members Board of Health
COMMITTEE DATE:	April 16, 2018
SUBJECT/REPORT NO:	Public Health Services 2017 Annual Report (BOH18010) (City Wide)
WARD(S) AFFECTED:	City Wide
PREPARED BY:	Jennifer Hohol (905) 546-2424, Ext. 6004
SUBMITTED BY: **SIGNATURE:**	Elizabeth Richardson, MD, MHSc, FRCPC Medical Officer of Health Public Health Services – Office of the Medical Officer of Health Healthy and Safe Communities Department

Council Direction:

Not Applicable.

Information:

In support of health system transformation across the province, the Ontario Public Health Standards (Standards) were recently reviewed and updated by the Ministry of Health and Long-Term Care (Ministry). The Standards outline the requirements that direct mandatory public health programs and services delivered by local public health units, and the modernized Standards became effective as of January 1, 2018.

In addition to program and service delivery requirements, the Standards outline organizational requirements of boards of health to demonstrate accountability to the Ministry for the work they do, how they do it, and the results achieved. It is an organizational requirement that all boards of health produce an annual financial and performance report to the general public. The Standards also include a Transparency Framework which outlines the type of information that boards of health are required to publicly disclose to support enhanced transparency in the public sector and promote public confidence in the public health system. As part of the Transparency Framework, it is the responsibility of boards of health that the annual financial and performance report be posted on the board of health website.

Appendix A to Report BOH18010 Public Health Services 2017 Annual Report: A Healthy, Safe and Supportive Community for All, satisfies the annual financial and performance reporting expectations of the organizational requirements. The Annual Report highlights work conducted across Public Health Services in 2017 and provides an opportunity to increase awareness in the community on current public health issues and public health services offered in Hamilton. To fulfil requirements of the Transparency Framework, the Annual Report will be made available to the public on the City of Hamilton website at https://www.hamilton.ca/public-health/reporting.

Appendices and Schedules Attached

Appendix A to Report BOH18010 – Public Health Services 2017 Annual Report: A Healthy, Safe and Supportive Community for All

A HEALTHY, SAFE AND SUPPORTIVE COMMUNITY FOR ALL

Hamilton

PUBLIC HEALTH SERVICES ANNUAL REPORT 2017

City of Hamilton Public Health Services reports to the Board of Health and is responsible for protecting and promoting the health and well-being of 536,917 residents of Hamilton.

The City of Hamilton Strategic Plan 2016-2025

Vision: To be the best place to raise a child and age successfully

The work of Public Health Services aligns with the City of Hamilton's Strategic Plan which establishes priorities including Community Engagement & Participation, Economic Prosperity & Growth, Healthy & Safe Communities, Culture & Diversity, Clean & Green, Built Environment & Infrastructure, and Our People & Performance.

CONTENTS

MESSAGE FROM MAYOR FRED EISENBERGER

As chair of Hamilton Public Health Services' Board of Health, I'm pleased to share with you the progress the organization has made in 2017 as we continue to offer quality public health services and strategies in support of the City's vision.

As I reflect on the achievements and work undertaken in 2017, I want to thank the team of public health professionals for their continued service to the citizens of Hamilton. The breadth and scope of the initiatives and issues undertaken this year from continued action on climate change, community response to the ongoing opioid crisis and helping push this community forward in support of Harm Reduction, and promoting mental well-being in schools are all working towards supporting our health where we live, work play and learn. The activities and accomplishments described in this report demonstrate the dedication of our staff, the leadership of our Board of Health, and the support from the community as we work to promote and protect the health of our community.

City of Hamilton Mayor
Fred Eisenberger

MESSAGE FROM GENERAL MANAGER HEALTHY AND SAFE COMMUNITIES DEPARTMENT

One of the City's strategic priorities is to be a Healthy & Safe Community meaning that Hamilton is a safe and supportive city where people are active, healthy, and have a high quality of life. We know health and well-being is grounded in our City and in the neighbourhoods where we live, work, play, and learn. However, we also know these factors vary widely from community to community and even from neighborhood to neighborhood. In this report, you will see some highlights of the work of Public Health Services in protecting our community from environmental health issues, the threat of rabies, and drug and substance use and also how we are changing how we work to deliver services that enable some of our youngest residents to reach their full health potential.

The work of Public Health Services, in particular the critical population health expertise, supports our whole community to better understand, prioritize and take collective action to protect, promote and improve health and wellbeing, community by community.

Paul Johnson

MESSAGE FROM THE MEDICAL OFFICER OF HEALTH

I am pleased to present the 2017 Annual Report: A Healthy, Safe and Supportive City for All. In Ontario, public health has been given a renewed mandate through the Ontario Public Health Standards with a focus on population health assessment, ensuring a health equity lens is applied to the programs and services we offer.

This year was particularly busy for the organization as staff reviewed and developed a strategy to implement requirements in the new Ontario Public Health Standards and conduct population health assessment to inform local priorities. This is about looking beyond traditional health measures to define a broader picture of city and neighborhood health including conditions such as housing, traffic collisions, how much money people make, injuries from falling, air pollution and the environment, availability and accessibility of healthy food, jobs, and the impact of drug and substance misuse.

Through this process, mental health and addictions, healthy weights, and health equity were identified as areas for action where public health can make the biggest impact on community health and wellbeing. I am immensely proud of all of the work of Public Health Services over the past year, and am eager to see what we can accomplish together and with our partners in the future.

Dr. Elizabeth Richardson

REIMAGINING HAMILTON AS A VILLAGE OF 100 PEOPLE

In order to take action and make the biggest impact on the health and wellbeing of the whole community it is important to understand community needs and issues using local data and evidence. We know Hamilton is a city of 536, 917 people but in order to think differently about health in our city what if we reimagined Hamilton as a village of 100 people?

THERE ARE 39 HOUSEHOLDS IN THE VILLAGE

2 households have high level of radon gas

11 households are occupied by a lone person

6 households are food insecure

$187 is the weekly cost for a family of four to eat healthy

AGE

22 0-19 years

26 20-39 years

34 40-64 years

17 65+ years

EDUCATION

18 villagers have less than high school education

23 villagers have a high school education

43 villagers have a post-secondary education

1 in 3 children are vulnerable in an area of school readiness

REIMAGINING HAMILTON AS A VILLAGE OF 100 PEOPLE CONTINUED

80.5 years is the average life expectancy (females live 5 years longer than males)

AMONG THE 87 VILLAGERS WHO ARE 12 YEARS AND OLDER:

- **64** have very good or excellent mental health
- **49** are overweight or obese
- **36** have used illicit drugs in their lifetime
- **54** have a strong sense of belonging to their community
- **26** had a flu shot in the past year
- **53** eat fruit and vegetables fewer than 5 times per day
- **18** are smokers

IMMIGRATION

- **75** villagers were born in Canada
- **25** villagers are immigrants

INCOME

- **16** villagers live in low income households
- **2** villagers earn over $100,000 per year (after taxes)

TAKING ACTION ON CLIMATE CHANGE

Climate change is a significant concern that is having widespread impacts on human and natural systems in our community and worldwide. The Hamilton Community Climate Change Action Plan outlines an approach to address climate change locally. Public Health Services has engaged in and leads many initiatives within this plan.

Business Energy Emissions Profile

In 2017, the City of Hamilton and Sustainable Hamilton Burlington released the City of Hamilton Business Energy and Emissions Profile (BEEP). The BEEP is an online tool that models energy consumption and greenhouse gas emissions, giving users the ability to monitor consumption, find areas for improvement, and track success. Explore the BEEP tool at www.climatechangehamilton.ca

Without immediate climate change action, it is predicted that Hamilton can continue to experience annual increases in:

- Temperature;
- Number of precipitation days;
- Frequency of heat days and warm nights; and
- Intensity, duration and frequency of extreme weather events such as heavy rain, ice storms and windstorms.

Bay Area Climate Change Partnership

Hamilton is a leader in collaboration and partnership development for addressing complex environmental issues. The Bay Area Climate Change Partnership between the City of Hamilton, City of Burlington and Mohawk College was established to support the communities of Hamilton and Burlington in working collaboratively on climate change, resulting in investments in energy efficiency, green infrastructure, job creation, extreme weather adaptation actions and clean technology. This initiative brings together leading stakeholders in academia, utilities, Indigenous populations, community organizations and industry to work collaboratively on climate change to ensure Hamilton and Burlington remain prosperous in a low carbon economy.

RESPONDING TO RACCOON RABIES OUTBREAK

At the end of 2015 Hamilton witnessed the first confirmed case of Raccoon Strain Rabies ever reported in Southwestern Ontario and the first case of raccoon rabies in Ontario in more than a decade. As rabies is a serious fatal disease Public Health quickly mobilized in response to the rabies threat. Staff have been working on a multi-faceted strategy to reduce rabies risk in our community in coordination with multiple agencies including City of Hamilton Animal Services, the Ontario Ministry Natural Resources and Forestry, Ministry of Agriculture, Food and Rural Affairs, neighbouring health units, and the veterinary community.

Aside from investigating exposures of animal bites and scratches, considerable energy continues to be focused on ensuring the community is aware of rabies risks and important precautions we can all take to keep our families and pets healthy and safe. This is accomplished through creative awareness campaigns; community education sessions about control and prevention; and tools for post rabies exposure care for medical professionals. Additionally, building on the success of the previous low cost rabies vaccine clinics, in 2017 staff partnered with local veterinary community and Animal Services to offer two low cost rabies vaccine clinics reducing financial barriers for the community and vaccinating 223 cats and dogs.

Learn more:
www.hamilton.ca/rabies

A HEALTHY, SUSTAINABLE, AND JUST FOOD SYSTEM FOR ALL

The City of Hamilton Food Strategy aims to create a city with a sustainable food system where all people, at all times, have economic and physical access to enough safe and nutritious food to meet their dietary needs and preferences. The Strategy covers the entire food system including food production, processing, distribution, access, consumption, and food waste management.

Partnerships are critical to the success of the Food Strategy. This year a Food Literacy Network Forum brought together community stakeholders who support learning about and working with food to share their work and ideas about food literacy. This forum spurred a Hamilton Food Literacy Network to support continued work within the Food Strategy. Collaboration is also happening with Ryerson University's Centre for Studies in Food Security to find available kitchen space across the city that can be used by community groups to engage in food skills programming.

Work is underway to build a more comprehensive food-focused online portal, including a Farm Map, for residents and visitors to celebrate Hamilton's local food and agricultural story. Public Health Services is also collaborating with the Recreation Division to provide training on healthy eating lesson plans to recreation staff with food programs in their facilities and consulting on kitchen development in centres identified for renovation.

Learn more: www.hamilton.ca/foodstrategy

Food Strategy goals:

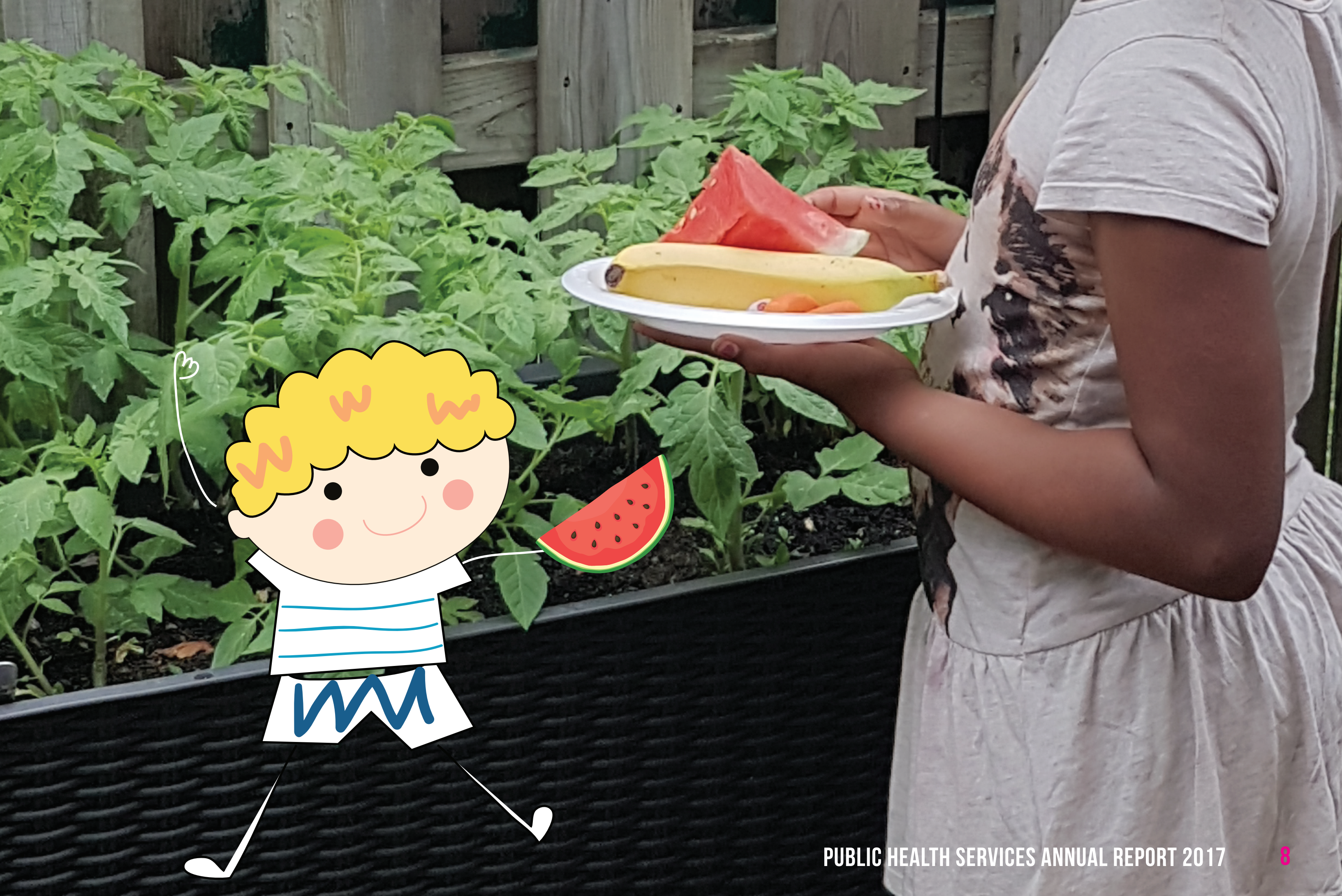
- Support food friendly neighbourhoods to improve access to healthy food for all residents
- Increase food literacy to promote healthy eating and empower all residents
- Support local food and help grow the agri-food sector
- Advocate for a healthy, sustainable, and just food system with partners and at all levels of government

RAISING HEALTHY KIDS TOGETHER

The Healthy Kids Community Challenge supports communities across the city in taking action to promote healthy behaviours, physical activity and healthy eating in children. With a focus on wards 6,7, and 8 community partners are working to improve the health of children.

Hamilton's Healthy Kids Community Challenge: Theme 3, Choose to boost veggies and fruits has seen 35 community partners working together to provide programs focused on healthy eating. These programs engaged over 10,000 children and families through programs that provided hands-on food skill development opportunities at schools, in the community; at local community gardens and at an urban farm.

Getting involved in your community during the Healthy Kids Community Challenge is easier than ever. For more information about the many programs that have been funded through the Healthy Kids Community Challenge please visit **www.hamilton.ca/healthykids**.



CHANGING HOW WE WORK: FAMILY-CENTRED BREASTFEEDING SUPPORT

At home breastfeeding support?

Breastfeeding may not always be easy, and in those early days and weeks it is often difficult for new parents to leave the home to access support. Traditionally, public health has offered most breastfeeding support through clinic appointments with a small focus on home visiting. Through discussion with public health clients, staff identified common barriers to accessing breastfeeding support outside of the home including available transportation, transportation or parking costs and child care needs associated with attending a clinic location. In addition to identifying barriers, clients were asked how they would like to receive breastfeeding support.

We provide free breastfeeding support in your home from Monday to Friday

Based on feedback from clients, Public Health Services ran a pilot offering more breastfeeding support to clients through home visiting. The results of the pilot showed that the breastfeeding services home visiting model reduced or eliminated barriers to accessing services and was rated as the clients first choice for how they would like to receive support. In addition to this model being preferred by the families we service, the pilot results showed that it is also a more efficient use of staff time. Based on the results and success of the home visiting model, breastfeeding services will continue to be offered through home visiting so new families can now better access the support they need in the comfort of their home.

Book an appointment for a home visit:

Call: 905-546-3550

Email:
breastfeedingsupport@hamilton.ca

Learn more:
www.hamilton.ca/breastfeeding

SUPPORTING HEALTHY SCHOOLS

Schools are an important setting to promote and protect the health of children and youth. Schools that focus on relationships between staff and students, the links between school and students' families, and effective connections to community-based services are better at promoting the skills to be physically and emotionally healthy for life.

Public Health Nurses work in partnership with school communities to link schools to available resources in Hamilton. Key health topics in schools included mental health promotion, healthy eating, sexual health and physical activity.

Improving Public Health Services in Schools

A review of the public health services offered in schools showed that positively impacting the health of students requires a comprehensive approach that extends beyond health and physical education to include school policy, the physical and social environment at school and the links between schools, families and communities.

To better provide services within schools, Public Health Services will use a Citywide approach to provide universal services to all schools such as dental screening, vision screening, school based immunizations, curriculum support and consultation on emerging health priorities. In addition to universal services, Public Health Nurses will also provide targeted services to focus schools within the City based on population health data and local school needs. This approach will be used in an effort to provide equitable services to areas in need.

ONLINE STUDENT VACCINE RECORD REPORTING & TRACKING IS NOW AVAILABLE

Parents are responsible for notifying Public Health Services each time their daycare or school-aged child receives a vaccine. Public Health keeps track of student vaccine records to safeguard the health of the community, and that in the event of a heightened disease risk in the community we can ensure everyone is protected from vaccine preventable diseases.

In the past parents had to phone or fax their children's vaccine records to public health each time their child received a vaccine.

Beginning in the 2017 school year parents can now report and track their child's vaccine records through a convenient, easy to use online portal.

For more information visit
www.hamilton.ca/vaccines

THE 5 WAYS: SUPPORTING MENTAL WELL-BEING WHERE YOU LIVE, WORK, PLAY AND LEARN

5 Ways to Mental Well-being

Actions that help all of us feel good and do well in life

Taking care of your mind is equally as important as taking care of your body. That's why Public Health Services supported a community campaign focusing on how to care for our mental well-being using the 5 Ways to Mental Well-Being. In 2017, The 5 Ways campaign was introduced in schools and it was instantly and enthusiastically embraced by the Hamilton Wentworth District School Board and the Hamilton Wentworth District Catholic School Board.

The 5 Ways to Mental Well-Being are evidence-based actions that when practiced regularly help enhance and maintain mental well-being. The 5 Ways to Mental Well-Being include:

- **Connect:** Build healthy relationships, spend time together with family, friends, and people in the community.
- **Keep learning:** Try something new, keep your mind active. Read books just for enjoyment. Try cooking, sewing, building, painting, visit an art gallery, museum, or library.
- **Be active:** Move to feel good. Being physically active can boost mood, reduce stress, increase energy levels, and improve concentration and confidence.
- **Take notice:** Be aware of your thoughts and feelings and the world around you.
- **Give back:** Find joy in helping others. Helping, sharing, and participating in the community is linked with an increased sense of purpose and satisfaction.

These are simple activities that we can do on a daily basis in order to promote feeling good about life, and support dealing with stress and challenges.

Learn more about 5 Way to Mental Well-Being: **www.hamilton.ca/5ways**

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RESPONDING TO OPIOIDS IN HAMILTON

In response to the growing concern about opioids locally and across the country, Public Health Services supported Mayor Fred Eisenberger's Opioid Summit in January 2017 establishing a working group to support a community wide response. The work group brought together partners from community organizations offering services related to opioid prevention, treatment, harm reduction and social justice to take collective action.

Since collaboration has begun, the group has developed a community opioid response plan, launched the Hamilton Opioid Information System to communicate alerts and opioid data, received provincial and municipal investments to enhance opioid response by supporting local naloxone distribution through expanded service hours to the Van Needle Syringe program, and shared common harm reduction focused campaign: the 4 C's of safety and the Good Samaritan Drug overdose Act.

Public Health Services and our partners in the community continue to focus on increasing availability of naloxone, and supporting the community work group in the development of a city-wide Drug Strategy.

For more information on the opioid response, visit the Hamilton Opioid Information System website at: **www.hamilton.ca/opioidmonitoring**

OPIOID STAKEHOLDER GROUP

The AIDS Network • Alternatives for Youth • City of Hamilton (Public Health Services, City Housing Hamilton, City Housing Services, Hamilton Fire Department, Hamilton Paramedic Service) • Criminal Lawyers Association • Crown Attorney's Office • De Dwa da dehs nye Aboriginal Health Centre • Drug Court • Hamilton Family Health Team • Hamilton & District Pharmacists' Association • Hamilton Addiction & Mental Health Collaborative • Hamilton Addiction Systems Collaborative • Hamilton Clinic • Hamilton Health Sciences • Hamilton Niagara Haldimand Brant Local Health Integration Network • Hamilton Police Services • Hamilton Wentworth Detention Centre • McMaster Family Health Team • McMaster University • McMaster University Department of Family Medicine • Mission Services of Hamilton • Mohawk College • Ontario Addiction Treatment Centres • People with Lived Experience • Regional Coroner • Shelter Health Team • St. Joseph's Healthcare Hamilton • Urban Core Community Health Centre • Wayside House of Hamilton • Wesley Urban Ministries

Prevent opioid overdose death and save lives using the 4 C's of safety:

1. **Careful Use -** Don't use alone, go slow by testing the effect with small amounts first.
2. **Carry naloxone -** Get a FREE naloxone kit, and training www.hamilton.ca/naloxone
3. **Call 9-1-1 for every overdose.** You, your friend or family member needs hospital care to survive.
4. **CPR -** Push Hard, Push Fast.

SUPPORTING HARM REDUCTION IN THE COMMUNITY

Injection drug use affects us all. Harms associated with injection drug use are many and include the spread of infectious diseases, accidental death and injury from overdose, poor mental health, unstable housing, injection-related litter, and the degradation of public spaces. Individual health and community impacts from drug misuse demonstrate a need for additional services and strategies in Hamilton.

Supervised Injection Sites: What are the needs?

A Supervised Injection Site Needs Assessment & Feasibility Study was conducted to determine the need, number, geographical location and service model for supervised injection services in Hamilton through consultation with the community and stakeholders.

OVERDOSES

Accidental opioid-related deaths have increased substantially each year in Hamilton.

2016
43
ACCIDENTAL OPIOID-OVERDOSE DEATHS IN HAMILTON

4X MORE THAN 2007

DRUG-RELATED EMERGENCY DEPARTMENT VISITS, HOSPITAL ADMISSIONS HAVE SHARPLY INCREASED IN THE LAST FIVE YEARS.

2017 BETWEEN JANUARY & NOVEMBER

378 PARAMEDIC RESPONSES TO SUSPECTED OPIOID OVERDOSE

WITH A HIGH CONCENTRATION OF THE CALLS RESPONDING IN THE DOWNTOWN AREA.

INFECTIOUS DISEASE

Accidental opioid-related deaths have increased substantially each year in Hamilton.

HAMILTON'S RATE OF HEPATITIS C INFECTION IS 32% HIGHER THAN THE PROVINCIAL AVERAGE.

THERE IS A HIGH DEMAND FOR HARM REDUCTION SERVICES SUCH AS

- NEEDLE SYRINGE PROGRAMS
- NALOXONE KITS.

IN 2017
1.2 MILLION CLEAN NEEDLES
DISTRIBUTED THROUGH HARM REDUCTION PROGRAMS

Results of the study showed that Hamilton would benefit from one or more supervised injection sites as this type of service has the potential to effectively address injection drug related issues by decreasing unsafe injection practices like needle sharing that can spread disease, decreasing death and disability from overdose, and decreasing public injections and injection drug litter by providing a clean and safe place for people to inject drugs. Recommendations from the study and support for a supervised injection site in Hamilton were endorsed by Hamilton City Council.

All recommendations from the Supervised Injection Site Needs Assessment & Feasibility Study can be found at: www.hamilton.ca/SIS

2017 QUICK FACTS

11169
Total inspections completed

1549
100% of the **1549** rabies exposures investigated within 1 day

1758
tobacco inspections

99.9%
of health hazard investigations initiated within **24** hours

6141
food inspections

7782
health connection calls

884
water inspections

5318
clients seen at dental clinic

551
residential care facility inspections

1854
clients seen at dental bus

1020
personal service setting inspections

72
Service provided in **48** elementary schools and **24** secondary schools

534
day care inspections

27,279
immunizations given

6
infection control complaint responses

1700
naloxone kits distributed

223
cats and dogs vaccinated at 2 low cost pop up rabies clinics

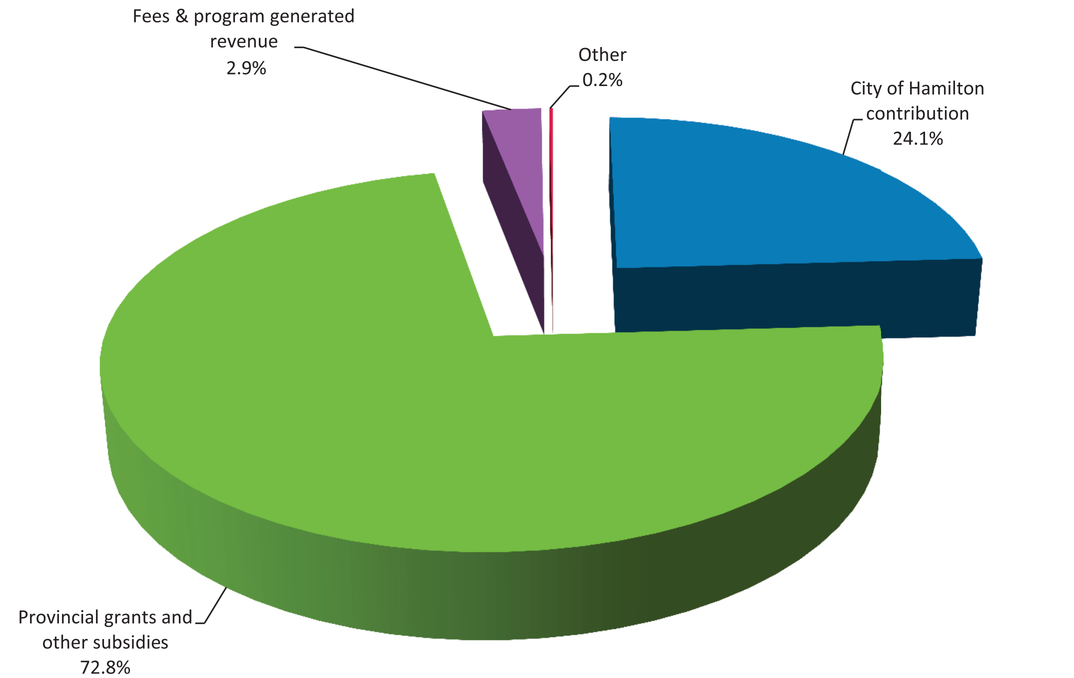
453
people reported as being revived by Public Health's Naloxone kits

2017 PUBLIC HEALTH SERVICES FUNDING

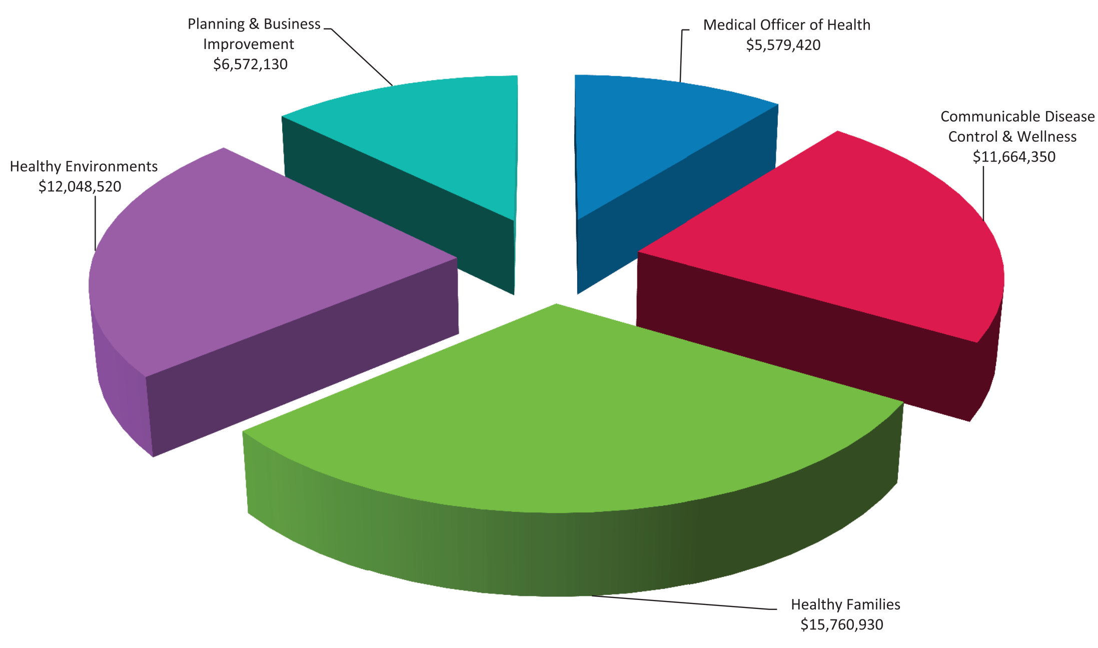
In 2017 the Government of Ontario provided funding for 72.8% of Hamilton Public Health Services budget, with 24.1% contributed by the City of Hamilton and 2.9% from program generated revenue.

2017 Approved Budget: $51,625,350

Funding Sources



2017 Approved Budget By Division



Hamilton

Hamilton

INFORMATION REPORT

TO:	Mayor and Members Board of Health
COMMITTEE DATE:	April 16, 2018
SUBJECT/REPORT NO:	Board of Health Self-Evaluation (BOH18011) (City Wide)
WARD(S) AFFECTED:	City Wide
PREPARED BY:	Jennifer Hohol (905) 546-2424, Ext. 6004
SUBMITTED BY: **SIGNATURE:**	Elizabeth Richardson, MD, MHSc, FRCPC Medical Officer of Health Public Health Services – Office of the Medical Officer of Health Healthy and Safe Communities Department

Council Direction:

Not Applicable.

Information:

Background

The Ontario Public Health Standards (Standards) outline requirements that direct mandatory public health programs and services delivered by local public health units. In addition to program and service delivery requirements, the Standards outline organizational requirements of boards of health to demonstrate accountability to the Ministry of Health and Long-Term Care for the work they do, how they do it, and the results achieved.

It is an organizational requirement that all boards of health conduct a self-evaluation process of its governance practices and outcomes that is completed at least every other year. The self-evaluation process must also include an analysis of the results, board of health discussion and implementation of recommendations for improvement. The self-evaluation process is intended to review Hamilton Public Health Services Board of

Health (BOH) practices, outcomes, and relationships with Public Health Services (PHS) management and is not intended to assess the operations of PHS at the program level.

The BOH conducted its first self-evaluation in 2014 (BOH14001) and repeated the evaluation again in 2016 (BOH16033). As a self-evaluation process is required at least every other year, the BOH is due to complete a self-evaluation in 2018 to ensure compliance with the Standards.

<u>Outcomes and Action</u>
Results from the 2016 BOH self-evaluation survey (BOH16033) showed opportunities for improvement including:

- Greater understanding of BOH member roles and responsibilities;
- Improved access to continuing education for BOH members; and
- Increased familiarity with the PHS Department Operational Work Plan.

Many quality improvement initiatives were implemented to address these opportunities for improvement. The first action was the nomination of public health governance leads from the BOH to represent the board at governance tables, advocate for effective public health governance and healthy public policy and act as a liaison for the BOH on governance matters. The public health governance leads have been actively engaged working with staff to support consultation on public health system transformation initiatives including the Expert Panel on Public Health and the submission of the Annual Service Plan and Budget. A public health governance lead also became the Board of Health Representative of the Central West Region on the Association of Local Public Health Agencies, a not-for-profit organization that provides leadership to the boards of health and public health units in Ontario. In addition, PHS staff have brought regular information updates to the BOH at mid-year and year-end on the progress made within the PHS Department Operational Work Plan to support increased familiarity with department priorities. PHS also continues to engage with BOH members one-on-one to support ongoing education and familiarity with the work of public health.

<u>Next Steps</u>
The 2018 self-evaluation process will be conducted in a similar way to that used in previous years, as it was successful in raising considerations for the BOH and will allow for comparison across the years.

BOH members will be asked to anonymously complete and submit an electronic survey (Appendix A) to reflect on and evaluate:

- BOH roles and responsibilities;
- Information sharing and decision making;
- Internal and external relations of the BOH;
- Planning; and
- BOH strengths, challenges, priorities and opportunities for improvement.

A link to the survey will be distributed to BOH members via email following the BOH meeting on April 16, 2018. Paper copies of the survey will be made available upon request to staff and submission of paper surveys will be coordinated on an individual basis. Completion of the survey is requested by May 7, 2018. Responses from the self-evaluation survey will be summarized with action plans for improvement informed through consultation with the Mayor as Chair of the BOH, the public health governance leads and the Chair of the Governance Sub-Committee. Results of the self-evaluation and proposed areas for improvement will be brought back to the BOH on June 18, 2018.

Appendices and Schedules Attached

Appendix A to Report BOH18011 – 2018 Board of Health Self-Evaluation Survey

2018 Board of Health Self-Evaluation Survey

SECTION I: Board of Health Roles and Responsibilities

1. Please indicate how strongly you agree or disagree with the following statements.

As a Board of Health member, I have a clear understanding of my roles and responsibilities under the:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a) Health Protection and Promotion Act	○	○	○	○	○
b) Ontario Public Health Standards	○	○	○	○	○
c) Ontario Public Health Standards - Organizational Standards	○	○	○	○	○

SECTION I Continued

2. Please indicate how strongly you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a) I feel confident in my ability to distinguish between my roles and responsibilities as an elected official under the Municipal Act and as a Board of Health member under the Health Protection and Promotion Act.	○	○	○	○	○
b) The Board of Health has the appropriate committee structure to exercise its responsibilities.	○	○	○	○	○
c) As a whole, the Board of Health fully understands its roles and responsibilities.	○	○	○	○	○
d) The Board of Health stays up to date with major developments in governance and public health best practices including new practices among peers.	○	○	○	○	○
e) The Board of Health is adequately prepared to oversee an emergency situation.	○	○	○	○	○
f) The Board of Health has an adequate process for handling urgent matters between meetings.	○	○	○	○	○
g) The Board of Health receives adequate information to approve the Public Health Services' budget.	○	○	○	○	○
h) The Board of Health receives adequate information on Public Health Services compliance with the Ontario Public Health Standards.	○	○	○	○	○

SECTION II: Board of Health Information Sharing and Decision Making

1. Please indicate how strongly you agree or disagree with the following statements.

As a Board of Health member:	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
a) I have trust and confidence in the information Public Health Services staff provide through presentations, reports and updates.	○	○	○	○	○
b) I find the information Public Health Services staff provide through presentations, reports and updates useful for informed decision-making.	○	○	○	○	○
c) I understand the role that data has in making informed decisions on public health program and service delivery.	○	○	○	○	○
d) I receive adequate data and information to make informed decisions on public health program and service delivery.	○	○	○	○	○
e) I received appropriate information at the initial Board of Health orientation at the time I joined to carry out my Board of Health role with confidence.	○	○	○	○	○
f) I believe that any material notice of wrongdoing or irregularities is responded to in a timely manner.	○	○	○	○	○

SECTION II Continued

2. Please indicate how strongly you agree or disagree with the following statements.

As a Board of Health member, I believe I have adequate access to continuing education including:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a) Population health information	○	○	○	○	○
b) Provincial government structure and funding from oversight ministries	○	○	○	○	○
c) Roles and responsibilities of Board of Health members	○	○	○	○	○
d) Emerging public health issues	○	○	○	○	○
e) Opportunities to participate in conferences and seminars by other organizations	○	○	○	○	○

SECTION III: Board of Health Relations

1. Please indicate how strongly you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a) A climate of mutual trust and respect exists between the Board of Health and the Medical Officer of Health.	○	○	○	○	○
b) There is sufficient time allocated for the full discussion of issues at Board of Health meetings.	○	○	○	○	○
c) As a Board of Health member, I feel comfortable raising an issue that might be unpopular or controversial.	○	○	○	○	○
d) All Board of Health members assist in developing and maintaining positive relations with key stakeholders involved in public health matters.	○	○	○	○	○

SECTION IV: Planning

1. Please indicate how strongly you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a) The Board of Health is contributing to the development of healthy public policy relevant to the Ontario Public Health Standards.	○	○	○	○	○
b) The Board of Health and Public Health Services have a clear strategic plan for programs and services that address the next three to five years.	○	○	○	○	○
c) As a Board of Health member, I am familiar with:					
Public Health Services Multi-Year Business Plan	○	○	○	○	○
Annual Service Plan & Budget	○	○	○	○	○
d) The following plans are relevant to our community's needs and interests:					
Public Health Services Multi-Year Business Plan	○	○	○	○	○
Annual Service Plan & Budget	○	○	○	○	○
e) The Board of Health considers the following plans when making decisions:	○	○	○	○	○
Public Health Services Multi-Year Business Plan	○	○	○	○	○
Annual Service Plan & Budget	○	○	○	○	○
f) The Board of Health considers organizational capacity including skills, finances and staffing when reviewing the:					
Public Health Services Multi-Year Business Plan	○	○	○	○	○
Annual Service Plan & Budget	○	○	○	○	○

SECTION V: Summary

1. What do you feel is the number one strength of the Board of Health as a committee?

2. What do you feel is the number one challenge for the Board of Health as a committee?

3. What is one way the Board of Health as a committee could improve its performance in the next year?

4. Do you have any other comments or suggestions?

Thank you for taking the time to complete this survey.

Hamilton

INFORMATION REPORT

TO:	Mayor and Members Board of Health
COMMITTEE DATE:	April 16, 2018
SUBJECT/REPORT NO:	Reduction of Airborne Particulates in Hamilton (BOH18018) (City Wide)
WARD(S) AFFECTED:	City Wide
PREPARED BY:	Matt Lawson (905) 546-2424, Ext. 5823
SUBMITTED BY & SIGNATURE:	Kevin McDonald Director, Public Health Services - Healthy Environments Division Healthy and Safe Communities Department

Council Direction:

The Board of Health, at its meeting of July 13, 2017, approved the following:

(b) That staff consult with Environment Hamilton, Clean Air Hamilton and the Ontario Ministry of Environment and Climate Change to review the Streets By-law 86-77, and develop a better legal instrument as well as other recommendations, to reduce airborne particulate in Hamilton and report back to the Board of Health;

(c) That Street By-law 86-77 be proactively enforced to discourage track-out violations in the industrial core, and;

(d) That staff be directed to enhance municipal Street sweeping in the industrial core.

The following report provides information related to the above motion.

Information:

By-law related to airborne particulates

Healthy Environments Division staff have actively engaged and consulted with members of Environment Hamilton, Clean Air Hamilton (CAH) and the Ontario Ministry of

Environment and Climate Change (MOECC) with respect to developing a legal tool, i.e., a by-law to help reduce airborne particulate in Hamilton.

A working group of Clean Air Hamilton (CAH) called the Fugitive Dust working group has been established that includes members of Environment Hamilton and the (MOECC). The objectives of CAH's working group are to:

- Improve levels of airborne particulate matter throughout the City, particularly in identified neighbourhoods with elevated levels, and;
- Effect behavioural changes on the parts of citizens and businesses when engaging in activities that may generate particulate matter.

To date, the Fugitive Dust working group has delivered workshops to construction companies operating in Hamilton on the subject of dust management, and has prepared a mailer containing information on requirements from all levels of government and resources available to meet these requirements. The mailer is intended to be distributed to construction and demolition companies operating in Hamilton before the beginning of the 2018 construction season.

The CAH working group has also been active in providing input toward a draft by-law. Additionally, Healthy Environments Division staff has met with staff from both Legal Services and Municipal Law Enforcement to discuss the development of a new by-law to assist in the control of airborne particulates in Hamilton. Staff is planning to bring back a recommendation report to the Board of Health (BOH) in Q1/2019 for consideration, once the new BOH has been formed. In the meantime, Healthy Environments Division staff will continue to consult with community stakeholders with respect to the scope of the proposed by-law.

Enforcement of 'Track-out' in the Industrial Core

Healthy Environments Division staff has consulted with Legal Services staff about proactive enforcement of 'track-out' onto Hamilton streets. A plan has been developed that identifies areas within the industrial core that have had historically recurring instances of track-out, such that active surveillance of track-out offences will be performed on a weekly basis.

Healthy Environments Division staff has been performing active surveillance of the industrial core to identify if any roadway access points have appeared to be non-compliant with the existing 'Streets By-law' with respect to track-out. In the event that a property is found to be non-compliant with the by-law, a letter is sent to the owner of the property in question and they are advised of the prohibitions relating to track-out contained within the Streets By-law, and that charges may result if additional instances of non-compliance are observed. To date, no charges have been laid.

Street Sweeping Enhancements

The City's current fleet of 17 street sweeping units are manufactured by Tymco, which are an efficient unit at collecting small particulates from the roadway. Tymco street sweepers hold an Environmental Technology Verification (ETV) validation from the International Organization for Standardization (ISO). The ETV verification validates the manufacturer's environmental performance claims about the street sweeper's ability to collect particles as small as 0.3 microns in size.

Healthy Environments Division staff has met with staff from Public Works (Roads) to discuss options for how street sweeping processes could be enhanced to assist in lowering airborne particulates in the industrial core. Upon learning about the motion approved at the July 2017 BOH meeting, Public Works staff voluntarily made the following enhancements to street sweeping processes:

1. **Timing**. In past practice, street sweepers were operational during non-daytime hours when traffic was expected to be lower volume in the industrial core. PW staff has moved to operate street sweepers at times that now include daytime hours, which will assist in reducing particulates associated with daytime traffic.
2. **Frequency.** Most streets within Hamilton receive street sweeping two times per month. Since November/2017, PW staff has increased the street sweeping frequency in the industrial core to three times per month, which increases sweeper operation time on the road by 33%.
3. **Flushing**. PW crews can flush water along stretches of Nikola Tesla Boulevard and Burlington Street, as needed, in order to reduce airborne particulate.

All of the above enhancements to road maintenance are expected to help lower the amount of airborne particulate circulating within the industrial core of the City.

Sweeping Program Pilot Lessons

1. Due to the increase of these Industrial Core enhancements it has impacted other sections of the sweeping program within the Downtown Core. As a result sweeping frequency of some main arterial/collector roads such as King Street and Cannon Street are being impacted as the result of the redeployment of existing sweeper inventory and required staff to operate. The impacts of this service level adjustment are being monitored regularly.

2. Increase wear and tear on equipment due to volume/type of debris in Industrial core.

3. During the winter season the sweeping program is hindered between first snowfall until early spring. If warm temperatures allow then sweeping may be completed during winter but no water can be used due to the below freezing temperature.

4. Due to decrease of sweeping during winter months, there is an increase in the accumulation of debris causing more effort to get back to normal levels.

Staff is monitoring the overall impact to the sweeping program. Should the minor enhancements undertaken to date be considered inadequate or diversion of equipment starts to negatively impact other areas, it may be necessary to consider expansion of the sweeper fleet. This expansion could include the purchase of an additional sweeper at approximately $350,000 and two full-time operators to run the enhanced program. A Business Case Enhancement could be considered for inclusion in the 2019 operating and capital budgets. Contracted service is not recommended as the sweepers on the City's hired equipment list do not have the same environmental equipment for particulates.

Appendices/Schedules Attached:

Not Applicable.

CITY OF HAMILTON
PUBLIC HEALTH SERVICES
Healthy Environments Division

TO:	Mayor and Members Board of Health
COMMITTEE DATE:	April 16, 2018
SUBJECT/REPORT NO:	Hamilton Airshed Modelling System (BOH18016) (City Wide) (Outstanding Business List Item)
WARD(S) AFFECTED:	City Wide
PREPARED BY:	Sally Radisic (905) 546-2424, Ext. 5549 Matt Lawson (905) 546-2424, Ext. 5823
SUBMITTED BY & SIGNATURE:	Kevin McDonald Director, Public Health Services - Healthy Environments Division Healthy and Safe Communities Department

RECOMMENDATIONS

(a) That staff work with Golder Associates to undertake sub-region analyses using the Hamilton Airshed Modelling System, and in consultation with key stakeholders and affected residents;

(b) That staff examine the feasibility of using Hamilton Airshed Modelling System to estimate morbidity and mortality outcomes associated with air pollution and report back to Board of Health, if necessary;

(c) That the Board of Health direct Public Health Services' staff to work with City of Hamilton Planning staff to review the Hamilton Airshed Modelling System analysis and determine appropriate applications for planning directions and decisions and report back to Planning Committee in Q1 2019;

(d) That the Board of Health request the Ministry of Environment and Climate Change to work with the City of Hamilton, other Ontario municipalities and levels of government regarding traffic-related air pollutants to address transboundary transportation contributions impacting the City of Hamilton;

(e) That the Board of Health advocate that the province of Ontario adopt the 24-hour Canadian Ambient Air Quality Standard for fine particulate matter (PM 2.5) of 28 micrograms per cubic metre of air (28 µg/m3) as air quality benchmarks for the maximum desirable concentration of particulate matter in the City of Hamilton; and

(f) Support the Ministry of the Environment and Climate Change in their proposal for a new policy focusing on Cumulative Effects Assessment in air approvals: "to more effectively consider cumulative impacts from multiple air pollution sources - both industrial and non-industrial" to address air quality issues in the City of Hamilton.

EXECUTIVE SUMMARY

In early 2015, Golder Associates was contracted to develop a comprehensive airshed model of the City of Hamilton (BOH13029(a)) through a partnership between the City and the Hamilton Industrial Environmental Association (HIEA). The development of the model is a primary milestone identified within the City of Hamilton's Air Quality Task Force Action Plan (BOH13029).

The Hamilton Airshed Modelling System (HAMS) was developed using emissions and meteorology data via the Community Multi-scale Air Quality (CMAQ). CMAQ is a state of the science, sophisticated model developed by the U.S. EPA capable of addressing regional air pollution problems such as those found in Hamilton.

HAMS helped us to understand both the types and place of origin of emissions contributing to Hamilton's airshed. The model distinguished between emissions generated locally, and those coming from outside Hamilton, be they from neighbouring regions, or further away.

The Hamilton emission profile was developed and showed the following in terms of the type of emissions:

Industrial 21.0%
Commercial 1.0%
Residential..0.5%
Agricultural...3.0%
Transportation 75.0%
- On-Road (e.g. trucks, cars)...41.0%
- Non-Road (e.g. rail)...34.0%

Transportation represents 75% of the total Hamilton emission profile. Further, local transportation represents over 74% of the local NOx and 37% of $PM_{2.5}$ emissions into the Hamilton airshed.

Industrial emissions represent 21% of the total Hamilton emission profile. Industrial activities generate products of combustion (such as CO, NOx, SO_2, and $PM_{2.5}$) as well as metals and benzo(a)pyrene (B(a)P).

Industrial activities are the largest local emitters of $PM_{2.5}$, SO_2, B(a)P and metals in the local airshed.

The model distinguished local emission sources from those that come from outside Hamilton. These are termed "transboundary emissions". The model shows that, of emissions that come from outside the Hamilton region, transportation activities represent over 62% of NOx emissions and over 75% of $PM_{2.5}$ emissions respectively. Further, industrial sources represent about 97% of transboundary SO_2 emissions and 61% of metal emissions that come from outside the Hamilton region.

The model weighs out the contributions of specific source sectors and activities for each of the contaminants of concern that we have measurements for. These "source apportionment" model simulations look at the place of origin of the contaminants to assess the relative importance of specific source sectors (i.e. Industrial, On-Road, Non-Road, Transboundary and other such as commercial, residential and biogenic/agriculture activities) with respect to $PM_{2.5}$, PM_{10}, O_3, SO_2, NO_2, benzene and B(a)P concentrations in Hamilton.

Local industrial activities contribute less than 20% by compound ($PM_{2.5}$, PM_{10}, SO_2, NO_2 and benzene) to air quality in Hamilton except for B(a)P where industry is the main source of that compound(~45%). Local on-road sources are a major contributor to NO_2 levels in the city. Transportation related emissions are the major contributor to transboundary emission for all compounds except SO_2 which is dominated by industrial sources. Ozone was shown to be constant across the city but reduces near the major highways where it reacts with NOx to create higher NO_2 levels near the roads. There is definite geographical variation in the profile of contributors to air quality within the city.

Overall the HAMS model provides better understanding of the sources of emissions into Hamilton's airshed, and relates these to the health and environmental impacts the contaminants have on our residents and our community. The model results suggest that air quality in Hamilton is hugely influenced by transboundary emissions with the exception of a few compounds including $PM_{2.5}$, SO_2, B(a)P and metals which are emitted by local industry. Therefore, emissions reductions in Hamilton will be dependent on local policies and programs but to a greater extent on advocacy for change at provincial and other levels of government.

Alternatives for Consideration – See Page 8

FINANCIAL – STAFFING – LEGAL IMPLICATIONS

Financial: Additional funding will be needed to perform any additional future analysis using the HAMS. If additional funding beyond existing and/or approved departmental budget is required, staff will report back to BOH before initiating any projects.

Staffing: Not Applicable.

Legal: Not Applicable.

HISTORICAL BACKGROUND (Chronology of events)

- **December 2013**: Board of Health members approve recommendations put forward from the Hamilton Air Quality Task Force Action Plan (BOH13029), which included the development of an airshed model for the City of Hamilton;

- **July 2014:** Board of Health approves the Medical Officer of Health be authorized and directed to negotiate and execute a funding agreement for the development of an airshed model with the Hamilton Industrial Environmental Association Inc. (HIEA) (BOH13029(a));

- **December 2014**: Funding agreement between City of Hamilton and HIEA signed;

- **January 2015:** Golder Associates procured to develop the Hamilton Airshed Modelling System;

- **January 2018:** Golder Associates announces that the HAMS data has been successfully validated and model results can be reported in near future, and;

- **March 2018:** Golder Associates present the HAMS at the 5th biennial 'Upwind/ Downwind' conference.

POLICY IMPLICATIONS AND LEGISLATED REQUIREMENTS

Not Applicable.

RELEVANT CONSULTATION

Public Health Services staff consulted with members of Clean Air Hamilton (CAH) about developing an airshed model for Hamilton. An advisory committee for the project was formed to monitor the progress of the development of the HAMS and to provide feedback requested from the contracted developer of the model (Golder Associates).

Members of CAH representing the following organizations participated on the HAMS advisory committee: Ontario Ministry of Environment & Climate Change (MOECC); the Hamilton Industrial Environmental Association (HIEA); Environment Hamilton; and Hamilton Public Health Services. In addition to the advisory committee, Golder Associates obtained an expert review of the analysis methodology and the modelling results to ensure the quality of data provided by the HAMS is of the highest quality.

ANALYSIS AND RATIONALE FOR RECOMMENDATION

Hamilton Airshed Modelling System (HAMS)

Air quality in an urban airshed like Hamilton's is influenced by local, regional and transboundary sources, as well as the prevailing geographical and meteorological conditions that transport, disperse and deposit air pollutants. The Hamilton Airshed Modelling System (HAMS) relies on the development of two key data sets including: meteorology and emissions. These data sets were combined via the application of the Community Multi-scale Air Quality (CMAQ) model which predicts spatially and temporally resolved concentrations of priority air contaminants including: particulate matter ($PM_{2.5}$, PM_{10}), ozone (O_3), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), benzene and benzo(a)pyrene (B(a)P) concentrations in Hamilton. CMAQ brings together three kinds of models including: a meteorological model (representing of atmospheric and weather conditions), an emissions model (representing of human-made and naturally occurring contributions in the atmosphere), and an air chemistry-transport model (predicting the atmospheric fate of air pollutants under varying conditions).

For HAMS, CMAQ was used to model four nested grid resolutions referred to as the following Tiers:

Tier I	36 km x 36 km comprising of Canada and US
Tier II	12 km x 12 km comprising of Ontario
Tier III	4 km x 4 km comprising of Hamilton Region
Tier IV	1.33 km x 1.33 km comprising of the Community Level

The capture of both local and regional emissions and chemistry is achieved via increasing grid resolution that becomes more detailed with proximity to the Hamilton study area.

Emissions Inventory

Data from provincial air regulatory and transportation planning agencies was used to develop a comprehensive emission dataset which includes parts of the US and Canada. Emissions for the compounds of interest were built up from activity data and integrated together for a composite of emissions from the various tiers.

Emission classifications included industrial, transportation (on-road and non-road such as airport, railway and marine activities), commercial, residential and agricultural for all four tiers. The Tier IV or Hamilton emission profile was developed and the distribution by total mass emission is as follows:

- Industrial 21.0%
- Commercial 1.0%
- Residential 0.5%
- Agricultural 3.0%
- Transportation 75.0%
  - On-Road (i.e. trucks, cars) 41.0%
  - Non-Road (i.e. rail) 34.0%

Transportation represents 75% of the total Hamilton emission profile. Further local transportation represents over 74% of the local NOx and 37% of $PM_{2.5}$ emissions into the Hamilton airshed.

Industrial emissions represent 21% of the total Hamilton emission profile. Industrial activities generate products of combustion (CO, NOx, SO_2, and $PM_{2.5}$) as well as metals and B(a)P and are the largest local emitters of $PM_{2.5}$, SO_2, B(a)P and metals in the local airshed.

Transboundary emissions are from sources outside the Hamilton region (i.e. the sum of Tier I, II and III). Therefore, from outside the Hamilton region, transportation activities represent over 62% of NOx emissions and over 75% of $PM_{2.5}$ emissions respectively. Further, from outside the Hamilton region, industrial sources represent about 97% of transboundary SO_2 emissions and 61% of metal emissions.

Hamilton Airshed Model Performance Evaluation

Model Performance Evaluation (MPE) is the process of testing a model's ability to accurately predict observations. Hamilton model results were compared with observations from the air quality monitoring network which includes regulatory stations (i.e. MOECC, Environment Canada) as well as the Hamilton Air Monitoring Network (HAMN). MPE was carried out for $PM_{2.5}$, PM_{10}, O_3, SO_2, NO_2, benzene and B(a)P.

Overall, the modelling system provides good results given the complexity of the model and inputs. CMAQ tends to over-predict concentrations with the exception of PM_{10} where the model under-predicts which is attributed to unaccounted local fugitive dust sources such as construction activities.

Source Apportionment Results

Source apportionment (i.e. place of contaminant origin) model simulations were used to assess the relative importance of specific source sectors (i.e. Industrial, On-Road, Non-Road, Transboundary and other such as commercial, residential and biogenic/agriculture activities) with respect to $PM_{2.5}$, PM_{10}, O_3, SO_2, NO_2, benzene and B(a)P concentrations in Tier IV Hamilton as shown in the table below.

Table 7-1: Tier IV Domain Annual Averaged Source Contribution (%)

Source	$PM_{2.5}$	PM_{10}	SO_2	NO_2	Benzene	B(a)P
Industrial	6%	6%	18%	4%	13%	48%
On-Road	1%	2%	1%	34%	6%	23%
Non-Road	1%	1%	17%	7%	12%	0%
Transboundary	91%	90%	64%	43%	68%	28%
Other	0.5%	0.5%	0.2%	12%	0.6%	0.3%

Averaged over the City local industrial emissions contribute less than 20% by compound ($PM_{2.5}$, PM_{10}, SO_2, NO_2 and benzene) to air quality in Hamilton except for B(a)P where industry is the main source of that compound.

It is important to point out that although B(a)P is hazardous to human health, in Hamilton, B(a)P is localized and concentrated around the industrial area with limited reach and impact on population health; whereas, $PM_{2.5}$ which is also hazardous to human health, is dispersed all over the City of Hamilton and has broader reach and higher impact on population health such that all residents are exposed on a continuous basis.

Local on-road sources are a major contributor to NO_2 levels in the city. Transportation related emissions are the major contributor to transboundary emission for all compounds except SO_2 which is dominated by industrial sources.

There is variation of the contribution profile depended on the area/ward within the City. For example, the contribution along Burlington Street would be greatly influenced by industrial sources than elsewhere. Similarly for near major roadways which flow through the City.

Conclusion

The results of the HAMS identify the contribution and nature of various local and transboundary sources of contaminants including: particulate matter ($PM_{2.5}$, PM_{10}), ozone (O_3), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), benzene and benzo(a)pyrene (B(a)P) concentrations in the Hamilton study area. Based on the findings, transboundary sources dominated the total emissions released into Hamilton with the exception of a few compounds including $PM_{2.5}$, SO_2, B(a)P and metals which are emitted by local industrial activities. Therefore, emissions reductions in Hamilton will be dependent on local policies and programs but to a greater extent on advocacy for change at provincial and other levels of government.

ALTERNATIVES FOR CONSIDERATION

Do nothing and allow the province to lead in the area of air quality management.

ALIGNMENT TO THE 2016 – 2025 STRATEGIC PLAN

Healthy and Safe Communities

Hamilton is a safe and supportive city where people are active, healthy, and have a high quality of life.

Clean and Green

Hamilton is environmentally sustainable with a healthy balance of natural and urban spaces.

APPENDICES AND SCHEDULES ATTACHED

Appendix A to Report BOH18016 - Golder's Results Report on Hamilton Airshed Modelling System (HAMS)

February 2018

HAMILTON AIRSHED MODELLING SYSTEM

Hamilton Airshed Modelling System Results

Submitted to:
Hamilton Industrial Environmental Association (HIEA)
270 Sherman Ave. N
Hamilton, ON L8L 6N4

REPORT

Report Number: 1418883

Distribution:

1 electronic copy - HIEA
1 electronic copy - Golder Associates

Golder Associates

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SUMMARY OF AIR QUALITY IN HAMILTON

1.0 INTRODUCTION

The objective of this study is to unravel the multifaceted air quality puzzle of the City of Hamilton with the aid of an airshed modelling system which can address the complex couplings among several air quality issues simultaneously across spatial scales ranging from local to hemispheric. Air quality in an urban airshed is influenced by local, regional and transboundary sources, as well as the prevailing geographical and meteorological conditions, which transport, disperse, and deposit air pollutants. These air pollutants may be released within the airshed or may be transported over long distances (hundreds of kilometers). An airshed modelling system must handle the different source combinations, the complex meteorology, and the transportation and dispersion of emissions to achieve realistic simulations of local impacts on air quality. The challenge is to determine the relevant set of sources and contaminants which influence air quality at a neighbourhood level and accurately account for their transport, transformation, dispersion, and deposition.

The Hamilton Airshed Modelling System (HAMS) relies on the development of two key data sets: emissions and meteorology. To represent the sources and compounds influencing air quality, an emissions inventory is required which includes both local and regional sources and accounts for contributions from human-made and natural sources. To represent the transport, and aid in the representation of the chemical transformation, dispersion and deposition of pollutants, a meteorological data set is needed, which will include the unique and challenging influences of the terrain in the Hamilton area. These data sets were combined through the application of the Community Multi-scale Air Quality (CMAQ) model, which is capable of predicting spatially and temporally resolved concentrations of priority air contaminants. CMAQ brings together three kinds of models:

- a meteorological model to represent atmospheric and weather activities;
- an emission model to represent human-made and naturally-occurring contributions to the atmosphere; and
- an air chemistry-transport model to predict the atmospheric fate of air pollutants under varying conditions.

1.1 Project Overview

The focus of the modelling project is to determine the contribution and nature of various local and transboundary sources (i.e., sources from outside Hamilton region, typically referred to as background sources, including contributions from both Canada and United States) on the air quality in the Hamilton region. The project was completed in the following five phases.

- Phase I – Detailed Work Plan: outlines the scope of work for the project, including the Airshed Modelling System Protocols that describe the approaches to be followed in Phases II through V. Some of these approaches were updated and modified as documented in the notes from HIEA committee meetings.
- Phase II – Emissions Inventory: emissions data acquisition and processing for the regional and local scale that are used as input to the air quality modelling.
- Phase III – Meteorology: meteorological data acquisition and processing for the regional and local scale meteorological modelling.
- Phase IV – Air Quality Modelling: air quality data acquisition for boundary and initial conditions in the model, as well as the collection of ambient air quality observations to support model performance evaluation.
- Phase V – Analysis of Modelling: comparison of the Airshed Modelling System with available monitoring data.

The air quality in the Hamilton Region was modelled by tracking the emission, dispersion and chemical transformation of selected contaminants in the airshed. The modelling is completed using four levels of nested spatial grids, providing both regional and local contributions to the air quality. The Hamilton airshed is part of the larger southern Ontario airshed, with influences from both south-western Ontario and the United States. The influences each have different emission profiles with respect to contaminants, quantity of emissions, and types of sources (e.g., stacks, roadways, area), as well as the specific location of the sources.

1.2 Priority Air Contaminants

The focus of the air quality modelling project is to determine the contribution and nature of various local and transboundary (i.e., sources from outside Hamilton region, typically referred to as background sources, including contributions from both Canada and United States) sources on the geographical distribution of ambient air concentrations to which Hamilton residents are exposed. Twenty (20) species listed in Table 1-1 were identified in consultation with HIEA for exploration in the HAMS.

Table 1-1: List of Compounds Selected for Modelling

Species	Symbol
Acrolein	C_3H_4O
Ammonia	NH_3
Benzene	C_6H_6
1,3 Butadiene	C_4H_6
Carbon Monoxide	CO
Formaldehyde	CH_2O
Nitrogen Oxides	NOx (NO + NO_2)
Particulate Matter less than 10 µm in diameter	PM_{10}
Particulate Matter less than 2.5 µm in diameter	$PM_{2.5}$
Sulphur Dioxide	SO_2
Volatile Organic Carbons (Anthropogenic/Biogenic)	VOCs
Ozone	O_3
Benzo(a)pyrene	B(a)P
Lead	Pb
Cadmium	Cd
Chromium (III)	Cr(III)
Chromium (VI)	Cr(VI)
Nickel	Ni
Mercury	Hg
Manganese	Mn

Particulate matter is not directly tracked in CMAQ and must be recombined using a number of aerosol components from the relevant size bins corresponding to the selected particulate matter species. In addition, benzo(a)pyrene is currently not a species that is included in the chemical mechanism. It has been added to CMAQ as a chemically inert tracer that still participates in deposition and dispersion.

1.3 Air Quality Modelling System

HAMS includes regional scale modelling of transboundary (i.e. outside of Hamilton, also referred to as background) and large scale influences, urban-scale modelling for local influences, meteorological data at regional and local scales, geophysical data at regional and local scales and emission inventories at regional and local scales.

The modelling system was based on the Community Multi-scale Air Quality (CMAQ) model, a chemical transport model (CTM), addressing multiple pollutants and different spatial scales. CMAQ simulates the various chemical and physical processes influencing the local air quality, including the emission, dispersion and chemical transformation of pollutants. The CMAQ modelling system consists of four pre-processors to the CTM, which provide information on the meteorology, meteorology-dependant chemical reactions and the concentration of species at the boundary and in the background (i.e. non-local sources). The meteorology and emissions inventory were developed for the selected modelling domains to allow for the focus on the Hamilton community.

1.4 Modelling Domain

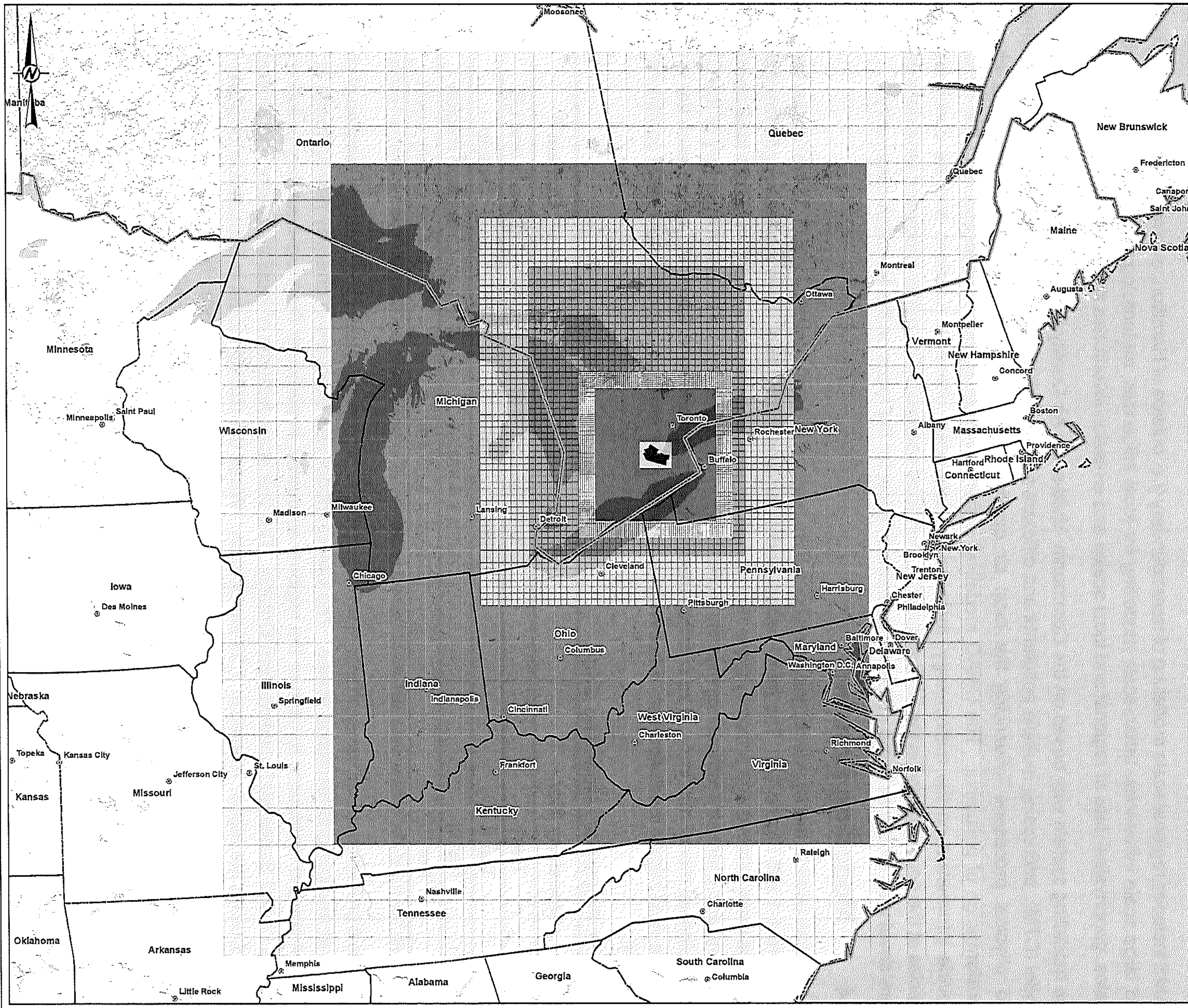
CMAQ was used to model nested grid resolutions from regional (36 km) down to local (1.33 km) scales as shown on Figure 1-1 and Figure 1-2. The multi-nested model domains, called tiers, have increasing grid resolution that becomes more detailed with proximity to the Hamilton study area, allowing for the capture of both local and regional emissions and chemistry without significantly increasing the complexity of the emission inventory or the CTM and meteorological model run times. The selected modelling tiers are shown in Table 1-2, where each tier is used to drive the next higher resolution tier. Effectively, each outer tier provides boundary and initial conditions for the inner tier.

Table 1-2: Preliminary Modelling Grids

Modelling Tier	Resolution	Domain(1)
Tier I	36 km x 36 km	Canada and US
Tier II	12 km x 12 km	Ontario
Tier III	4 km x 4 km	Hamilton Region
Tier IV	1.33 km x 1.33 km	Community Level

Note: (1)Both Tier II and Tier III have small portions of the norther-eastern US in their domain, but Canada forms the dominant portion.

CMAQ is a proven chemical transport model with the ability to capture the production, loss and reaction of chemical species at multiple grid resolution scales. The CMAQ model was executed in one-way nesting mode at the 36, 12 and 4 km grid resolutions to capture the regional air quality, in particular the trans-boundary pollution coming from the United States and southwestern Ontario. The fine scale features of local air quality and emissions are captured using the higher resolution 1.33 km domain. When the CMAQ model is executed in one-way nesting mode, it indicates that the meteorology is communicated to the chemistry model, but there is no influence of the resulting chemistry (i.e. aerosols) that is communicated back to the meteorology. The information is only communicated one way.



LEGEND
- City
- City of Hamilton
- State and Province Boundary
- Country Boundary
- Waterbody
- Tier IV 1 km CMAQ
- Tier IV 1 km WRF
- Tier III 4 km CMAQ
- Tier III 4 km WRF
- Tier II 12 km CMAQ
- Tier II 12 km WRF
- Tier I 36 km CMAQ
- Tier I 36 km WRF

0 200 400 600
1:7,500,000 Kilometres

REFERENCE(S)
BASE DATA FROM ESRI.PROJECTION: LAMBERT CONFORMAL CONIC.

CLIENT
HAMILTON INDUSTRIAL ENVIRONMENTAL ASSOCIATION

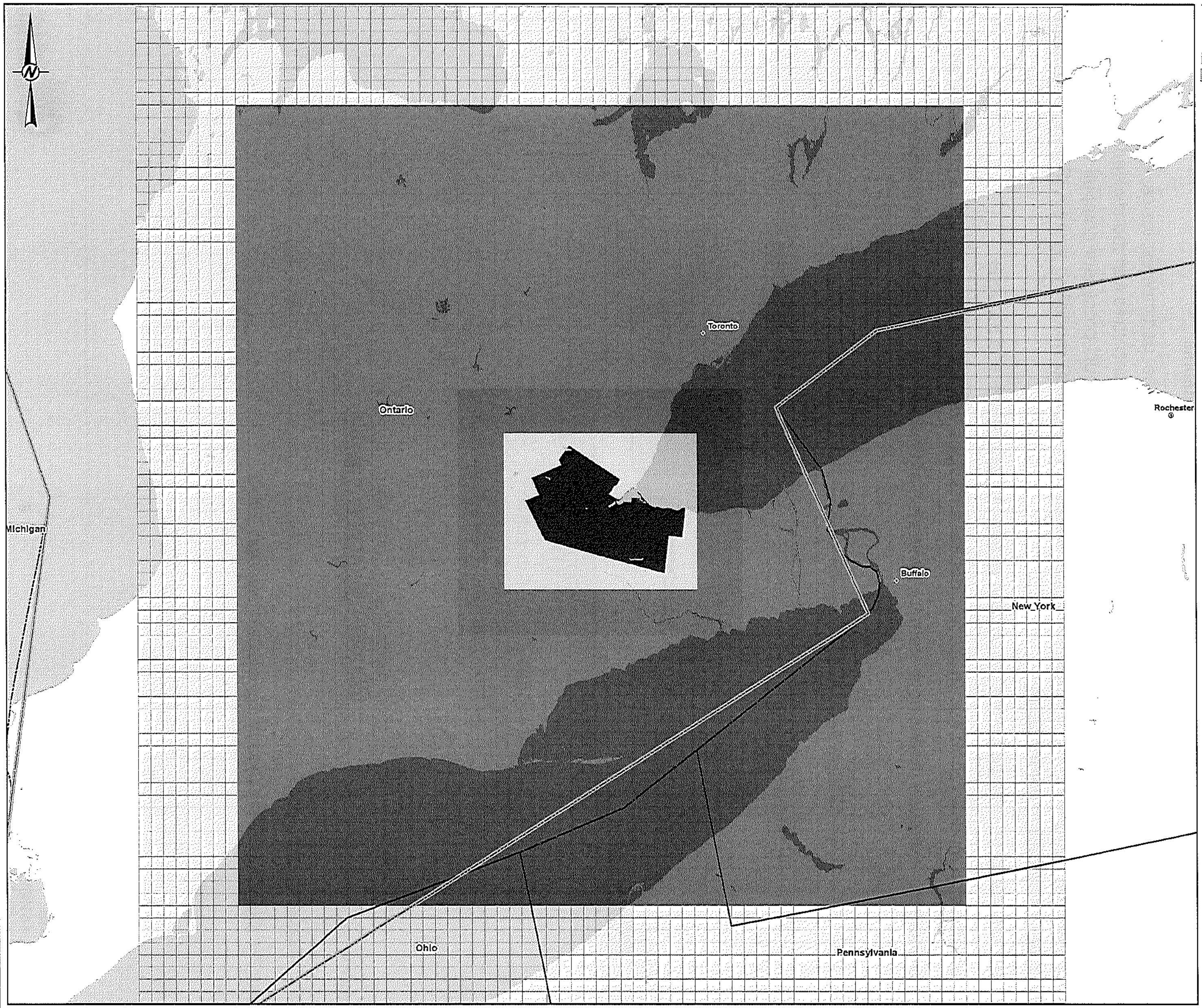
PROJECT
AIRSHED MODELLING TIERS

TITLE
MODELLING AND EMISSION GRIDS FOR HAMILTON AIRSHED MODELLING SYSTEM

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-03-09
DESIGNED	KD
PREPARED	KD
REVIEWED	JK
APPROVED	JLK

PROJECT NO.	CONTROL	REV.	FIGURE
1418883	0001	1.0	1-1



REFERENCE(S)
BASE DATA FROM ESRI.PROJECTION: LAMBERT CONFORMAL CONIC.

CLIENT
HAMILTON INDUSTRIAL ENVIRONMENTAL ASSOCIATION

PROJECT
AIRSHED MODELLING TIERS

TITLE
TIER III AND IV MODELLING AND EMISSION GRIDS FOR HAMILTON AIRSHED MODELLING SYSTEM

CONSULTANT

Golder Associates

YYYY-MM-DD	2015-03-09
DESIGNED	KD
PREPARED	KD
REVIEWED	JK
APPROVED	JLK

PROJECT NO.	CONTROL	REV.	FIGURE
1418883	0001	1.0	1-2

2.0 AIRSHED MODELLING SYSTEM DESCRIPTION

Numerical air quality models simulate the emissions, chemistry and physics of the atmosphere. CMAQ is a numerical air quality model that relies on scientific first principles to predict the concentration of airborne gases and particles from the transport, chemical change and dispersion of compounds released into the atmosphere. As information about the emissions and properties of compounds and classes of compounds is included, CMAQ can also inform users about the chemical composition of a mixture of pollutants.

The purpose of CMAQ is to provide technically sound estimates of ozone, particulates, toxics, and acid deposition. CMAQ is designed to meet the needs of the scientific community and concerned community leaders by combining current knowledge in atmospheric science and air quality modeling, multi-processor computing techniques, and an open-source framework into a single modeling system. The CMAQ modelling system (Figure 2-1) contains three types of modelling components:

- a meteorological module for the description of atmospheric states and motions;
- an emission models for human-made and natural emissions that are injected into the atmosphere; and
- a chemistry-transport modelling system for simulation of the chemical transformation and fate.

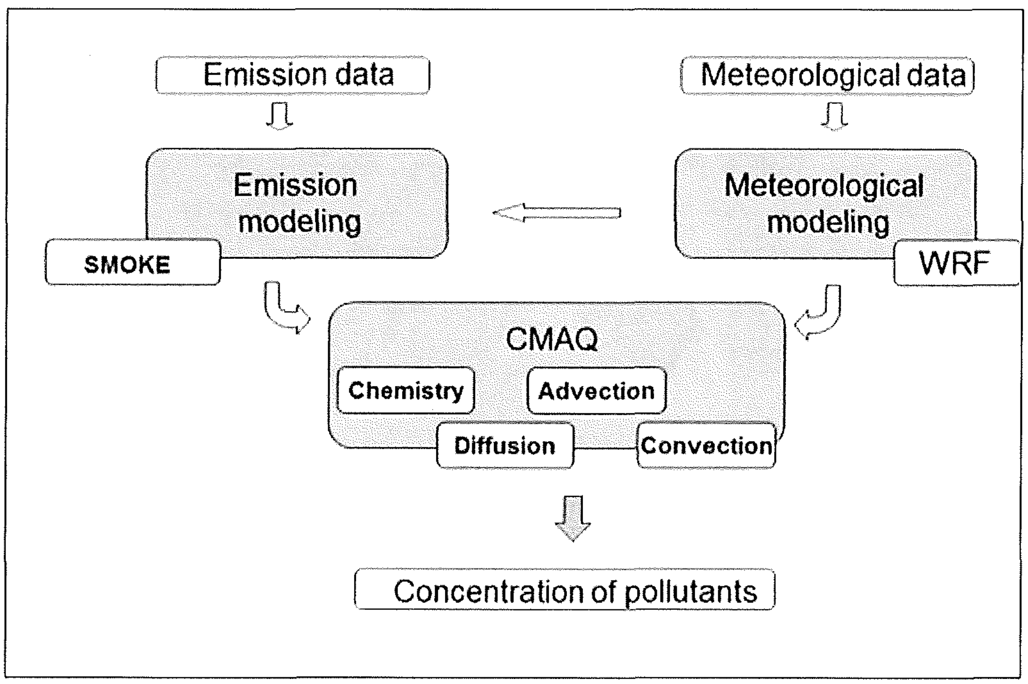


Figure 2-1: CMAQ Modelling System (University of Houston, 2014)

2.1 Meteorological Modelling

The Weather Research and Forecasting (WRF) Nonhydrostatic Mesoscale Model (NMM) model (NCAR, 2018) was selected to generate 3-dimenisional hourly meteorological data for the dispersion and chemical modelling. This model is the operational version of the WRF model, a next-generation mesoscale numerical weather prediction system.

Global meteorological data is used to initialize the model and provide boundary conditions. WRF uses actual land use and terrain data, and a number of physics options have been selected to ensure appropriate model characterization of meteorological conditions.

Validation of the WRF output was undertaken prior to undertaking the air quality modelling to demonstrate the appropriateness of the meteorological data for this assessment (APPENDIX A).

2.2 Emissions Modelling

The goal of air emissions modelling is to prepare gridded, hourly emissions estimates of speciated compounds suitable for input into CMAQ (APPENDIX B). The Sparse Matrix Operator Kernel Emissions (SMOKE) processing system was applied to the relevant emission and source data including;

- Human-made emissions data covering industrial point & area, non-road (commercial marine shipping, locomotives and aircraft) and others sources;
- data supporting the Model of Emissions of Gases and Aerosols from Nature (MEGAN) biogenic emissions model;
- spatial allocation, temporal allocation, and speciation data; and
- general input data.

Emissions data sets were derived from multiple agencies (e.g., United States Environmental Protection Agency (USEPA), Environment Canada and Ministry of Environment and Climate Change) as well as other municipal and regional agencies and industries in Hamilton.

SMOKE v.3.6 (CMAS, 2014) estimates spatially and temporally resolved, speciated emissions for on-road mobile, non-road mobile, area, point, fire and biogenic emission sources, among others, for photochemical grid models. SMOKE is principally an emission processing system and not a true emissions modelling system in which emissions estimates are simulated from first principles. This means that, with the exception of on-road mobile, biogenic, and some non-road mobile sources, SMOKE is an efficient tool for converting emissions inventory data into the formatted time varying and spatially consistent emission files required by CMAQ.

For the on-road mobile sources, the emissions rates were based on input mobile source activity data, emission factors estimated using the Motor Vehicle Emission Simulator (MOVES2014 [USEPA, 2014]), and outputs from transportation travel-demand models.

2.3 Air Quality Modelling

The air quality modelling was carried out with the aid of the CMAQ modelling system v5.0.2 (CMAS, 2015). CMAQ is a publicly available photochemical transport model, which can be run at a variety of spatial and temporal resolutions. For the purposes of this project, CMAQ was run at a variety of spatial resolutions, capturing both the local and long-range transport impacts on local air quality in Hamilton, Ontario for 2012. The selected model options have been evaluated in peer-reviewed literature and are the best options suited for the proposed air quality modelling study.

The core of CMAQ is the Chemical Transport Model (CTM) and several pre-processors including the Meteorological-Chemistry Interface Processor (MCIP), initial and boundary conditions processors (ICON and BCON) and a photolysis rates processor (JPROC), as shown in Figure 2-2. The US Environmental Protection Agency (EPA) continues to improve and develop new modules for the CMAQ model and typically provides a new release each year. EPA's Community Modelling and Analysis Systems (CMAS) centre supports the coordination, update and distribution of the modelling systems, data bases, and documentation.

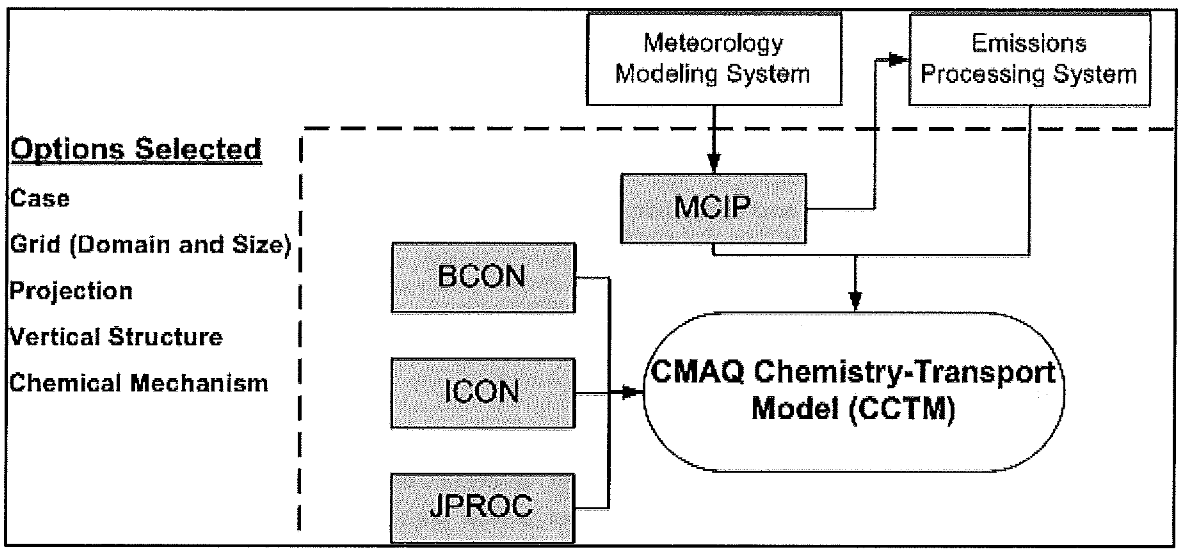


Figure 2-2: CMAQ Chemistry-Transport Model (CCTM) and Input Processors (Figure 2-1 in CMAS, 2015)

The mathematical representation of gas-phase and heterogeneous atmospheric chemistry from plume-scale to global modelling has led to a new generation of chemical kinetic mechanisms for tropospheric simulations. The two mechanisms most commonly used for urban and regional air quality modelling are the Carbon Bond Mechanism (CBM) developed at Systems Applications, International (Gery et al, 1989) and the Statewide Air Pollution Research Centre (SAPRC) mechanism maintained at the University of California, Riverside (Carter, 2010a,b). For the Hamilton modelling, the most current, tested version of the CBM chemistry was implemented in the regional chemical transport model.

SUMMARY OF AIR QUALITY IN HAMILTON

CMAQ is initialized using initial and boundary conditions down-scaled from a global chemical transport model (GCTM) as provided by Dr. B. Henderson and his research team at the University of Florida (Henderson, 2014). Initial conditions refer to the concentrations of the priority air contaminants in each model grid cell at the start of the CTM simulation. The initial conditions interact with the temporally- and spatially-resolved emissions estimates and undergo dispersion, transport and chemical transformations within the model. The boundary conditions refer to the concentrations of the priority air contaminants, as well as other chemical species included in the model, at the boundaries of the model (i.e., edges of the grid). The boundary conditions are provided by a GCTM, allowing the values to vary with space and time across the edge of the boundaries. This provides considerable improvement over assuming the chemical species are zero at the boundaries and allows for the communication of global background values into the model.

There are known limitations with the air quality modelling approach, in particular with the chemical mechanism, initial and boundary conditions, and the overall coupled WRF-SMOKE-CMAQ system. Each chemical mechanism is faced with the challenge of capturing the complex chemical interactions in the ambient atmosphere in a way that can be reasonably represented. This requires approximations and assumptions within the mechanism and, accordingly, different mechanisms may provide different predictions for the study area of interest. It should be noted that these chemical mechanisms are peer-reviewed through ambient air quality studies and represent the state of the science. Similarly, approximations and assumptions need to be made surrounding the initial and boundary conditions depending on what information is available for each of the desired chemical species. For example, static profiles may have to be used at the boundaries for chemical species that are not represented in the GCTM. In the end, a model can only be as good as its inputs (e.g., meteorology, emissions, and boundary conditions) and the state of the science (e.g., chemical mechanisms, understanding of interactions in the ambient atmosphere). Therefore, while CMAQ may have limitations, it remains a premiere model to capture the influence of long range transport and local sources on ambient air quality in a desired study area.

To test HAMS, modelled results for a number of species were compared to observations for the 2012 (APPENDIX C).

3.0 METEOROLOGY MODELLING RESULTS

The meteorological grid was prepared to cover the four domain regions (Table 1-2) with the aid of the WRF meteorological model. The year 2012 was selected because it was the most recent year available with complete meteorological data available that matches the emissions data used in the study.

The NCEP North American Mesoscale (NAM) model data was used to initialize the WRF model. These data have a six-hour temporal resolution and include surface pressure, geopotential height, temperature, soil values, ice cover, relative humidity, u- and v-winds, vertical motion, vorticity and ozone. The NAM analysis data provides the WRF model with boundary and initial conditions. Since mesoscale modelling is an initial value problem, having superior boundary and initial conditions has a very high impact on the accuracy of model output. NAM has a spatial resolution of 12 by 12 km, and is currently a recommended data base for WRF model initialization.

Topographic information for WRF was developed from the WRF Processing System (WPS) GEOGRID processor. The 36 km grid was based on the 5 min (~9 km) Geophysical Data Center global data. The 12 km grid was based on the 2 min (~4 km) Geophysical Data Center Global data. The 4 and 1.33 km grid was based on the 30 second (~900 m) data. The other WPS preprocessor programs include UNGRIB, and METGRID, and together these were used to develop the WRF model inputs.

The domains were selected based on the Community Multi-Scale Air Quality (CMAQ) modelling domains, with the WRF domains being larger than the corresponding modelling domains to provide a "buffer" zone around each dispersion modelling domain. The WRF modelling used 40 vertical layers with an approximately 12 m deep surface layer.

Detailed analysis of the metrics provided over the four domains demonstrated that WRF did well at replicating observed atmospheric values of temperature, mixing ratio, wind speed and wind direction (APPENDIX A). Monthly and annual analyses demonstrated a high level of accuracy in reproducing observations, even in the region surrounded by the Great Lakes (Tier IV). A summary of the overall annual model performance statistics and appropriate benchmarks is provided in Table 3-1. Model performance met all appropriate benchmarks (values should be compared to long-term benchmarks, where available, and Short-Term Benchmarks when no long-term range is provided).

Figure 3-1 and Figure 3-2 present the observed and predicted windroses for Tier IV (at the Hamilton Airport), respectively. The wind roses show a high degree of similarity between the observations and the predictions from WRF.

SUMMARY OF AIR QUALITY IN HAMILTON

Table 3-1: Annual Model Performance Statistics and Benchmarks

Model Performance Statistics	Tier I	Tier II	Tier III	Tier IV	Normal Benchmark	Complex Conditions Benchmark
Temperature Bias	0.14	0.14	0.28	0.67	-0.5 K ≤ X ≤ 0.5 K	-1.0 K ≤ X ≤ 1.0 K
Temperature Error	2.28	2.39	2.25	2.24	X ≤ 2.0 K	X ≤ 3.0 K
Mixing Ratio Bias	0.40	0.32	0.34	0.27	-1.0 g/kg ≤ X ≤ 1.0 g/kg	
Mixing Ratio Error	1.27	1.17	1.07	0.93	X ≤ 2.0 g/kg	
Wind Direction Bias	5.30	1.09	0.62	1.79	-10 ° ≤ X ≤ 10 °	
Wind Direction Error	30.35	30.10	30.35	29.88	X ≤ 30 °	
Wind Speed Bias	0.00	-0.07	-0.09	0.04	-5 m/s ≤ X ≤ 5 m/s	
Wind Speed RMSE	1.69	1.71	1.66	1.59	X ≤ 2 m/s	

Notes:

- Normal benchmark applies to multi-day meteorological modelling episodes of duration less than 60 days that do not cross climatological seasons and/or non-complex conditions
- Complex condition benchmark applies to episodes of greater than 60 days or episodes that cross climatological seasons, or modelling regions with complex meteorological conditions.

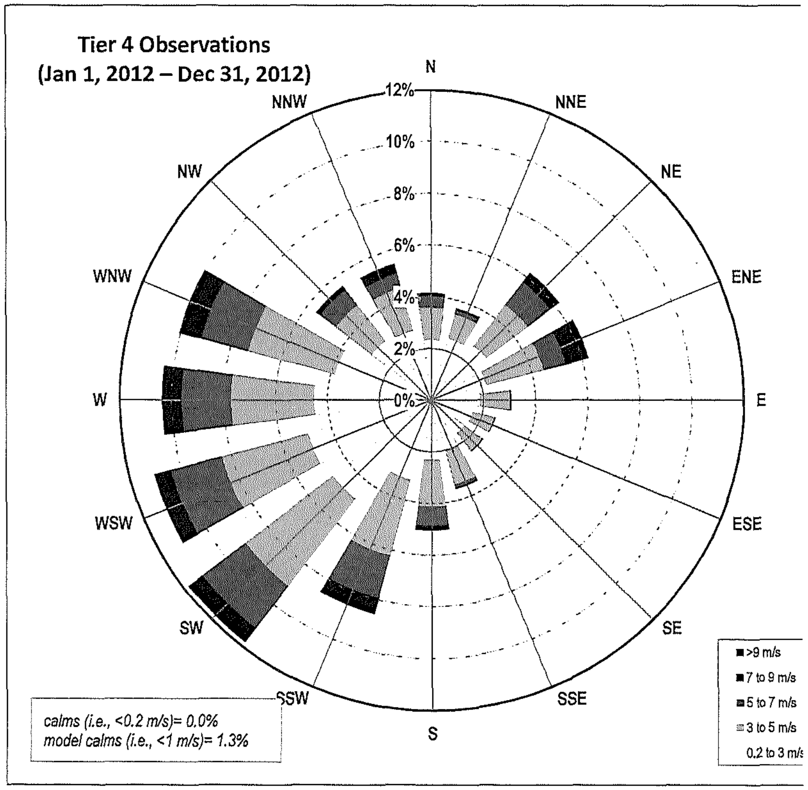


Figure 3-1: Windrose for Tier IV Observed Winds

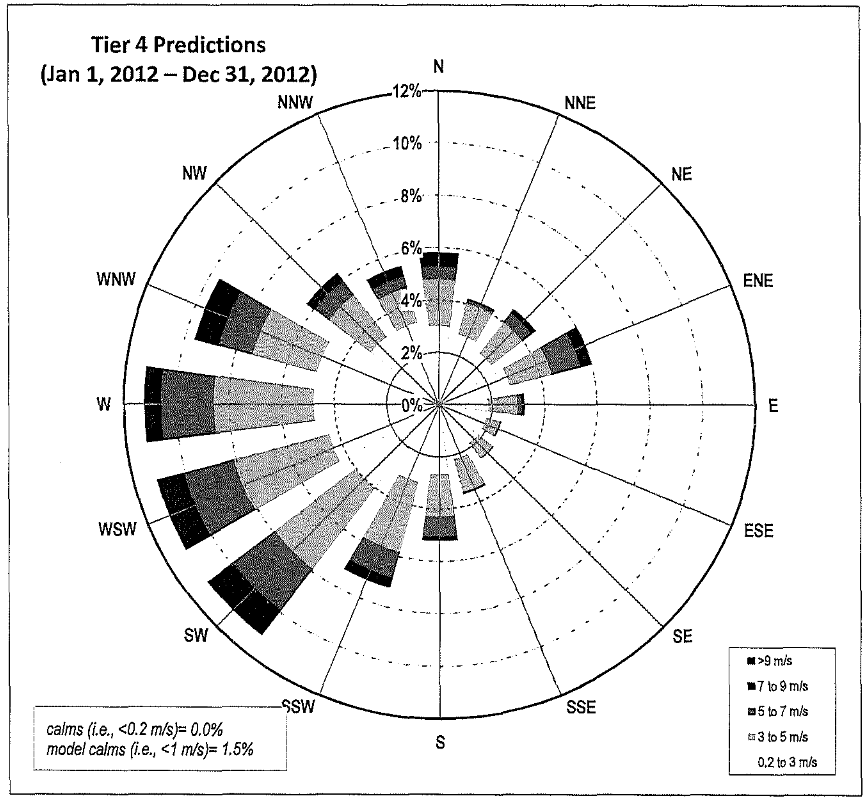


Figure 3-2: Windrose for Tier IV Predicted Winds

4.0 EMISSION INVENTORY RESULTS

The first step in preparing the emissions inputs to the modelling is the development of an emissions inventory. An emissions inventory is a database of sources of air pollution and their release characteristics for a specified geographic area and time period based on human-made and/or natural activities. To address the contribution from various sources to the Hamilton airshed, a multi-tier approach was used to segregate the emissions by geographic location (Figure 1-1). Information from provincial air regulatory and transportation planning agencies was processed into the required format. As shown in Figure 1-1, the computational domain was divided into four concentric areas with varying grid density. The emissions inventory required the merging of:

- the most recent pertinent US/CDN federal inventory; and
- high-resolution, local-specific emissions, estimated from local and provincial landuse and activity data in the Hamilton region.

Emissions data calculated were identified and categorised based on the origin or source of the emission as per Table 4-1. Effectively, a "bottom up" high-resolution approach was used to develop the higher resolution emission inventories of Tier II through IV, while a "top-down" approach was used for the lower resolution emission inventory of Tier I.

Table 4-1: Emission Source Classification

Emission Classification	Type	Definition
Industrial	➢ Point(1)	➢ Elevated stacks
	➢ Area	➢ Industrial areas
Commercial and Residential	➢ Area	➢ Natural gas usage, autobody shops, dry cleaners, commercial solvents, other residential heating sources
On-Road	➢ Area	➢ On-road vehicles (trucks, cars, motorcycles)
Non-Road	➢ Area	➢ Airport, marine, rail and lawn mowers,
Biogenic and Agricultural	➢ Area	➢ Non-anthropogenic activities

(1) Industrial point sources appear in all four tiers. Only emissions from the US have commercial and non-road point sources in addition to industrial point sources. These only impact the first three tiers.

Emission summaries for key compounds in each tier are presented in Figure 4-1. Tier I dominated the total emissions released into the computational domain with the exception of a few compounds.

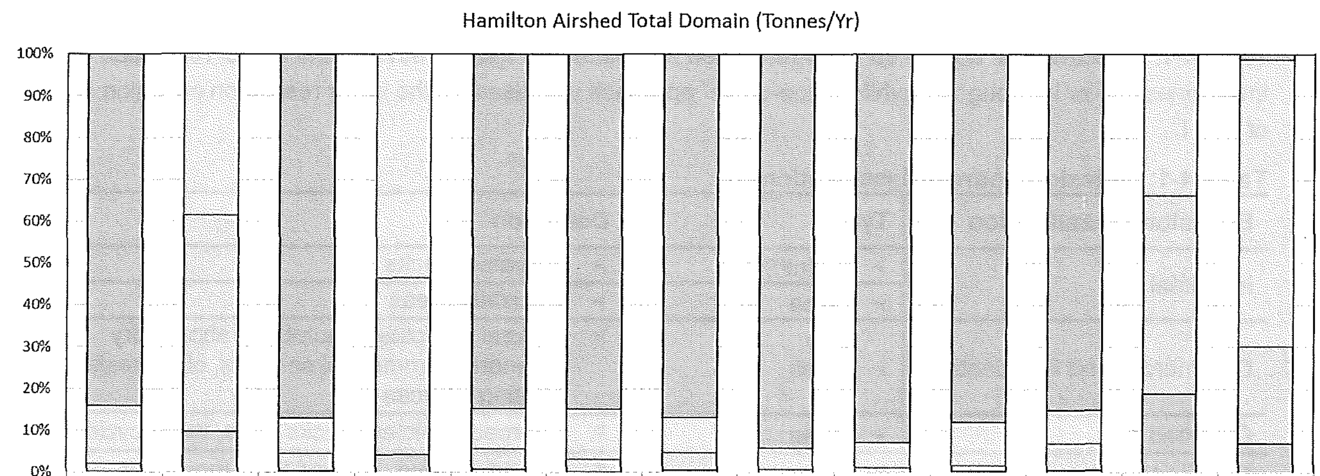
Figure 4-2 and Table 4-2 present a summary of Tier IV emissions by category, with details provided in APPENDIX B. Tier IV emissions generated from residential and commercial activities are typically the lowest except for VOCs from commercial operations (e.g., auto repair, dry cleaning). Transportation related activities (i.e., on-road and non-road) have similar emission profiles including significant emissions of products on combustion such as CO, NOx, SO_2 and fine particulate matter ($PM_{2.5}$). Local transportation represents over 74% of the local NOx and 37% of $PM_{2.5}$ emissions into the Hamilton airshed. Industrial activities generate products of combustions (CO, NOx, SO_2 and $PM_{2.5}$) as well as metals and B(a)P and are the largest local emitters of $PM_{2.5}$, SO_2, B(a)P and metals in the local airshed. Industrial emitters represent about 21% of the total emissions into the airshed.

SUMMARY OF AIR QUALITY IN HAMILTON

Transboundary emissions are from sources which are outside the Hamilton region (i.e., the sum of Tier I, II and III). Their contribution to the modelling domain are provided on Figure 4-3 and Table 4-3. Transportation activities represent over 62% of NOx emissions and over 75% of $PM_{2.5}$ emissions, respectively. Industrial sources represent about 97% of transboundary SO_2 emissions and 61% of metal emissions.

The geographic distribution of emissions varies by compound. In Tier IV, Figure 4-4 and Figure 4-5 show the geographic variation of NOx for area and point sources while Figure 4-6 and Figure 4-7 show B(a)P emissions for area and point sources, respectively. The NOx area emissions are well correlated with the major highways in the region such as QEW, 403 and Hwy 6 as well as the urban centers such Hamilton and Brantford. The B(a)P emissions correlate with industrial and on-road sources.

Although the emission inventory is comprehensive, some emission sources may not have been included such as fugitive emissions from construction activities.



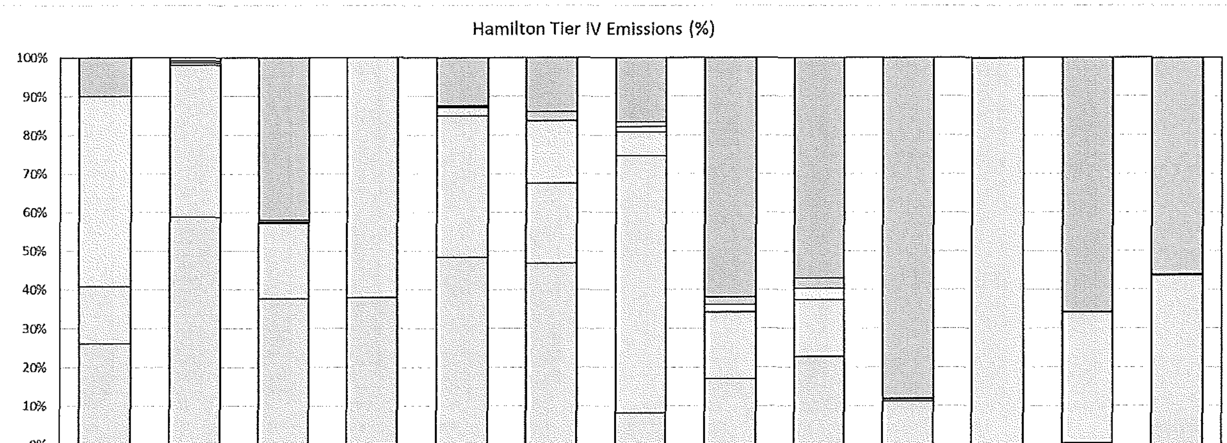
	Acetaldehyde	Acrolein	Benzene	1,3 Butadiene	CO	Formaldehyde	NOX	PM10	PM2.5	SO2	VOCs	B(a)P	Metals
Tier I	214,807	0	84,276	0	13,410,709	145,458	5,483,584	4,280,950	1,322,840	4,399,446	1,121,738	0	3
Tier II	35,872	66	8,074	257	1,507,911	20,802	532,095	225,630	84,845	509,786	103,452	0	186
Tier III	4,796	89	3,986	202	798,926	4,908	262,111	34,723	15,854	71,865	85,209	1	63
Tier IV	372	17	422	20	103,606	422	36,531	1,818	1,244	15,994	7,025	0	19

Figure 4-1::Tier I to IV Emissions [Tonnes/Year] for 2012

SUMMARY OF AIR QUALITY IN HAMILTON

Table 4-2: Tier IV Distribution of Compounds by Sector Classification [Tonnes/Year]

Pollutant	Industrial	Commercial	Residential	Agriculture	On-Road	Non-Road	Total
Acetaldehyde	36.7	0.1	0.1	182.7	55.1	97.0	371.6
Acrolein	0.2	0.1	0.1	0.0	6.5	9.8	16.6
Benzene	177.0	2.2	0.0	1.7	82.0	159.1	421.9
1,3 Butadiene	0.0	0.0	0.0	0.0	12.5	7.6	20.2
Carbon Monoxide	12,806.1	366.7	205.8	2,232.9	37,851.1	50,143.5	103,606.1
Formaldehyde	58.6	10.0	0.4	68.3	87.1	197.9	422.3
Nitrogen Oxides	6,079.9	435.8	482.6	2,258.1	24,262.3	3,012.5	36,531.0
PM_{10}	1,126.4	33.1	35.8	4.7	309.9	308.6	1,818.5
$PM_{2.5}$	709.1	33.1	35.8	0.0	182.8	282.9	1,243.7
Sulphur Dioxide	14,079.8	2.6	3.1	43.0	62.6	1,802.9	15,994.0
Volatile Organic Compounds	7.1	0.0	0.0	0.0	3,508.8	0.0	3,516.0
Benzo(a)pyrene	0.2	0.0	0.0	0.0	0.1	0.0	0.3
Metals	10.5	0.0	0.0	0.0	0.0	8.2	18.8



	Acetaldehyde	Acrolein	Benzene	1,3 Butadiene	CO	Formaldehyde	NOX	PM10	PM2.5	SO2	VOCs	B(a)P	Metals
Industrial	9.9%	0.9%	42.0%	0.0%	12.4%	13.9%	16.6%	61.9%	57.0%	88.0%	0.2%	65.7%	56.0%
Commercial	0.0%	0.5%	0.5%	0.0%	0.4%	2.4%	1.2%	1.8%	2.7%	0.0%	0.0%	0.0%	0.1%
Residential	0.0%	0.6%	0.0%	0.0%	0.2%	0.1%	1.3%	2.0%	2.9%	0.0%	0.0%	0.0%	0.2%
Agriculture	49.2%	0.0%	0.4%	0.0%	2.2%	16.2%	6.2%	0.3%	0.0%	0.3%	0.0%	0.2%	0.0%
On-Road	14.8%	39.2%	19.4%	62.1%	36.5%	20.6%	66.4%	17.0%	14.7%	0.4%	99.8%	33.8%	0.1%
Non-Road	26.1%	58.8%	37.7%	37.9%	48.4%	46.9%	8.2%	17.0%	22.7%	11.3%	0.0%	0.3%	43.6%

Figure 4-2: Tier IV Emissions Distribution by Sector Classification

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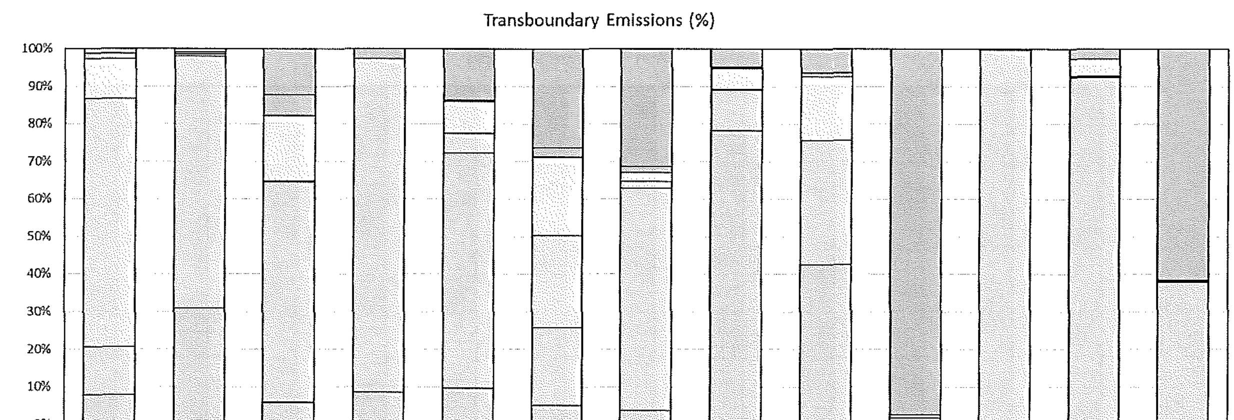
SUMMARY OF AIR QUALITY IN HAMILTON

Table 4-3: Transboundary Distribution of Compounds by Sector Classification [Tonnes/Year]

Pollutant	Industrial	Commercial	Residential	Agriculture	On-Road	Non-Road	Total
Acetaldehyde	3,425.2	3,433.1	27,242.5	168,690.5	32,542.3	20,141.7	255,475.3
Acrolein	1.4	0.7	0.9	0.0	103.7	47.7	154.4
Benzene	11,762.9	5,456.3	16,820.4	127.2	56,529.6	5,639.2	96,335.5
1,3 Butadiene	12.4	0.0	0.0	0.0	406.8	39.0	458.3
Carbon Monoxide	2,137,160	73,809	1,313,677	845,657	9,822,728	1,524,512	15,717,546
Formaldehyde	45,073.9	4,153.6	35,879.1	41,984.1	35,140.6	8,936.7	171,167.9
Nitrogen Oxides	1,966,144.0	107,313.9	144,210.1	114,689.5	3,710,371.5	235,061.0	6,277,790.1
PM_{10}	218,657.1	20,806.8	253,207.1	2,838.9	492,808.5	3,552,984.2	4,541,302.6
$PM_{2.5}$	90,472.4	15,476.8	239,396.7	1,712.1	471,267.8	605,213.0	1,423,538.8
Sulphur Dioxide	4,846,503.2	51,014.6	32,533.8	673.6	8,417.3	41,954.3	4,981,096.9
Volatile Organic Compounds	179.0	0.0	0.0	0.0	94,241.2	0.0	94,420.2
Benzo(a)pyrene	0.0	0.0	0.1	0.0	1.1	0.0	1.2
Metals	155.3	0.7	0.6	0.0	0.1	95.7	252.5



	Acetaldehyde	Acrolein	Benzene	1,3 Butadiene	CO	Formaldehyde	NOX	PM10	PM2.5	SO2	VOCs	B(a)P	Metals
Industrial	1.3%	0.9%	12.2%	2.7%	13.6%	26.3%	31.3%	4.8%	6.4%	97.3%	0.2%	2.7%	61.5%
Commercial	1.3%	0.5%	5.7%	0.0%	0.5%	2.4%	1.7%	0.5%	1.1%	1.0%	0.0%	0.0%	0.3%
Residential	10.7%	0.6%	17.5%	0.0%	8.4%	21.0%	2.3%	5.6%	16.8%	0.7%	0.0%	4.4%	0.3%
Agriculture	66.0%	0.0%	0.1%	0.0%	5.4%	24.5%	1.8%	0.1%	0.1%	0.0%	0.0%	0.5%	0.0%
On-Road	12.7%	67.1%	58.7%	88.8%	62.5%	20.5%	59.1%	10.9%	33.1%	0.2%	99.8%	91.9%	0.1%
Non-Road	7.9%	30.9%	5.9%	8.5%	9.7%	5.2%	3.7%	78.2%	42.5%	0.8%	0.0%	0.5%	37.9%

Figure 4-3: Transboundary Emissions Distribution by Sector Classification (%)

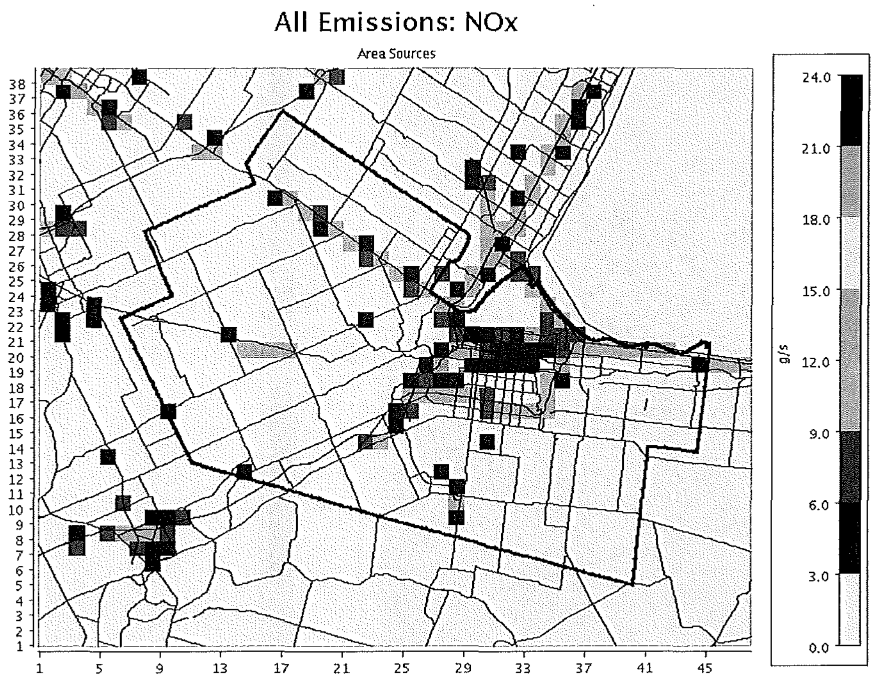


Figure 4-4: Geographical Distribution of Area Sources for Tier IV NOx Emissions (g/s)

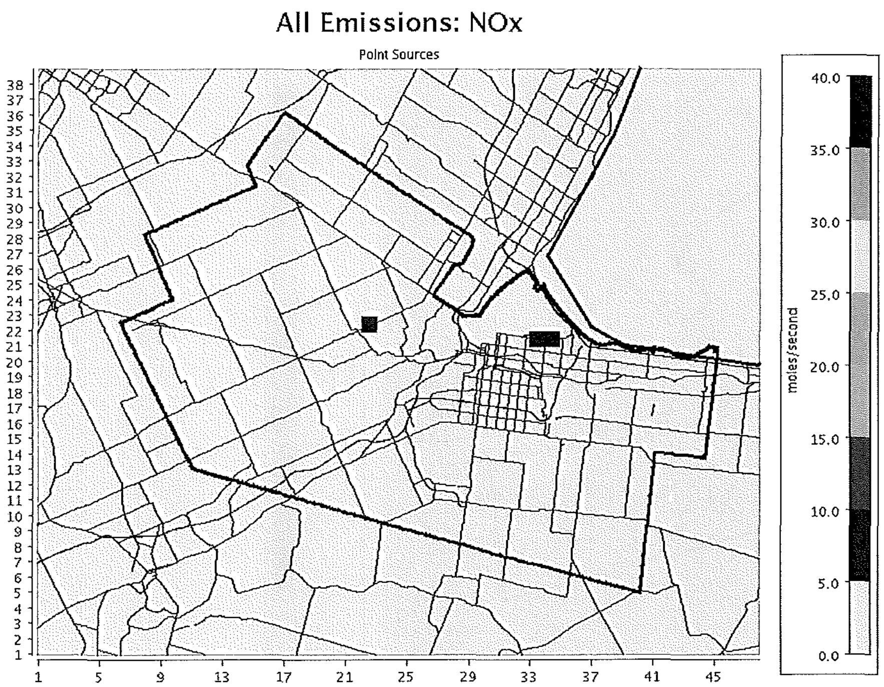


Figure 4-5: Geographical Distribution of Point Sources for Tier IV NOx Emissions (g/s)

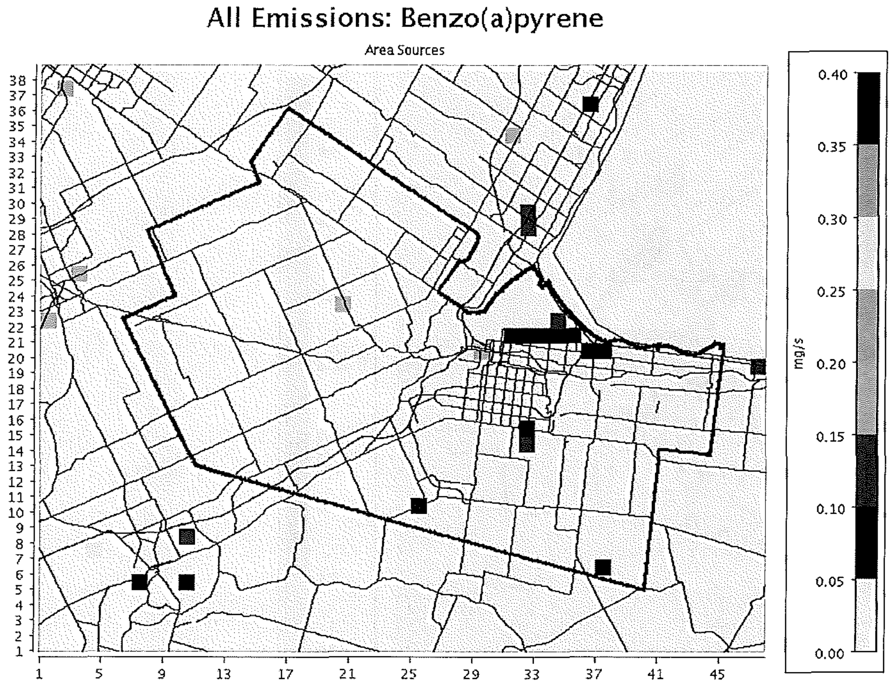


Figure 4-6: Geographical Distribution of Area Sources for Tier IV B(a)P Emissions (ng/s)

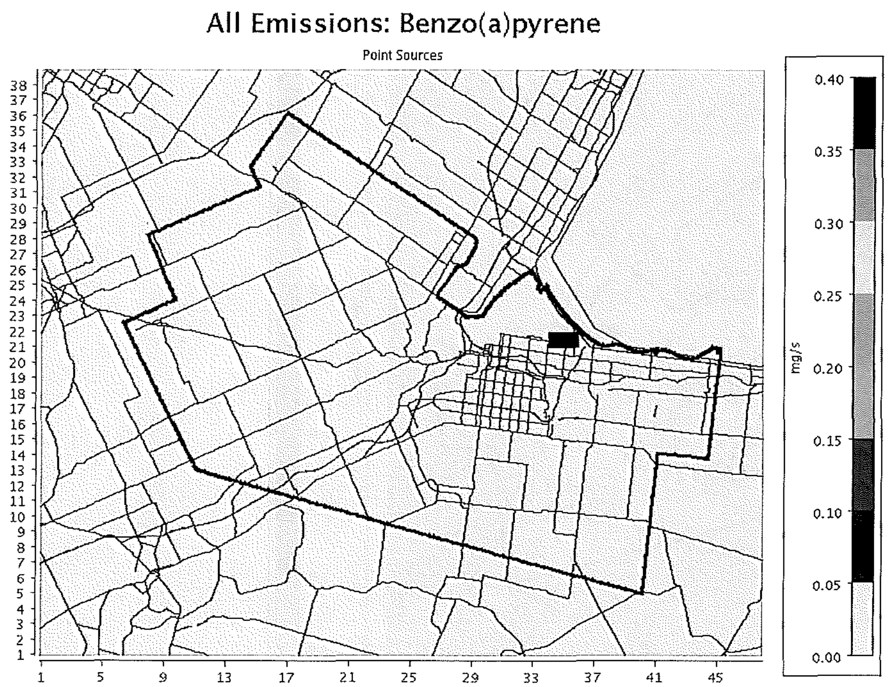


Figure 4-7: Geographical Distribution of Point Sources for Tier IV B(a)P Emissions (ng/s)

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5.0 AIR QUALITY MODELLING PERFORMANCE RESULTS

Model Performance Evaluation (MPE) is the process of testing a model's ability to accurately estimate observed atmospheric properties over a range of meteorological and geophysical conditions. The purpose of the MPE is to demonstrate whether the HAMS performs with sufficient reliability to justify its use in tracing the sources influencing the airshed, determining potential health impacts, and developing emissions control strategies, among others (APPENDIX C). In the absence of Canadian guidance on MPEs, the EPA recommendations on what should be reported in a MPE are used as guidance. The following provides a summary of the guidance:

- The mean bias (MB), mean error or root mean square error (ME or RMSE), normalized mean bias (NMB) and/ or fractional bias (FB), normalized mean error (NME) and/or fractional error (FE) of observed-predicted values of air pollutants are estimated.
- Model evaluation statistics are calculated for the highest temporal resolution available, as well as the regulatory averaging times.
- Processing steps for the MPE, including how the predicted and observed data were paired and whether data are spatially/temporally averaged before the statistics are calculated.
- Modelled values are taken from the grid cell that contains the monitoring site.
- Both spatial displays and time series at monitoring sites are considered in the MPE.

The U.S. Regional Planning Organizations (RPOs) have established model performance goals and criteria for $PM_{2.5}$, PM_{10} and components of fine particle mass based on previous model performance for ozone and fine particles (e.g., Boylan and Russell, 2006; Morris et al., 2004a,b; 2009). Table 5-1 summarizes the model performance goals and criteria developed by the RPOs for particulate matter (PM) to assist in interpreting the evaluating regional model performance for PM species.

Table 5-1: Model Performance Goals and Criteria for 24-Hour PM.

Fractional Bias (FB)	Fractional Error (FE)	Comment
≤±30%	≤50%	Goal for PM model performance, considered good performance
≤±60%	≤75%	Criteria for PM model performance, considered average performance

Existing air quality in Hamilton has been monitored over the last number of years. The current monitoring network includes regulatory stations (i.e., MOECC, Environment Canada) as well as the Hamilton Air Monitoring Network (HAMN) as shown on Figure 5-1 and Figure 5-2. Table 5-2 presents the list of monitoring stations and relevant compounds of interest which were used for the MPE. The monitoring stations collect additional parameters but were not used in the MPE.

Table 5-2: List of Air Monitoring Stations and Compounds of Interest in Hamilton During 2012

Station Information			Compounds of Interest						
Station Name	Station ID	Owner	SO_2	NO_2	O_3	$PM_{2.5}$	PM_{10}	Benzene	B(a)P
Brantford	61402	MOECC		✓	✓	✓			
Burlington	63001	MOECC		✓	✓	✓			
Hamilton Downtown	60512	MOECC	✓	✓	✓	✓		✓	✓
Hamilton Mountain	60513	MOECC	✓	✓	✓	✓			
Gertrude / Depew	STN29113	HAMN					✓	✓	✓
STN29153	STN29153	HAMN					✓		
STN29154	STN29154	HAMN					✓		
STN29168	STN29168	HAMN					✓		
STN29170	STN29170	HAMN					✓		
STN29565	STN29565	HAMN					✓		
Niagara / Land	STN29567	HAMN	✓	✓			✓		✓
Pier 25	STN29547	HAMN							✓
Beach Strip	STN29102	HAMN						✓	

LEGEND

Monitoring Stations

Municipal Boundary

Station Name	Station ID
Brantford	61402
Burlington	63001
Hamilton Downtown	60512
Hamilton Mountain	60513
Gertrude / Depew	STN29113
STN29153	STN29153
STN29154	STN29154
STN29168	STN29168
STN29170	STN29170
STN29565	STN29565
Niagara / Land	STN29567
Pier 25	STN29547
Beach Strip	STN29102

0 5,000 10,000
1:150,000 Metres

REFERENCE(S)
1. BASEDATA - MNRF LIO, OBTAINED 2017
2. IMAGERY - EARTHSTAR GEOGRAPHICS SIO © 2018 MICROSOFT CORPORATION
3. COORDINATE SYSTEM - NAD 1983 UTM ZONE 17N PROJECTION: TRANSVERSE MERCATOR DATUM: NORTH AMERICAN 1983

CLIENT
HAMILTON INDUSTRIAL ENVIRONMENTAL ASSOCIATION

PROJECT
ADDITIONAL EFFORT TRACKING

TITLE
MONITORING STATION LOCATIONS

CONSULTANT
Golder Associates

YYYY-MM-DD	2018-01-08
DESIGNED	RA
PREPARED	RA
REVIEWED	JK
APPROVED	JLK

PROJECT NO.	CONTROL	REV.	FIGURE
1418883 (9999)	0005	A.	5-1

LEGEND

Monitoring Stations

Municipal Boundary

Station Name	Station ID
Brantford	61402
Burlington	63001
Hamilton Downtown	60512
Hamilton Mountain	60513
Gertrude / Depew	STN29113
STN29153	STN29153
STN29154	STN29154
STN29168	STN29168
STN29170	STN29170
STN29565	STN29565
Niagara / Land	STN29567
Pier 25	STN29547
Beach Strip	STN29102

0 1,000 2,000
1:40,000 Metres

REFERENCE(S)
1. BASEDATA - MNRF LIO, OBTAINED 2017
2. IMAGERY - EARTHSTAR GEOGRAPHICS SIO © 2018 MICROSOFT CORPORATION
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CLIENT
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YYYY-MM-DD	2018-01-08
DESIGNED	RA
PREPARED	RA
REVIEWED	JK
APPROVED	JLK

PROJECT NO.	CONTROL	REV.	FIGURE
1418883 (9999)	0005	A.	5-2

SUMMARY OF AIR QUALITY IN HAMILTON

A summary of the HAMS performance statistics are presented in Table 5-3. The modelling system provides generally reasonable results given the complexity of the model and inputs. CMAQ tends to over-predict concentrations with the exception PM_{10} where the model under-predicts based on the mean bias (MB). Model results are within a factor of two for all compounds (i.e., a FB ≤ 67%). The modelling system meets the criteria for $PM_{2.5}$ and PM_{10} model performance. The lack of a large body of observational data may contribute to the poor metrics for benzene. The paired observed and predicted quantile-quantile plots for PM, ozone, SO_2, NO_2, benzene and B(a)P are provided on Figure 5-3 to Figure 5-9.

Time series analysis of observed versus modelled results for the compounds are shown on Figure 5-10 and Figure 5-11. The results show that the model results follow the observed result but tend to over-predict during the winter season. The over-prediction of the NO_2 is evident throughout the year and is consistent at approximately 10 ppb, which suggest that transboundary emissions are influencing the results. There is a tendency to over-predict in the winter for the other compounds, with the exception of ozone which is under-predicted. There is sparse observed data available with respect to benzene and B(a)P (due to the sampling schedule) to make any reliable statement.

The under-prediction of PM_{10} is likely due to unaccounted local sources generating fugitive dust. These sources are likely track-out from the industrial sources, road construction activities and other local construction which are very short duration and have not been quantified. The PM_{10} from these sources includes a coarse size fraction which tends to contribute very locally. From the time-series analysis, the over-prediction occurs during the summer months when fugitive dust generation is highest from construction activities and drier weather.

Table 5-3: Summary of 2012 Tier IV Performance Statistics for All Tier IV Monitoring Stations

		Statistics							
Compound	**Units**	**Observed Mean**	**Model Mean**	**MB**	**RMSE**	**NMB**	**NME**	**FB**	**FE**
$PM_{2.5}$	µg/m³	6.7	10.2	3.47	7.21	51.4%	78.9%	36.2%	64.3%
PM_{10}	µg/m³	23.5	15.4	-8.11	17.68	-34.5%	51.6%	-41.6%	63.5%
O_3	ppb	27.4	23.8	-3.61	12.45	-13.2%	36.9%	-29.2%	50.3%
SO_2	ppb	4.5	6.9	2.32	7.08	51.1%	110.8%	53.5%	89.2%
NO_2	ppb	10.3	20.4	10.14	13.65	98.4%	110.3%	67.1%	77.0%
Benzene	µg/m³	1.73	2.46	0.73	4.92	42.4%	118.9%	57.0%	90.1%
B(a)P	ng/m³	1.23	2.21	0.98	2.90	79.7%	170.4%	59.1%	122.5%
Performance Goal for PM								**≤ ±30%**	**≤ 50%**
Performance Criteria for PM								**≤ ±60%**	**≤ 75%**

SUMMARY OF AIR QUALITY IN HAMILTON

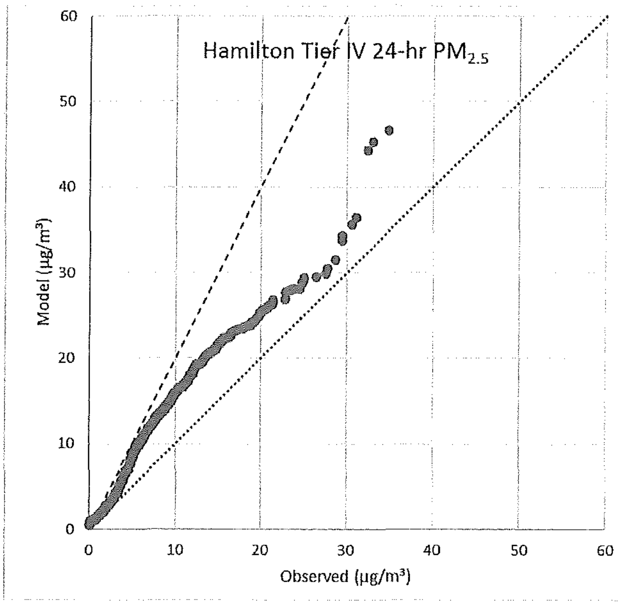

Figure 5-3: Unpaired Comparison of Model vs Observed $PM_{2.5}$ at Hamilton Tier IV Monitoring Stations

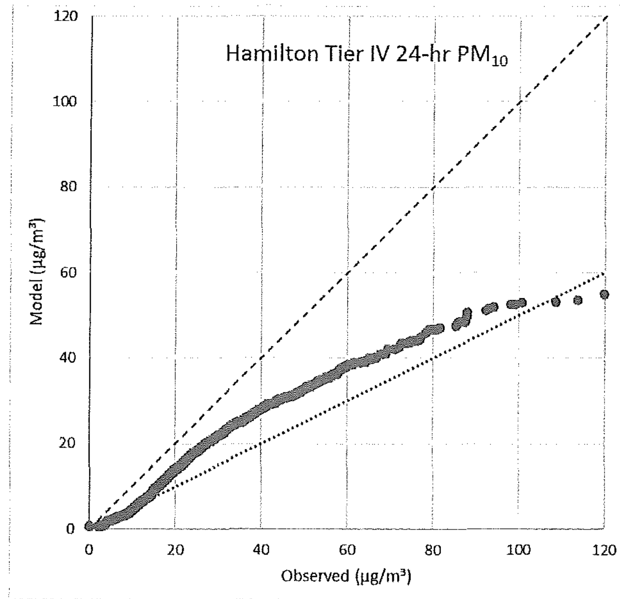

Figure 5-4: Unpaired Comparison of Model vs Observed PM_{10} at Hamilton Tier IV Monitoring Stations

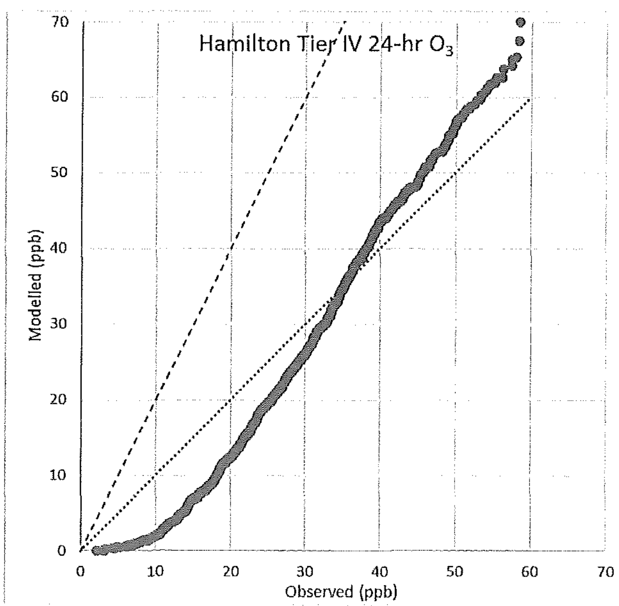

Figure 5-5: Unpaired Comparison of Model vs Observed O_3 at Hamilton Tier IV Monitoring Stations

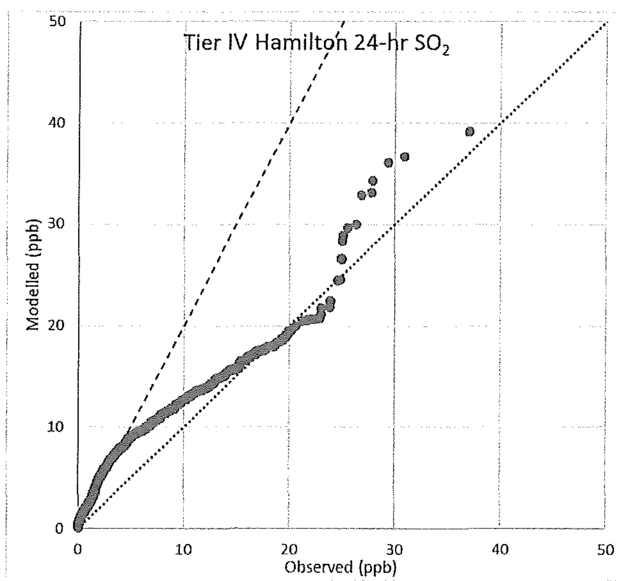

Figure 5-6: Unpaired Comparison of Model vs Observed SO_2 at Hamilton Tier IV Monitoring Stations

SUMMARY OF AIR QUALITY IN HAMILTON

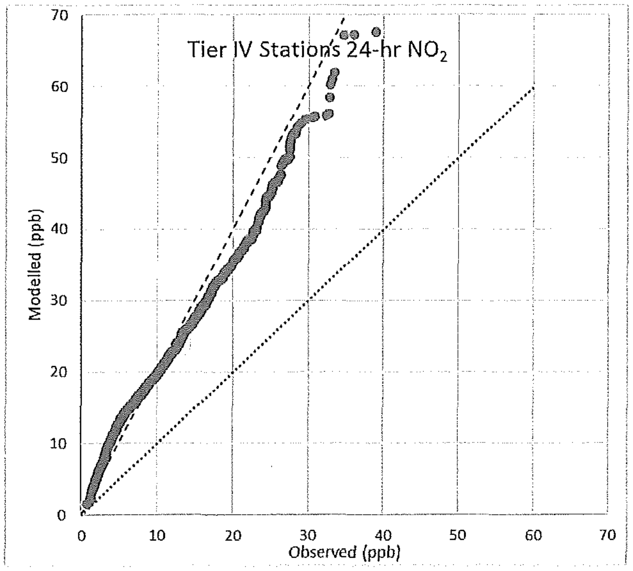

Figure 5-7: Unpaired Comparison of Model vs Observed NO_2 at Hamilton Tier IV Monitoring Stations

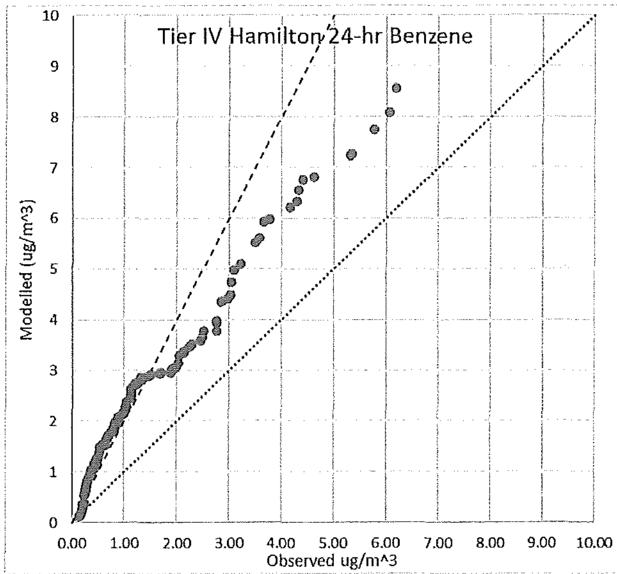

Figure 5-8: Unpaired Comparison of Model vs Observed Benzene at Hamilton Tier IV Monitoring Stations

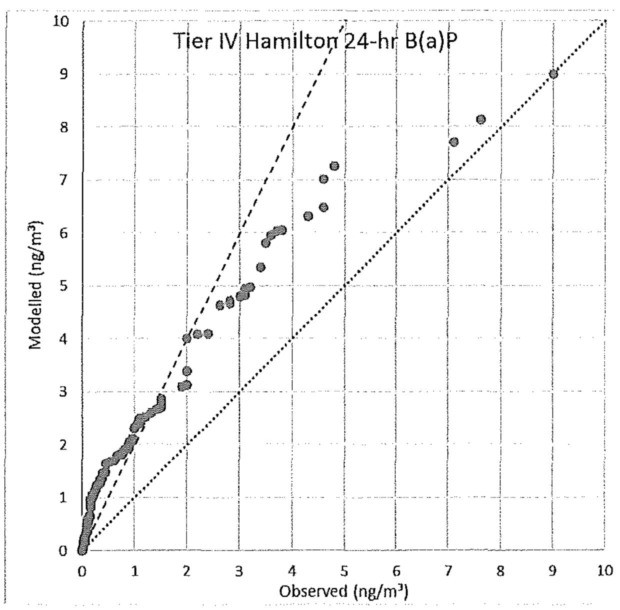

Figure 5-9: Unpaired Comparison of Model vs Observed Benzo(a)pyrene at Hamilton Tier IV Monitoring Stations

SUMMARY OF AIR QUALITY IN HAMILTON

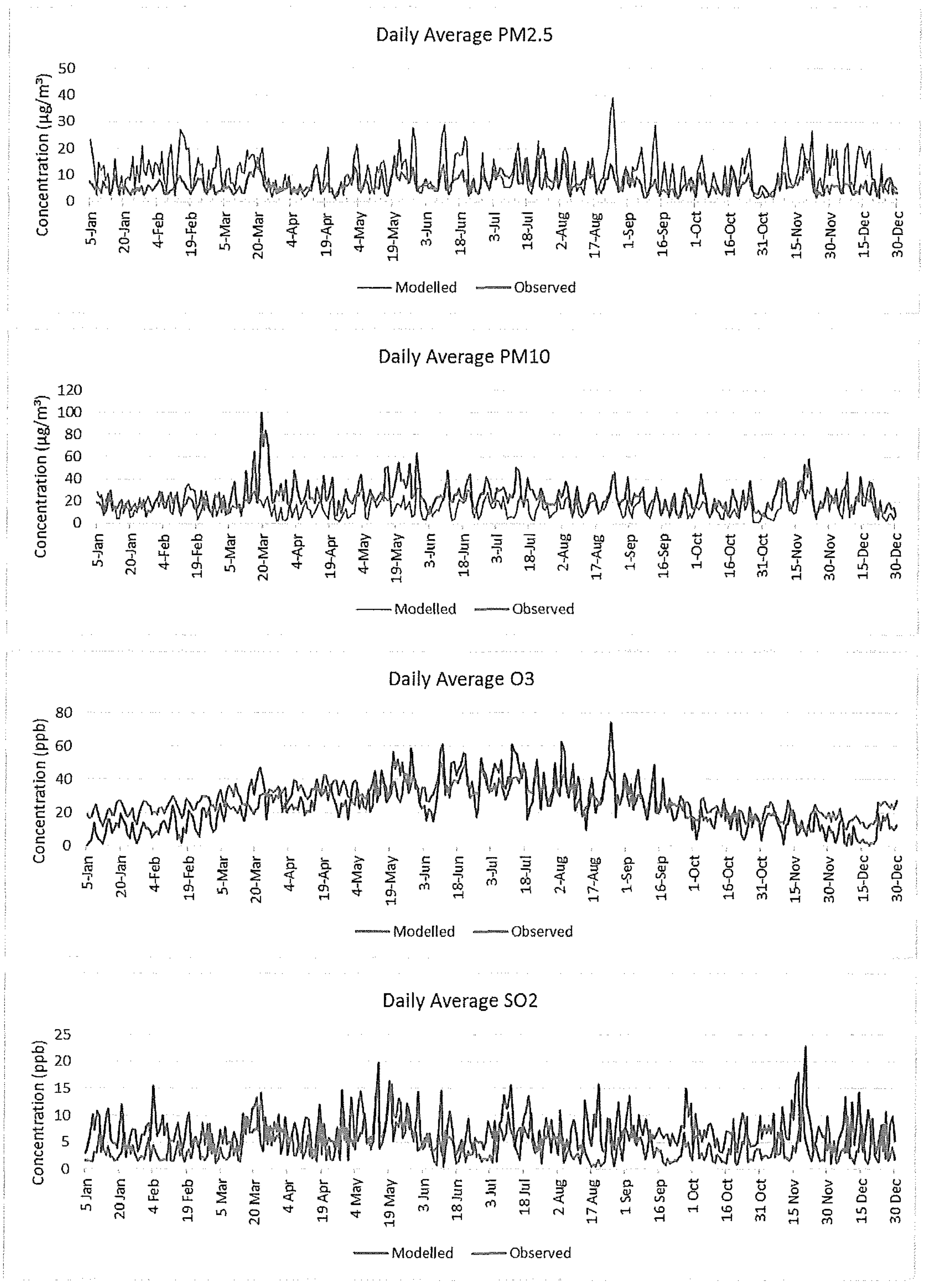

Figure 5-10: Time Series of Modelled vs Observed Daily Average $PM_{2.5}$, PM_{10}, O_3 and SO_2

SUMMARY OF AIR QUALITY IN HAMILTON

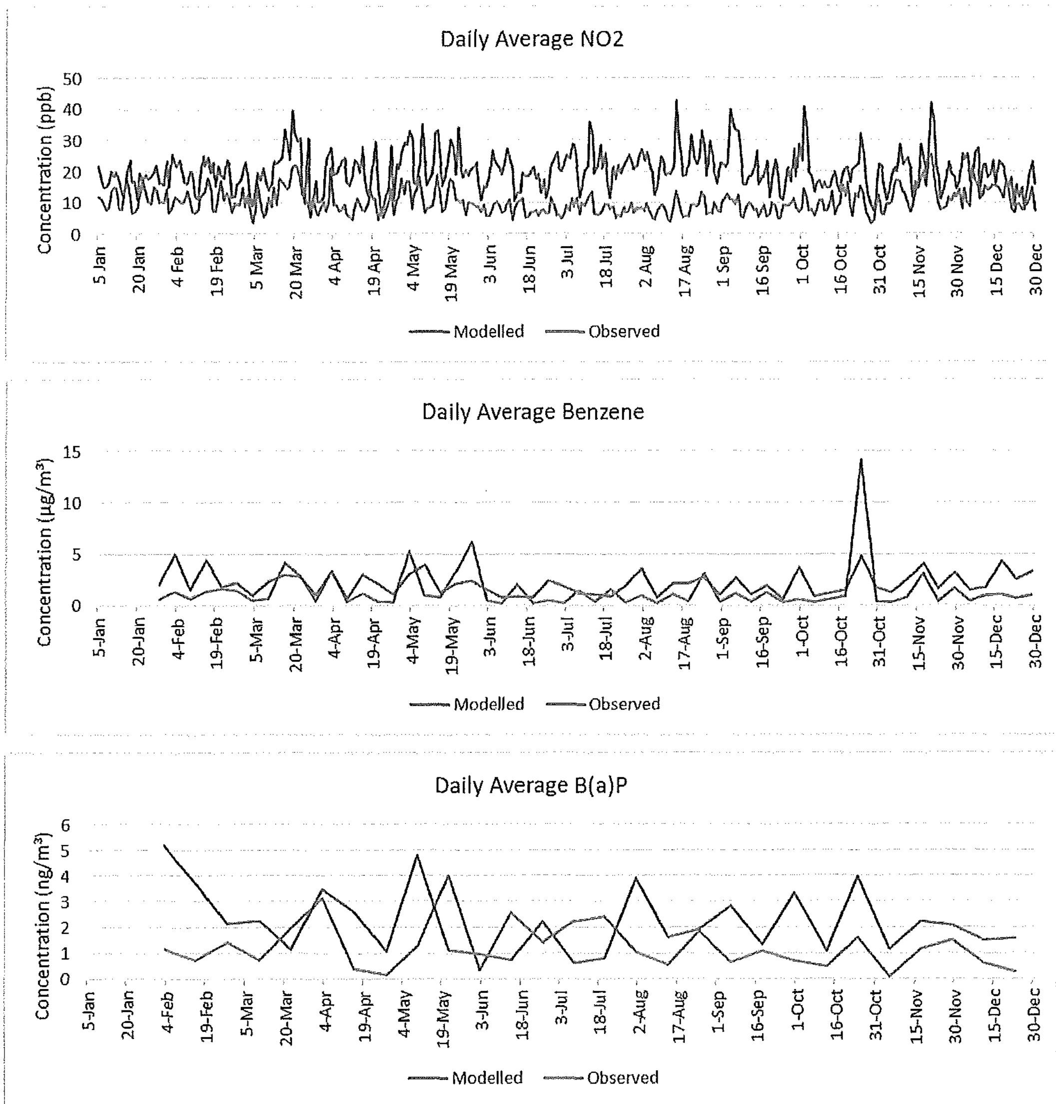

Figure 5-11: Time Series of Modelled vs Observed Daily Average NO_2, Benzene and Benzo(a)pyrene Concentrations

6.0 MODEL AND SOURCE APPORTIONMENT RESULTS

A summary of the 2012 HAMS Tier IV maximum daily and annual average for twenty (20) compounds of interest are provided in Table 6-1. The daily value is derived from hourly values at a specific grid square and compared to other daily values to determine the maximum overall concentration. The annual average is derived from the average of daily values over an entire year. The difference between the maximum daily values and the annual average indicates that the region experiences high magnitude events but the average conditions are much lower, by at least an order of magnitude.

Table 6-1: Maximum Daily and Annual Average Compound Concentration in 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/m³	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/m³	10	100
Particulate Matter less than 2.5 µm in diameter	$PM_{2.5}$	µg/m³	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/m³	0.0024	0.10
Cadmium	Cd	µg/m³	0.0031	0.10
Chromium (III)	Cr(III)	µg/m³	0.00015	0.016
Chromium (VI)	Cr(VI)	µg/m³	0.000039	0.0082
Nickel	Ni	µg/m³	0.00028	0.012
Mercury	Hg	ppb	0.00026	0.0063
Manganese	Mn	µg/m³	0.00093	0.080

Notes: All values have been rounded to two significant digits

The source apportionment simulations were carried out for one month of each season for 2012 as well as for an ensemble average of all four months to represent a year for the Tier IV domain. The Tier III domain results were used for initial conditions and a minimum of a five day spin up time was used for each simulation. These source apportionment model simulations were used to assess the relative importance of specific source sectors on $PM_{2.5}$, PM_{10}, O_3, SO_2, NO_2, benzene and B(a)P concentrations in Hamilton.

6.1 Source Apportionment Approach

The "base case" model simulation includes all 2012 emissions sources driven by the 2012 meteorological data for all tiers, including Tier IV, and these results were used in the MPE discussed above. Subsequently the emissions from a selected source group are eliminated, known as the "zero-out" approach. The importance of that source is assessed by evaluating the change in ambient air quality as the difference (absolute and percentage) in compound concentration between the base case (with the source group) minus the scenario without the source group. This is referred to as a "brute force" approach.

6.1.1 *Zero-Out Source Apportionment Simulations*

The following zero-out simulations were carried out to evaluate the contribution to the air quality compounds of interest:

1. On-road mobile sources (Scenario 1): For this simulation, all on-road mobile source emissions within Tier IV were eliminated (i.e., zeroed-out). All other sources throughout the modelling domain, including Tier IV industrial, non-road, biogenic/agricultural and commercial / residential in all regions, were kept at 2012 base case levels. The Tier IV on-road mobile source contributions are presented in Figure 4-2 for the compounds of interest.

2. Industrial sources (Scenario 2): All industrial stationary source emissions within Tier IV were zeroed-out. All other sources throughout the modelling domain were kept at 2012 base case levels. The Tier IV industrial source contributions are presented in Figure 4-2 for the compounds of interest.

3. Non-road mobile sources (Scenario 3): All non-road mobile source (rail, airport and marine) emissions within Tier IV were zeroed-out. All other sources throughout the modelling domain were kept at 2012 base case levels. The Tier IV non-road source contributions are presented in Figure 4-2 for the compounds of interest.

4. Transboundary only (Scenario 4): All sources emissions within Tier IV were zeroed-out. All other sources throughout the modelling domain were kept at 2012 base case levels. The Tier IV source contributions are presented in Figure 4-2 for the compounds of interest.

In the following sections, contributions will be presented for On-Road (Scenario 1), Industrial (Scenario 2), Non-road (Scenario 3), Transboundary (Scenario 4) and Other. The Other category is composed of the remaining emission sources, namely commercial, residential, and biogenic/agriculture. These sources are not anticipated to have a large impact on the air quality compounds of interest.

6.2 $PM_{2.5}$ Concentrations

Aerial plots of the maximum daily and annual average for $PM_{2.5}$ are shown on Figure 6-1 and Figure 6-2, respectively. The $PM_{2.5}$ levels show distinctly different spatial patterns with maximum levels occurring west of the industrial corridor, near the intersection of Hwy 403 and Hwy 8. The annual average plot shows a similar plot around the end of Lake Ontario in Hamilton.

Maximum daily averages can be above 45 $\mu g/m^3$ over the region on any day. The sharp gradient in concentrations around Hamilton Harbour is reflective of the transportation and industrial activity in the area. The annual average in the region is about 9 $\mu g/m^3$ with exception around the industrial corridor where the level can be higher (i.e., 20 $\mu g/m^3$). As the MPE for $PM_{2.5}$ achieved the objective but over-predicted slightly, the results are conservative and credible.

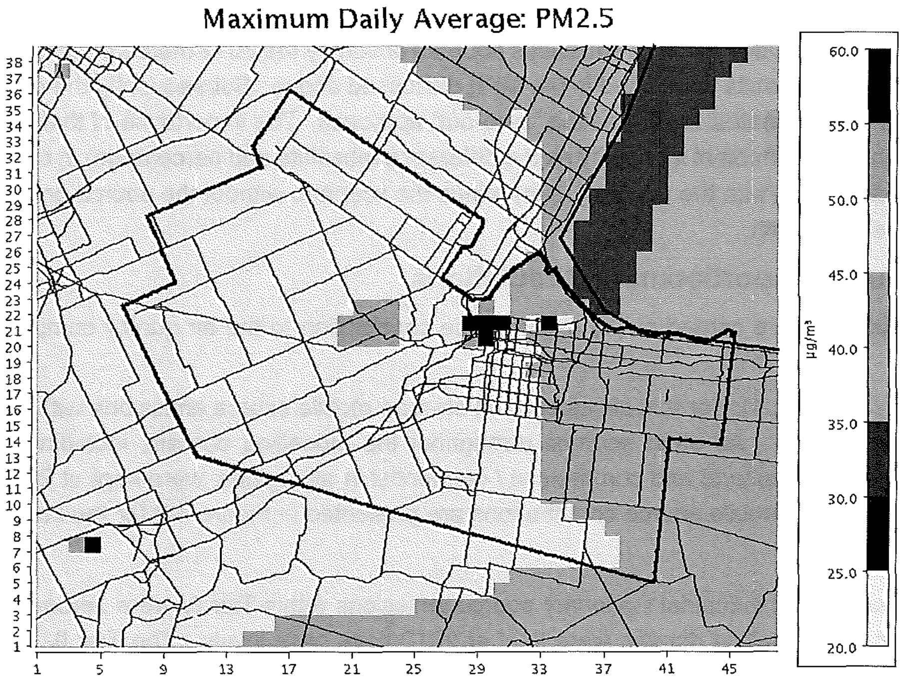

Figure 6-1: Maximum Daily $PM_{2.5}$ Concentration over Tier IV Hamilton

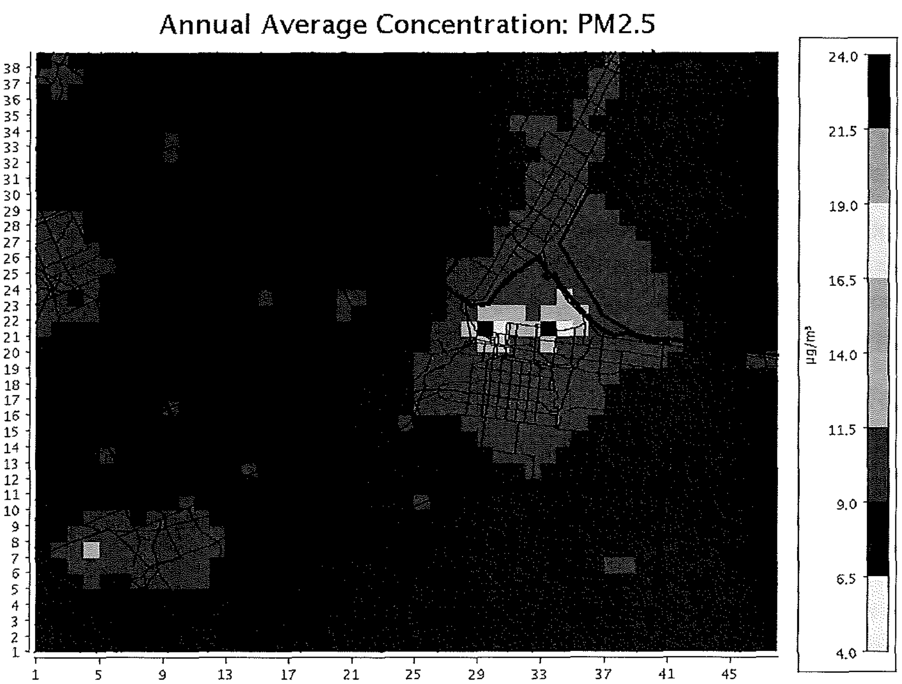

Figure 6-2: Annual Average $PM_{2.5}$ Concentration over Tier IV Hamilton

6.2.1 Source Apportionment of $PM_{2.5}$

Contributions from the five scenarios are quantified as the difference of concentrations from the base simulation and corresponding zero-out simulations. Absolute and relative (%) contributions from each source sector are analysed and reported in Table 6-2 and Figure 6-3 by specific month. Transboundary levels based on emissions outside of the Tier IV domain dominate the regional $PM_{2.5}$ levels in Hamilton. From Figure 4-3, transboundary $PM_{2.5}$ levels are primarily from transportation (on-road and non-road) related emissions representing about 75% of the $PM_{2.5}$ transboundary emissions. Maximum domain average levels occur during the winter season (December) which is also the highest transboundary contribution. Local industrial sources contribute a maximum of 7% to levels during the spring (April) while local transportation sources (on-road and non-road) contribute about 2% to $PM_{2.5}$ levels, annually.

Table 6-2: Tier IV Domain Averaged Source Percent Contribution By Month - $PM_{2.5}$

Source	April	July	October	December	Annual
Industrial	7%	6%	6%	4%	6%
On-Road	2%	1%	2%	2%	1%
Non-Road	2%	2%	2%	1%	1%
Transboundary	88%	91%	90%	93%	91%
Other	0.6%	0.5%	0.6%	0.2%	0.4%
Concentration (µg/m³)	**4.59**	**7.69**	**6.32**	**9.49**	**7.02**

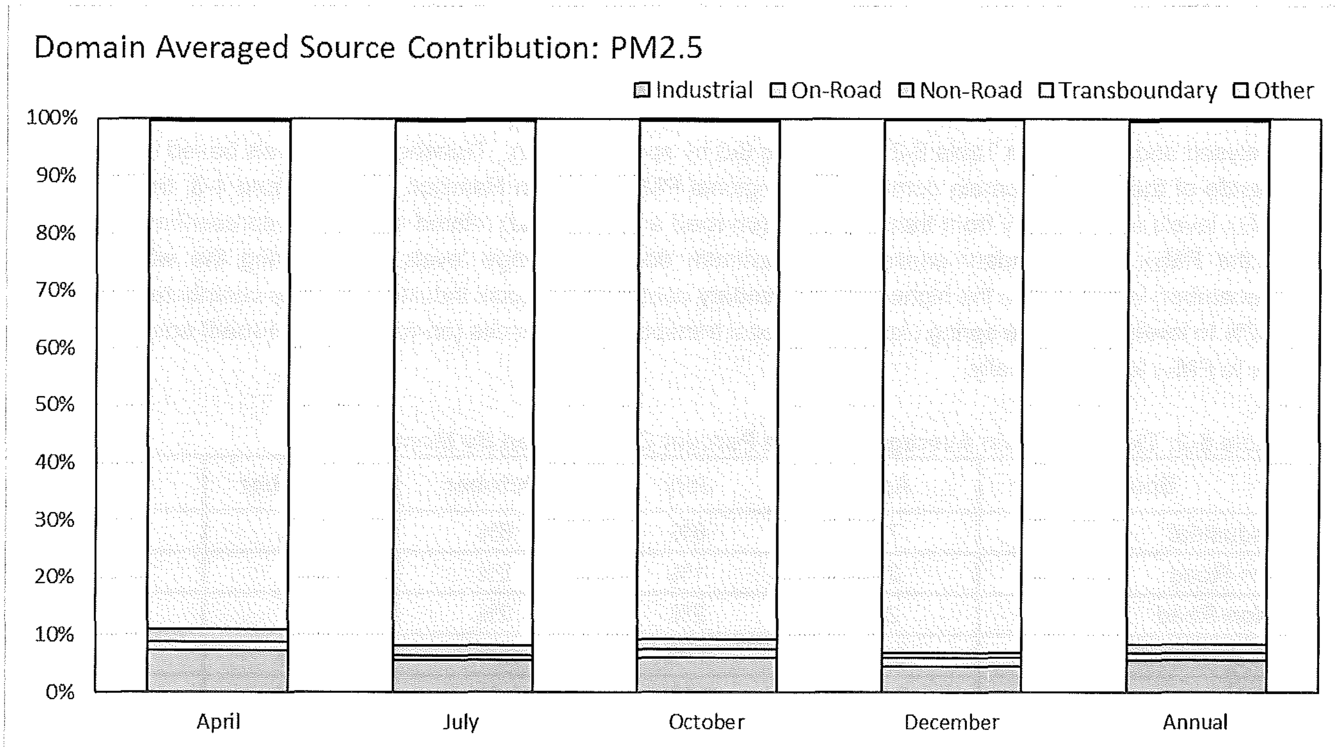

Figure 6-3: Domain Average Source Contribution by Month: $PM_{2.5}$

6.3 PM_{10} Concentrations

The geographical distribution of the maximum daily and annual average PM_{10} levels is presented on Figure 6-4 and Figure 6-5, respectively. Similar to the $PM_{2.5}$ concentrations, the maximum PM_{10} concentrations are found along the industrial corridor with sharply declining gradients to the north and south of corridor. The maximum PM_{10} concentration again occurs at the intersection of the two main roadways. Maximum daily PM_{10} levels can reach up to 100 µg/m³ but the annual average is generally less than 13 µg/m³ except along the industrial corridor which can be higher (i.e. 65 µg/m³). As expected PM_{10} concentrations are greater than the $PM_{2.5}$ levels.

PM_{10} levels were shown to be under-predicted but the monitoring stations are located close to the industrial corridor and do not include fugitive emissions. The results outside of the industrial area are likely acceptable and credible.

SUMMARY OF AIR QUALITY IN HAMILTON

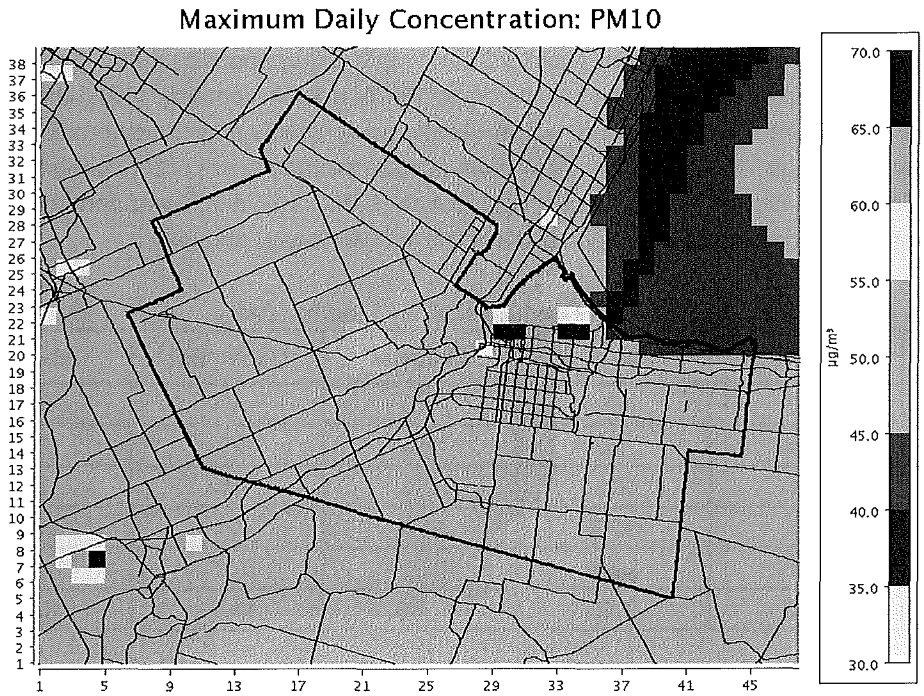

Figure 6-4: Maximum Daily PM_{10} Concentration over Tier IV Hamilton

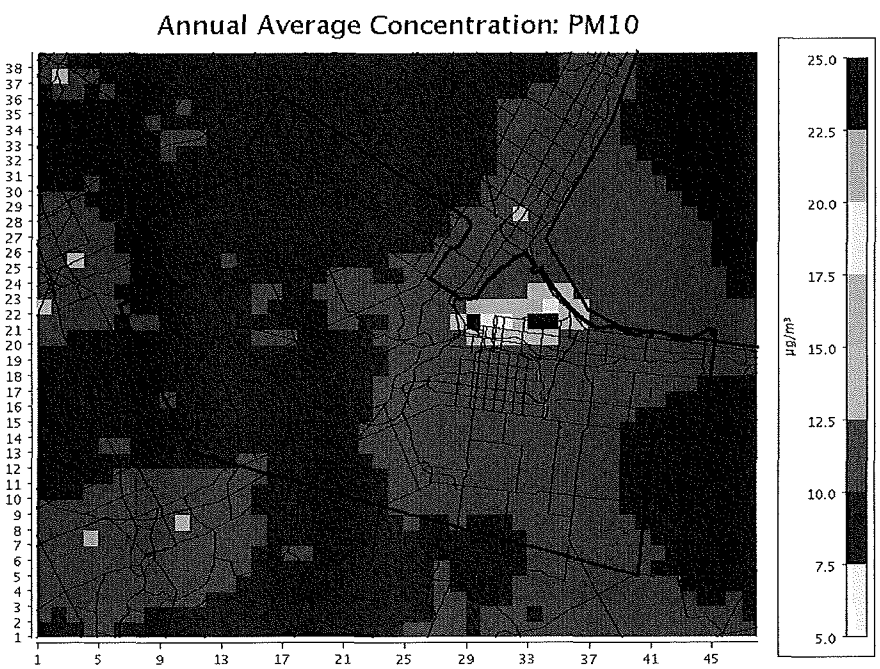

Figure 6-5: Annual Average PM_{10} Concentration over Tier IV Hamilton

6.3.1 Source Apportionment of PM_{10}

Contributions from the five scenarios are presented on Table 6-3 and Figure 6-6 by specific month. Similar to the $PM_{2.5}$ profile, transboundary levels based on emissions outside of the Tier IV domain dominate (90%) the regional PM_{10} levels in Hamilton. From Figure 4-3, transboundary PM_{10} levels are primarily from transportation related emissions representing over 90% of the PM_{10} emissions. Maximum domain average levels occur during the winter season (December) which is also the highest transboundary contribution (92%). Industrial levels contribute 8% to levels during the spring (April). On-road sources contribute about 2% to PM_{10} levels, annually.

Table 6-3: Tier IV Domain Averaged Source Percent Contribution By Month – PM_{10}

Source	April	July	October	December	Annual
Industrial	8%	6%	6%	5%	6%
On-Road	2%	1%	2%	2%	2%
Non-Road	2%	2%	2%	1%	1%
Transboundary	88%	90%	90%	92%	90%
Other	0.6%	0.5%	0.5%	0.2%	0.4%
Concentration (µg/m³)	**5.35**	**8.46**	**7.48**	**11.11**	**8.10**

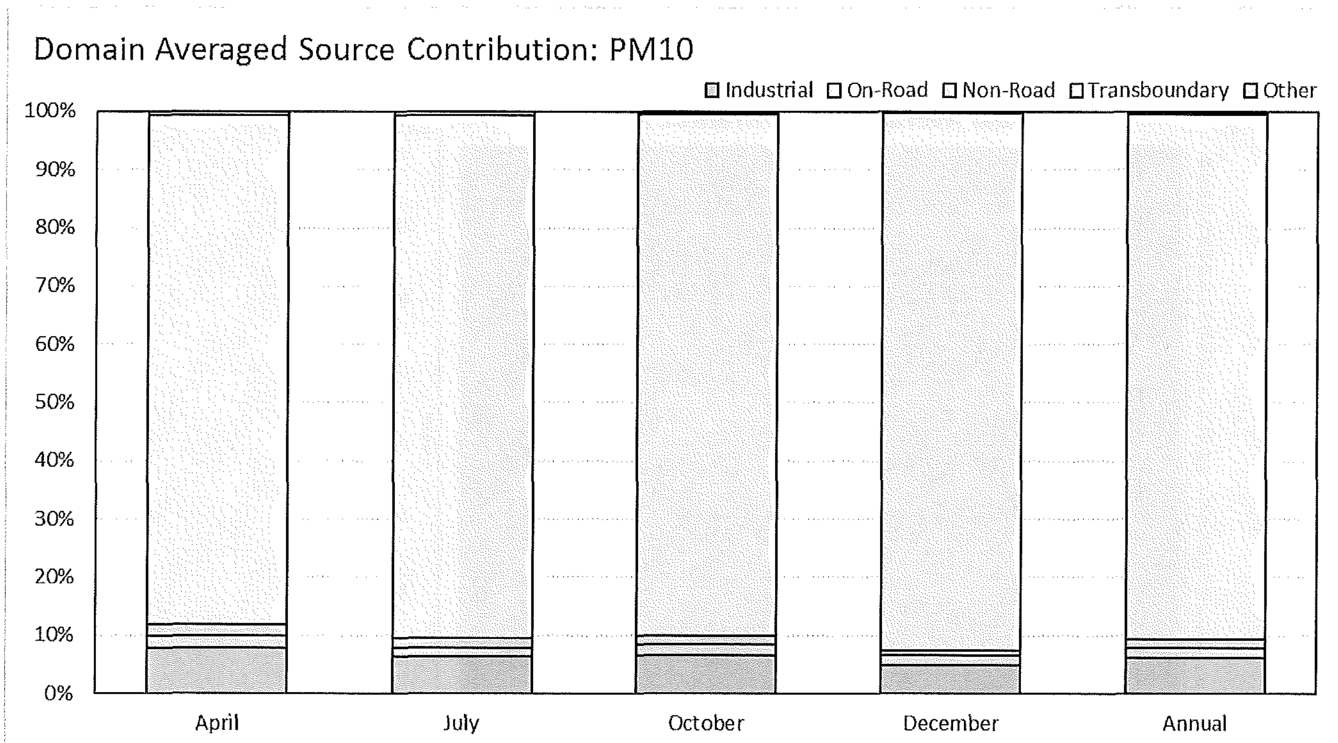

Figure 6-6: Domain Average Source Contribution by Month: PM_{10}

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6.4 Ozone Concentrations

Aerial plots of the maximum daily and annual average for O_3 are shown on Figure 6-7 and Figure 6-8, respectively. The O_3 levels show distinctly different spatial patterns from other compounds because of the reactivity and land-use. Highest daily levels occur over Lake Ontario because of the lack of ozone depletion over water and a depression of levels over the major roadways in the region. The major roadway patterns are distinctly shown on Figure 6-7. The annual average plot shows a similar plot around the end of Lake Ontario in Hamilton. The annual concentrations show an increasing gradient toward the southeast, approaching the USA.

Maximum daily averages range between 50 and 100 ppb over the region on any particular day. The annual average in the region ranges between 16 and 30 ppb.

The MPE analysis suggests that the model results are accurate and there is good confidence in the results.

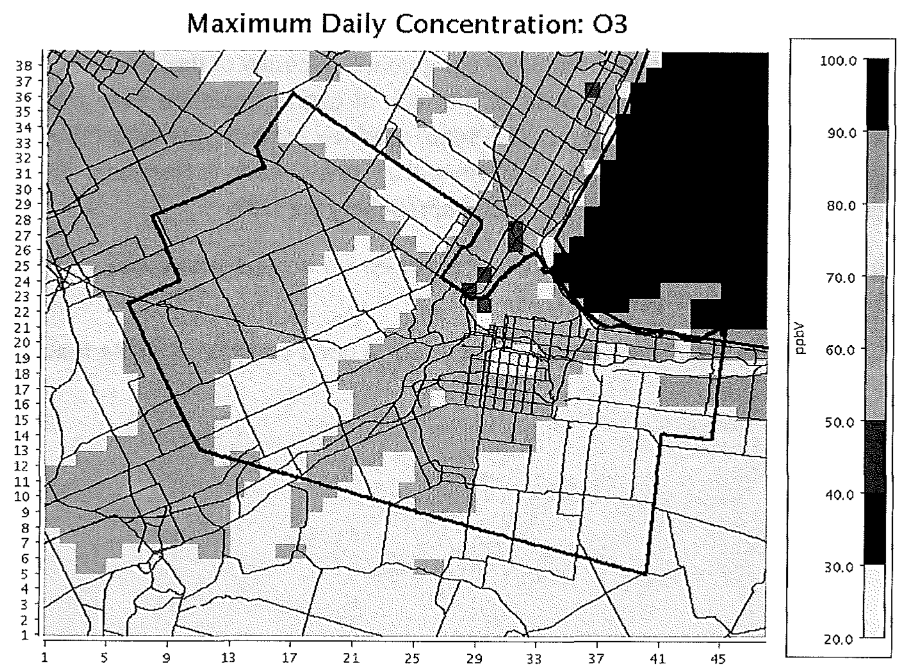

Figure 6-7: Maximum Daily O_3 Concentration over Tier IV Hamilton

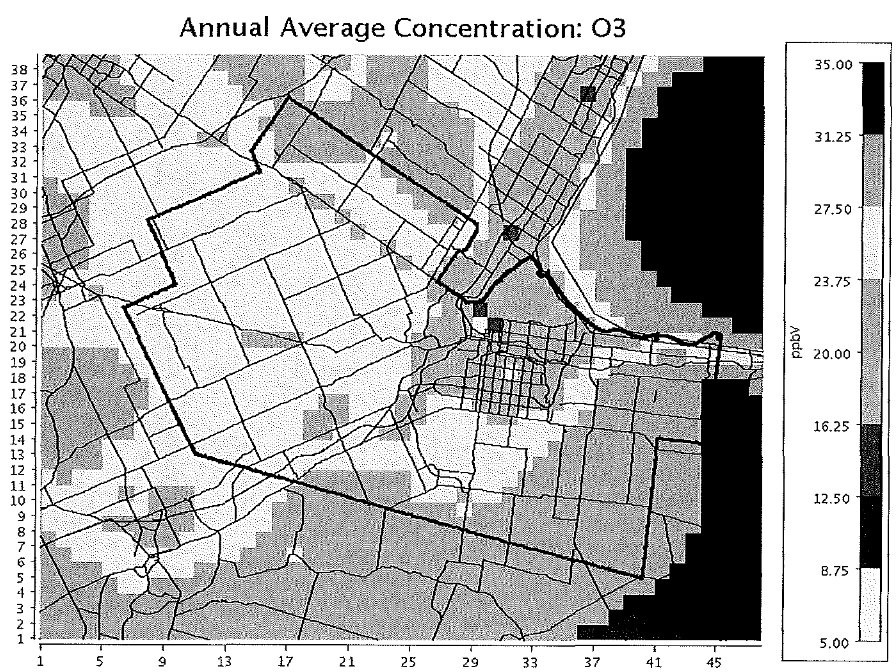

Figure 6-8: Annual Average O_3 Concentration over Tier IV Hamilton

6.4.1 Source Apportionment of Ozone

It is important to understand the chemistry regimes that impact the formation of ozone. The two major precursors for ozone are NO_X and VOCs, with the relationship between them driven by non-linear photochemistry. Despite the complex chemistry, the relationship can be divided into two different regimes: NO_X-limited and VOC-limited (Jacob, 1999). In the NO_X-limited regime the ozone production is limited by the supply of NO_X, so a change in the NO_X concentrations directly impacts the ozone production (e.g. an increase in NO_X results in an increase in ozone). In the VOC-limited regime the ozone production is limited by the supply of VOCs, however, ozone production is inversely proportional to NO_X. In this regime, changes in NO_X typically have much smaller impacts as the impact of VOCs is the limiting factor in the reaction. With the inverse relationship, it's important to note that an increase in NO_X results in a decrease in ozone, assuming the hydrocarbons remain relatively constant.

The source apportionment of ozone is heavily impacted by the changing concentrations of NO_X and VOCs in the different "zero out" simulations. For most of simulations considered, there is significant reduction in the amount of NO_X emissions present in Tier IV (boundary conditions remain constant). Averaged over the domain, this leads to an increase in ozone, resulting in a negative contribution. This would indicate that, on average, the domain is in a VOC-limited regime. However, this response is averaged over the domain of Tier IV, within different geographic regions the response could be different. The response of ozone and its source contribution needs to be further examined considering the chemistry regime present in the region of interest.

6.5 Sulphur Dioxide Concentrations

The geographical distribution of the maximum daily and annual average SO_2 levels is presented on Figure 6-9 and Figure 6-10 respectively. Similar to the particulate concentrations, the maximum concentrations are found along the industrial corridor with sharply decreasing gradients to the north and south of corridor. The maximum again occurs at the intersection of the two main roadways. Maximum daily levels range between 10 and 30 ppb but the annual average is generally less than 4 ppb except for the industrial corridor which can be higher (i.e. 24 ppb or greater).

MPE results for SO_2 indicate that the results are acceptable but there is tendency to over-predict especially during the winter season, so the results will be conservative.

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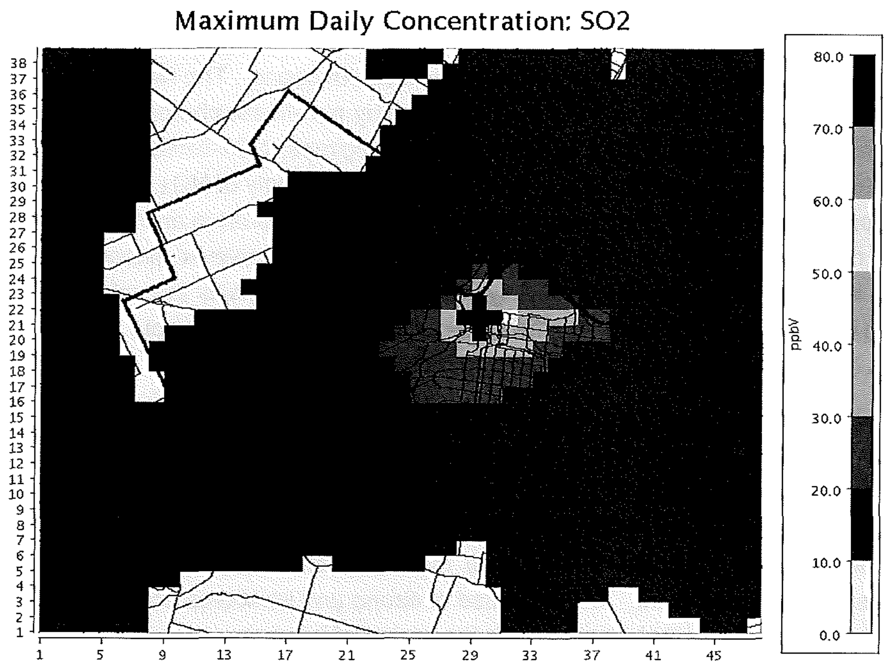

Figure 6-9: Maximum Daily SO_2 Concentration over Tier IV Hamilton

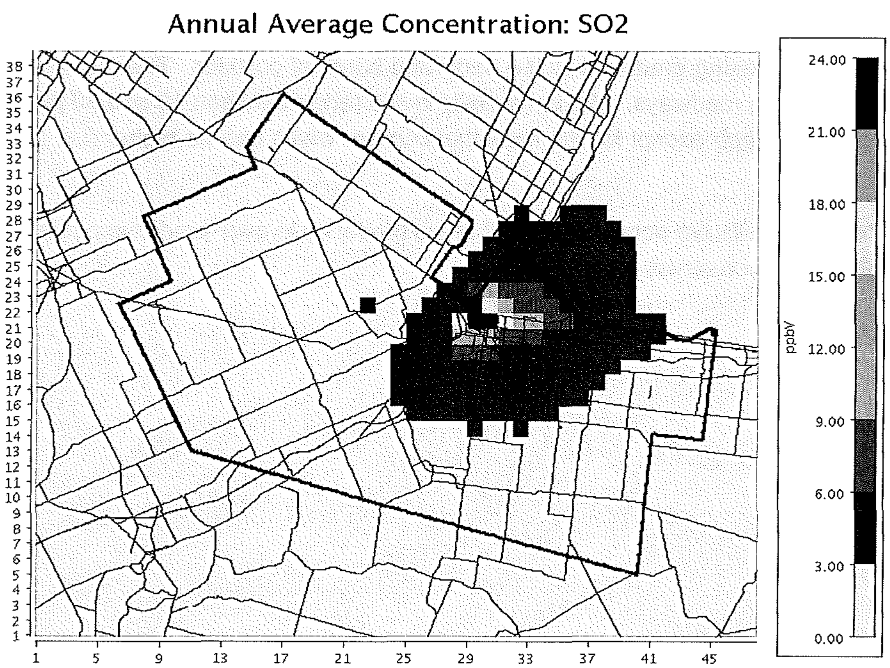

Figure 6-10: Annual Average SO_2 Concentration over Tier IV Hamilton

6.5.1 Source Apportionment of SO_2

The five source group contributions are analysed and reported in Table 6-4 and Figure 6-11 by specific month. For SO_2 there is more seasonal variability with the sector contributions. The local industrial (~31%) and non-road (~25%) contributions are greater during the summer (July) season than any of the other seasons. Maximum domain average levels occur during the fall season (October) which is also the highest transboundary contribution (77%). On-road sources contribute approximately 1% to SO_2 levels. Transboundary represents about 69% of the annual contribution to levels within Hamilton of which 97% are from industrial sources (Figure 4-3)

Table 6-4: Tier IV Domain Averaged Source Percent Contribution By Month – SO_2

Source	April	July	October	December	Annual
Industrial	18%	31%	12%	12%	17%
On-Road	1%	1%	0%	0%	1%
Non-Road	16%	25%	10%	11%	14%
Transboundary	65%	43%	77%	76%	69%
Other	0.0%	0%	0.4%	0.0%	0.1%
Concentration (ppb)	**1.96**	**1.48**	**2.83**	**2.76**	**2.26**

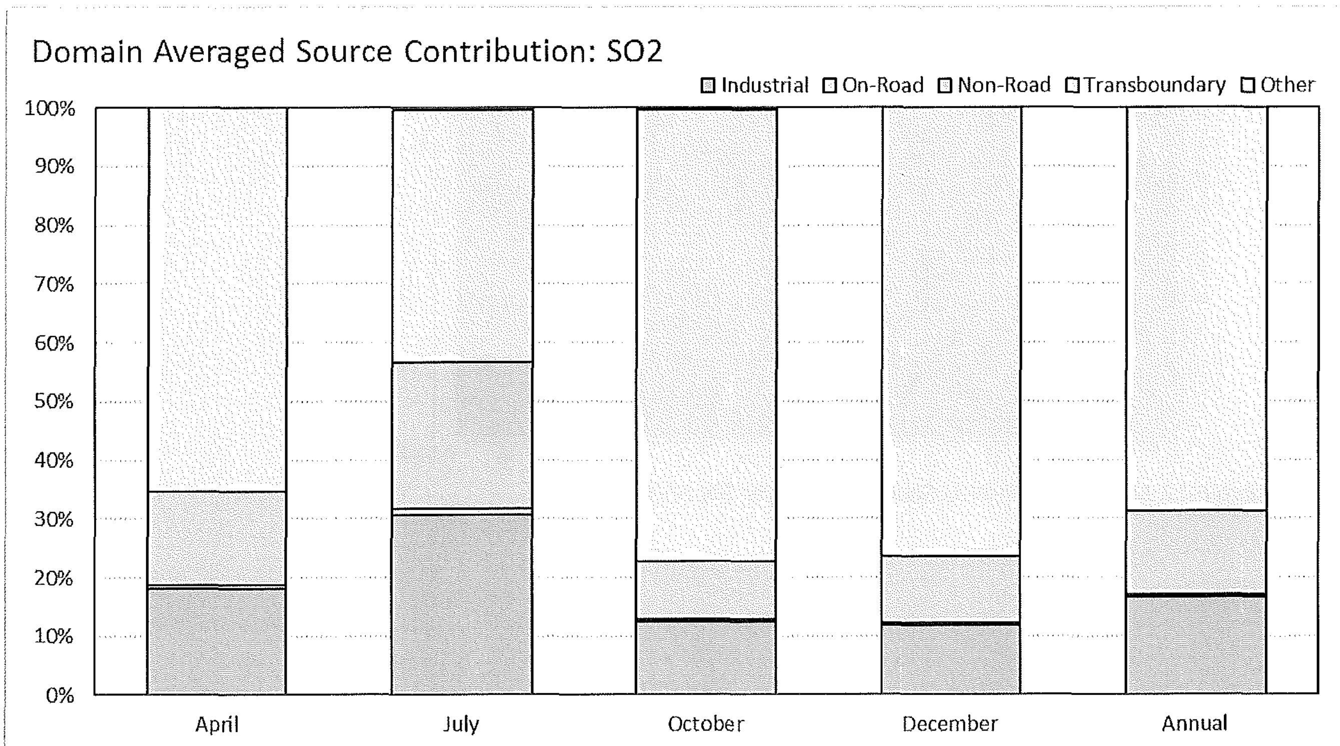

Figure 6-11: Domain Average Source Contribution by Month: SO_2

6.6 Nitrogen Dioxide Concentrations

The geographical distribution of the maximum daily and annual average NO_2 levels is presented on Figure 6-12 and Figure 6-13, respectively. The NO_2 spatial concentration is similar to the ozone spatial pattern but with higher concentrations along the major roadway corridors rather than a suppression of levels. The maximum again occurs at the intersection of the two main roadways. While the NO_2 and O_3 levels are expected to be correlated, under high NO_X (NO_2 + NO) concentrations, the O_3 concentration is limited by the amount of hydrocarbons (VOCs) available. Under these conditions, the O_3 varies inversely with the NO_X but varies linearly with hydrocarbon concentrations. Maximum daily levels of NO_2 range between 30 and 50 ppb but the annual average is generally less than 13 ppb, except for the industrial corridor which can be higher (i.e. 36 ppb).

From the MPE results, the model over-predicts by a constant 10 ppb over the entire year which is conservative. The over-prediction is likely due to an overestimate of transboundary levels flowing into the airshed but the results are within a factor of two. Sassi et. al. (2015) show that updates to the representation of mobiles in the Canadian national emissions inventory could lead to reductions in the transboundary levels.

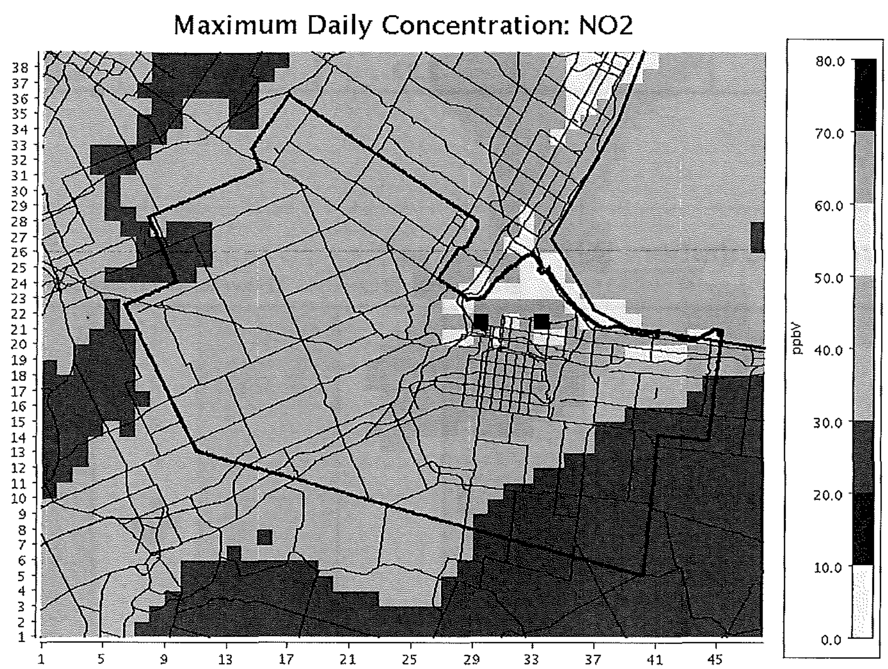

Figure 6-12: Maximum Daily NO_2 Concentration over Tier IV Hamilton

SUMMARY OF AIR QUALITY IN HAMILTON

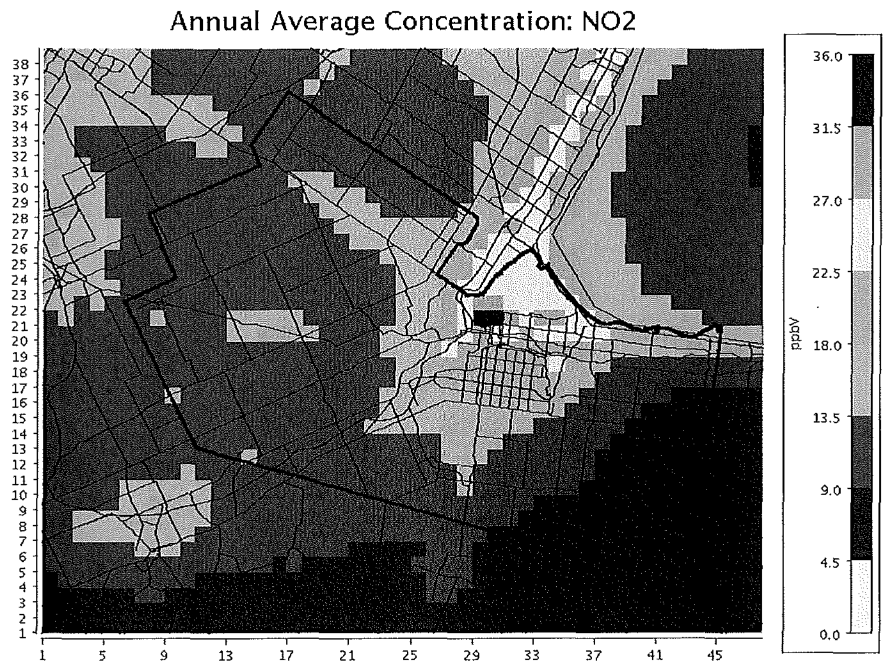

Figure 6-13: Annual Average NO_2 Concentration over Tier IV Hamilton

6.6.1 Source Apportionment of NO_2

Contributions from the five source groups are analysed and reported in Table 6-5 and Figure 6-14 by specific month. There is more seasonal variability of the sector contributions. On-road (~34%) and transboundary (~44%) contributions vary significantly over all four seasons. Transboundary levels are primarily made up of industrial (31%) and on-road (59%) sources as shown on Figure 4-3). Local on-road sources have a higher contribution during spring (April) and summer (July) while transboundary levels are lower. Maximum domain average levels occur during the winter season (December), which is also the highest transboundary contribution (67%). Industrial sources contribute about 4% to NO_2 levels.

Table 6-5: Tier IV Domain Averaged Source Percent Contribution By Month – NO_2

Source	April	July	October	December	Annual
Industrial	5%	5%	3%	2%	4%
On-Road	41%	44%	34%	19%	34%
Non-Road	9%	10%	6%	4%	7%
Transboundary	34%	26%	42%	67%	44%
Other	11%	14%	15%	8%	12%
Concentration (ppb)	**10.51**	**11.85**	**13.22**	**14.38**	**12.49**

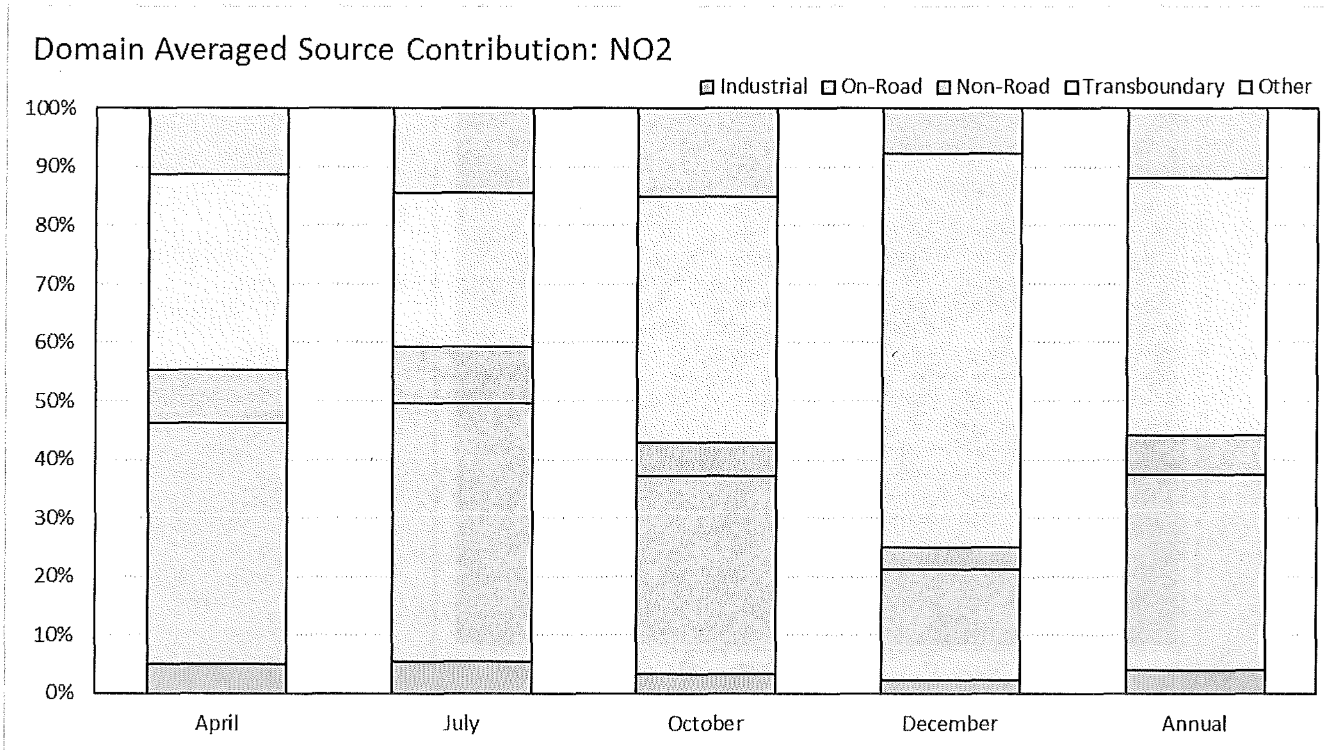

Figure 6-14: Domain Average Source Contribution by Month: NO_2

6.7 Benzene Concentrations

The geographical distribution of the maximum daily and annual average benzene levels are presented on Figure 6-15 and Figure 6-16, respectively. Generally, the maximum concentrations are found along the industrial corridor with sharply decreasing gradients to the north and south of corridor. The maximum occurs near the industrial sources along Burlington Street East. Maximum daily levels range between 0 and 4 ppb but the annual average is generally less than 1.5 ppb, except for the industrial corridor which can be higher (i.e. 6 ppb).

The MPE for benzene is fairly weak but the results demonstrate that the model is conservative in its estimate of local concentrations.

SUMMARY OF AIR QUALITY IN HAMILTON

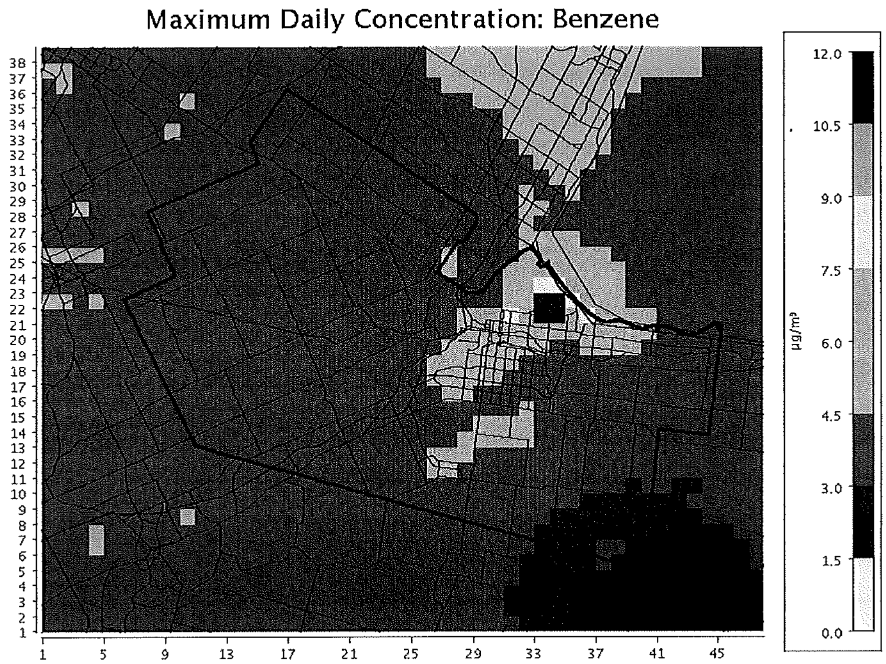

Figure 6-15: Maximum Daily Benzene Concentration over Tier IV Hamilton

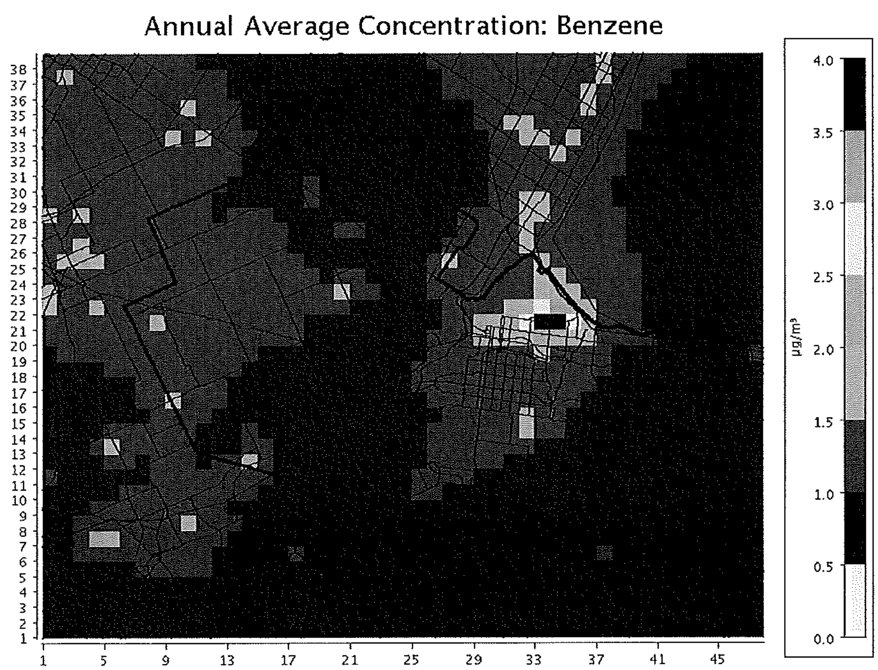

Figure 6-16: Annual Average Benzene Concentration over Tier IV Hamilton

6.7.1 Source Apportionment of Benzene

Contributions from the five source groups are presented in Table 6-6 and Figure 6-17 by specific month. There is more seasonal variability of the sector contributions. The industrial (12%), non-road (12%) and transboundary (70%) contributions vary over all four seasons. Transboundary benzene levels can be attributed primarily to mobile sources (Figure 4-3). On-road and non-road have higher contributions during spring (April) and summer (July) while transboundary levels are lower. Maximum domain average levels occur during the winter season (December), which is also the highest transboundary contribution (81%). On-road sources contribute about 6% to benzene levels.

Table 6-6: Tier IV Domain Averaged Source Percent Contribution By Month – Benzene

Source	April	July	October	December	Annual
Industrial	18%	16%	13%	8%	12%
On-Road	7%	6%	6%	5%	6%
Non-Road	15%	19%	13%	6%	12%
Transboundary	60%	58%	68%	81%	70%
Other	1%	1%	1%	0%	1%
Concentration (µg/m³)	**0.61**	**0.88**	**0.99**	**1.52**	**1.00**

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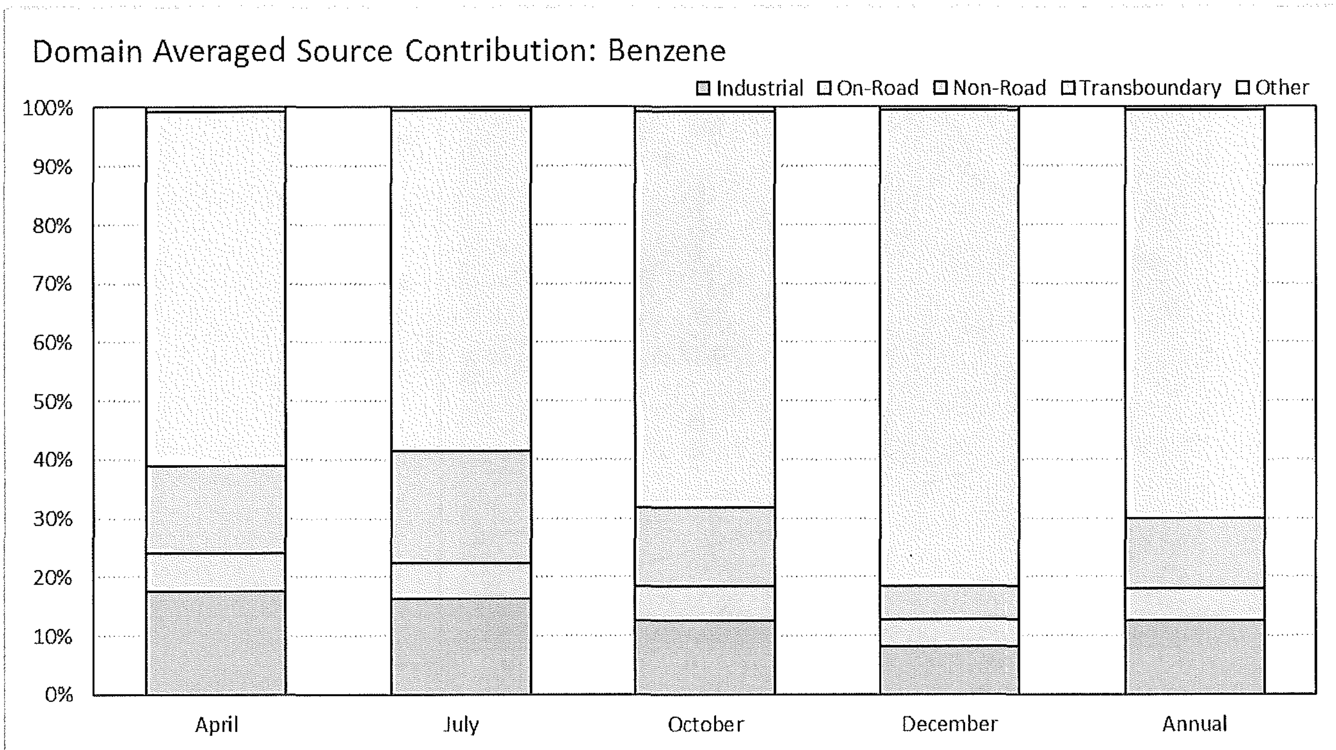

Figure 6-17: Domain Average Source Contribution by Month: Benzene

6.8 Benzo(a)pyrene Concentrations

The geographical distribution of the maximum daily and annual average B(a)P levels is presented on Figure 6-18 and Figure 6-19, respectively. The geographic extent shows that B(a)P is localized to the Hamilton industrial corridor and southern end of Lake Ontario. Similar to benzene, the maximum occurs near the industrial sources along Burlington Street East. Maximum daily levels range between 0 and 16 ng/m^3 but the annual average is generally less than 0.3 ng/m^3 except for the industrial corridor which can be higher (i.e. 6 ng/m^3).

The MPE for B(a)P is fairly weak but the results are over-predicted and demonstrate that the model is conservative in simulating B(a)P.

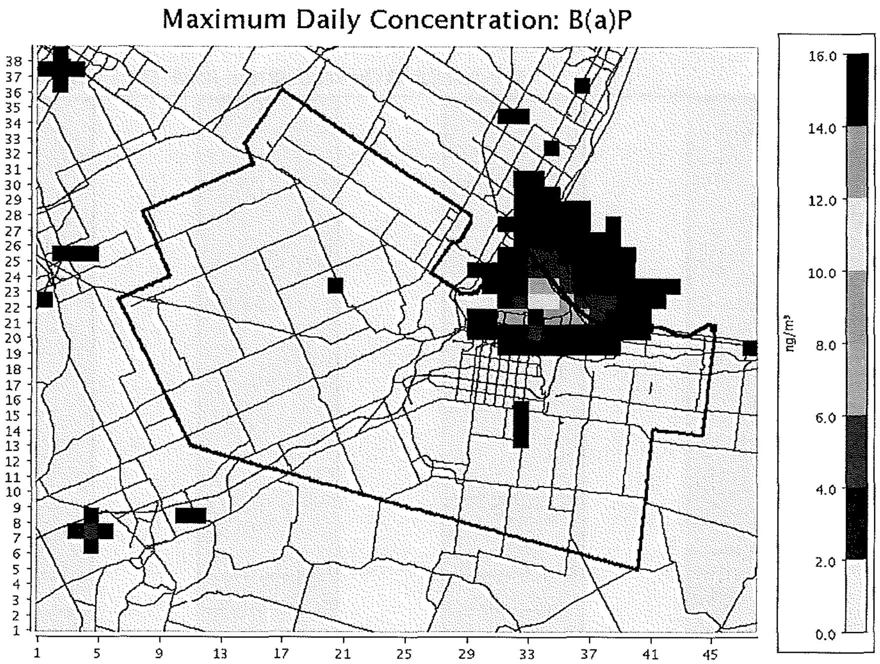

Figure 6-18: Maximum Daily Benzo(a)pyrene Concentration over Tier IV Hamilton

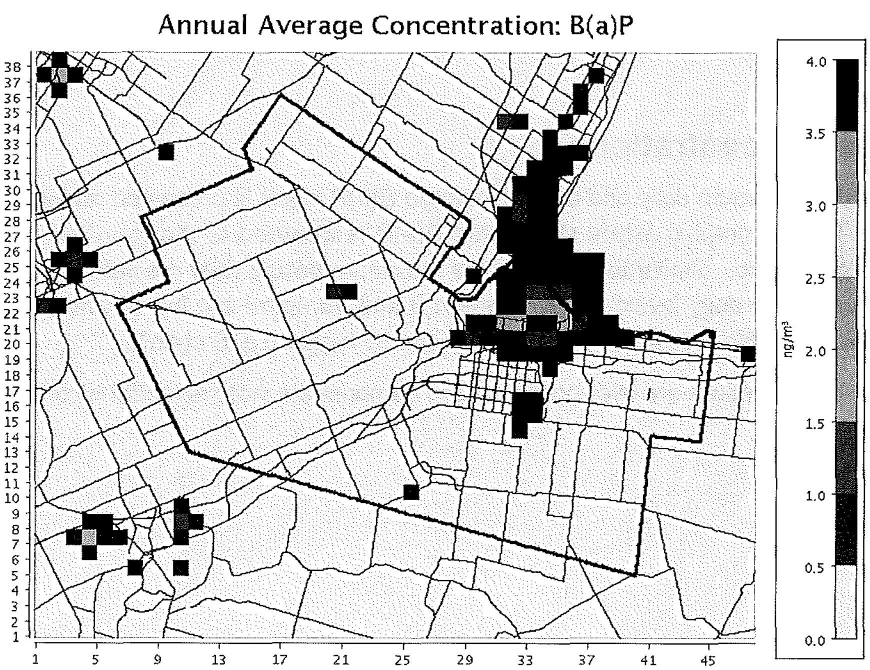

Figure 6-19: Annual Average Benzo(a)pyrene Concentration over Tier IV Hamilton

6.8.1 Source Apportionment of Benzo(a)pyrene

Contributions from the five source groups are presented in Table 6-7 and Figure 6-20 by specific month. There is more seasonal variability of the sector contributions. Industrial (47%), on-road (23%) and transboundary (29%) contributions vary over all four seasons. On-road and non-road have higher contribution during summer (July) and fall (October) while transboundary levels are lower. Maximum domain average levels occur during the winter season (December) which is also the highest transboundary contribution (41%). The transboundary is primarily made up of on-road (91%) sources (Figure 4-3).

Table 6-7: Tier IV Domain Averaged Source Percent Contribution By Month – Benzo(a)Pyrene

Source	April	July	October	December	Annual
Industrial	53%	59%	47%	36%	47%
On-Road	22%	22%	25%	23%	23%
Non-Road	0.2%	0.4%	0.3%	0.1%	0.2%
Transboundary	24%	18%	27%	41%	29%
Other	0.3%	0.3%	0.3%	0.3%	0.3%
Concentration (ng/m^3)	**0.21**	**0.23**	**0.25**	**0.36**	**0.26**

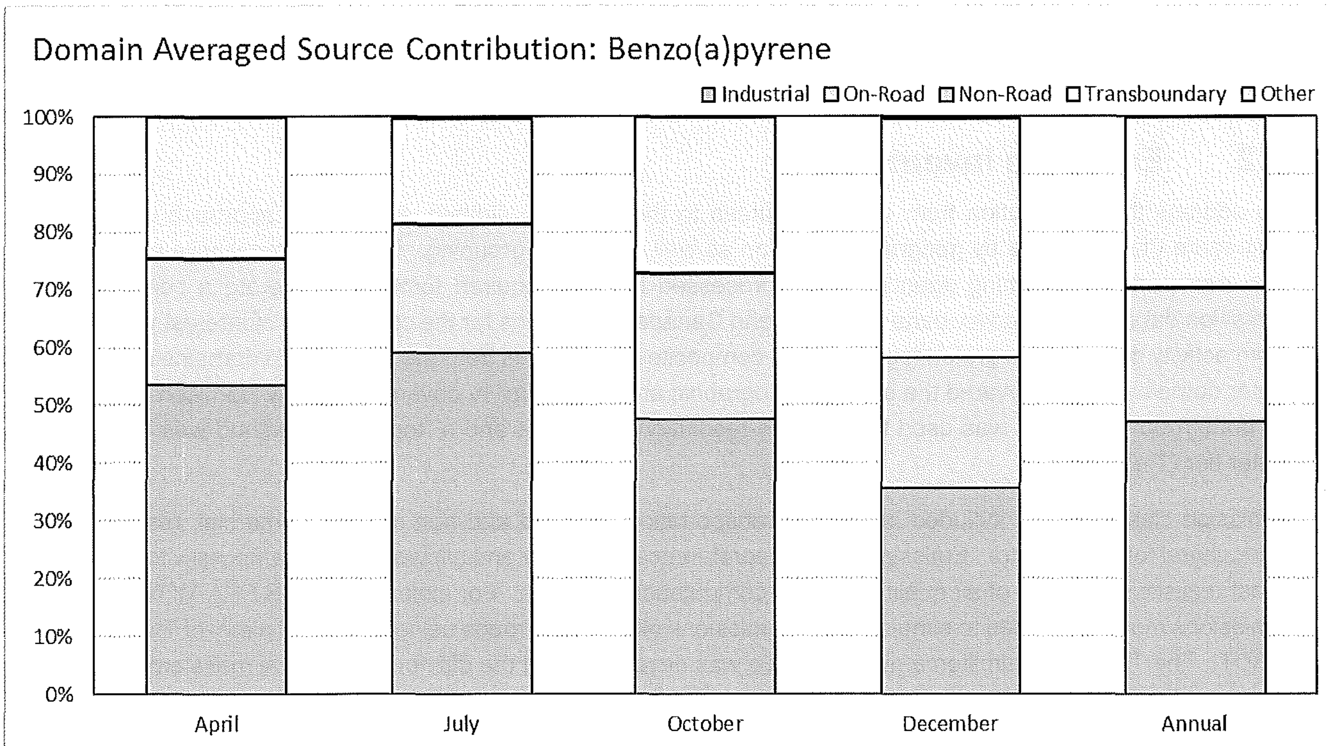

Figure 6-20: Domain Average Source Contribution by Month: Benzo(a)pyrene

7.0 SUMMARY AND RECOMMENDATIONS

The Hamilton Airshed Modelling System (HAMS) was designed and implemented using the coupled SMOKE, WRF, and CMAQ modelling system. The objective of the program was to examine the regional air quality and determine relative contributions of a range of selected source sectors to various chemical compounds. Seventeen compounds of interested were included in the evaluation of which seven were carried forward for source apportionment evaluation. The computational domains were developed over a nested grid with spatial resolutions ranging from 36 km to 12 km to 4 km to 1.33 km, with the innermost domain having the highest resolution. The densest grid (i.e., 1.33 km) was overlaid on the City of Hamilton. The outer grids provided boundary conditions and initial conditions for the inner grids, in order to capture the influence outside of the domain of interest.

Source sector contributions were obtained via specific modelling scenarios where specific source sectors are zeroed out and the resultant change in compound concentration is observed by season. The results of the HAMS were evaluated against observations within the Hamilton region to determine the level of confidence in the results, for both the meteorology and air quality. The emissions inventory was evaluated by examining the model, the spatial and temporal distribution of the emissions, and indirectly through the resulting air quality.

7.1 Meteorology Performance Evaluation

The meteorological performance at the selected meteorological observation site (e.g. airport sites) within the study domain was carried out. Generally, there was good meteorological performance for the Hamilton region. Detailed analysis of the metrics provided over the four domains demonstrated that WRF did well at replicating observed atmospheric values of temperature, mixing ratio, wind speed and wind direction. Monthly and annual analyses demonstrated a high level of accuracy in reproducing observations, even in the region surrounded by the Great Lakes (Tier IV).

7.2 Emission Inventory

To address the contribution from various sources to the Hamilton airshed, a multi-tier approach was used to segregate the emissions by geographic location as well as source grouping. Data from provincial air regulatory and transportation planning agencies were processed into the required format to generate a comprehensive emission dataset which cover parts of the US and Canada. Emissions for the compounds of interest were built up from activity data and integrated together for a composite of emissions from the various grid domains or tiers. The outer domain or Tier I covered the greatest geographic area while Tier IV covered primarily Hamilton. Effectively, a "bottom-up" approach was used for the high-resolution inner tiers and a "top-down" method was used for the outer tier (Tier I).

Emission classifications included industrial, transportation (on-road and non-road), commercial, residential and agricultural for all four tiers. Emissions were georeferenced spatially and allowed to vary temporally to capture the most realistic simulation of air quality over the computational domain. For example, the US EPA MOVES on-road emissions model was used to simulate traffic emissions along major roads using Ontario Ministry of Transportation AADT. The Tier IV or Hamilton emission profile was developed and the distribution by total mass emission is

- Industrial 21%;
- Commercial 1%;
- Residential 0.5%;
- Agriculture 3%;

- On-Road 41%;
- Non-Road 34%;

Transportation represents over 75% of the total Hamilton emission profile while industrial emissions are about 21% of the total. Sulphur dioxide emissions and B(a)P emissions are primarily from industrial sources while transportation tends to be the main source of the other compounds. This is similar to the transboundary emissions which flow into the Hamilton domain.

There is confidence in the emission inventory that was developed. The emission inventory is based on a robust compilation of activities but some activities are not accounted for. These are generally fugitive emissions as would come from fires, construction activities and track-out for industrial/commercial operations. Industrial emissions are based on reported emissions to federal and provincial agencies and are of good quality.

7.3 Hamilton Airshed Model Performance Evaluation

Model Performance Evaluation (MPE) is the process of testing a model's ability to accurately predict observations. Hamilton model results were compared with observations from the air quality monitoring network which includes regulatory stations (i.e., MOECC, Environment Canada) as well as the Hamilton Air Monitoring Network (HAMN). MPE was carried out for $PM_{2.5}$, PM_{10}, O_3, SO_2, NO_2, benzene and B(a)P.

The modelling system provides good results given the complexity of the model and inputs. CMAQ tends to over-predict concentrations with the exception PM_{10} where the model under-predicts based on the mean bias (MB). Model results are within a factor of two for all compounds (i.e., a FB $\leq$ 67%). The modelling system meets the criteria for $PM_{2.5}$ and PM_{10} model performance. The under-prediction of PM_{10} is attributed to unaccounted local fugitive dust sources such as construction activities which have a bias towards larger size particulates.

The time series of observed versus modelled results shows good correlation except for winter months where the model tends to over predict concentrations.

7.4 Model Results and Source Apportionment

A summary of the HAMS maximum daily and annual average for seventeen compounds of interest are provided on Table 7-1 within Tier IV for 2012. Generally, maximum concentrations occurred along Burlington Ave E and at the intersection of Hwy 403 and Hwy 8, depending on the compound of interest. Ozone and NO_2 aerial plots show that the concentrations correlate with the major roadways.

Four simulations were performed using the zero-out method, where the emissions from the source sector of interest are eliminated in the CMAQ model simulations and contributions are assessed by evaluating the difference in predicted air quality between the zero-out simulations and the base case simulation. Five source apportionment simulations were performed for the following emissions source sectors within Tier IV:

- Industrial
- On-Road – on-road transportation activates;
- Non-Road – airport, railway, marine activities;
- Transboundary – no emissions within Tier IV; and
- Other – commercial, residential and biogenic/agriculture activities.

The source apportionment simulations were carried out for a selected month of each season for 2012 as well as for an ensemble average of all four months to represent a year for the Tier IV domain. The Tier III domain results were used for initial conditions and a minimum of a five day spin up time was used for each simulation. The source apportionment by source sectors on $PM_{2.5}$, PM_{10}, SO_2, NO_2, benzene and B(a)P concentrations in Hamilton are presented in Table 7-1. Local industrial emissions contribute less than 20% by compound to air quality in Hamilton except for B(a)P where it is the main source of that compound. Local on-road sources are a major contributor to NO_2 levels in the city. Transportation related emissions are the major contributor to transboundary emissions for all compounds except SO_2 which is dominated by industrial sources.

Table 7-1: Tier IV Domain Annual Averaged Source Contribution (%)

Source	$PM_{2.5}$	PM_{10}	SO_2	NO_2	Benzene	B(a)P
Industrial	6%	6%	18%	4%	13%	48%
On-Road	1%	2%	1%	34%	6%	23%
Non-Road	1%	1%	17%	7%	12%	0%
Transboundary	91%	90%	64%	43%	68%	28%
Other	0.5%	0.5%	0.2%	12%	0.6%	0.3%

7.5 Conclusions

The results of the Hamilton Airshed Modelling System demonstrate that the model is conservative in the simulation of air quality levels within the City of Hamilton. The results meet published objectives which provides confidence in the results of the modelling simulations.

7.6 Recommendations

The following areas could be pursued to add further detail and clarification to the modelling results presented in this report.

Monitoring

As discussed in Section 5.0 and Section 7.3, there are fugitive dust sources that are missing from the modelled emissions inventory but is being captured by the monitoring data. The emission source inventory should be improved for PM_{10} to account for the missing fugitive dust sources. As well, the monitoring locations for PM_{10} within Tier IV should be reviewed to improve the capture of fugitive sources, as well as address where there is minimal fugitive dust generation.

Update National Emissions Inventories

As described in APPENDIX B, the emissions for Tier I were provided by the 2006 national emissions inventory for Canada. Environment and Climate Change Canada has released an updated national emissions inventory representing the base year of 2010, which is closer to the modelled year of 2012 in HAMS. Part of this update was an improved on-road mobile inventory and improved representation of point sources, among others (Sassi et. al., 2015). These improvements lead to a reduction in the compounds examined, most notably NO_X, which could lead to reductions in the transboundary concentrations of NO_X and other compounds in Tier IV.

Transboundary Contributions

As described in Section 6.0, the transboundary contribution in Tier IV was examined using the "zero out" approach. The transboundary contribution of the lower resolution tiers (i.e., Tiers I through III) was inferred based on the relative contribution of sources to the emissions inventory. To further explore the transboundary contribution in Tier IV, more information is needed in the lower resolution tiers. As an initial screening process, the "zero out" approach could be applied to the lower resolution tiers to help clarify the impact of different source categories outside of Tier IV, as well as the relative impact of emissions from Canada and the United States. For detailed information, the HAMS could be updated to use the CMAQ Integrated Source Apportionment Method (CMAQ ISAM) to track source contributions. It should be noted that this methodology requires additional input information to CMAQ and requires CMAQ to be run sequentially (i.e. significant increase in computational time), where the current HAMS is set up to take advantage of multiple processors by running each month in parallel.

Policy Development

As discussed in Section 6.4.1, it is important to understand the chemistry regimes present in the region to understand the impact of restricting emissions of NO_X or VOCs. Without this consideration, policies may have different impacts in different regions of Tier IV. To aid in policy development, policy regions could be developed and the chemistry regimes within them examined for the impact of proposed policy.

In Section 6.0, the source apportionment averaged over Tier IV is presented. To support policy development, this information could be averaged over geographic regions of interest instead of over the total domain. It is anticipated that the source contribution would vary to some degree by location, depending on the influence of more localized sources.

Improved Understanding of Benzo(a)pyrene

Currently in the HAMS, B(a)P is represented as an inert tracer. It is emitted into the atmosphere but not allowed to interact chemically (i.e. only emission, dispersion, and deposition are considered). Peer-reviewed, published chemical mechanisms for B(a)P are available but would require validation within the HAMS. The compatibility of any mechanism with the existing chemical mechanism within HAMS would have to be examined, as well as the availability of monitoring data to validate the implementation.

Additionally, the national emissions inventories are limited in their information about B(a)P. It is unclear how large the background B(a)P concentration should be and whether all significant sources of B(a)P from all tiers are being captured. It is likely that the transboundary B(a)P from the lower resolution tiers is being underestimated, leading to low modelled concentrations. More information about B(a)P in the lower resolution tiers would improve the understanding of the sources of B(a)P.

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APPENDIX A

Meteorological Performance Analysis

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February 2018

HAMILTON AIRSHED MODELLING SYSTEM WRF MODEL APPLICATION AND EVALUATION

Hamilton Airshed Modelling System

Submitted to:
Hamilton Industrial Environmental Association (HIEA)
270 Sherman Ave. N.
Hamilton, ON L8L 6N4

REPORT

Report Number: 1418883 (3000)

Distribution:

Electronic copy - HIEA
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1.0 INTRODUCTION

This report was prepared by Golder Associates Ltd. (Golder) and is part of the Hamilton Airshed Modelling System Final Report (Golder Project No. 1418883).

This report was compiled to describe the model performance evaluation (MPE) undertaken to demonstrate the validity of the data. There are typically two components to a MPE: the operational evaluation and the scientific evaluation. This report summarizes the operational evaluation, which was undertaken to determine the model's reliability in reproducing 1-hour average ground-level wind speed, wind direction, temperature, and precipitation across the three modelling domains.

Benchmarks have been used to understand how good the prognostic modelling results are, relative to other applications. Meteorological variables have been compared to benchmarks to indicate WRF's performance. The benchmarks include bias and error in temperature, wind speed and mixing ratio, and wind direction bias and root mean squared error (RMSE) between the model and databases of existing data. Previous studies in the U.S. have used the following benchmarks for each variable, to judge whether current modelling is on par with previous studies, and will be referred to herein:

- Temperature bias: less than or equal to 0.5 °K; alternative of ≤ 1.0 °K for complex conditions.
- Temperature error: less than or equal to 2.0 °K; alternative of ≤ 3.0 °K for complex conditions.
- Mixing ratio bias: less than or equal to +/- 1.0 g/kg.
- Mixing ratio error: less than or equal to 2.0 g/kg.
- Wind direction bias: less than or equal to +/- 10 degrees.
- Wind direction error: less than or equal to 30 degrees.
- Wind speed bias: less than or equal to +/-5 m/s.
- Wind speed RMSE: less than or equal to 2 m/s.

The Model Performance Evaluation and Plotting Software (MAPS) package has been used to quantitatively assess the WRF model's performance in generating meteorological data. In MAPS, observations of meteorological elements (e.g. such as wind speed and direction, temperature) at various time periods have been compared to the prognostic meteorological data generated by WRF. The Meteorological Assimilation Data Ingest System (MADIS) archive was the primary source of meteorological observations for the WRF data assimilation and model evaluation. The evaluation includes comparisons between 1-hr modelled predictions and surface and aloft meteorological measurements.

1.1 WRF Overview

WRF is a next-generation mesoscale prognostic meteorological model routinely used to develop meteorological fields for urban- and regional-scale photochemical, fine particulate and regional haze regulatory modelling studies. Developed jointly by the National Center for Atmospheric Research and the National Centers for Environmental Prediction, WRF is maintained and supported as a community model by researchers and practitioners around the globe. The code supports two modes: the Advanced Research WRF (ARW) version and the Non-hydrostatic Mesoscale Model (NMM) version. WRF-ARW has become the new standard model used in place of the older Mesoscale Meteorological Model (MM5) for regulatory air quality applications in the United States.

WRF features multiple dynamic cores and a software architecture allowing for computational parallelism and system extensibility. WRF is suitable for a broad spectrum of applications across scales ranging from meters to thousands of kilometers. WRF allows researchers the ability to conduct simulations reflecting either real data or idealized configurations. WRF provides an operational forecasting model that is flexible and computationally efficient, while offering the advances in physics, numerics, and data assimilation contributed by the research community. Information on running the WRF system can be found in the WRF User's Guide.

1.2 Justification for use of WRF Models

The WRF meteorological model was developed as a replacement to MM5; therefore, MM5 is no longer supported. While the MM5 model was the primary mesoscale modeling tool to support air quality modeling for the past decade, WRF is now routinely used in air quality model applications and has been obtaining model performance that is as good as or better than MM5. WRF has not only been applied in warm region climes, but it has also seen recent, extensive adaptation to Arctic regions for both seasonal and multi-year simulations. EPA has also adopted the WRF meteorological model for their regulatory air quality model applications. For these reasons, the WRF meteorological model was selected for the Hamilton Airshed Modelling System.

2.0 METHODOLOGY

For this project, WRF simulations were developed for a full year (2012), and the model results (e.g., wind speed and direction, temperature, mixing ratio) were compared with available surface and aloft meteorological observations, paired in time and space.

2.1 Model Selection and Application

The Weather Research and Forecasting – Advanced Research WRF (WRF-ARW) model version 3.6.1 was selected for this project. This is the only currently-supported core for the WRF model, and its use is recommended for applications using advanced chemistry modelling (such as CMAQ).

The NCEP North American Mesoscale (NAM) model data was used to initialize the WRF model. These data have a six hour temporal resolution. The analyses are available on the surface, at 26 mandatory and other pressure levels from 1,000 millibar (mb) to 10 mb, in the surface boundary layer, at some sigma layers, the tropopause and a few others. Parameters include surface pressure, geopotential height, temperature, soil values, ice cover, relative humidity, u- and v-winds, vertical motion, vorticity and ozone.

The NAM analysis data provides the WRF model with boundary and initial conditions. Since mesoscale modelling is an initial value problem, having superior boundary and initial conditions has a very high impact on the accuracy of model output. NAM has a spatial resolution of 12 by 12 km, and is currently a recommended data base for WRF model initialization.

Topographic information for WRF was developed from the WRF Processing System (WPS) GEOGRID processor. The 36 km grid will be based on the 5 min (~9 km) Geophysical Data Center global data. The 12 km grid will be based on the 2 min (~4 km) Geophysical Data Center Global data. The 4 and 1.33 km grid will be based on the 30 second (~900 m). The other WPS preprocessor programs include UNGRIB, and METGRID, and together these were used to develop the model inputs.

The four domains were selected based on the Community Multi-Scale Air Quality (CMAQ) modelling domains, with the WRF domains being larger than the corresponding modelling domains to provide a "buffer" zone around each dispersion modelling domain. The WRF modelling used 40 vertical layers with an approximately 12 m deep surface layer.

The topographic, vegetation and land-use, and physics configuration used in the WRF modelling were detailed in Appendix A (Meteorology Protocol) of the Hamilton Airshed Modelling System Detailed Work Plan.

2.2 Evaluation Approach

Meteorological inputs required by the CMAQ model include hourly estimates of the three-dimensional distribution of winds, temperature, and humidity. Accordingly, the objective of the WRF performance evaluation was to assess these meteorological fields for the 2012 modelling year, against observation data in all four modelling domains.

2.2.1 Components of the WRF Evaluation

The WRF modeling system is now well-established with a development and refinement history of over a decade. The model has seen extensive use worldwide by many agencies, consultants, university scientists and research groups. Thus, the current version of the model, as well as its predecessor versions, has been extensively "peer-reviewed" and considerable algorithm development and module testing has been performed with all the important process components. Given that the WRF model code and algorithms have already undergone significant peer review, performance testing of the WRF model in this study was focused on an operational versus a scientific evaluation for the specific Hamilton Regional Modelling project.

Typical of other meteorological model application studies for air quality modeling purposes, the WRF model performance was compared both against established metrics and against other modeling studies. Emery et. al. (2001) derived and proposed a set of daily performance "benchmarks" for typical meteorological model performance. These standards were based upon the evaluation of about thirty mesoscale meteorological model simulations of multi-day episodes in support of air quality modeling. During this time (the mid to late 1990's) the mesoscale meteorological models were typically applied to provide meteorological fields for ozone air quality models. These multi-day episodes were typically chosen because of the high ozone levels which often occur during fairly stagnant summertime conditions.

Because of a lack of other information, these benchmarks have been adopted for use in annual and seasonal meteorological modeling studies. Since the synoptic conditions are so varied during a year, and are often times so different than the synoptic conditions typical of high urban ozone concentrations, the use of such benchmarks is problematic. They must be viewed as being applied as guideline numbers. That is, the purpose of these benchmarks is not to give a passing or failing grade to any one particular meteorological model application, but rather to put its results into the proper context of other models and meteorological data sets.

Recognizing that the episodic benchmarks may not be appropriate for longer term simulations, McNally (2009) analyzed multiple annual runs and suggested an alternative set of benchmarks for temperature, namely a guideline of +/- 1.0 K for bias and 3.0 K for gross error, and recognized that a single set of criteria may not be appropriate given the competing complexities of meteorological modeling in different areas.

Previous studies in the U.S. have used the following benchmarks for each variable, to judge whether current modelling is on par with previous studies:

- Temperature bias: less than or equal to 0.5 °K; alternative of ≤ 1.0 °K for complex conditions.
- Temperature error: less than or equal to 2.0 °K; alternative of ≤ 3.0 °K for complex conditions.
- Mixing ratio bias: less than or equal to +/- 1.0 g/kg.
- Mixing ratio error: less than or equal to 2.0 g/kg.
- Wind direction bias: less than or equal to +/- 10 degrees.
- Wind direction error: less than or equal to 30 degrees.
- Wind speed bias: less than or equal to +/-5 m/s.
- Wind speed RMSE: less than or equal to 2 m/s.

2.2.2 Data Supporting Meteorological Model Evaluation

Hourly surface and upper-air meteorological observations were obtained from the MADIS to support the evaluation of WRF surface temperature, water vapor, and wind fields. In the northeastern U.S., and Canada, the MADIS system includes surface and upper-air meteorological data from numerous networks including NCDC observations and data from Environment Canada stations.

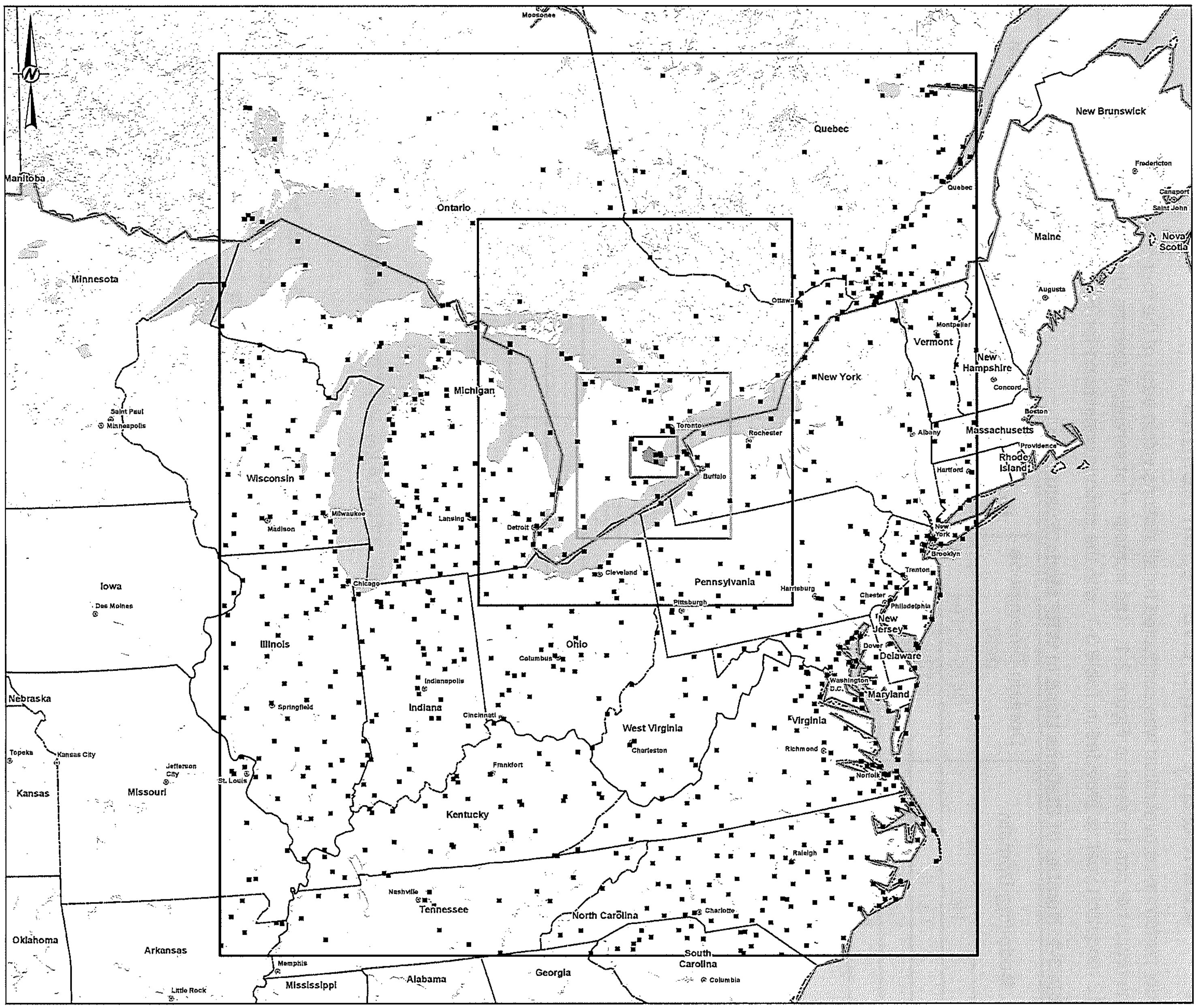
Figure 2-1 shows the WRF modelling domains and the locations of all the meteorological stations within these domains for which data were available to complete the model evaluation. The following table provides a listing of the meteorological stations used in Tier IV.

Table 2-1: Meteorological Stations in Tier IV

Station Name	Station ID	MADIS ID	Location
Guelph Turfgrass	6143089	CTGT	43° 32' 59.9994", 80° 13' 0.12"
Burlington Piers (AUT)	6151061	CWWB	43° 17' 59.9994", 79° 47' 59.9994"
Hamilton RBG CS	6153301	CXHM	43° 17' 23.9994", 79° 54' 35.9994"
Vineland Station RCS	6139148	CXVN	43° 10' 47.9994", 79° 24' 0"
Hamilton A	6153193	CYHM	43° 10' 0.1194", 79° 55' 59.88"
Kitchener/Waterloo	6144239	CYKF	43° 28' 0.12", 80° 22' 59.88"
Elora RCS	6142286	CZEL	43° 38' 31.5594", 80° 24' 41.76"

2.2.3 Evaluation Tools

The primary tool used for evaluating the WRF surface meteorological fields was the METSTAT program. This tool calculates a suite of model performance statistics using surface wind speed, wind direction, temperature, and water vapour mixing ratio, for user-specified subdomains. Model performance evaluation metrics used in evaluating the WRF model include temperature and water mixing ratio bias and error, wind direction bias and error, and wind speed root mean square error (RMSE). The METSTAT program calculates a full suite of statistical metrics based on Tesche, 1994 and Tesche et al., 2001.



LEGEND
- Meteorological Station
- City
- City of Hamilton
- State and Province Boundary
- Country Boundary
- Waterbody
- Tier IV 1 km WRF Modelling Boundary
- Tier III 4 km WRF Modelling Boundary
- Tier II 12 km WRF Modelling Boundary
- Tier I 36 km WRF Modelling Boundary

0 200 400 600
1:7,500,000 Kilometres

REFERENCE(S)
BASE DATA FROM ESRI.PROJECTION: LAMBERT CONFORMAL CONIC.

CLIENT
HAMILTON INDUSTRIAL ENVIRONMENTAL ASSOCIATION

PROJECT
METEOROLOGY

TITLE
METEOROLOGICAL STATIONS

CONSULTANT
Golder Associates

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DESIGNED	KD
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APPROVED	JLK

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3.0 WRF PERFORMANCE EVALUATION RESULTS

A statistical evaluation of the WRF model performance was undertaken to demonstrate the capability of the model to generate realistic and appropriate meteorological data over each of the four modelling tiers that are included in this study.

3.1 Quantitative Model Evaluation Results

Model performance evaluation was conducted for all stations within each of the four tiers. The stations identified within each tier can be seen in Figure 2-1. The number of observation stations identified within each tier for the 2012 modelling year, is provided in Table 3-1, with the stations considered for Tier IV provided in Table 3-2.

Table 3-1: Number of Stations Used in WRF Model Evaluation

Modelling Domain	Domain Dimensions (km)	Model Resolution (km)	No. of Observation Stations
Tier I	1475 x 1764	36	643
Tier II	612 x 756	12	99
Tier III	300 x 324	4	33
Tier IV	92 x 80	1.33	7

Table 3-2: Stations Considered for Tier IV WRF Model Evaluation

Station Name	Station ID	MADIS ID	Location
Guelph Turfgrass	6143089	CTGT	43° 32' 59.9994", 80° 13' 0.12"
Burlington Piers (AUT)	6151061	CWWB	43° 17' 59.9994", 79° 47' 59.9994"
Hamilton RBG CS	6153301	CXHM	43° 17' 23.9994", 79° 54' 35.9994"
Vineland Station RCS	6139148	CXVN	43° 10' 47.9994", 79° 24' 0"
Hamilton A	6153193	CYHM	43° 10' 0.1194", 79° 55' 59.88"
Kitchener/Waterloo	6144239	CYKF	43° 28' 0.12", 80° 22' 59.88"
Elora RCS	6142286	CZEL	43° 38' 31.5594", 80° 24' 41.76"

3.1.1 Temperature Bias and Error

Temperature bias and error statistics for the 36 km, 12 km, 4 km and 1.33 km modelling domains are presented in Table 3-3.

The Tier IV domain average temperature bias and error are shown in Figure 3-1. This "soccer plot" depicts the monthly average bias versus the monthly average error over the entire 1.33 km modelling domain. It is desirable to have all monthly values inside the benchmark outlines. The outer "goal" is for complex simulations and a reasonable target for Tier IV which lies within the Great Lakes Basin and is strongly influenced by lake breezes. The inner "goal" is the standard benchmark (see Section 1.0 for the full list of benchmarks).

WRF MODEL APPLICATION AND EVALUATION

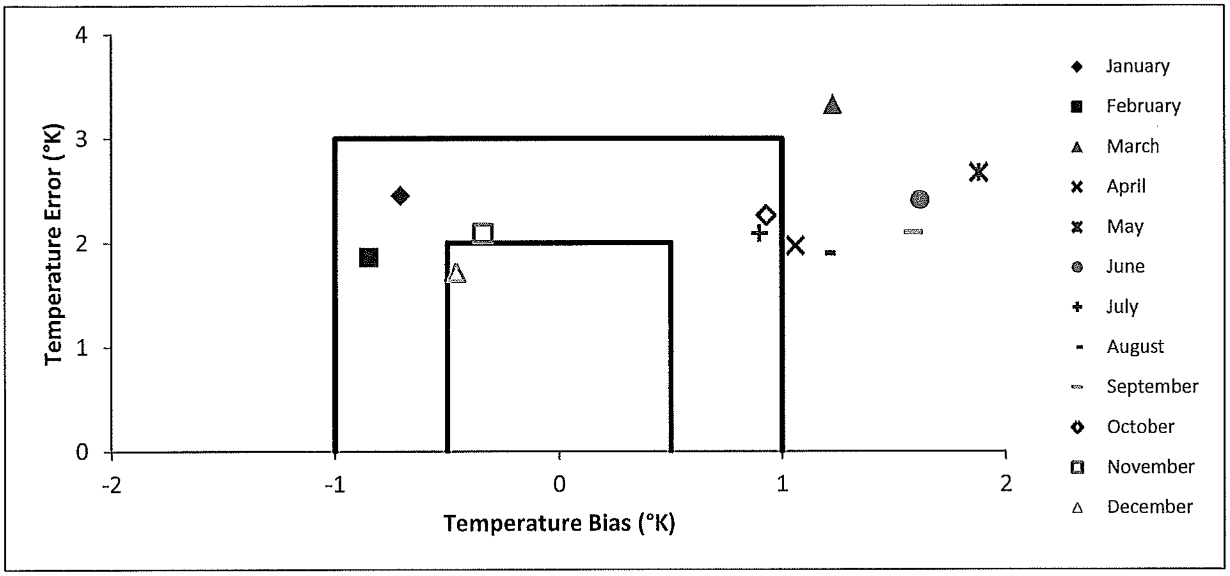

Figure 3-1: Monthly Temperature Error vs. Temperature Bias for Tier IV

One month of the data set falls within the standard benchmark (December) and a further five months fall within the complex conditions benchmark (January, February, July, October, and November). The remaining months showed a positive temperature bias (temperatures were over-predicted by the WRF model). May showed the highest bias (1.88 °K). It is likely that the over-prediction of temperatures by the WRF model in the spring and summer months shows a limitation in the ability of the model to fully encompass the mitigating effect of the Great Lakes, especially Lake Ontario, on spring and summer temperatures. While not ideal, the WRF temperature data are acceptable for use in the CMAQ assessment.

Figure 3-2 provides a comparison of the observed and predicted temperatures, the temperature bias and the root mean square error (RMSE) for January 2012 for Tier IV (1.33 km spacing), Figure 3-3, Figure 3-4, and Figure 3-5 provide the same for April, August, and October, providing a sample of the data for each season.

Across the four tiers, the bias in predicted temperature was found to be between -1.62 °K (Tier II, February) and 1.88 °K (Tier IV, May) and the absolute error in temperature was found to be between 1.72 °K (Tier IV, December) and 3.46 °K (Tier II, March).

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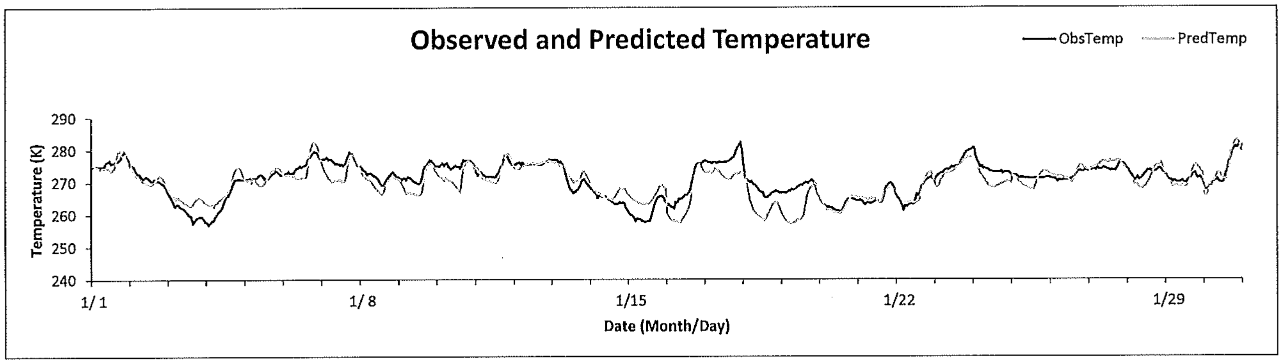
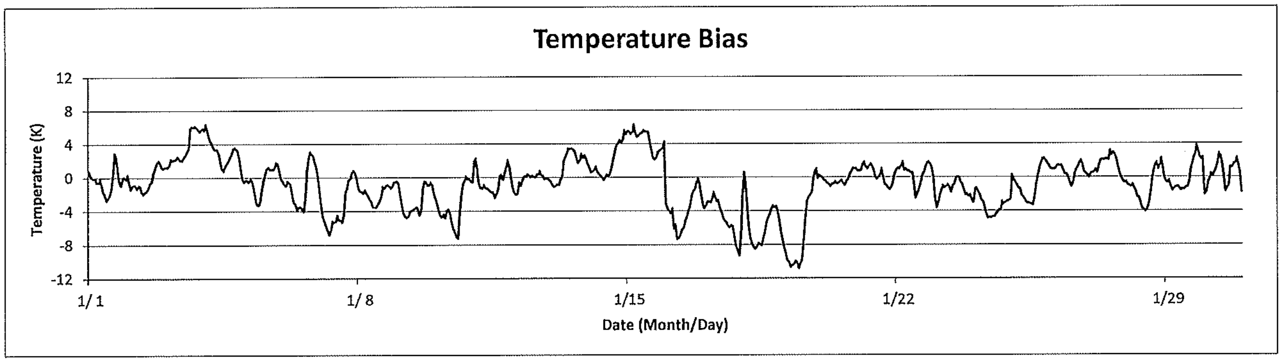
Table 3-3: Temperature Bias and Error for all Tiers

Month	Tier I		Tier II		Tier III		Tier IV	
	Temperature Bias	Temperature Error	Temperature Bias	Temperature Error	Temperature Bias	Temperature Error	Temperature Bias	Temperature Error
January	-0.95	2.63	-1.05	2.71	-0.89	2.60	-0.71	2.45
February	-1.20	2.55	-1.62	2.57	-1.40	2.19	-0.85	1.86
March	-0.38	2.86	-0.22	3.46	0.45	3.24	1.23	3.32
April	0.65	2.27	0.79	2.28	0.73	2.10	1.06	1.97
May	0.60	2.19	0.91	2.45	1.19	2.42	1.88	2.67
June	0.52	1.96	0.78	2.19	1.13	2.33	1.62	2.41
July	0.85	2.07	0.57	2.02	0.63	2.00	0.90	2.09
August	0.91	1.85	0.95	1.86	0.92	1.81	1.20	1.90
September	1.09	2.00	1.26	2.04	1.26	2.00	1.59	2.10
October	0.52	2.20	0.50	2.28	0.65	2.18	0.93	2.26
November	-0.35	2.31	-0.45	2.45	-0.49	2.26	-0.34	2.09
December	-0.59	2.48	-0.72	2.41	-0.77	1.91	-0.46	1.72
Annual	0.14	2.28	0.14	2.39	0.28	2.25	0.67	2.24

Note:
Annual has been calculated as the average of the monthly values.





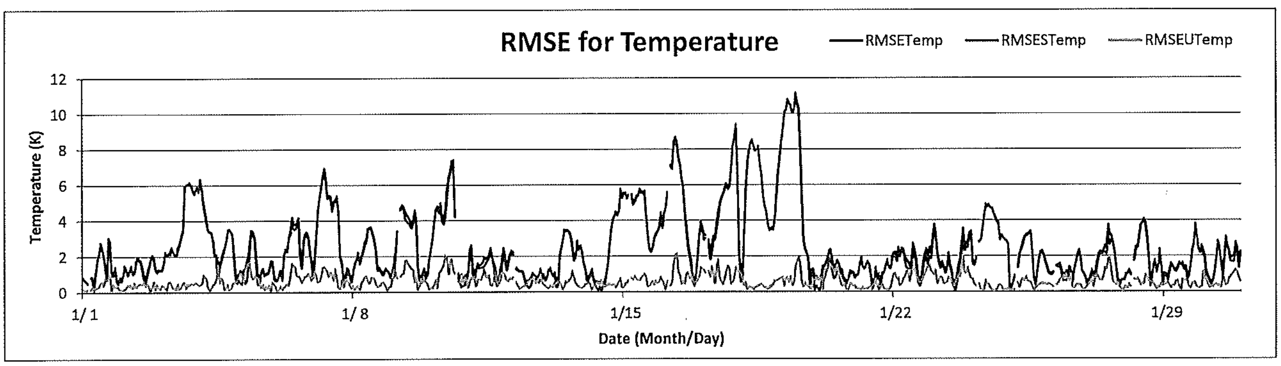


Figure 3-2: Observed and Predicted Temperature and Statistics – January 2012 Tier IV

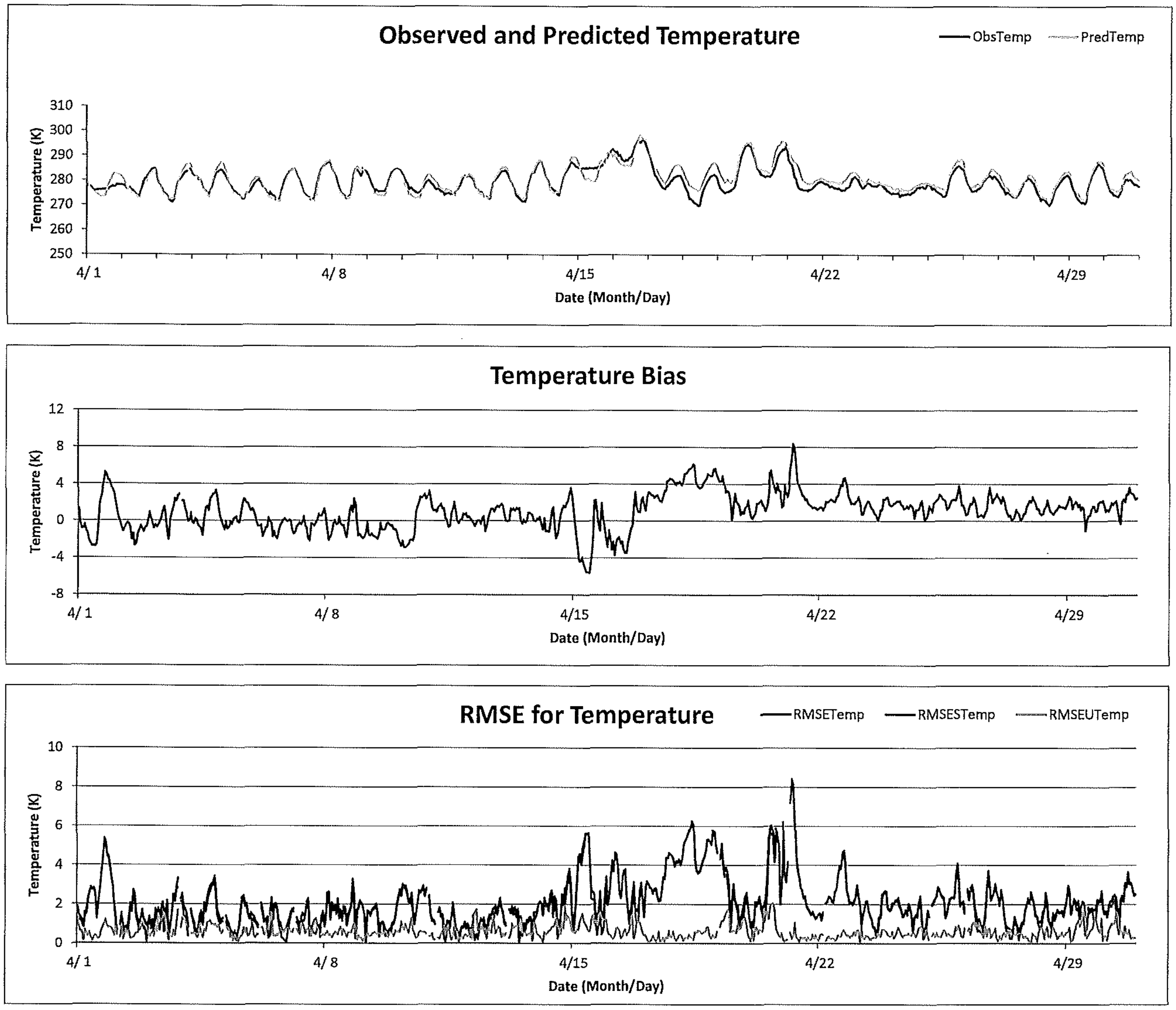


Figure 3-3: Observed and Predicted Temperature and Statistics – April 2012 Tier IV

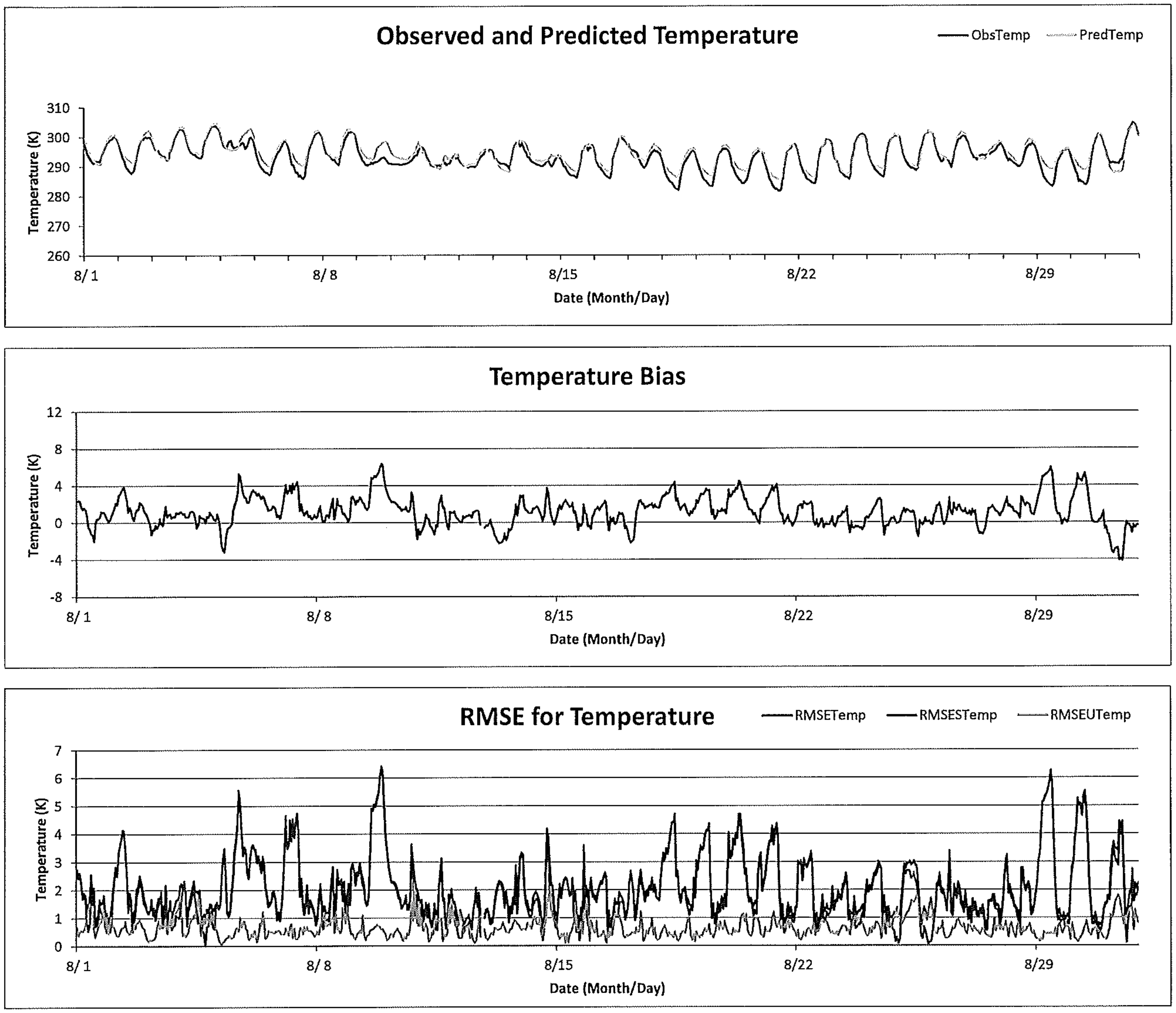


Figure 3-4: Observed and Predicted Temperature and Statistics – August 2012 Tier IV

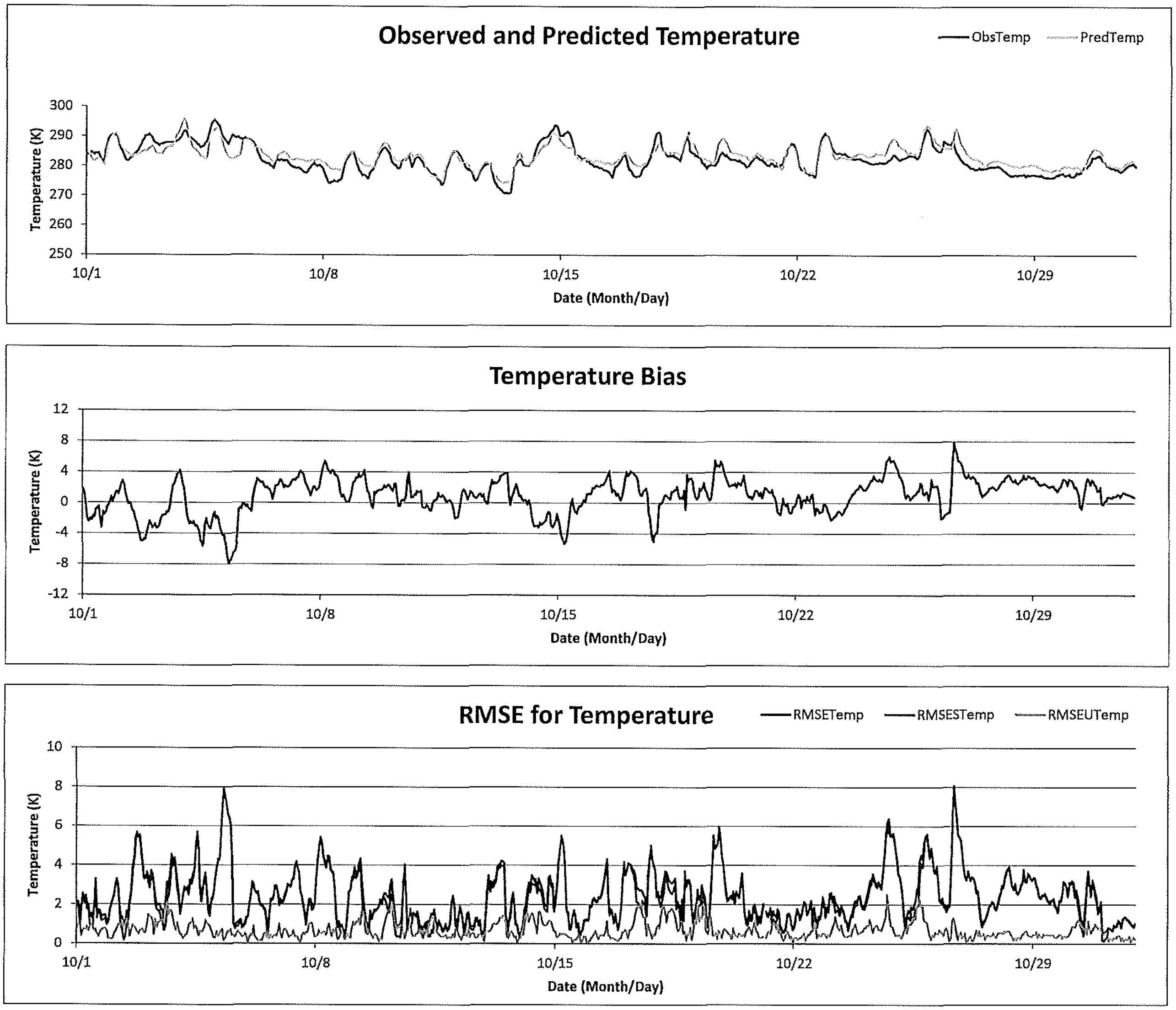


Figure 3-5: Observed and Predicted Temperature and Statistics – October 2012 Tier IV

3.1.2 Mixing Ratio Bias and Error

Mixing ratio statistics for the 36 km, 12 km, 4 km and 1.33 km modelling domains are presented in Table 3-4.

The Tier IV domain average mixing ratio bias and error are shown in Figure 3-6. This "soccer plot" depicts the monthly average bias versus the monthly average error over the entire 1.33 km modelling domain. It is desirable to have all monthly values inside the benchmark outline. The "goal" shown is for all simulations (see Section 1.0 for the full list of benchmarks).

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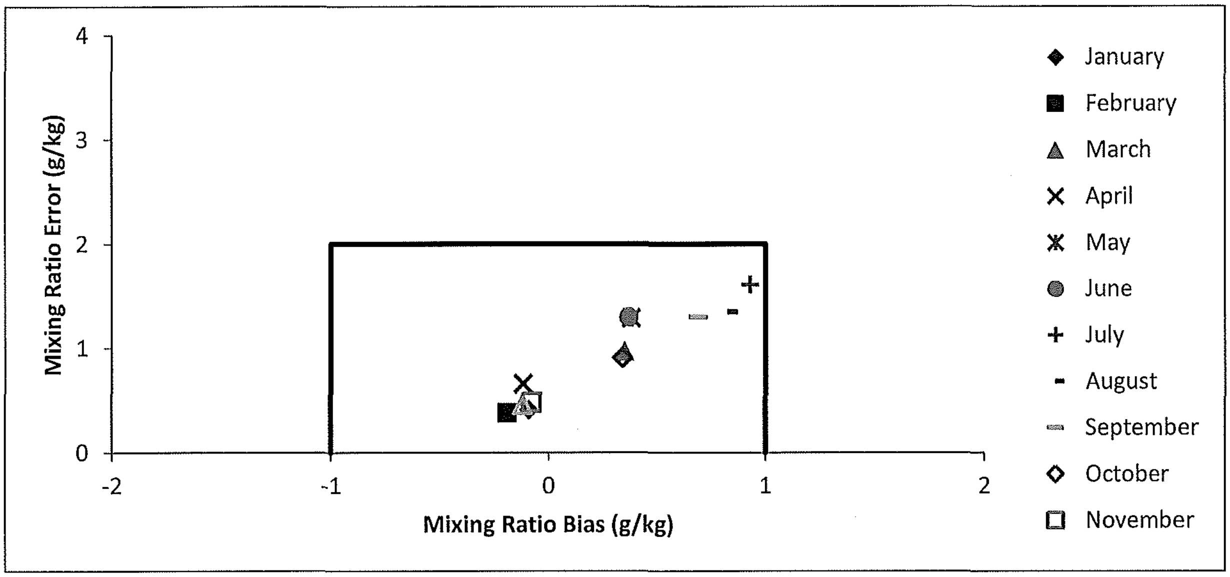

Figure 3-6: Monthly Mixing Ratio Error vs. Mixing Ratio Bias for Tier IV

All monthly data falls within the benchmark. July showed the highest bias and error. The WRF mixing ratio data are completely acceptable for use in the CMAQ assessment.

Figure 3-7, Figure 3-8, Figure 3-9, and Figure 3-10 provide comparisons of the observed and predicted mixing ratio (humidity) bias, error and RMSE for January, April, August and October 2012, respectively, for Tier IV (1.33 km spacing).

Across the four tiers, the bias in predicted mixing ratio was found to be between –0.23 g/kg (Tier II, December) and 1.37 g/kg (Tier IV, May) and the absolute error in mixing ratio was found to be between -0.23 g/kg (Tier II, December) and 1.37 g/kg (Tier I, July).

Across the four tiers, the bias in predicted mixing ratio was found to be between -1.62 °K (Tier II, February) and 1.88 °K (Tier IV, May) and the absolute error in temperature was found to be between 1.72 °K (Tier IV, December) and 3.46 °K (Tier I, July).

Table 3-4: Mixing Ratio (Humidity) Bias and Error for all Tiers

Month	Tier I		Tier II		Tier III		Tier IV	
	Humidity Bias	Humidity Error	Humidity Bias	Humidity Error	Humidity Bias	Humidity Error	Humidity Bias	Humidity Error
January	-0.06	0.63	-0.08	0.54	0.03	0.49	-0.09	0.41
February	-0.11	0.64	-0.21	0.53	-0.16	0.43	-0.19	0.38
March	0.32	1.31	0.27	1.22	0.31	1.03	0.35	0.97
April	0.24	1.06	-0.03	0.85	0.05	0.74	-0.12	0.66
May	0.42	1.71	0.23	1.68	0.04	1.45	0.38	1.29
June	0.85	1.66	0.85	1.61	0.73	1.52	0.37	1.30
July	1.37	2.45	1.04	2.21	0.69	1.89	0.93	1.61
August	1.03	1.77	1.04	1.67	1.01	1.64	0.83	1.35
September	0.58	1.50	0.56	1.40	0.77	1.36	0.69	1.30
October	0.26	1.06	0.30	1.08	0.45	1.08	0.34	0.91
November	0.08	0.60	0.09	0.58	0.20	0.59	-0.08	0.48
December	-0.17	0.83	-0.23	0.72	-0.05	0.57	-0.12	0.46
Annual	0.40	1.27	0.32	1.17	0.34	1.07	0.27	0.93

Note:
Annual has been calculated as the average of the monthly values.

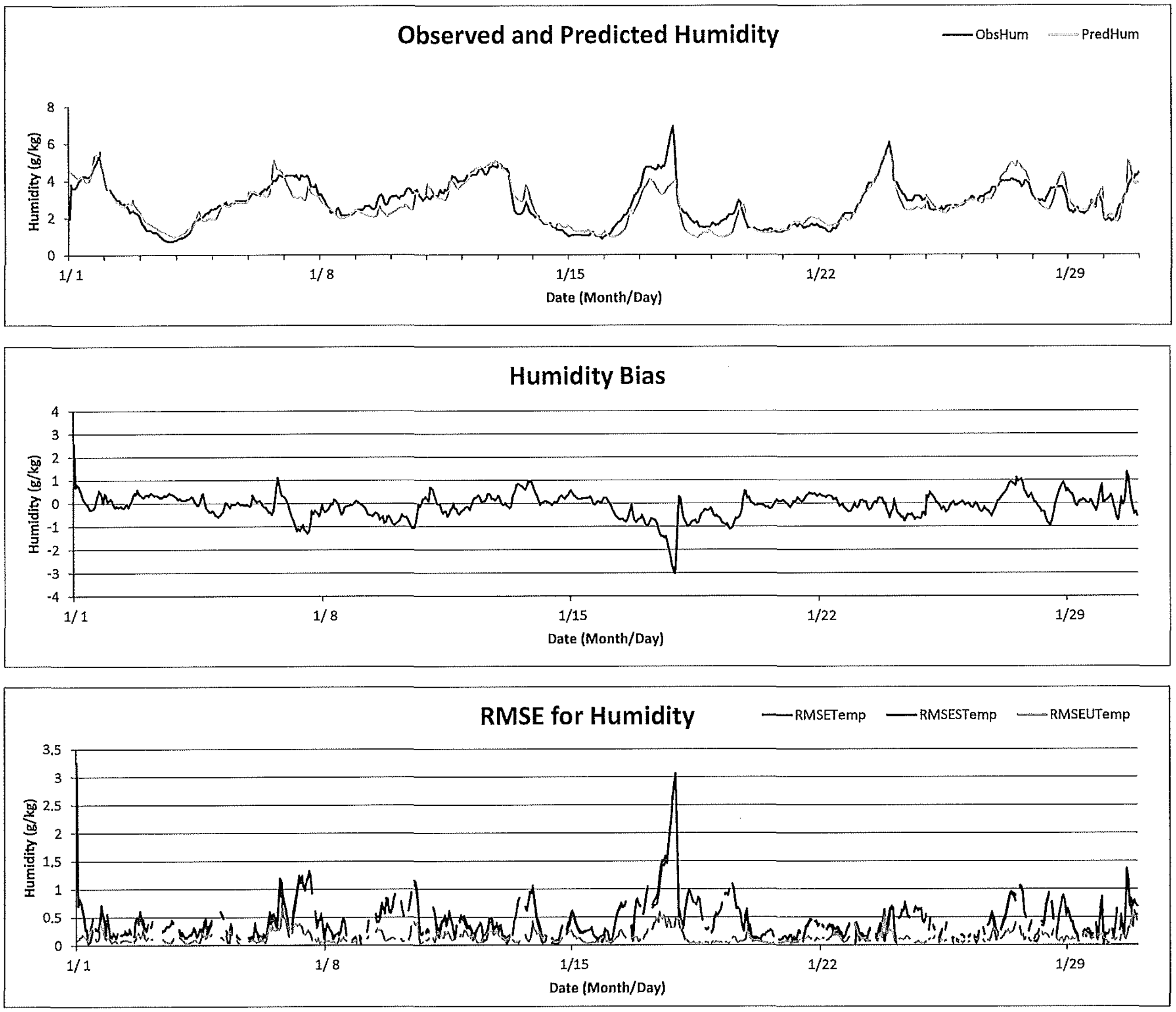

Figure 3-7: Observed and Predicted Water Mixing Ratio (Humidity) and Statistics – January 2012 Tier IV

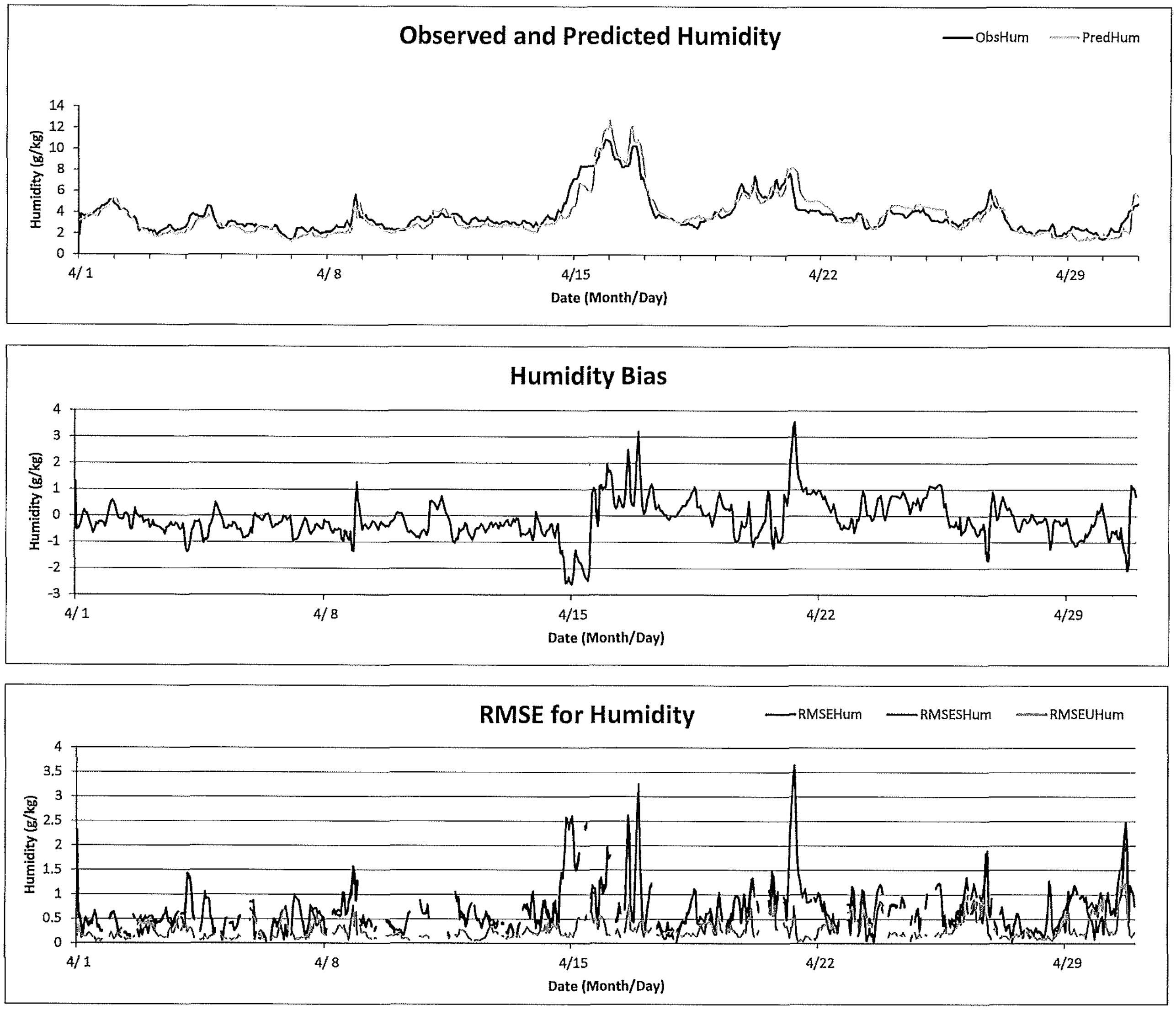

Figure 3-8: Observed and Predicted Water Mixing Ratio (Humidity) and Statistics – April 2012 Tier IV

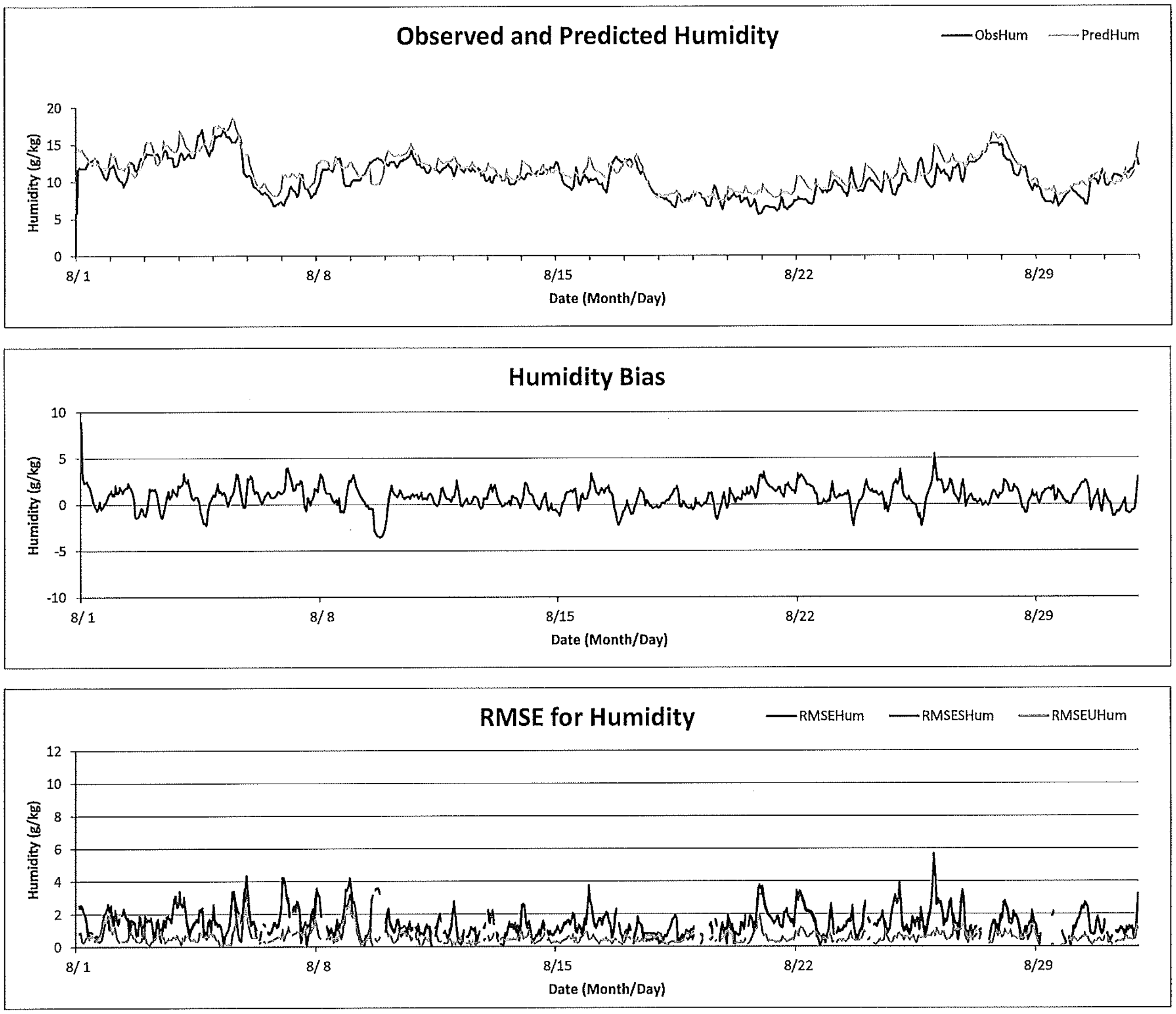

Figure 3-9: Observed and Predicted Water Mixing Ratio (Humidity) and Statistics – August 2012 Tier IV

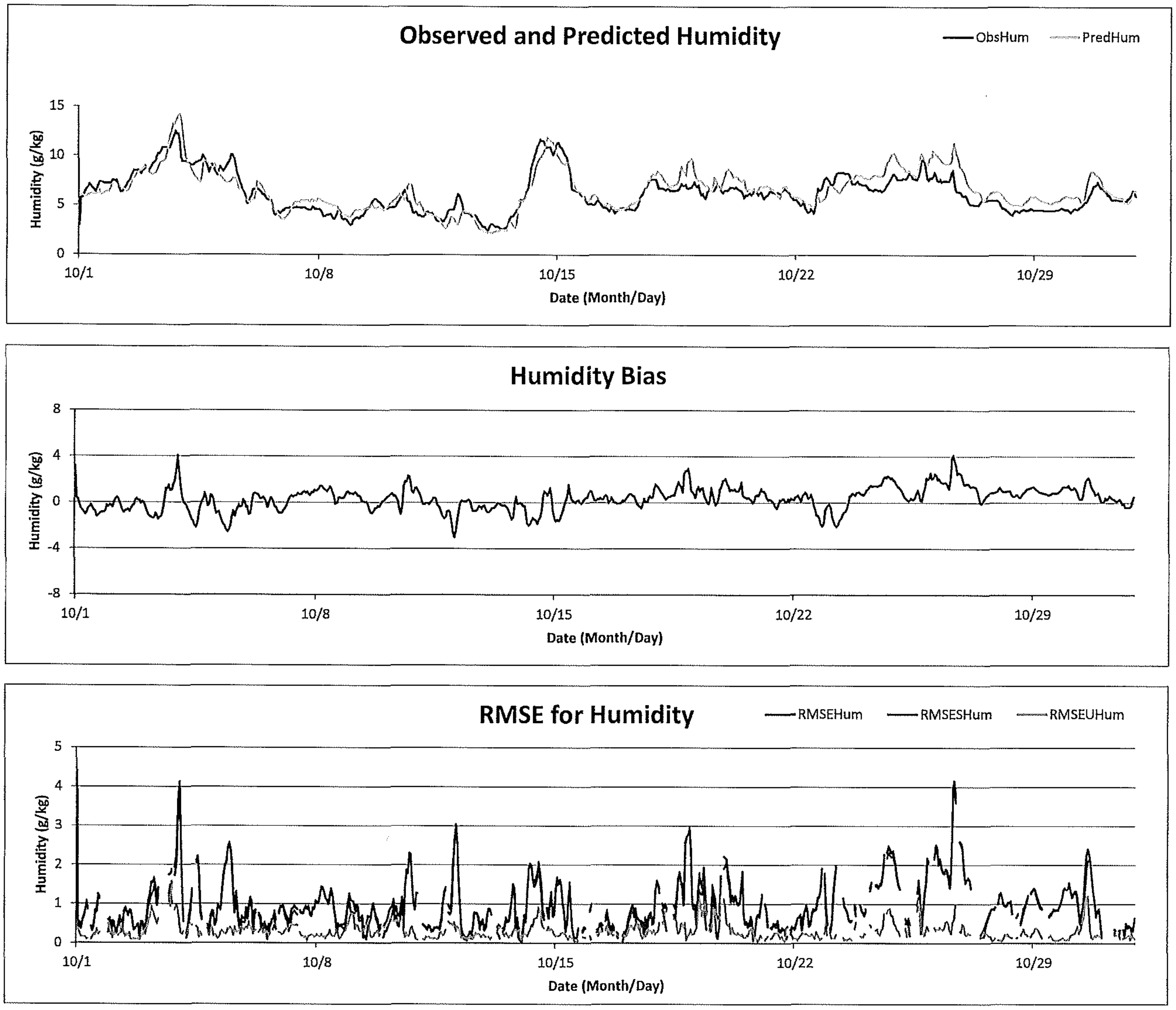

Figure 3-10: Observed and Predicted Water Mixing Ratio (Humidity) and Statistics – October 2012 Tier IV

3.1.3 Wind Data Bias, Error and RMSE

3.1.3.1 Wind Speed

The RMSE for the wind speed for the 36 km, 12 km, 4 km, and 1.33 km modelling domains are presented in Table 3-5. Wind speed RMSE was found to be between 1.35 m/s (Tier IV, August) and 2.02 m/s (Tier II, January).

Table 3-5: Wind Speed RMSE for all Tiers

Month	Tier I	Tier II	Tier III	Tier IV
January	1.97	2.02	1.97	1.81
February	1.76	1.75	1.75	1.67
March	1.83	1.91	1.86	1.76
April	1.81	1.86	1.74	1.71
May	1.58	1.56	1.49	1.46
June	1.56	1.61	1.61	1.56
July	1.48	1.50	1.45	1.51
August	1.47	1.48	1.41	1.35
September	1.56	1.62	1.50	1.43
October	1.79	1.86	1.79	1.69
November	1.63	1.58	1.54	1.48
December	1.80	1.80	1.77	1.61
Annual	1.69	1.71	1.66	1.59

The Tier IV domain wind speed RMSE and wind speed bias are shown in Figure 3-11. This "soccer plot" depicts the monthly average wind speed RMSE versus the monthly average wind speed bias over the entire 1.33 km modelling domain. It is desirable to have all monthly values inside the benchmark outline. The "goal" shown is for all simulations (see Section 1.0 for the full list of benchmarks). All prognostic data set fall within the benchmark, demonstrating that the WRF wind data are acceptable for use in the CMAQ assessment.

3.1.3.2 Wind Direction

Wind direction bias and error statistics for the 36 km, 12 km, 4 km and 1.33 km modelling domains are presented in Table 3-6.

Across the four tiers, the bias in predicted wind direction was found to be between -1.29 ° (Tier IV, August) and 6.80 ° (Tier I, October), and the absolute error in wind direction was found to be between 23.75 ° (Tier II, January) and 38.75 ° (Tier II, July).

Annual wind roses for the observed and predicted winds for Tier IV are provided in Figure 3-12 and Figure 3-13, respectively. The wind roses show a high degree of similarity between the observations and the predictions from WRF.

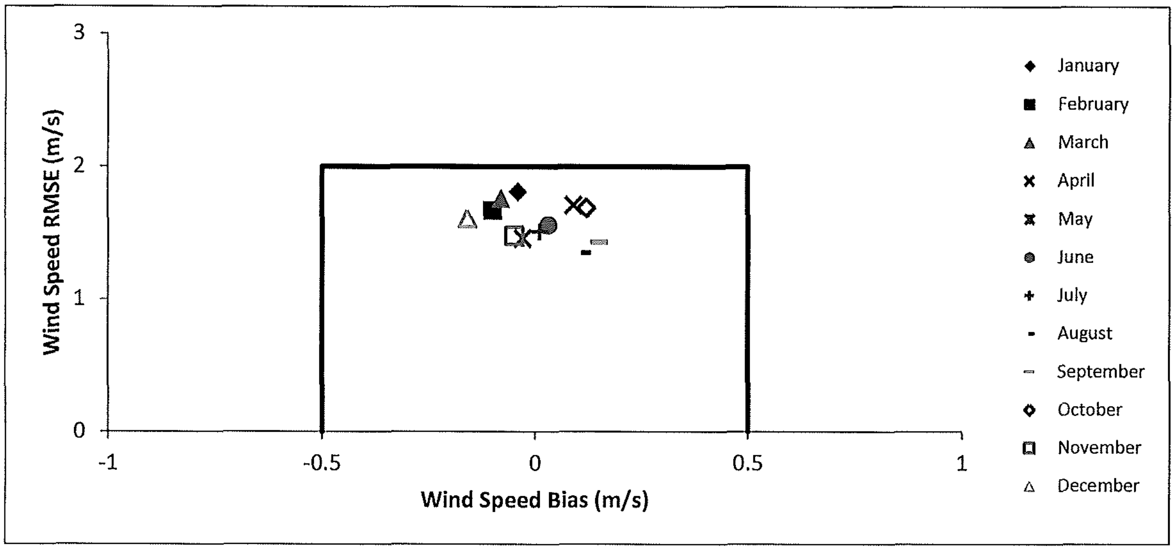

Figure 3-11: Wind Speed RMSE vs. Wind Speed Bias for Tier IV

Table 3-6: Wind Direction Bias and Error for all Tiers

Month	Tier I		Tier II		Tier III		Tier IV	
	Wind Direction Bias	Wind Direction Error	Wind Direction Bias	Wind Direction Error	Wind Direction Bias	Wind Direction Error	Wind Direction Bias	Wind Direction Error
January	4.86	24.87	0.54	23.75	0.97	24.41	1.89	23.94
February	3.42	26.75	-1.01	26.09	-1.12	26.03	1.02	26.20
March	5.51	29.33	0.84	29.31	-0.44	30.65	0.76	30.83
April	4.05	28.70	0.69	27.59	1.69	27.15	4.14	27.77
May	5.33	33.86	2.10	36.40	0.34	37.32	1.86	37.81
June	6.46	31.11	3.56	30.21	3.15	29.46	4.82	27.68
July	6.04	38.69	1.21	38.75	1.41	36.98	1.84	36.38
August	4.74	37.31	0.35	35.57	-0.01	35.33	-1.29	36.03
September	4.31	34.47	-0.14	35.12	-0.34	34.71	-1.28	32.66
October	6.80	25.86	1.24	24.67	-0.24	27.07	0.38	26.10
November	6.70	26.47	1.93	27.59	0.99	27.65	4.65	25.75
December	5.38	26.76	1.82	26.20	1.05	27.46	2.69	27.39
Annual	5.30	30.35	1.09	30.10	0.62	30.35	1.79	29.88

Note:
Annual has been calculated as the average of the monthly values.

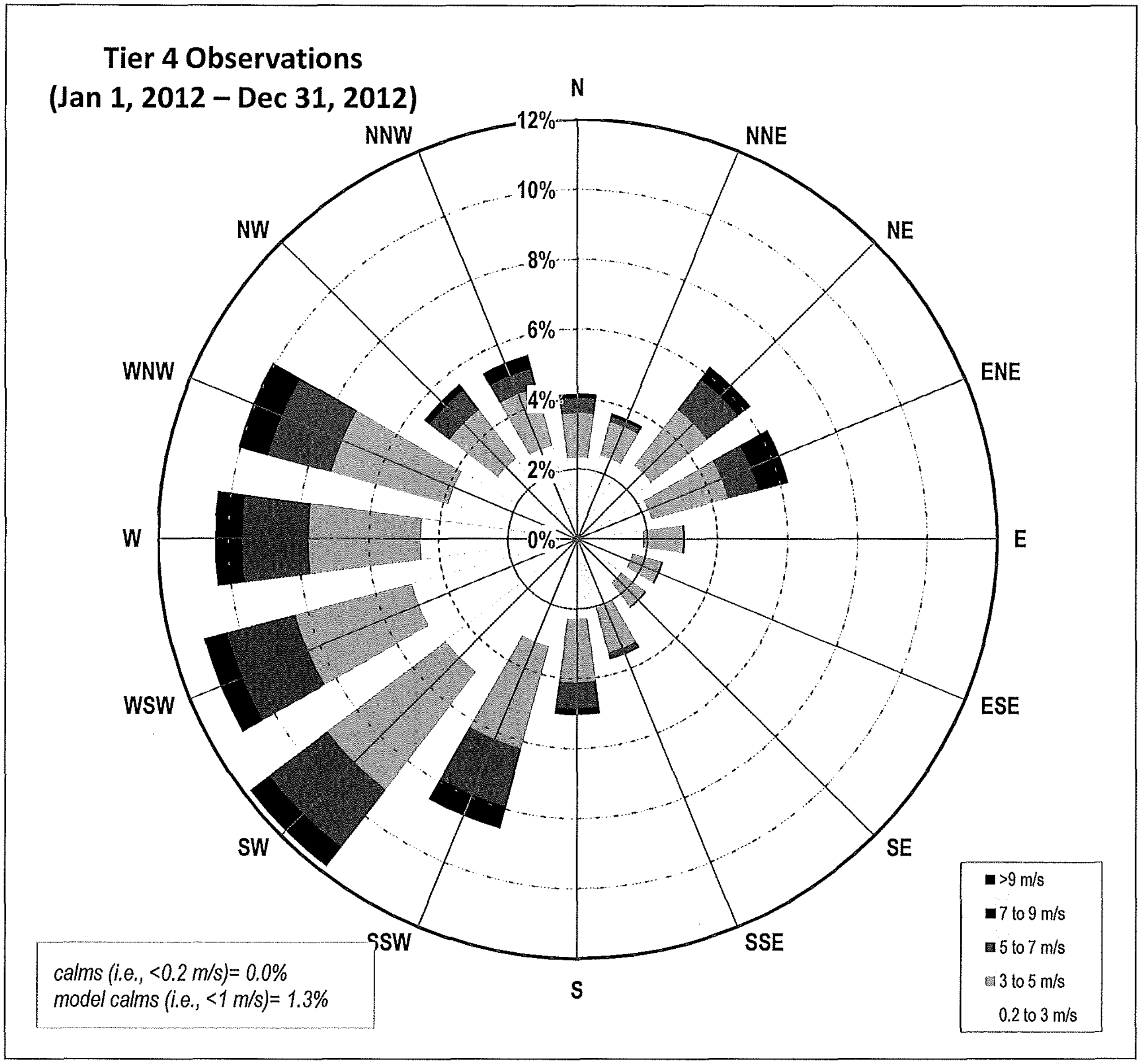

Figure 3-12: Windrose for Tier IV Observed Winds

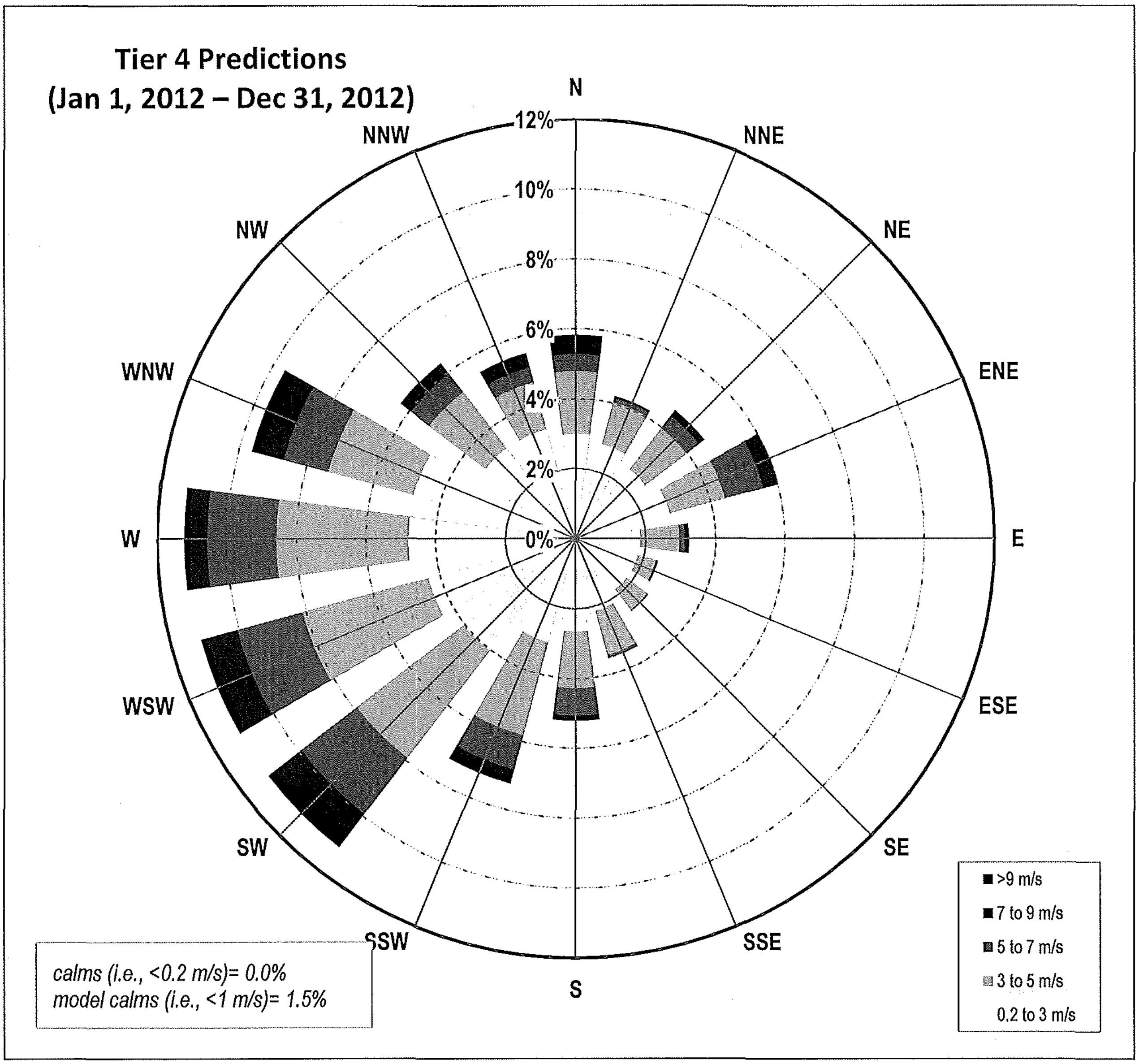

Figure 3-13: Windrose for Tier IV Predicted Winds

3.1.3.3 Wind Direction vs Wind Speed

The Tier IV domain wind direction error and wind speed RMSE are shown in Figure 3-14. This "soccer plot" depicts the monthly average wind direction error versus the monthly average wind speed RMSE over the entire 1.33 km modelling domain. It is desirable to have all monthly values inside the benchmark outline. The "goal" shown is for all simulations (see Section 1.0 for the full list of benchmarks).

Seven months of the prognostic data set fall within the benchmark (April, June, October, November, and December) while five months show a wind direction error greater than the benchmark (March, May, July, August, and September), showing that the gross wind direction error can be higher than 30° in these months. Wind speed RMSE was always less than 2 m/s, meeting the benchmark criteria in all months. While it is preferable to have all monthly values fall within the benchmarks provided, the WRF wind data are acceptable for use in the CMAQ assessment.

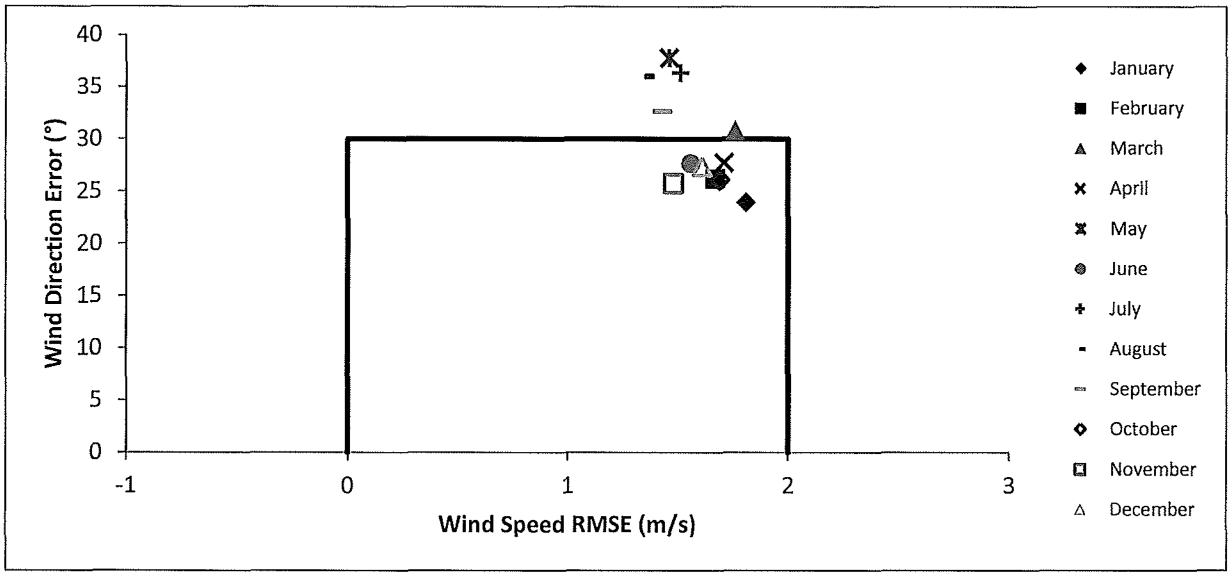

Figure 3-14: Monthly Wind Direction Error vs. Wind Speed RMSE for Tier IV

4.0 SUMMARY AND CONCLUSIONS

Bias and error statistics for temperature, mixing ratio (humidity), wind direction, and RMSE for wind speed were *estimated for the model predictions in all four modelling tiers for the Hamilton Airshed Study.*

A summary of the overall annual model performance statistics and appropriate benchmarks is provided in Table 4-1. Model performance met all appropriate benchmarks (values should be compared to long-term benchmarks, where available, and Short-Term Benchmarks when no long-term range is provided). This assessment demonstrates that the WRF model has suitably characterized actual meteorological conditions across all four modelling domains, and is suitable for the CMAQ modelling study. Overall, the wind direction error and temperature bias, on a monthly basis, were found to fall slightly outside preferred benchmarks, however all other parameters met or exceeded performance levels.

Table 4-1: Annual Model Performance Statistics and Benchmarks

Model Performance Statistics	Tier I	Tier II	Tier III	Tier IV	Normal Benchmark	Complex Conditions Benchmark
Temperature Bias	0.14	0.14	0.28	0.67	-0.5 K ≤ X ≤ 0.5 K	-1.0 K ≤ X ≤ 1.0 K
Temperature Error	2.28	2.39	2.25	2.24	X ≤ 2.0 K	X ≤ 3.0 K
Mixing Ratio Bias	0.40	0.32	0.34	0.27	-1.0 g/kg ≤ X ≤ 1.0 g/kg	
Mixing Ratio Error	1.27	1.17	1.07	0.93	X ≤ 2.0 g/kg	
Wind Direction Bias	5.30	1.09	0.62	1.79	-10 ° ≤ X ≤ 10 °	
Wind Direction Error	30.35	30.10	30.35	29.88	X ≤ 30 °	
Wind Speed Bias	0.00	-0.07	-0.09	0.04	-5 m/s ≤ X ≤ 5 m/s	
Wind Speed RMSE	1.69	1.71	1.66	1.59	X ≤ 2 m/s	

Notes:
Normal benchmark applies to multi-day meteorological modelling episodes of duration less than 60 days that do not cross climatological seasons and/or non-complex conditions
Complex condition benchmark applies to episodes of greater than 60 days or episodes that cross climatological seasons, or modelling regions with complex meteorological conditions.

Detailed analysis of the metrics provided over the four domains demonstrated that WRF did well at replicating observed atmospheric values of temperature, mixing ratio, wind speed and wind direction. Monthly and annual analyses demonstrated a high level of accuracy in reproducing observations, even in the region surrounded by the Great Lakes (Tier IV) which can be challenging for prognostic models. The WRF prognostic meteorological data are very suitable for use in the CMAQ model for the Hamilton Airshed Study.

5.0 REFERENCES

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Emery, C., E. Tai, and G. Yarwood, 2001. "Enhanced Meteorological Modeling and Performance Evaluation for Two Texas Ozone Episodes." Prepared for the Texas Natural Resource Conservation Commission, prepared by ENVIRON International Corporation, Novato, CA. 31-August.

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Report Signature Page

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APPENDIX B

Emission Inventory Analysis

February 2018

HAMILTON AIRSHED MODELLING SYSTEM EMISSIONS INVENTORY REPORT

Hamilton Airshed Modelling System

Submitted to:
Hamilton Industrial Environmental Association (HIEA)
270 Sherman Ave. N.
Hamilton, ON L8L 6N4

REPORT

Report Number: 1418883 (2000)

Distribution:

Electronic copy - HIEA
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1.0 INTRODUCTION

Air emissions that impact an airshed, such as Hamilton, can come from various sources at varying distances such as long-range transport (i.e., hundreds of kilometres) or short-distances (i.e., hundreds of meters) and be subject to various atmospheric chemical transformations (i.e., ozone or secondary particulate matter). In addition, these emissions can either be released into the atmosphere at elevated location (i.e., stacks) or at ground-level (i.e., traffic). The impact of these physical sources becomes highly complex when addressing the variability of emissions with time of day or day of year. An emissions inventory will take into account the geographical and temporal variation of emissions, as well as the chemical species being released.

Source categories used for the study are presented on Table 1-1. All sources were modelled as either point or area sources. Industrial sources can be comprised of elevated stacks (i.e. point sources) as well as area sources (i.e. fugitive industrial sources) depending on the physical characteristics of the source of the emission. Point sources are any stationary source that releases emissions through tall stacks at elevated heights directly into the atmosphere. Area sources are effectively conglomerations of small point sources such as a home or office building, or a diffuse stationary source, such as wildfires or agricultural tilling. These sources cannot be quantified into direct emissions such as point sources but are grouped to represent emissions over a small defined area. Mobile sources include a wide variety of vehicles, engines, and equipment that generate emission and that move (or can be moved) from place to place. Mobile sources can be separated into on-road and non-road sources. On-road mobile sources refer to those that transport passengers or freight (e.g. cars and trucks) while non-road mobile sources refer to airports, railways and marine ports as well as to the vehicles, engines, and equipment used for construction, agriculture, off-road transportation (e.g. forestry activities), recreation, and many other purposes (e.g., lawn mowing, etc). Biogenic emissions are those produced by actions of living organisms, (e.g. vegetation and animals) and include such emissions as VOCs from vegetation and NO from soil. These emissions are processed as area source emissions.

As many emission sources as possible were assigned to the point source category because these sources typically have better temporal and spatial data. Any stationary sources for which stack information is available were modelled as a stationary point source.

Table 1-1: Emission Source Classification

Emission Classification	Type	Definition
Industrial	Point(1)	Elevated stacks
	Area	Industrial areas
Commercial and Residential	Area	Natural gas usage, autobody shops, dry cleaners, commercial solvents, other residential heating sources
On Road	Area	On-road vehicles (trucks, cars, motorcycles)
Nonroad	Area	Airport, marine, rail and lawn mowers,
Biogenic and Agricultural	Area	Non-anthropogenic activities

Note:
(1) Industrial point sources appear in all four tiers. Only emissions from the US have commercial and non-road point sources in addition to industrial point sources. These only impact the first three tiers.

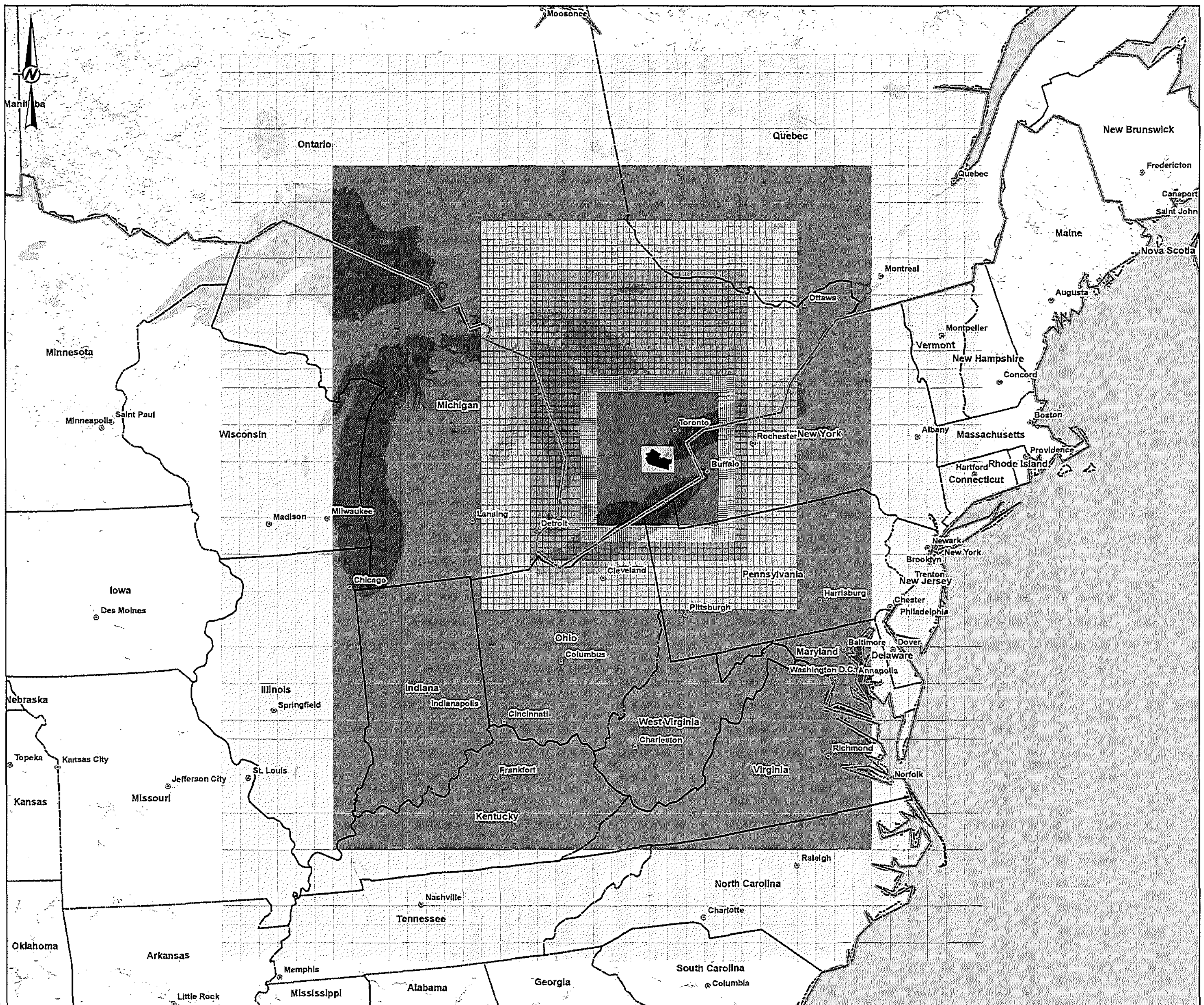
To address the contribution from various emission sources to the Hamilton airshed, a multi-tier approach was used to segregate the emissions by geographic location (Figure 1-1 and Figure 1-2). As shown in Figure 1-1 and Figure 1-2, the computational domain was divided into four concentric areas with varying grid density;

- Tier I at 36 km x 36 km grid resolution (primarily US United States ();
- Tier II at 12 km x 12 km grid resolution (generally South Western Ontario);
- Tier III at 4 km x 4 km grid resolution (City of Hamilton); and
- Tier IV at 1.33 km x 1.33 km grid resolution (City of Hamilton – Community Level).

The emissions inventory, over the four tiers, required the merging of the most recent and pertinent National Emissions Inventories (Canada and the US) and high-resolution, location-specific emissions, estimated from local and provincial land-use and activity data in the Hamilton region. Information from provincial air regulatory agencies and transportation planning agencies was processed into the required format. For the 2012 base year, emissions estimates based on a number of available data sets and models. Emissions were processed for sources falling within US and Canada are identified in the following sections.

1.1 SMOKE

SMOKE v.3.6 (CMAS, 2014) estimates spatially and temporally resolved, speciated emissions for on-road mobile, non-road mobile, area, point, fire and biogenic emission sources, among others, for all modern photochemical grid models. SMOKE is principally an emission processing system and not a true emissions modelling system in which emissions estimates are simulated from first principles. This means that, apart from on-road mobile, biogenic, and some non-road mobile sources, its purpose is to provide an efficient tool for converting emissions inventory data into the formatted emission files required by an air quality simulation (photochemical) model. For on-road and some non-road mobile sources, SMOKE simulates emissions rates based on input mobile source activity data, emission factors estimated using the Motor Vehicle Emission Simulator (MOVES2014; USEPA, 2014), and outputs from transportation travel-demand models. The following sections discuss the geographic distribution of the emission estimates, with an emphasis placed on the Tier IV study area. The emissions vary temporally with month, day and hour according to the SCC code (CMAS, 2014). No profiles were updated with site-specific information, the default profiles were used for all tiers. For the emissions processed with MOVES2014, the temporal variation is discussed in Section 2.2.5, below.



LEGEND
- City
- City of Hamilton
- State and Province Boundary
- Country Boundary
- Waterbody
- Tier IV 1 km CMAQ
- Tier IV 1 km WRF
- Tier III 4 km CMAQ
- Tier III 4 km WRF
- Tier II 12 km CMAQ
- Tier II 12 km WRF
- Tier I 36 km CMAQ
- Tier I 36 km WRF

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Kilometres

REFERENCE(S)
BASE DATA FROM ESRI.PROJECTION: LAMBERT CONFORMAL CONIC.

CLIENT
HAMILTON INDUSTRIAL ENVIRONMENTAL ASSOCIATION

PROJECT
AIRSHED MODELLING TIERS

TITLE
MODELLING AND EMISSION GRIDS FOR HAMILTON AIRSHED MODELLING SYSTEM

CONSULTANT	YYYY-MM-DD	2015-03-09
Golder Associates	DESIGNED	KD
	PREPARED	KD
	REVIEWED	JK
	APPROVED	JLK

PROJECT NO.	CONTROL	REV.	FIGURE
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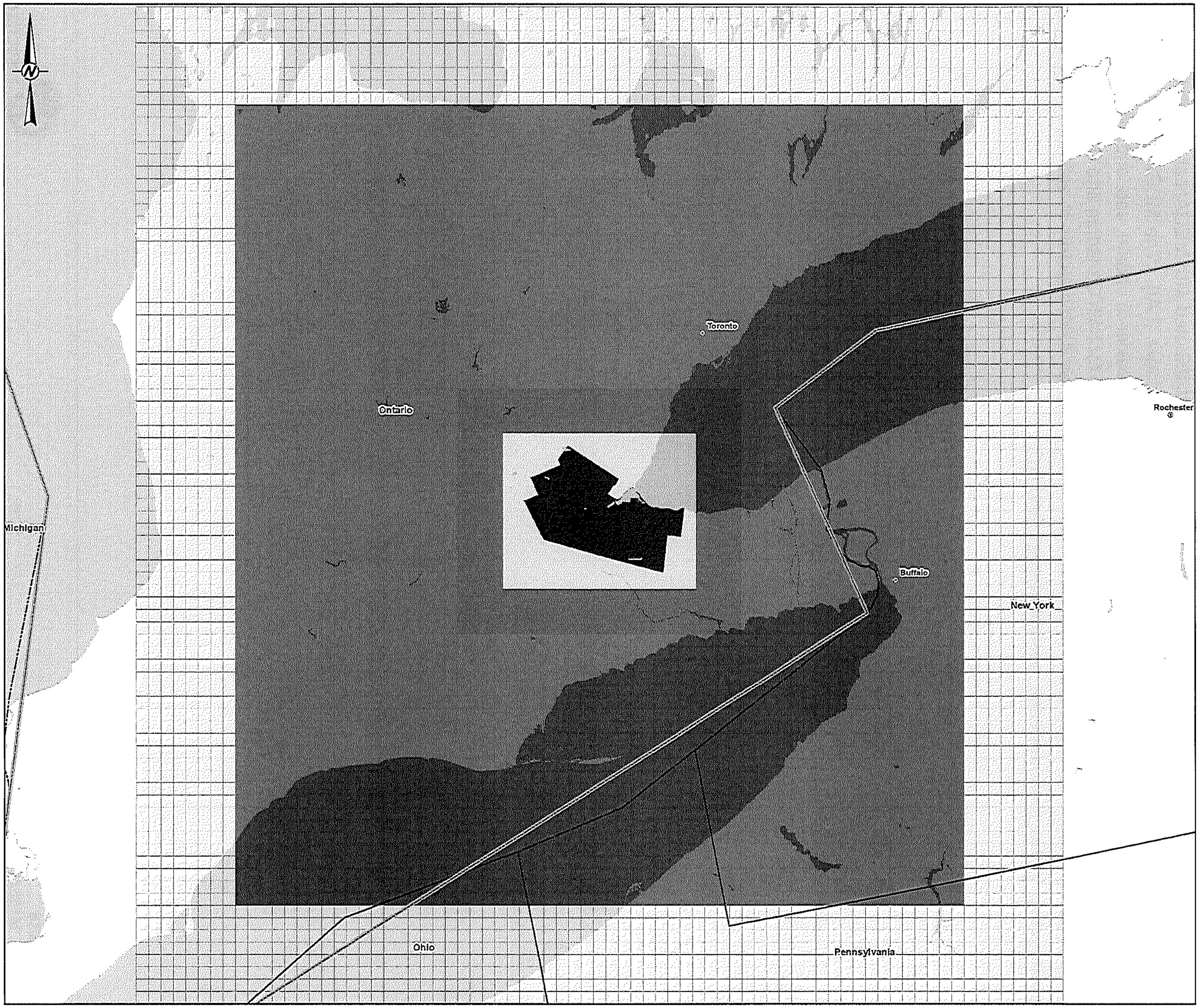

LEGEND
- City
- City of Hamilton
- State and Province Boundary
- Country Boundary
- Waterbody
- Tier IV 1 km CMAQ
- Tier IV 1 km WRF
- Tier III 4 km CMAQ
- Tier III 4 km WRF

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Kilometres
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REFERENCE(S)
BASE DATA FROM ESRI.PROJECTION: LAMBERT CONFORMAL CONIC.

CLIENT
HAMILTON INDUSTRIAL ENVIRONMENTAL ASSOCIATION

PROJECT
AIRSHED MODELLING TIERS

TITLE
TIER III AND IV MODELLING AND EMISSION GRIDS FOR HAMILTON AIRSHED MODELLING SYSTEM

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-03-09
DESIGNED	KD
PREPARED	KD
REVIEWED	JK
APPROVED	JLK

PROJECT NO.	CONTROL	REV.	FIGURE
1418883	0001	1.0	1-2

1.2 MEGAN

The Model of Emissions of Gases and Aerosols from Nature (MEGAN) was used to estimate biogenic emissions. The MEGAN (UCAR, 2015) was developed to estimate biogenic emissions of reactive gases and aerosols needed for both regional air quality models (RAQMs) and global chemistry and transport models (GCTMs) (Guenther et al., 2012). Driving variables include land cover, weather, and atmospheric chemical composition. MEGAN is a global model with a base resolution of ~1 km. Global land cover data distributed with MEGAN at a 1-km resolution include plant functional type (PFT), emissions factors, and leaf area index (LAI). The MEGAN model uses an approach similar to previous terrestrial biogenic emission models but is easier to update, use, and expand to other chemical compounds and plant functional types. MEGAN was executed for both Canadian and US emissions with the appropriately gridded PFT, gridded LAI, gridded meteorology, and emissions factors to estimate emissions of isoprene, other VOCs, monoterpenes, sesquiterpenes, and NO.

2.0 EMISSION ESTIMATES

2.1 National Emissions Inventories

As described in the Emissions Protocol, emissions from US sources were taken from EPA's 2011 NEI (USEPA, 2015) and categorised by SCC code. Additionally, the EPA's Clean Air Markets Division (CAMD) publishes electric generating utilities (EGU) sector activity and emissions information on a quarterly basis for units subject to reporting under the agency's various continuous emissions monitoring (CEM) regulations. Other pollutants from US EGUs were be derived from the 2011 NEI. Surrogate data files were developed for each SCC code to spatially distribute the data at the appropriate resolution as well as provide temporal distribution.

For Canada, the Tier I emissions were quantified using Environment Canada's 2006 SMOKE emissions inventory (Environment Canada, 2006), which represents the most complete and representative emissions inventory at the launch of the study. Environment Canada's 2006 emissions inventory is a Canada-wide inventory of emissions, aggregated by sector (e.g., industrial, commercial, residential, agricultural), with provincial data provided for transportation-related sources (e.g., roads, rail, marine). Using the grid definitions for Tier I within SMOKE, only the relevant information to the study area was extracted. No additional information was used to augment the emissions in Tier I, apart from the biogenic emissions provided by MEGAN (biogenic emissions are not covered in Environment Canada's 2006 emissions inventory).

A summary of the combined Canadian and US Emissions for Tier I, processed with the aid of SMOKE and MEGAN, are provided in Table 2-1.

Table 2-1: Tier I 2012 Emissions by Classification as Processed by SMOKE [tonnes/year]

Pollutant	Industrial	Commercial	Residential	Agriculture	On-Road	Non-Road	Total
Acetaldehyde	2.85E+03	3.07E+03	2.55E+04	1.51E+05	2.87E+04	4.09E+03	2.15E+05
Acrolein(1)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzene	9.42E+03	5.18E+03	1.56E+04	1.05E+02	4.98E+04	4.25E+03	8.43E+04
1,3 Butadiene(1)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon Monoxide	1.89E+06	6.57E+04	1.22E+06	7.39E+05	8.52E+06	9.79E+05	1.34E+07
Formaldehyde	4.08E+04	3.10E+03	2.97E+04	3.72E+04	3.09E+04	3.74E+03	1.45E+05
Nitrogen Oxides	1.79E+06	9.46E+04	1.22E+05	8.56E+04	3.19E+06	1.95E+05	5.48E+06
PM_{10}	2.02E+05	1.83E+04	2.31E+05	2.58E+03	4.56E+05	3.37E+06	4.28E+06
$PM_{2.5}$	7.98E+04	1.37E+04	2.18E+05	1.60E+03	4.37E+05	5.72E+05	1.32E+06
Sulphur Dioxide	4.28E+06	4.53E+04	3.06E+04	3.16E+02	7.23E+03	3.32E+04	4.40E+06
Volatile Organic Compounds(1)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(a)pyrene	0.00E+00	0.00E+00	0.00E+00	8.53E-04	0.00E+00	0.00E+00	8.53E-04
Metals (2)	2.83E+00	4.44E-01	6.31E-02	4.91E-03	0.00E+00	3.55E-02	3.38E+00

Notes:
(1) These compounds are not specifically speciated out in the national emission inventories but are likely contained as part of lumped species categories based on reactivity.
(2) Includes lead, cadmium, chromium (III/IV), nickel, mercury and manganese.

2.2 Developed Emissions

2.2.1 Industrial Sources

Industrial sources within Ontario include emissions reported to the National Pollutant Release Inventory (NPRI) from large industrial operations in existence in 2012 (Environment and Climate Change Canada, 2014). Any stationary source that usually releases emissions through stacks at elevated heights for which individual source records are maintained and reported to the NPRI and for which annual emissions exceed a specified threshold level are included. Industrial activities which emit compounds in amounts that are below their applicable reporting thresholds were also addressed. These below threshold emissions were back calculated with aid of reported data from NPRI (i.e, activity or emission data) and industry specific emission factors. These emission estimates provide an improved emission data set for modelling.

For local large emitters within the Hamilton area, the NPRI emission data was supplemented with more specific physical information (i.e., stack exit parameters) taken from the latest Emission Summary and Dispersion Modelling (ESDM) reports for facilities that provided these reports. Industrial sources within the portion of Tier II and Tier III that cover the US are downscaled from the EPA's 2011 NEI used in Tier I. The downscaling addresses the difference in the spatial resolution between the tiers and is performed using information provided with the EPA's 2011 NEI (e.g. spatial surrogates).

The total 2012 industrial emission rates processed by SMOKE by tier are tabulated in Table 2-2 and included US and Canadian sources for Tiers III and II, respectively. Generally, Tiers II, III & IV represent about 83%, 14% and 3%, respectively of the emissions released into the airshed when considering all species in Table 2-2. Tier II which covers the largest area represents the largest emissions, except for B(a)P, where Tier IV represents about 85% of the emissions. The largest mass quantity is SO_2 which is emitted from Tier I at about 498 ktonne/yr and represents about 86% of the SO_2 emissions.

Table 2-2: 2012 Industrial Source Emissions as Processed by SMOKE [Tonnes/year]

Pollutant	Tier II(1)	Tier III(1)	Tier IV	Total
Acetaldehyde	2.70E+02	3.05E+02	3.67E+01	6.12E+02
Acrolein	5.14E-01	9.10E-01	1.55E-01	1.58E+00
Benzene	1.11E+03	1.24E+03	1.77E+02	2.52E+03
1,3 Butadiene	1.24E+01	2.18E-02	3.69E-03	1.24E+01
Carbon Monoxide	2.18E+05	2.79E+04	1.28E+04	2.59E+05
Formaldehyde	3.34E+03	9.01E+02	5.86E+01	4.30E+03
Nitrogen Oxides	1.34E+05	3.81E+04	6.08E+03	1.78E+05
PM_{10}	1.15E+04	5.04E+03	1.13E+03	1.77E+04
$PM_{2.5}$	7.14E+03	3.54E+03	7.09E+02	1.14E+04
Sulphur Dioxide	4.98E+05	6.55E+04	1.41E+04	5.78E+05
Volatile Organic Compounds	1.09E+02	6.99E+01	7.11E+00	1.86E+02
Benzo(a)pyrene	1.85E-03	3.06E-02	1.80E-01	2.13E-01
Metals	1.43E+02	9.59E+00	1.05E+01	1.63E+02

Note:
(1) Includes US and Canadian emissions for Tier II and III.

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Industrial emissions from all tiers were processed with the aid of SMOKE and geographically distributed according to NPRI/NEI databases. Temporal (i.e., time of day) distribution of emissions was also carried out with the aid of SMOKE using the SCC codes of the emission activities. In addition, SMOKE was also used to speciate compounds based on the SCC codes. The geographic distribution of industrial emissions, for QA/QC purposes, was visually checked to ensure they were located correctly. Figure 2-1 shows the geographic distribution of NOx from industrial area sources in Tier IV, while Figure 2-2 shows the geographical distribution of NOx from industrial point sources only.

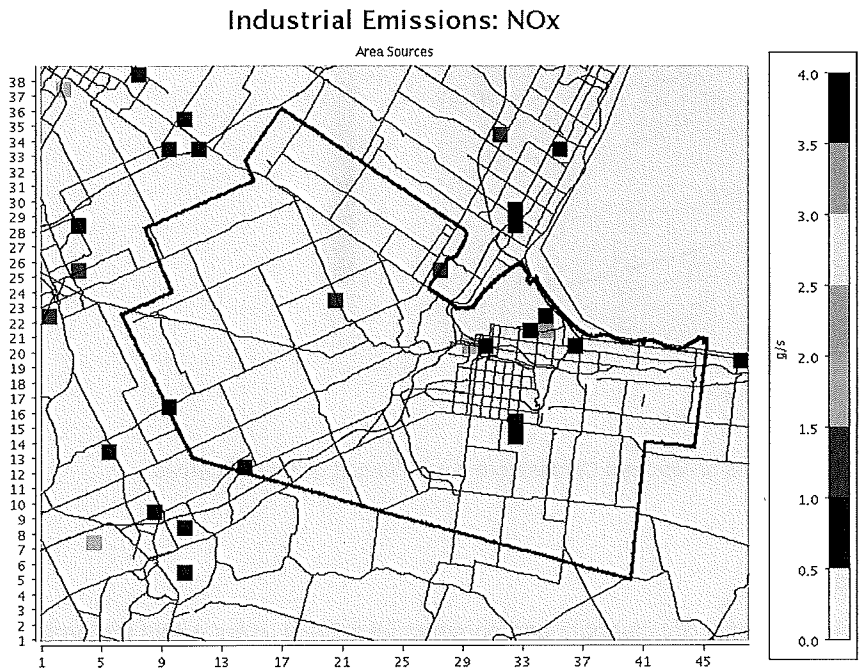

Figure 2-1: Geographic Distribution of Emissions Nitrogen Oxides from Tier IV Industrial Area Sources

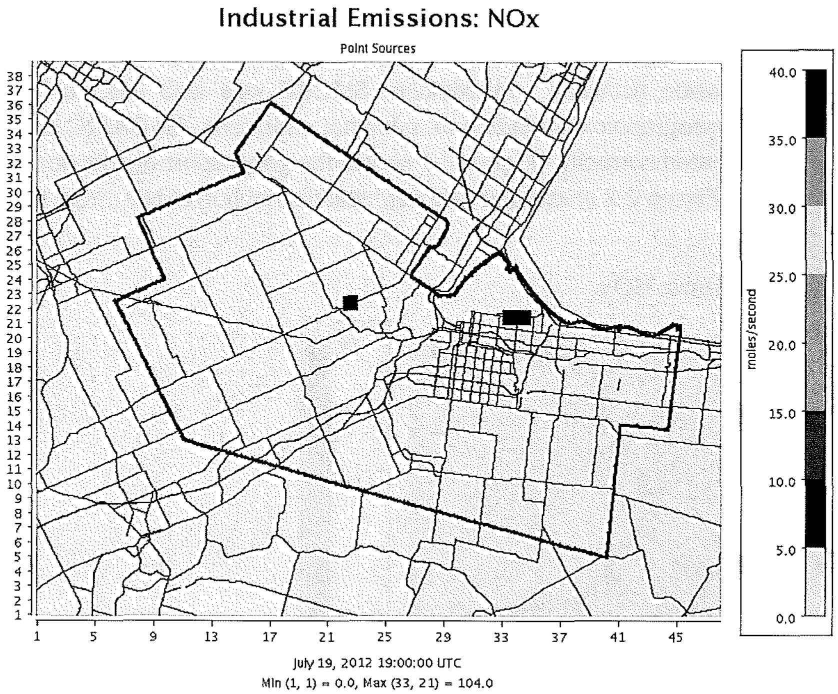

Figure 2-2: Geographic Distribution of Emissions of Nitrogen Oxides from Tier IV Industrial Point Sources

2.2.2 Commercial Sources

Commercial sources include autobody shops, dry cleaners and commercial solvent users within the project area. In Ontario, there are currently no reporting requirements for commercial facilities outside the City of Toronto. In the City of Toronto, commercial emissions are reported annually as part of the ChemTRAC bylaw. This data is publicly available and emissions are reported on a per facility basis for all commercial facilities within the City of Toronto boundary. Golder used the 2012 ChemTRAC data (City of Toronto, 2013) to develop emission factors by population or by household for a variety of commercial operations (e.g. dry cleaners) that were applied to other urban populations in Ontario, including the City of Hamilton. Similar to the industrial sources, the US commercial sources within Tier II and Tier III are downscaled from the EPA's 2011 NEI, with the downscaling addressing the difference in the spatial resolution between Tier I and the tier of interest. A summary of the commercial emission rates processed By SMOKE for Tier II to Tier IV are presented in Table 2-3, below. As illustrated in Table 2-3, commercial emissions are dominated by VOCs which reflects the auto parts, painting and solvent industries in the City.

Commercial emissions from all tiers were entered into SMOKE and geographically distributed using information from either the location of emissions from the NEI database or using population data as a surrogate. Temporal distribution of emissions was performed by SMOKE using the SCC codes of the emission activities. Similarly, SMOKE was also used to speciate pollutants further, using the SCC codes.

Figure 2-3 presents the geographic distribution of commercial nitrogen oxide emissions from Tier IV. The figure shows that emissions are in the most populous areas of the City.

Table 2-3: Tier II to IV Commercial Emissions Processed by SMOKE [Tonnes/Year]

Pollutant	Tier II	Tier III	Tier IV	Total
Acetaldehyde	3.19E+02	4.86E+01	6.76E-02	3.68E+02
Acrolein	2.66E-01	4.72E-01	8.00E-02	8.18E-01
Benzene	2.23E+02	5.38E+01	2.16E+00	2.79E+02
1,3 Butadiene	6.35E-03	1.13E-02	1.91E-03	1.95E-02
Carbon Monoxide	5.59E+03	2.57E+03	3.67E+02	8.53E+03
Formaldehyde	2.83E+02	7.70E+02	1.00E+01	1.06E+03
Nitrogen Oxides	8.52E+03	4.17E+03	4.36E+02	1.31E+04
PM_{10}	1.98E+03	5.69E+02	3.31E+01	2.58E+03
$PM_{2.5}$	1.42E+03	3.56E+02	3.31E+01	1.81E+03
Sulphur Dioxide	3.81E+03	1.92E+03	2.62E+00	5.73E+03
Volatile Organic Compounds	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(a)pyrene	1.74E-05	3.09E-05	5.23E-06	5.36E-05
Metals	1.33E-01	1.54E-01	2.51E-02	3.12E-01

HAMILTON AIRSHED EMISSIONS INVENTORY

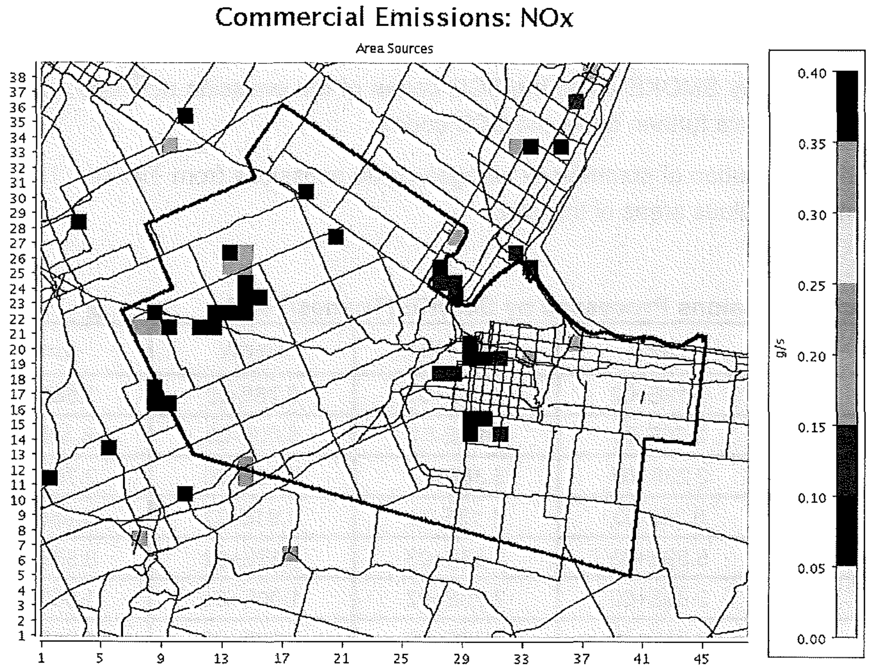

Figure 2-3: Geographic Distribution of Emissions of Nitrogen Oxides from Tier IV Commercial Sources

2.2.3 Residential Sources

The main residential sources of emissions are natural gas combustion and combustion from other main heating sources such as oil, propane and wood. For residential sources in Ontario, Golder used natural gas consumption data for the City of Hamilton along with emission factors obtained from the USEPA WEBFIRE database (USEPA, 2015) to prepare emission estimates for natural gas combustion. Where gas purchasing records were not available, Golder used a surrogate approach using the average natural gas consumption per household for 2012. A distinction was made between urban and rural areas to account for differences in activities and fuel usages that was based on available land use and population information

Oil, electricity and wood are used for home heating where natural gas is not available. Residential areas not served by natural gas were assumed to use one of these three types of fuels. Data from Statistics Canada was used to estimate the energy breakdown across Ontario and emissions were applied based on land use and population data. Similar to the industrial sources, the US commercial sources within Tier II and Tier III are downscaled from the EPA's 2011 NEI, with the downscaling addressing the difference in the spatial resolution between Tier I and the tier of interest.

Oxides of carbon and nitrogen are the dominate emission compounds from residential natural gas usage. Residential emissions from all tiers were entered into SMOKE and geographically distributed using information using population data as a surrogate. Temporal distribution of emissions was carried out with the aid of SMOKE using the SCC codes for the appropriate fuel combustion. Similarly, SMOKE was also used to speciate pollutants further, using the SCC codes. Plot files were produced showing the geographic distribution of emissions for QA/QC purposes. Figure 2-4 presents the geographic distribution of nitrogen oxide emissions from Tier IV.

Table 2-4: Tier II to IV Residential Emissions Processed By SMOKE [Tonnes/year]

Pollutant	Tier II	Tier III	Tier IV	Total
Acetaldehyde	1.40E+03	3.13E+02	7.96E-02	1.71E+03
Acrolein	3.49E-01	5.57E-01	9.46E-02	1.00E+00
Benzene	1.09E+03	1.64E+02	1.08E-02	1.26E+03
1,3 Butadiene	7.49E-03	1.33E-02	2.26E-03	2.30E-02
Carbon Monoxide	7.85E+04	1.50E+04	2.06E+02	9.37E+04
Formaldehyde	5.80E+03	3.79E+02	3.95E-01	6.18E+03
Nitrogen Oxides	1.75E+04	4.87E+03	4.83E+02	2.29E+04
PM_{10}	1.94E+04	3.01E+03	3.58E+01	2.24E+04
$PM_{2.5}$	1.85E+04	2.70E+03	3.58E+01	2.13E+04
Sulphur Dioxide	1.67E+03	2.77E+02	3.09E+00	1.95E+03
Volatile Organic Compounds	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(a)pyrene	5.24E-02	3.64E-05	6.16E-06	5.24E-02
Metals	3.95E-01	1.76E-01	2.95E-02	6.00E-01

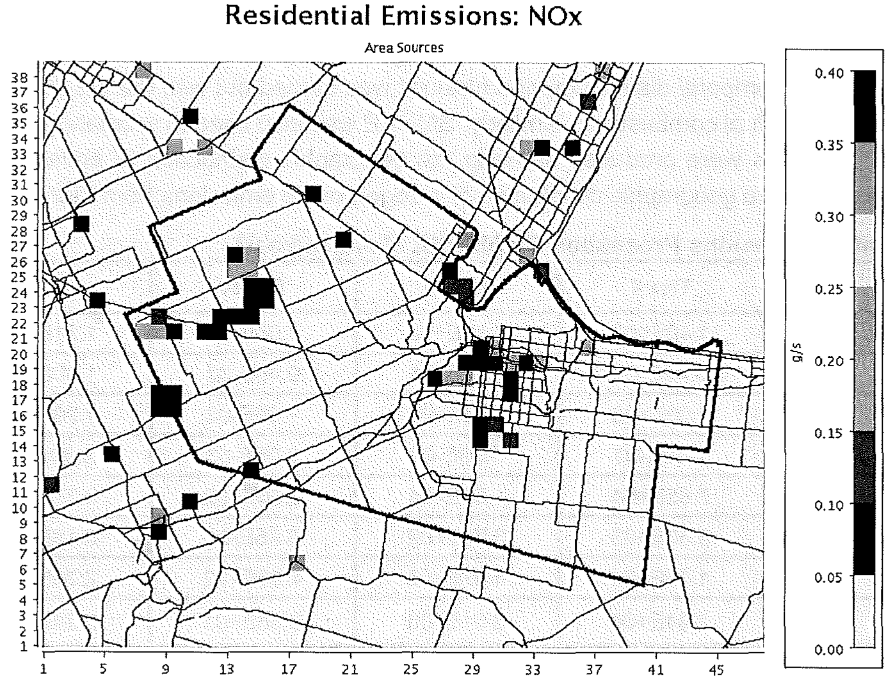

Figure 2-4: Geographic Distribution of Emissions of Nitrogen Oxides from Tier IV Residential Sources

2.2.4 Biogenic and Agricultural Sources of Emissions

Natural sources of emissions are from biogenic and geogenic sources. Biogenic emissions include VOC species such as isoprene, monoterpenes, other VOCs and sesquiterpenes. Biogenic emissions also include NO emissions from soils. Geogenic emissions can include SO_2 emissions from volcanoes and sea salts. As mentioned in Section 1.2, the MEGAN model was executed for both Canadian and US emissions with the appropriately gridded PFT, gridded LAI, gridded meteorology, and emissions factors to estimate emissions of isoprene, other VOCs, monoterpenes, sesquiterpenes, and NO.

Other natural sources of emissions, such as windblown dust, were derived from the 2011 NEI (USEPA, 2015). Emissions from tractors and farming related equipment were estimated using the US EPA NONROAD model and Processed by SMOKE for temporal and spatial allocation, based on SCC code (Table 2-5). Figure 2-5 shows the geographic distribution of emissions of nitrogen oxides Tier IV which are highest in non-urban, agricultural areas.

Emissions from forest fires are not captured in the emission inventory as 2012 was a very low year for forest fires and none where identified in the computational domain (NRCAN, 2017).

Table 2-5: Tier II to IV Biogenic and Agricultural Emissions Processed By SMOKE [Tonnes/year]

Pollutant	Tier II	Tier III	Tier IV	Total
Acetaldehyde	1.40E+03	2.76E+03	1.83E+02	4.33E+03
Acrolein	3.49E-01	0.00E+00	0.00E+00	3.49E-01
Benzene	1.09E+03	8.88E+00	1.66E+00	1.10E+03
1,3 Butadiene	7.49E-03	0.00E+00	0.00E+00	7.49E-03
Carbon Monoxide	7.85E+04	2.54E+04	2.23E+03	1.06E+05
Formaldehyde	5.80E+03	9.20E+02	6.83E+01	6.79E+03
Nitrogen Oxides	1.75E+04	1.28E+04	2.26E+03	3.26E+04
PM_{10}	1.94E+04	4.23E+01	4.65E+00	1.94E+04
$PM_{2.5}$	1.85E+04	1.10E+01	0.00E+00	1.85E+04
Sulphur Dioxide	1.67E+03	2.10E+02	4.30E+01	1.92E+03
Volatile Organic Compounds	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(a)pyrene	5.24E-02	2.88E-03	5.96E-04	5.59E-02
Metals	3.95E-01	1.66E-02	3.43E-03	4.15E-01

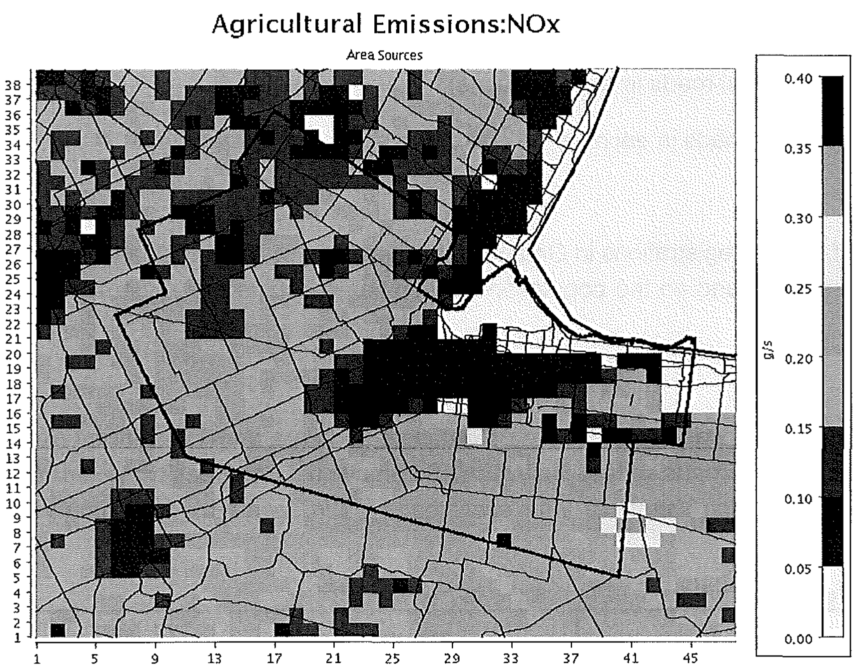

Figure 2-5: Geographic Distribution of Emissions of Nitrogen Oxides from Tier IV Biogenic/Agricultural Sources

2.2.5 On-Road Mobile Sources

On-road mobile sources of emissions include a range of motor vehicle types, including cars, taxis, commercial vehicles, buses, and motorcycles. They emit a range of air pollutants, including $PM_{2.5}$, PM_{10}, SO_2, NOx, CO and VOCs emitted from the tailpipe. Additionally, $PM_{2.5}$ and PM_{10} are emitted through tire wear, brake wear, and road abrasion as well as evaporative emissions of VOCs. The latest publicly available information to develop an inventory of on-road mobile sources which resolves hourly variations in emissions throughout the day, based on weekday and weekend activity, which varied by month.

The inventory depends on emission factors for each compound on specified road types, including expressways, major arterials routes, and other roads with significant traffic volume. Emission factors were developed with the aid of the USEPA Office of Transportation and Air Quality's Motor Vehicle Emission Simulator, MOVES2014. For Canadian vehicle emissions the required fleet information to drive MOVES2014 was not available and data from a representative US county (Wayne County, Michigan) was used as a surrogate. This data was updated where possible, as described in the sections below:

Road Type Distribution

There are four main vehicle road types in MOVES2014:

- urban restricted (e.g. highways where access is restricted by an access ramp in an urban locations);
- urban unrestricted (e.g. arterial and local roads in urban locations);
- rural restricted e.g. highways where access is restricted by an access ramp in rural locations); and
- rural unrestricted(e.g. arterial and local roads in rural locations).

A GIS framework was used to classify all roads in each tier as one of the above four categories.

Vehicle Population

Information on the total number of vehicle registrations in Ontario was taken from Statistics Canada data for 2016 (Statistic Canada, 2016) and pro-rated based on the population of each tier to estimate the quantity of different vehicle types in each tier.

Vehicle Kilometres Travelled

Annual Average Daily Traffic (AADT) data was taken from MTO datasets and data from different municipalities, where available and applied to the relevant roads spatially using a GIS framework. For roads where this data was not available, assumptions were made using typical data for each road type in each tier. A summary of these assumptions is provided below:

Table 2-6: AADT assumptions for roads where traffic data was not available

Road Type	Tier II	Tier III	Tier IV
Rural Restricted	5,000	10,000	10,000
Rural Unrestricted	1,000 on arterials 500 on local roads	1,000 on arterials 500 on local roads	1,000 on arterials 500 on local roads
Urban Restricted	40,000	100,000	100,000
Urban Unrestricted	10,000 on arterials 1,000 on local roads	10,000 on arterials 1,000 on local roads	10,000 on arterials 1,000 on local roads

Total Vehicle Kilometers Travelled (VKT) were calculated by multiplying each AADT by the road length that it applies to. Total VKT for each tier is provided on Table 2-7.

Table 2-7: Total VKT by Tier [km]

Road Type	Tier II	Tier III	Tier IV
Rural Restricted	17,504,350	16,830,706	1,402,597
Rural Unrestricted	36,254,882	22,572,924	1,662,081
Urban Restricted	2,440,803	76,374,080	16,083,443
Urban Unrestricted	23,407,451	86,428,101	15,782,642
TOTAL	79,607,485	202,205,811	34,930,763

Vehicle Type Distribution

Thirteen different vehicle types were identified for use in the MOVES2014 model. The breakdown of different vehicle types on each of the four road types was estimated using MTO and region/municipality traffic data. The breakdown used on Tier IV roads is provided below:

Table 2-8: Tier IV Vehicle Type Distribution

Vehicle Type	Rural Restricted	Rural Unrestricted	Urban Restricted	Urban Unrestricted
Motorcycle (Gas)	1.11%	1.19%	1.11%	0.10%
Passenger Car (Gas)	79.55%	84.59%	79.55%	77.90%
Passenger Truck (Gas)	1.62%	1.73%	1.62%	1.59%
Light Commercial Truck (Gas)	1.82%	1.93%	1.82%	3.11%
Transit Bus (Gas)	1.41%	1.50%	1.41%	2.41%
School Bus (Gas)	1.82%	1.93%	1.82%	3.11%
Refuse Truck (Gas)	1.41%	1.50%	1.41%	2.41%
Single Unit Short Haul Truck (Gas)	0.07%	0.08%	0.07%	0.19%
Single Unit Long Haul Truck (Gas)	0.02%	0.02%	0.02%	0.04%
Combination Short Haul Truck (Gas)	0.07%	0.08%	0.07%	0.17%
Passenger Car (Diesel)	0.03%	0.03%	0.03%	0.06%
Passenger Truck (Diesel)	0.03%	0.03%	0.03%	0.06%
Light Commercial Truck (Diesel)	0.56%	0.62%	0.56%	0.67%
Intercity Bus (Diesel)	1.88%	0.71%	1.88%	1.34%
Transit Bus (Diesel)	0.56%	0.62%	0.56%	0.67%
School Bus (Diesel)	1.88%	0.71%	1.88%	1.34%
Refuse Truck (Diesel)	1.88%	0.71%	1.88%	4.73%
Single Unit Short Haul Truck (Diesel)	0.56%	0.62%	0.56%	0.04%
Combination Short Haul Truck (Diesel)	1.88%	0.71%	1.88%	0.08%
Combination Long Haul Truck (Diesel)	1.88%	0.71%	1.88%	0.08%

Vehicle Age Distribution

Default North American Vehicle age distributions provided by MOVES2014 were used, based on the baseline year of 2012.

Vehicle Speed Distribution

Vehicle speed distributions were estimated for each vehicle type using information on Ontario speed limits by each of the four road types and distribution breakdowns by vehicle type based on MOVES default data for North America. Vehicle speed distributions vary by vehicle type, road type, day of the week and hour of day. Vehicle speed distribution for passenger vehicles travelling on weekdays at 8am are provided below for each of the four road types.

Table 2-9: Vehicle Speed Distribution by Road Type and Speed

Speed Bin[1]	Rural Restricted	Rural Unrestricted	Urban Restricted	Urban Unrestricted
<2.5 mph	0%	3%	1%	11%
2.5 mph ≤ speed < 7.5 mph	1%	4%	4%	15%
7.5 mph <= speed < 12.5 mph	1%	3%	5%	8%
12.5 mph <= speed < 17.5 mph	1%	3%	4%	7%
17.5 mph <= speed <22.5 mph	1%	3%	4%	8%
22.5 mph <= speed < 27.5 mph	1%	4%	3%	9%
27.5 mph <= speed < 32.5 mph	1%	5%	3%	10%
32.5 mph <= speed < 37.5 mph	1%	7%	3%	11%
37.5 mph <= speed < 42.5 mph	1%	9%	4%	9%
42.5 mph <= speed < 47.5 mph	1%	10%	5%	7%
47.5 mph <= speed < 52.5 mph	2%	11%	7%	4%
52.5 mph <= speed < 57.5 mph	5%	13%	13%	3%
57.5 mph <= speed < 62.5 mph	11%	13%	20%	2%
62.5 mph <= speed < 67.5 mph	21%	9%	22%	1%
67.5 mph <= speed < 72.5 mph	30%	6%	16%	1%
>72.5 mph	34%	3%	9%	0%

Note:
(1) MOVES2014 is US based software and therefore the speed categories are in mph = miles per hour.

Meteorology

The temperature and relative humidity values were extracted from the WRF 2012 modelling datasets to create a meteorological dataset for MOVES2014. Once the emission factors for each road type were calculated, they were applied to the grid cells according to the length of each road type passing through the grid.

Summary of Emissions

A summary of the on-road vehicular emissions from Tiers II to IV are presented in Table 2-10, below. Carbon monoxide and nitrogen oxides are the most abundant emissions as well as VOCs and fine particulate matter.

Table 2-10: Tier II to IV On-road Emissions Processed By SMOKE [Tonnes/year]

Pollutant	Tier II	Tier III	Tier IV	Total
Acetaldehyde	2.93E+03	9.24E+02	5.51E+01	3.91E+03
Acrolein	4.90E+01	5.47E+01	6.53E+00	1.10E+02
Benzene	5.13E+03	1.64E+03	8.20E+01	6.85E+03
1,3 Butadiene	2.32E+02	1.75E+02	1.25E+01	4.19E+02
Carbon Monoxide	8.79E+05	4.28E+05	3.79E+04	1.34E+06
Formaldehyde	3.13E+03	1.10E+03	8.71E+01	4.32E+03
Nitrogen Oxides	3.31E+05	1.87E+05	2.43E+04	5.42E+05
PM_{10}	3.06E+04	6.40E+03	3.10E+02	3.73E+04
$PM_{2.5}$	2.87E+04	5.44E+03	1.83E+02	3.43E+04
Sulphur Dioxide	7.32E+02	4.57E+02	6.26E+01	1.25E+03
Volatile Organic Compounds	5.17E+04	4.26E+04	3.51E+03	9.78E+04
Benzo(a)pyrene	4.37E-01	6.54E-01	9.28E-02	1.18E+00
Metals	4.26E-02	1.06E-01	1.83E-02	1.67E-01

Figure 2-6 presents the geographic distribution of on-road nitrogen oxide emissions from Tier IV which follow the locations of major arterial roads and highways. Temporal variation of emissions was calculated based with the aid of SMOKE and a typical weekday is provided in Figure 2-7. The figure shows bimodal peaks corresponding to morning and evening rush hour periods.

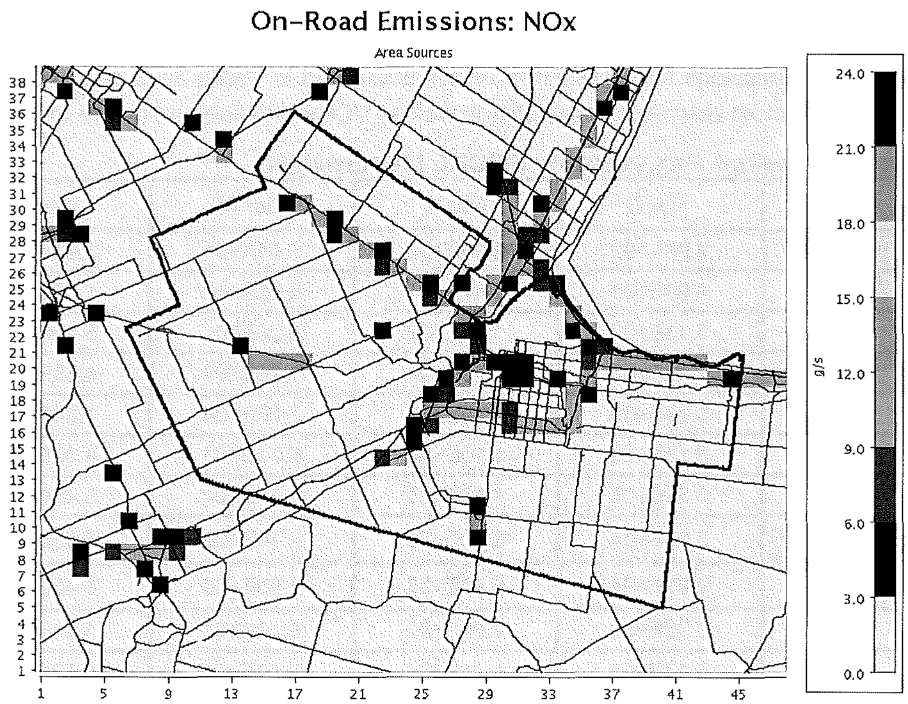

Figure 2-6: Geographic Distribution of Emissions of Nitrogen Oxides from Tier IV On-Road Sources

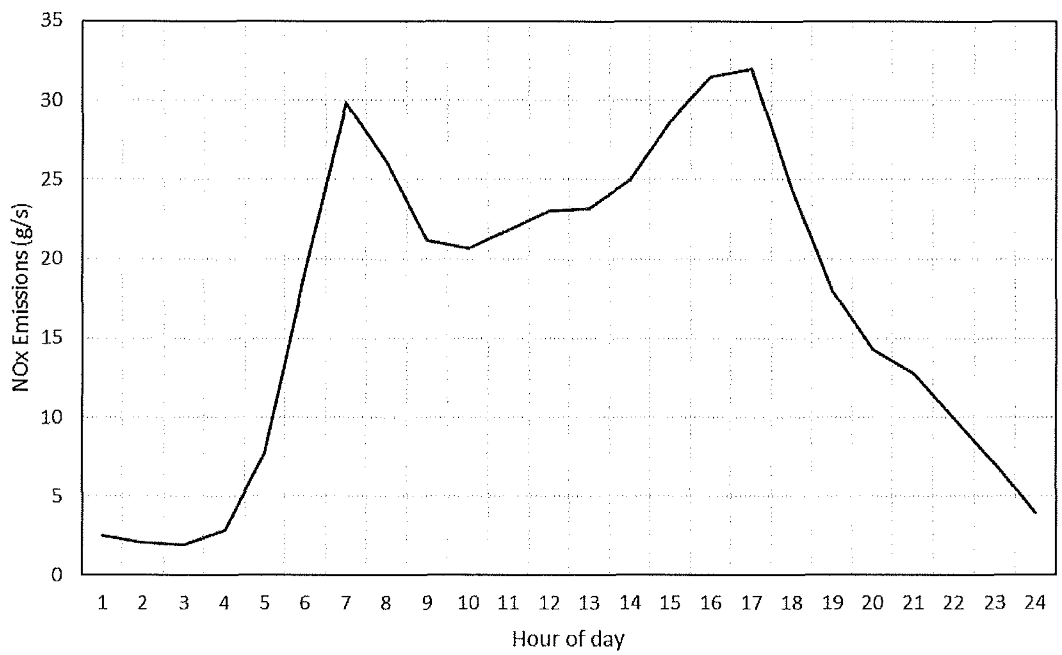

Figure 2-7: Weekday Diurnal Variation of Nitrogen Oxide emissions from Tier IV On-Road Sources

2.2.6 Non-road Mobile Sources

A variety of engines and equipment types that comprise non-road mobile sources exist. Among these are construction equipment (e.g. dozers, cranes), lawn and garden equipment (e.g. lawnmowers, string trimmers, chain saws, etc), aircrafts, locomotives, marine vessels (both commercial and recreational), and various miscellaneous types of equipment (e.g. forklifts, airport ground support equipment). Similar to the industrial sources, the US non-road sources within Tier II and Tier III are downscaled from the EPA's 2011 NEI, with the downscaling addressing the difference in the spatial resolution between Tier I and the tier of interest.

To generate emissions for airports in Ontario, publicly available emissions data for major airports was used where available. The emissions from other airports in the Tier II to Tier IV computational domains were prorated from the 2012 Environment Canada inventory using relevant flight activity data by airport. Not all the compounds of interest were reported and further speciation was carried out with the aid of US EPA speciation data for aircraft (Billings, et al, 2002). The emissions were geographically allocated to the cells where each airport is located.

Marine emissions were calculated in a similar manner to the airport emissions. In Ontario, the emissions from marine ports in the Tier II to Tier IV computational domains were prorated from the 2012 Environment Canada inventory using the total tonnage by port as a surrogate for activity. Further speciation is carried out with the aid of US EPA speciation data for marine emissions (Billings, et al, 2002). The emissions were geographically allocated to the cells where each port is located.

Railway emissions were sub-divided into passenger and freight emissions using energy consumption data for each from Natural Resource Canada (NRCAN, 2014). Passenger train (GO and VIA) schedule data were downloaded and incorporated into the spatial allocation of passenger emissions across the passenger lines. Further speciation was carried out with the aid of US EPA speciation data for rail emissions (Billings et. al., 2002), where necessary. The annual emissions for passengers and goods trains were allocated separately to hourly emissions using passenger and goods train temporal profiles in SMOKE.

Lawn and garden equipment includes gasoline fired lawn mowers and trimmers, among other equipment. Activity data and emission factors were taken from the typical values recommended by the USEPA for assessing the operation of lawn mowers and trimmers. A summary of total non-road emissions processed by SMOKE for Tier II to IV is presented below in Table 2-11.

Table 2-11: Tier II to Tier IV Total Non-Road Emissions Processed By SMOKE [Tonnes/Year]

Pollutant	Tier II	Tier III	Tier IV	Total
Acetaldehyde	1.56E+04	4.51E+02	9.70E+01	1.62E+04
Acrolein	1.56E+01	3.21E+01	9.78E+00	5.74E+01
Benzene	5.08E+02	8.85E+02	1.59E+02	1.55E+03
1,3 Butadiene	1.23E+01	2.67E+01	7.64E+00	4.66E+01
Carbon Monoxide	2.45E+05	3.00E+05	5.01E+04	5.96E+05
Formaldehyde	4.36E+03	8.35E+02	1.98E+02	5.40E+03
Nitrogen Oxides	2.49E+04	1.55E+04	3.01E+03	4.34E+04
PM_{10}	1.62E+05	1.97E+04	3.09E+02	1.82E+05
$PM_{2.5}$	2.90E+04	3.80E+03	2.83E+02	3.31E+04
Sulphur Dioxide	5.22E+03	3.50E+03	1.80E+03	1.05E+04
Volatile Organic Compounds	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(a)pyrene	3.98E-05	6.39E-03	8.26E-04	7.25E-03
Metals	4.27E+01	5.30E+01	8.19E+00	1.04E+02

Figure 2-8 presents the geographic distribution of on-road nitrogen oxide emissions from Tier IV which follows the major rail lines.

Emissions from road construction activities are not included in the inventory because of a lack of information on the where and when they occurred. These activities would contribute primarily to particulate matter emissions including PM_{10}.

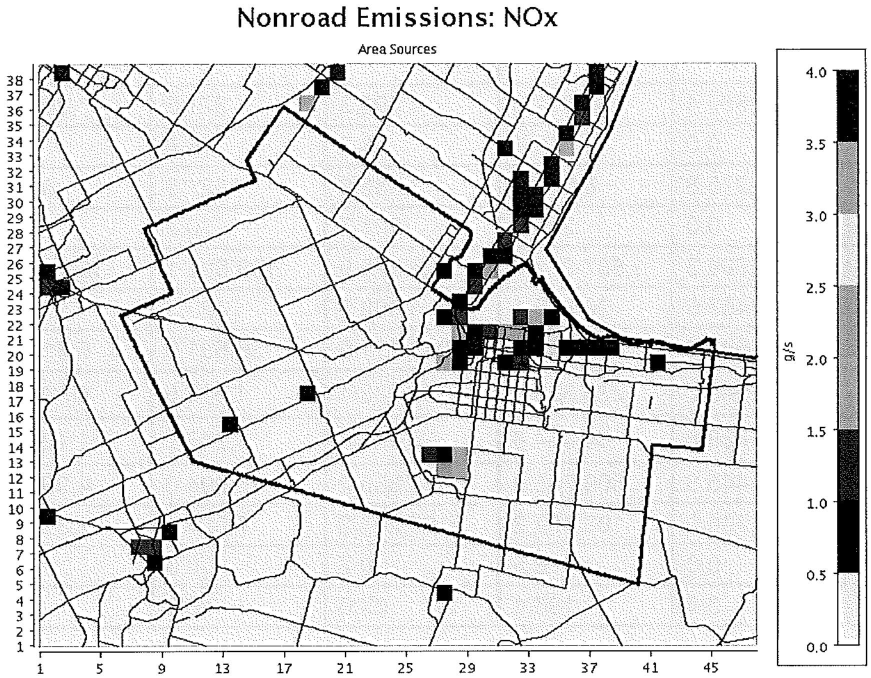

Figure 2-8: Geographic Distribution of Emissions of Nitrogen Oxides from Tier IV Non-Road Sources

2.3 Total Emissions

Emission summaries for key compounds in each tier are presented in Table 2-12. Tier I dominates the total emissions released into the computational domain with the exception of a few compounds. The percentage by tier is presented graphically in Figure 2-9 against key compound. Appendix A provides the summary of the distribution of emissions by tier and by source category.

Tier IV emissions by source classification is provided on Table 2-13 and Figure 2-10. Tier IV emissions generated from residential and commercial activities are generally the lowest except for VOCs from commercial operations (e.g., auto repair, dry cleaning). Transportation related activities (i.e., on-road and non-road) have similar emission profiles including significant emissions of products on combustion such as CO, NOx, SO_2 and fine particulate matter ($PM_{2.5}$). Local transportation represents over 65% of the local NOx and 36% of $PM_{2.5}$ emissions into the Hamilton airshed. Industrial activities generate products of combustions (CO, NOx, SO_2 and $PM_{2.5}$) as well as metals and B(a)P. Industrial activities are the largest local emitters of $PM_{2.5}$, SO_2, B(a)P and metals in the local airshed. Industrial emitters represent about 21% of the total emissions into the airshed.

Background emissions are from US and Canada sources which are outside the Hamilton region (i.e., the sum of Tier I, II and III). Their contribution to the modelling domain are provided on Table 2-14 and Figure 2-11.Transportation activities represent 63% of NOx emissions and 76% of $PM_{2.5}$ emissions, respectively. Industrial sources represent about 97% of background SO_2 emissions and 61% of metal emissions.

Table 2-12: Tier I to IV Emissions [Tonnes/year] for 2012

Pollutant	Tier I	Tier II	Tier III	Tier IV	Total
Acetaldehyde	214,807.4	35,871.6	4,796.3	371.6	255,846.9
Acrolein	0.0	65.7	88.7	16.6	171.0
Benzene	84,275.8	8,073.9	3,985.9	421.9	96,757.5
1,3 Butadiene	0.0	256.6	201.7	20.2	478.5
Carbon Monoxide	13,410,709.3	1,507,911.0	798,925.9	103,606.1	15,821,152.4
Formaldehyde	145,457.6	20,802.1	4,908.2	422.3	171,590.2
Nitrogen Oxides	5,483,583.8	532,095.4	262,111.0	36,531.0	6,314,321.2
PM_{10}	4,280,949.7	225,629.8	34,723.1	1,818.5	4,543,121.0
$PM_{2.5}$	1,322,839.5	84,844.8	15,854.5	1,243.7	1,424,782.5
Sulphur Dioxide	4,399,445.8	509,785.9	71,865.2	15,994.0	4,997,090.9
Volatile Organic Compounds	1,121,738.0	103,452.2	85,209.2	7,024.8	1,317,424.2
Benzo(a)pyrene	0.0	0.5	0.7	0.3	1.5
Metals	3.4	186.1	63.0	18.8	271.2

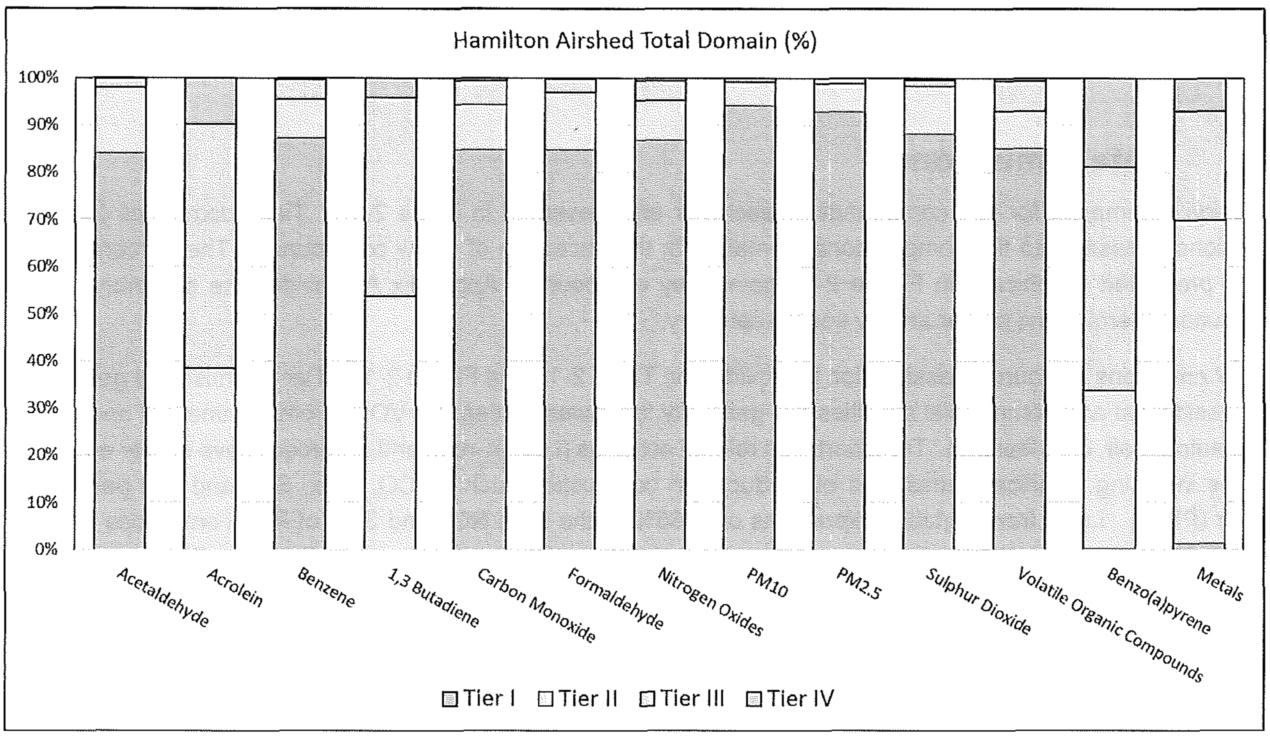

Figure 2-9: Tier I to IV Emissions [%] for 2012

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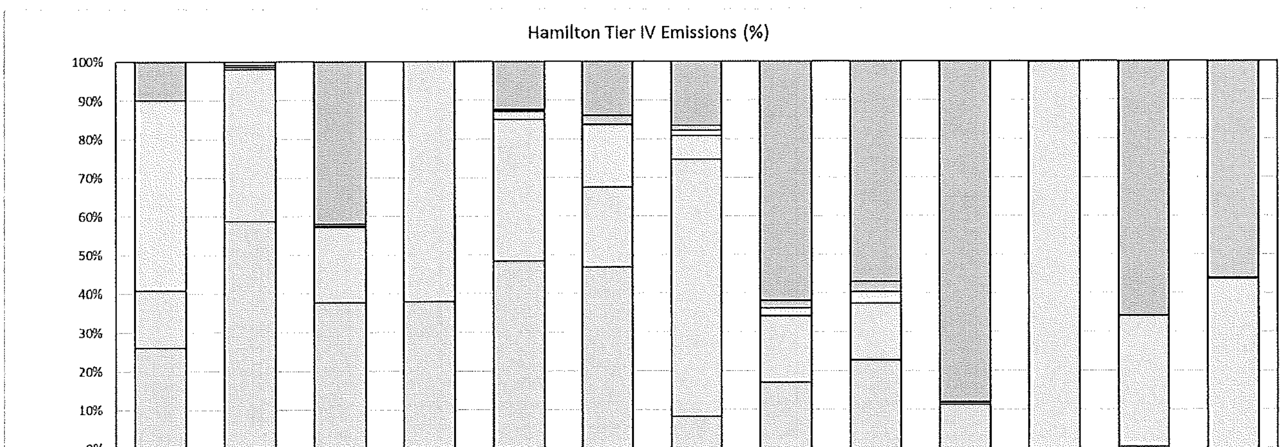
HAMILTON AIRSHED EMISSIONS INVENTORY

Table 2-13: Tier IV Emissions Processed By SMOKE, MEGAN and MOVES2014 [Tonnes/year]

Pollutant	Industrial	Commercial	Residential	Agriculture	On-Road	Non-Road	Total
Acetaldehyde	36.7	0.1	0.1	182.7	55.1	97.0	371.6
Acrolein	0.2	0.1	0.1	0.0	6.5	9.8	16.6
Benzene	177.0	2.2	0.0	1.7	82.0	159.1	421.9
1,3 Butadiene	0.0	0.0	0.0	0.0	12.5	7.6	20.2
Carbon Monoxide	12,806.1	366.7	205.8	2,232.9	37,851.1	50,143.5	103,606.1
Formaldehyde	58.6	10.0	0.4	68.3	87.1	197.9	422.3
Nitrogen Oxides	6,079.9	435.8	482.6	2,258.1	24,262.3	3,012.5	36,531.0
PM_{10}	1,126.4	33.1	35.8	4.7	309.9	308.6	1,818.5
$PM_{2.5}$	709.1	33.1	35.8	0.0	182.8	282.9	1,243.7
Sulphur Dioxide	14,079.8	2.6	3.1	43.0	62.6	1,802.9	15,994.0
Volatile Organic Compounds	7.1	0.0	0.0	0.0	3,508.8	0.0	3,516.0
Benzo(a)pyrene	0.2	0.0	0.0	0.0	0.1	0.0	0.3
Metals	10.5	0.0	0.0	0.0	0.0	8.2	18.8

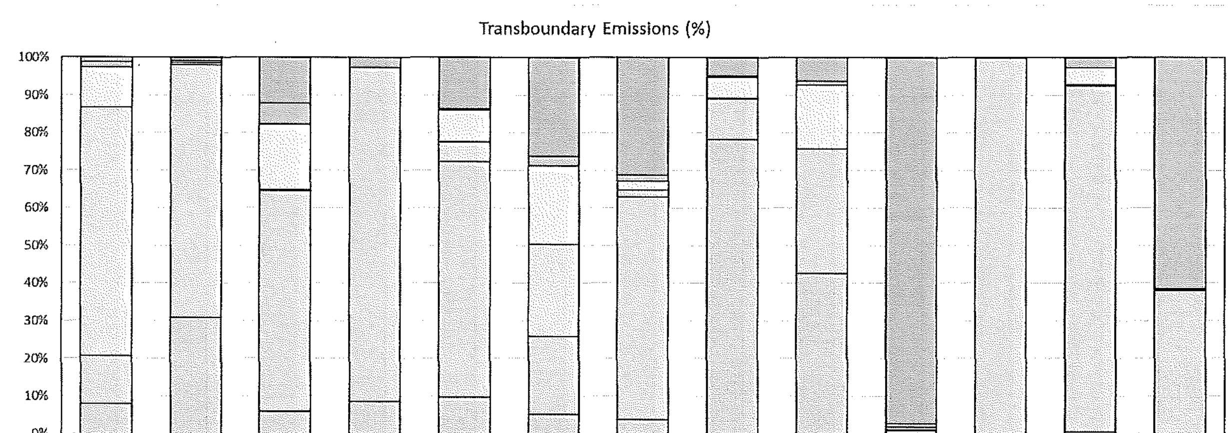


	Acetaldehyde	Acrolein	Benzene	1,3 Butadiene	CO	Formaldehyde	NOX	PM10	PM2.5	SO2	VOCs	B(a)P	Metals
Industrial	9.9%	0.9%	42.0%	0.0%	12.4%	13.9%	16.6%	61.9%	57.0%	88.0%	0.2%	65.7%	56.0%
Commercial	0.0%	0.5%	0.5%	0.0%	0.4%	2.4%	1.2%	1.8%	2.7%	0.0%	0.0%	0.0%	0.1%
Residential	0.0%	0.6%	0.0%	0.0%	0.2%	0.1%	1.3%	2.0%	2.9%	0.0%	0.0%	0.0%	0.2%
Agriculture	49.2%	0.0%	0.4%	0.0%	2.2%	16.2%	6.2%	0.3%	0.0%	0.3%	0.0%	0.2%	0.0%
On-Road	14.8%	39.2%	19.4%	62.1%	36.5%	20.6%	66.4%	17.0%	14.7%	0.4%	99.8%	33.8%	0.1%
Non-Road	26.1%	58.8%	37.7%	37.9%	48.4%	46.9%	8.2%	17.0%	22.7%	11.3%	0.0%	0.3%	43.6%

Figure 2-10: Tier IV Emissions Processed for 2012 (%)

Table 2-14: Background Emissions Processed By SMOKE, MEGAN and MOVES2014 [Tonnes/year]

Pollutant	Industrial	Commercial	Residential	Agriculture	On-Road	Non-Road	Total
Acetaldehyde	3,425.2	3,433.1	27,242.5	168,690.5	32,542.3	20,141.7	255,475.3
Acrolein	1.4	0.7	0.9	0.0	103.7	47.7	154.4
Benzene	11,762.9	5,456.3	16,820.4	127.2	56,529.6	5,639.2	96,335.5
1,3 Butadiene	12.4	0.0	0.0	0.0	406.8	39.0	458.3
Carbon Monoxide	2,137,160	73,809	1,313,677	845,657	9,822,728	1,524,512	15,717,546
Formaldehyde	45,073.9	4,153.6	35,879.1	41,984.1	35,140.6	8,936.7	171,167.9
Nitrogen Oxides	1,966,144.0	107,313.9	144,210.1	114,689.5	3,710,371.5	235,061.0	6,277,790.1
PM_{10}	218,657.1	20,806.8	253,207.1	2,838.9	492,808.5	3,552,984.2	4,541,302.6
$PM_{2.5}$	90,472.4	15,476.8	239,396.7	1,712.1	471,267.8	605,213.0	1,423,538.8
Sulphur Dioxide	4,846,503.2	51,014.6	32,533.8	673.6	8,417.3	41,954.3	4,981,096.9
Volatile Organic Compounds	179.0	0.0	0.0	0.0	94,241.2	0.0	94,420.2
Benzo(a)pyrene	0.0	0.0	0.1	0.0	1.1	0.0	1.2
Metals	155.3	0.7	0.6	0.0	0.1	95.7	252.5



	Acetaldehyde	Acrolein	Benzene	1,3 Butadiene	CO	Formaldehyde	NOX	PM10	PM2.5	SO2	VOCs	B(a)P	Metals
Industrial	1.3%	0.9%	12.2%	2.7%	13.6%	26.3%	31.3%	4.8%	6.4%	97.3%	0.2%	2.7%	61.5%
Commercial	1.3%	0.5%	5.7%	0.0%	0.5%	2.4%	1.7%	0.5%	1.1%	1.0%	0.0%	0.0%	0.3%
Residential	10.7%	0.6%	17.5%	0.0%	8.4%	21.0%	2.3%	5.6%	16.8%	0.7%	0.0%	4.4%	0.3%
Agriculture	66.0%	0.0%	0.1%	0.0%	5.4%	24.5%	1.8%	0.1%	0.1%	0.0%	0.0%	0.5%	0.0%
On-Road	12.7%	67.1%	58.7%	88.8%	62.5%	20.5%	59.1%	10.9%	33.1%	0.2%	99.8%	91.9%	0.1%
Non-Road	7.9%	30.9%	5.9%	8.5%	9.7%	5.2%	3.7%	78.2%	42.5%	0.8%	0.0%	0.5%	37.9%

Figure 2-11: Background Emissions Processed for 2012 (%)

The geographic distribution of emissions varies by compound. Figure 2-12 to Figure 2-15 show the geographic variation of NOx and B(a)P emissions within Tier IV for both area and point sources, respectively. The NOx emissions are well correlated with the major highways in the region such as QEW, 403 and Hwy 6, as well as the urban centers such as Hamilton and Brantford. The B(a)P emissions correlate with industrial and mobile (on-road and non-road) sources.

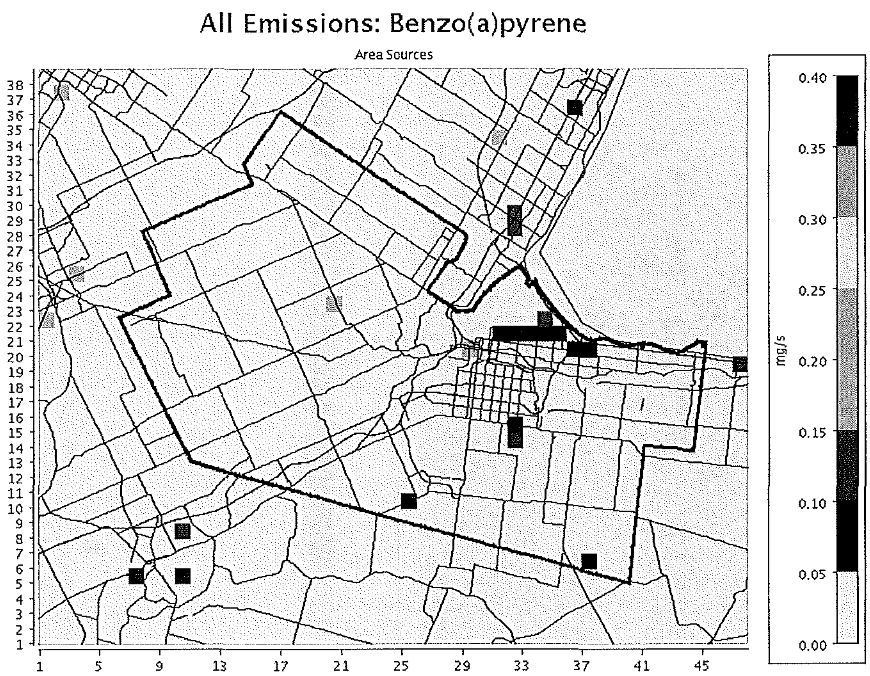


Figure 2-12: Geographic Distribution of Emissions Benzo(a)pyrene from Tier IV Area Sources

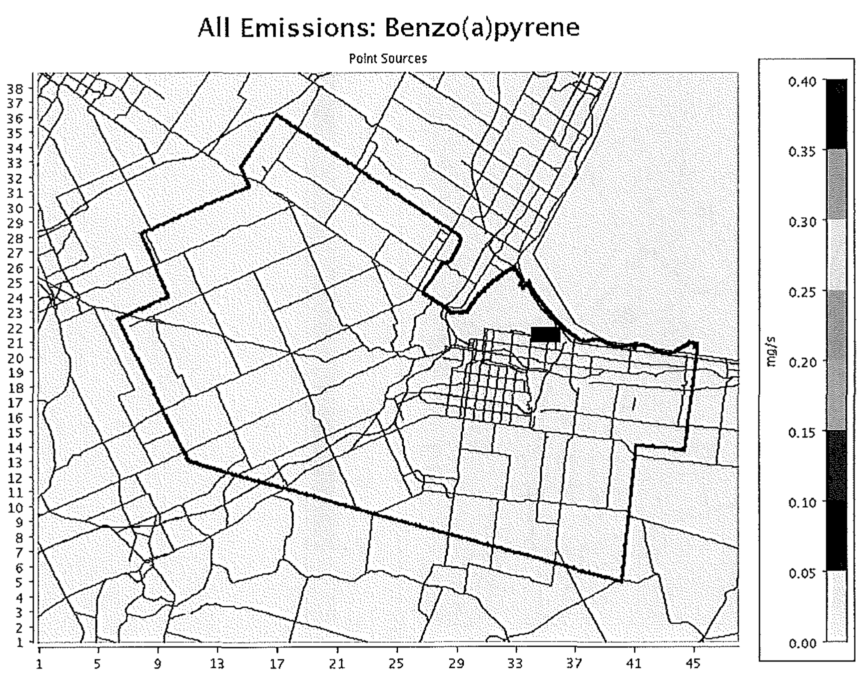


Figure 2-13: Geographic Distribution of Emissions Benzo(a)pyrene from Tier IV Point Sources

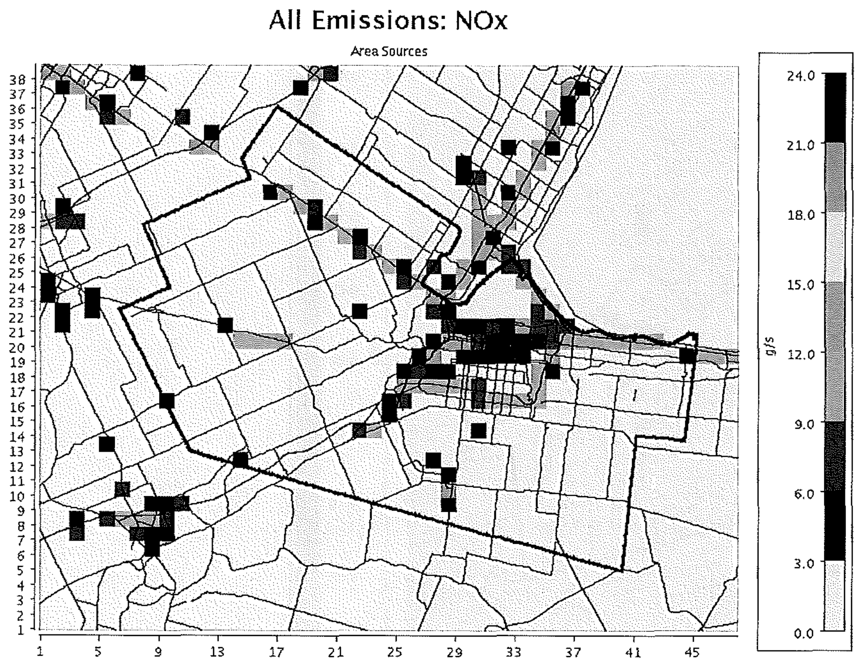


Figure 2-14: Geographic Distribution of Emissions of Nitrogen Oxides emissions from Tier IV Area Sources

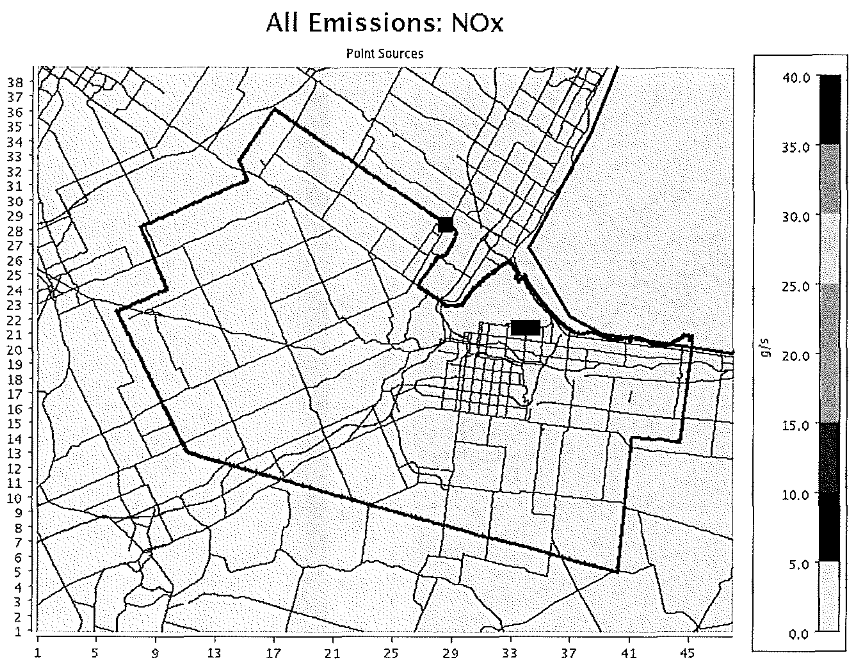


Figure 2-15: Geographic Distribution of Emissions of Nitrogen Oxides emissions from Tier IV Point Sources

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3.0 SUMMARY

An emission inventory was developed for the Hamilton region and beyond using a combination of publicly available data from federal inventories and available high-resolution, locale-specific emissions estimated by local and provincial, agencies in the Hamilton region. Information was used from provincial air regulatory and transportation planning agencies and manipulated as necessary into the required format for input into the modelling system used for this project.

Emission rates were spatially and temporally allocated using a combination of source specific data, where available and surrogate data based on population and/or land use. Throughout the course of the emissions inventory development, various methods were used to ensure routine QA was completed. Processing error messages provided by emissions modelling programs, including SMOKE, were routinely reviewed for each model run and addressed as necessary during inventory development. Summary tables were created to compare emissions of different pollutants by emission category and by model tier to check the data for consistency. Spatial summary plots were also reviewed to identify appropriate correlation of emissions to the largest emission sources and temporal profiles were produced to illustrate variation over daily and annual averaging periods. The emissions data was QA'd to confirm its reliability for use in the development of the CMAQ.

Emissions generated from residential and commercial activities are generally the lowest, except for VOCs from commercial operations (e.g., auto repair, dry cleaning). Transportation related activities (i.e., on-road and non-road) have similar emission profiles including significant emissions of products of combustion, such as CO, NOx, SO_2 and fine particulate matter ($PM_{2.5}$). Overall Transportation activities have high NOx and $PM_{2.5}$ emissions respectively. Industrial activities generate products of combustions as well as metals and benzo(a)pyrene (B(a)P). They are the largest emitters of $PM_{2.5}$, SO_2, B(a)P and metals in the local airshed.

The geographic distribution of emissions varies by compound. The NOx emissions are well correlated with the major highways in the region such as QEW, 403 and Hwy 6 as well as the urban centers such Hamilton and Brantford. The B(a)P emissions correlate with industrial and mobile (on-road and non-road) sources.

Emissions from forest fires and construction activities were not included in the emissions inventory. There were no local forest fires in the computation domain and emissions from fires in the City are not well documented for use in the modelling system. Similarly, for construction activities, there is a lack of information on the duration and amount of construction in the area. Construction activities include large machinery movement, demolition and track out would contribute to particulate levels. Generally, fugitive dust emissions are likely under estimated.

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Report Signature Page

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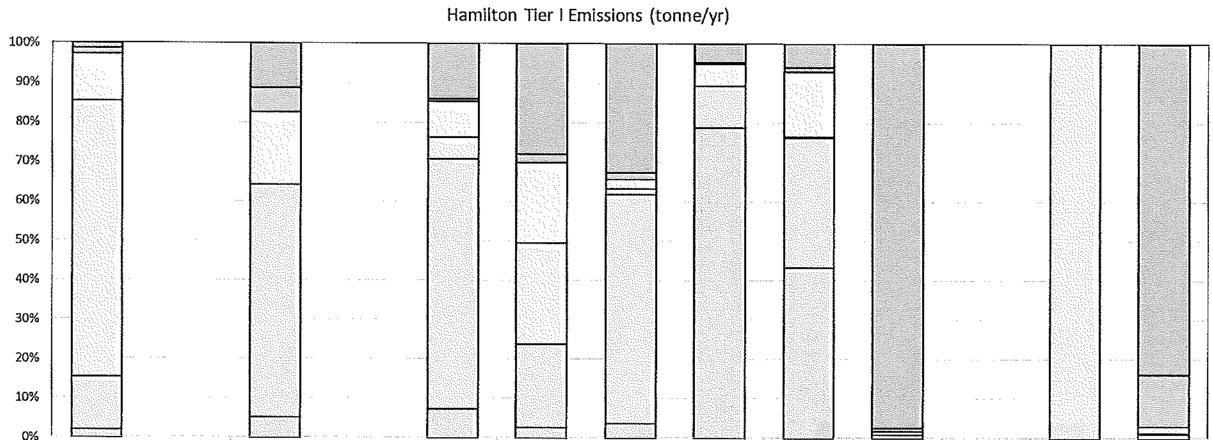
APPENDIX A

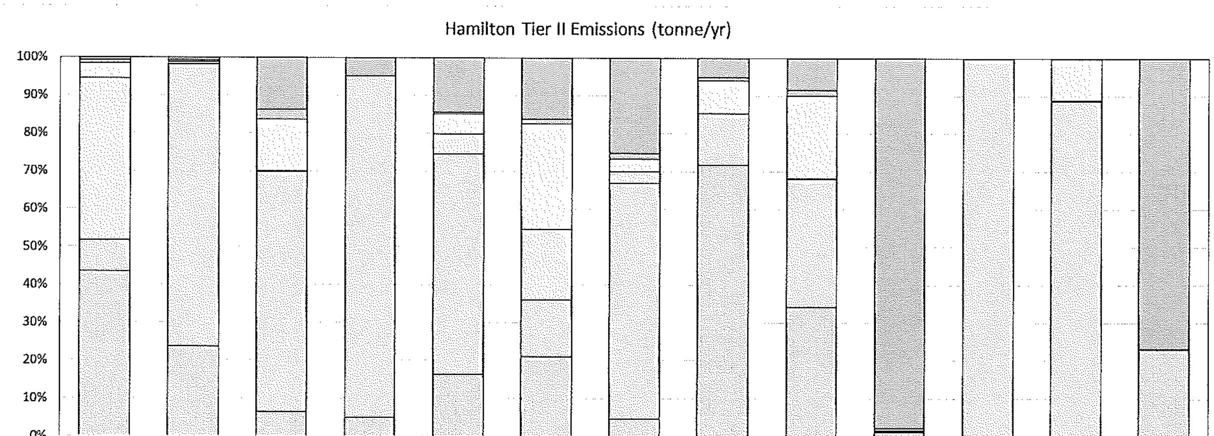
Tier Emissions By Sector Group

APPENDIX A
Emissions by Sector Group and Tier

The following figures are further to the information presented in the Hamilton Airshed Modelling System Emissions Inventory Report, and provide summaries of the distribution of emissions by tier and by source category.



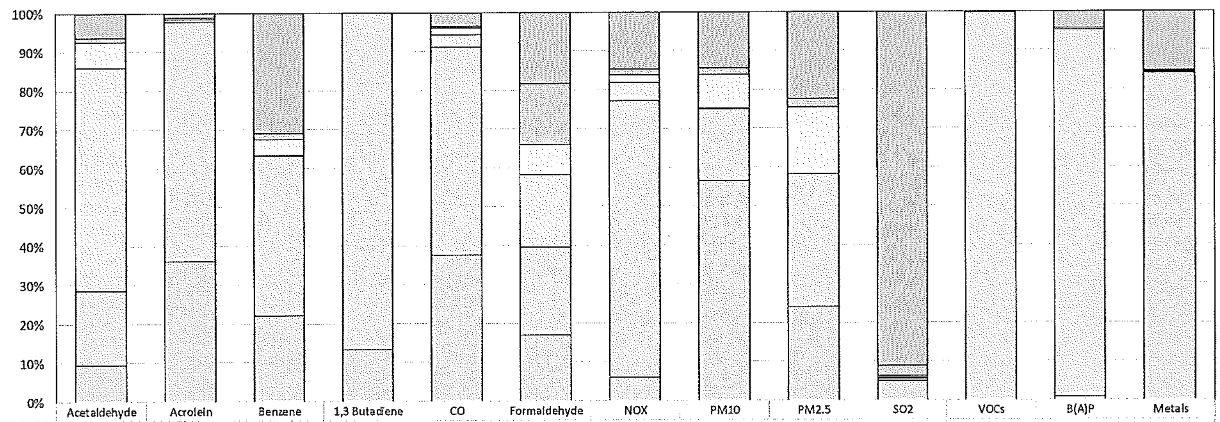
	Acetaldehyde	Acrolein	Benzene	1,3 Butadiene	CO	Formaldehyde	NOX	PM10	PM2.5	SO2	VOCs	B(a)P	Metals
Industrial	2,850	0	9,417	0	1,891,002	40,833	1,794,274	202,120	79,791	4,282,803	0.00	0.00	2.83
Commercial	3,065	0	5,180	0	65,651	3,101	94,629	18,258	13,699	45,285	0.00	0.00	0.44
Residential	25,534	0	15,562	0	1,220,196	29,701	121,798	230,848	218,170	30,586	0.00	0.00	0.06
Agriculture	150,582	0	105	0	739,133	37,173	85,588	2,578	1,596	316	0.00	0.00	0.00
On-Road	28,689	0	49,766	0	8,515,953	30,911	3,192,622	455,832	437,146	7,228	0.0	0.0	0.0
Non-Road	4,088	0	4,246	0	978,773	3,739	194,673	3,371,312	572,437	33,229	0.0	0.0	0.0



	Acetaldehyde	Acrolein	Benzene	1,3 Butadiene	CO	Formaldehyde	NOX	PM10	PM2.5	SO2	VOCs	B(a)P	Metals
Industrial	269.9	0.5	1109.1	12.4	218259.8	3340.3	133744.5	11,492	7,138	498,198	109	0.0018	142.84
Commercial	319.4	0.3	222.6	0.0	5589.0	282.6	8518.1	1979.75	1422.00	3812.41	0.00	0.0000	0.13
Residential	1395.8	0.3	1093.7	0.0	78495.3	5799.5	17538.0	19,353	18,523	1,671	0.00	0.0524	0.39
Agriculture	15353.3	0.0	13.1	0.0	81097.5	3890.8	16300.1	218	105	147	0.00	0.0017	0.01
On-Road	2929.4	49.0	5127.4	231.9	879073.1	3126.2	331104.3	30574.6	28681.0	732.2	51671.5	0.4	0.04
Non-Road	15603.6	15.6	508.0	12.3	245396.3	4362.8	24890.5	162011.7	28975.2	5224.6	0.0	0.0	42.7

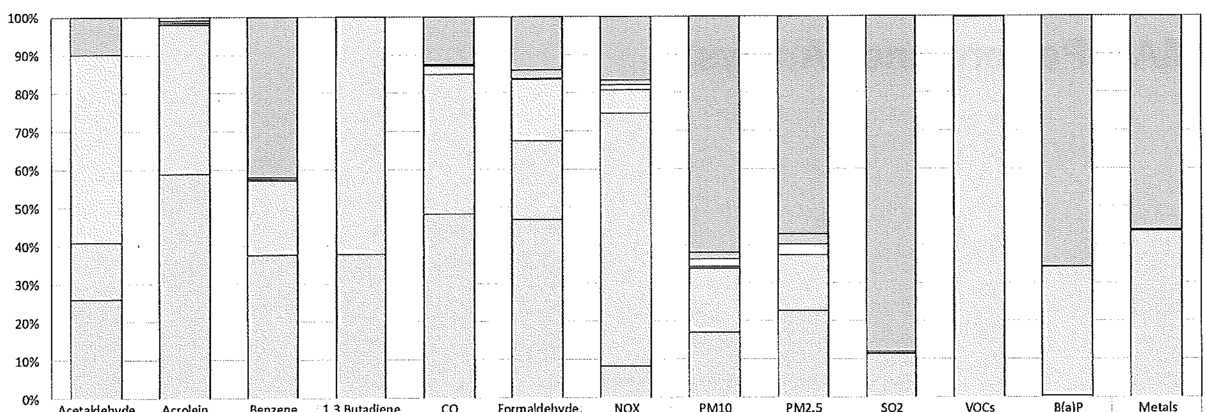
APPENDIX A
Emissions by Sector Group and Tier

Hamilton Tier III Emissions (tonne/yr)



	Acetaldehyde	Acrolein	Benzene	1,3 Butadiene	CO	Formaldehyde	NOX	PM10	PM2.5	SO2	VOCs	B(A)P	Metals
☐ Industrial	305.0	0.9	1237.1	0.0	27897.9	900.9	38125.9	5044.4	3542.9	65502.3	69.9	0.0306	9.59
☐ Commercial	48.6	0.5	53.8	0.0	2569.3	770.3	4166.4	568.6	355.9	1917.2	0.0	0.0000	0.15
☐ Residential	312.9	0.6	164.4	0.0	14986.3	378.7	4874.0	3005.4	2703.1	277.0	0.0	0.0000	0.18
☐ Agriculture	2755.2	0.0	8.9	0.0	25427.5	920.1	12801.3	42.3	11.0	210.2	0.0	0.0029	0.02
☐ On-Road	924.1	54.7	1636.4	174.9	427701.9	1103.1	186645.5	6401.6	5440.8	457.3	42569.6	0.6541	0.11
☐ Non-Road	450.5	32.1	885.3	26.7	300343.1	834.9	15497.9	19660.8	3800.7	3501.2	0.0	0.0064	52.98

Hamilton Tier IV Emissions (tonne/yr)



	Acetaldehyde	Acrolein	Benzene	1,3 Butadiene	CO	Formaldehyde	NOX	PM10	PM2.5	SO2	VOCs	B(a)P	Metals
☐ Industrial	36.7	0.2	177.0	0.0	12,806.1	58.6	6,079.9	1,126.4	709.1	14,079.8	7.1	0.2	10.5
☐ Commercial	0.1	0.1	2.2	0.0	366.7	10.0	435.8	33.1	33.1	2.6	0.0	0.0	0.0
☐ Residential	0.1	0.1	0.0	0.0	205.8	0.4	482.6	35.8	35.8	3.1	0.0	0.0	0.0
☐ Agriculture	182.7	0.0	1.7	0.0	2,232.9	68.3	2,258.1	4.7	0.0	43.0	0.0	0.0	0.0
☐ On-Road	55.1	6.5	82.0	12.5	37,851.1	87.1	24,262.3	309.9	182.8	62.6	3,508.8	0.1	0.0
☐ Non-Road	97.0	9.8	159.1	7.6	50,143.5	197.9	3,012.5	308.6	282.9	1,802.9	0.0	0.0	8.2

n:\active\2014\1187\1418883 hiea - airshed modelling - hamilton\report\final\appendix b - emissions report\1418883-001-app-reva p2000 appendix a.docx

APPENDIX C

CMAQ Performance Analysis

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February 2018

HAMILTON AIRSHED MODELLING SYSTEM MODEL PERFORMANCE EVALUATION

Hamilton Airshed Modelling System

Submitted to:
Hamilton Industrial Environmental Association (HIEA)
270 Sherman Ave. N
Hamilton, ON L8L 6N4

REPORT

Report Number: 1418883

Distribution:

1 electronic copy - HIEA
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Golder Associates

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MODEL PERFORMANCE EVALUATION

MODEL PERFORMANCE EVALUATION

1.0 INTRODUCTION

This report was prepared by Golder Associates Ltd. (Golder) and is part of the Hamilton Airshed Modelling System Final Report (Golder Project No. 1418883).

Air quality modelling can be completed with a number of publicly available models, which vary in complexity from screening models to regional-scale photochemical transport models. For the Hamilton Airshed Modelling System, a regional-scale photochemical model, the Community Multiscale Air Quality (CMAQ) modelling system, has been selected to capture the transboundary and local influences on ambient air quality in the Hamilton region.

Numerical air quality models simulate the emissions, chemistry and physics of the atmosphere. CMAQ is a numerical air quality model that relies on scientific first principles to predict the concentration of airborne gases and particles from the transport, chemical change and dispersion of compounds released into the atmosphere. As information about the emissions and properties of compounds and classes of compounds are included, CMAQ can also inform users about the chemical composition of a mixture of pollutants.

The purpose of CMAQ is to provide technically sound estimates of ozone, particulates, toxics, and acid deposition. CMAQ is designed to meet the needs of the scientific community and concerned community leaders by combining current knowledge in atmospheric science and air quality modeling, multi-processor computing techniques, and an open-source framework into a single modeling system.

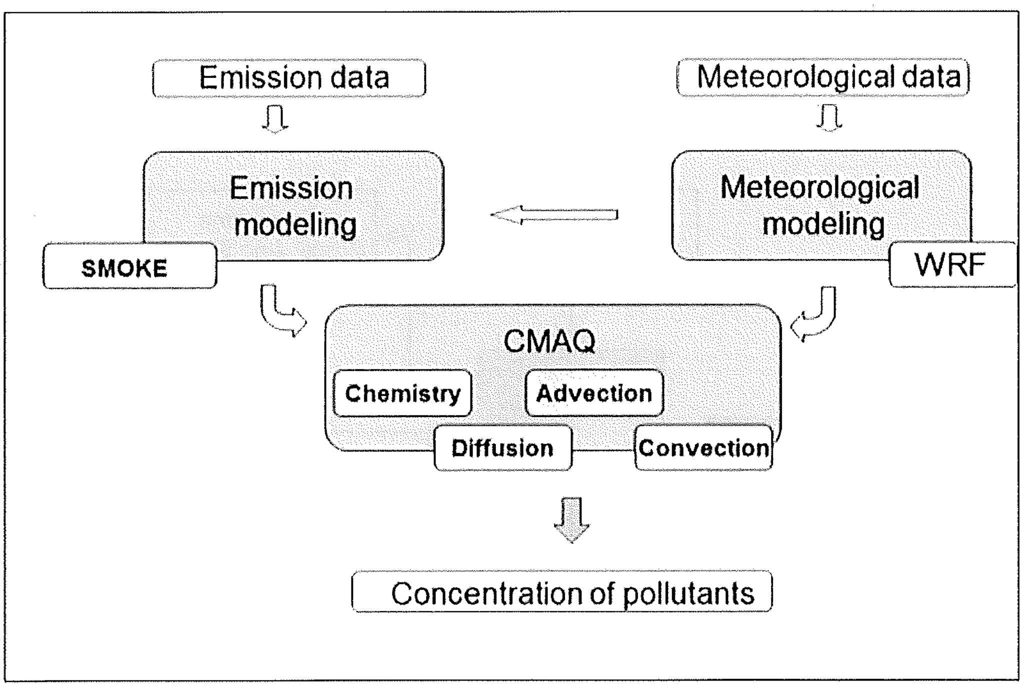


Figure 1-1: CMAQ Modelling System (University of Houston, 2014)

2.0 COMMUNITY MULTISCALE AIR QUALITY (CMAQ) MODELLING SYSTEM

CMAQ v5.0.2 (CMAS, 2010) is a 'one-atmosphere' photochemical grid model capable of addressing ozone, particulate matter (PM), visibility and acid deposition at regional scale for periods up to one year (Byun and Ching, 1999; Byun and Schere, 2006). The CMAQ modelling system was designed to approach air quality as a whole by including state-of-the-science capabilities for modelling multiple air quality issues, including tropospheric ozone, fine particles, toxics, acid deposition, and visibility degradation. CMAQ was designed to have multi-scale capabilities so that separate models were not needed for urban and regional scale air quality modelling. The CMAQ modelling system contains three types of modelling components:

1. a meteorological module for the description of atmospheric states and motions,
2. an emission models for man-made and natural emissions that are injected into the atmosphere, and
3. a chemistry-transport modelling system for simulation of the chemical transformation and fate.

CMAQ has been evaluated extensively for several applications both within the U.S. and outside the U.S. (Hanna and Benjey, 2006). The CMAQ source code is highly transparent and modular to facilitate extensibility through community development. There is an active worldwide CMAQ Users Network.

CMAQ consists of a core Chemical Transport Model (CTM) and several pre-processors including the Meteorological-Chemistry Interface Processor (MCIP), initial and boundary conditions processors (ICON and BCON) and a photolysis rates processor (JPROC), as shown in Figure 2-1. The US Environmental Protection Agency (EPA) continues to improve and develop new modules for the CMAQ model and typically provides a new release each year. EPA's Community Modelling and Analysis Systems (CMAS) centre supports the coordination, update and distribution of the modelling systems, data bases, and documentation (www.cmascenter.org).

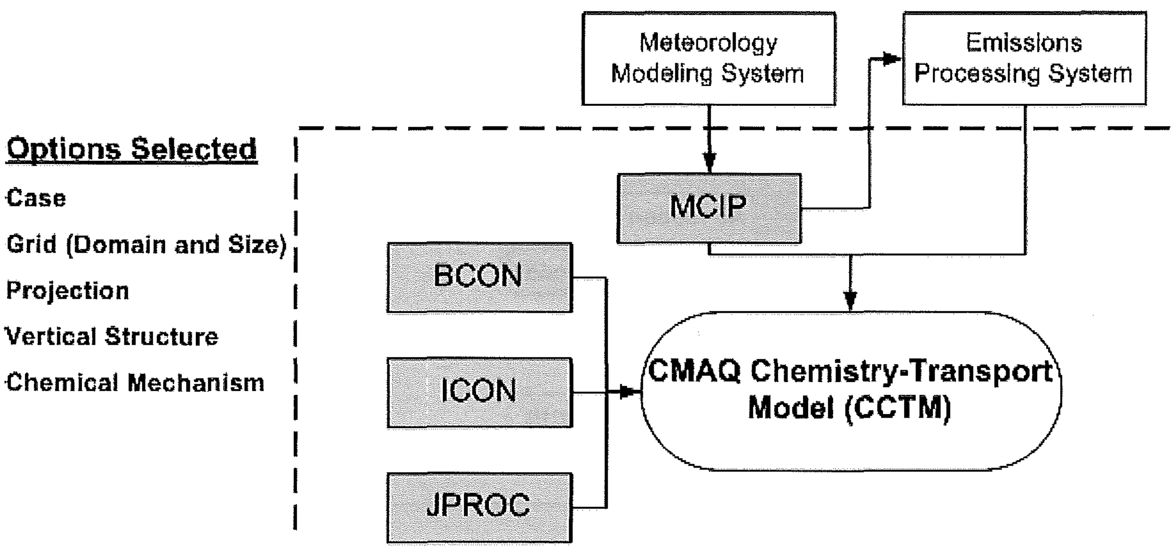


Figure 2-1: CMAQ Chemistry-Transport Model (CCTM) and Input Processors (Figure 2-1 in CMAS, 2015)

Continued improvement in the mathematical representation of gas-phase and heterogeneous atmospheric chemistry from plume-scale to global modelling has led to a new generation of chemical kinetic mechanisms for tropospheric simulations. The two mechanisms most commonly used in the U.S. for urban and regional air quality modelling are the Carbon Bond Mechanism (CBM) developed at Systems Applications, International (Gery et al, 1989) and the Statewide Air Pollution Research Centre (SAPRC) mechanism maintained at the University of California, Riverside (Carter, 2010a,b).

2.1 Selected Model Options

CMAQ Version 5.0.2 (released May 2014) was used, although a new version of CMAQ (v5.2, released June 2017) is currently available. This newer version was released after the launch of the project and the completion of the detailed work plan. The various CMAQ Chemical Transport Model (CTM) model configuration selected for the Hamilton Airshed Modelling system are presented in Table 2-1.

Table 2-1: Selected CMAQ Model Options for all Tiers

Model Option	CMAQ
Model Version	Version 5.0.2
Horizontal Resolution	36/12/4/1.33 km
Grid Nesting	One-way
Vertical Layers	NZ = 30
Horizontal Advection	Piecewise Parabolic Method (PPM)
Vertical Advection	PPM
Horizontal Diffusion	Spatially Varying
Vertical Diffusion	k_Z (Eddy Diffusion)
Minimum Vertical Diffusivity	1.0 m^2/s
Meteorology	Derived from MCIP output
Gas-Phase, Aerosol, and Aqueous-Phase Chemical Mechanism	Carbon Bond version 5 (CB05) gas-phase mechanism with active chlorine chemistry, updated toluene mechanism, mercury, and air toxics, sixth-generation CMAQ aerosol mechanism with sea salt and speciated PM, aqueous/cloud chemistry (CB05TUMP_AE6_AQ)
Gas-Phase Chemistry Solver	Modified Euler Backward Iterative (MEBI)
Dry Deposition	CMAQ dry deposition velocity routine instrumented for multipollutant modeling (M3DRY_MP)
Plume-in-Grid	Off
Initial Concentrations	Derived from ICON output
Boundary Conditions	GEOS-CHEM global chemical transport model or outer tier
Aerosol Mass Conservation Patch	Yes
Emissions (Typical)	2012

The progressive body of peer-reviewed literature suggests that for the proposed modelling domains, the selection of CMAQ options is best suited for the air quality modelling study (e.g., Wong et al. 2011; EPA 2003). These options have been used in other air quality modelling studies over a similar domain (e.g., Spak et al. 2012; Holloway et. al., 2012).

2.2 Model Inputs

CMAQ was executed with the following inputs:

- Three-dimensional hourly meteorological fields from the Weather Research Forecast (WRF) model;
- Three-dimensional hourly emissions as processed with/generated from emission models;
- Three dimensional initial conditions and boundary conditions generated from the downscaling software of the global climate models or outer tier;
- Topographic information used in the meteorological processing;
- Land use categories from the meteorological processing; and
- Photolysis rates generated by the CMAQ JPROC pre-processor.

2.2.1 Emissions

The emissions data for seventeen (17) compounds were processed with the aid of the Sparse Matrix Operator Kernel Emissions (SMOKE) model. SMOKE v.3.6 (CMAS, 2014) estimates spatially and temporally resolved, speciated emissions for on-road mobile, non-road mobile, area, point, fire and biogenic emission sources, among others, for all modern photochemical grid models. SMOKE is principally an emission processing system and not a true emissions modelling system in which emissions estimates are simulated from first principles. This means that, with the exception of on-road mobile, biogenic, and some non-road mobile sources, its purpose is to provide an efficient tool for converting emissions inventory data into the formatted emission files required by an air quality simulation (photochemical) model. For on-road and some non-road mobile sources, SMOKE simulates emissions rates based on input mobile source activity data, emission factors estimated using the Motor Vehicle Emission Simulator (MOVES2014 [USEPA, 2014]), and outputs from transportation travel-demand models. The 36/12/4/1.33 km emission domains are shown in Figure 3-1 and Figure 3-2. SMOKE was used to simulate the industrial, commercial, residential, agricultural, and non-road emissions for all tiers.

For Tiers II through IV the on-road mobile emissions were processed with MOVES2014 using hourly variations in emissions with considerations for differences between weekday and weekend activity as well as variations by month. Road type, traffic volume and road length in each grid cell were also considered in MOVES2014. Where fleet information for Canada isn't available, data from a representative US county is used as a surrogate.

For all tiers, biogenic emissions were processed using the Model of Emissions of Gases and Aerosols from Nature (MEGAN) to estimate biogenic emissions. MEGAN was developed to estimate biogenic emissions of reactive gases and aerosols needed for both regional air quality models (RAQMs) and global chemistry and transport models (GCTMs) (Guenther et al., 2012). Driving variables include land cover, weather, and atmospheric chemical composition. MEGAN is a global model with a base resolution of ~1 km. Global land cover data distributed with MEGAN at a 1-km resolution include plant functional type (PFT), emissions factors, and leaf area index (LAI).

2.2.2 Meteorology (MCIP)

The CMAQ Chemical Transport Model (CTM) meteorological inputs were generated by processing the WRF meteorological model output using the CMAQ Meteorological-Chemistry Interface Program (MCIP). The latest MCIP Version 4.1 (released July 2012) was used to extract 36/12/4/1.33 km fields from WRF simulation outputs. The 36/12/4/1.33 km WRF domains are shown in in Figure 3-1 and Figure 3-2.

2.2.3 Photolysis Tables

The CMAQ JPROC processor was used to calculate clear-sky photolysis rates (or J-values) for each date. JPROC uses default values for total aerosol loading and date-specific data for total ozone column from Total Ozone Mapping Spectrometer (TOMS) satellites. TOMS data for the year 2010 are available daily from http://toms.gsfc.nasa.gov/eptoms/ep.html. The photolysis input table for the 12/4/1.33 km modeling was the same as the 36-km modeling.

2.2.4 Initial and Boundary Conditions (ICs/BCs)

Regional chemical transport models (CTMs) require the specification of chemical concentrations on their lateral and top boundaries. Most research to date on this topic has focused on lateral and top boundary conditions (BCs) for tropospheric ozone. Simple boundary condition treatments such as "zero-gradient", where the spatial gradients of the chemical species are assumed to be zero on the boundaries, have been shown to be inadequate. Model performance is considerably improved with the use of time-invariant chemical lateral boundary conditions based on observations, compared to zero-gradient boundary conditions (Samaali et al., 2009). Accurate simulations of air quality in the Hamilton region is strongly dependent on the treatment of precursor species along the 36 km grid inflow boundaries (e.g., Tai et al., 2008) and considerable improvements in model simulation accuracy may be achieved in regional air-quality models from a careful choice of the methodology used to specify lateral and top boundary conditions (Makar et al., 2010).

The CMAQ CTM (CCTM) requires Boundary Conditions (BC) inputs to specify the assumed concentrations along the outer lateral edges of the 36 km modelling domain (see Figure 3-1) that are in the CCTM BCON input file. Initial Conditions (ICs) are also needed to be specified for the first day of the model simulation. The 12 km, 4 km, and 1.33 km domains are nested within the 36 km grid using one-way grid nesting, which means that the nested domain are run after the coarse domain and there is no feedback from the fine nest to the coarse domain. The BCs for the 12 km CMAQ modelling domain were obtained by processing the CMAQ CTM 36 km domain output using the CMAQ BCON processor to generate an hourly 12 km BC input file. The ICs for the 12 km domain were obtained from the 36 km CCTM modelling results. Similarly, the BCs/ICs for the 4 km and 1.33 km modelling domains were obtained from the 12 km and 4 km CCTM modelling results, respectively. For each tier, an initialization of 5 days or "spin-up" was allowed for the boundary conditions and initial conditions to disperse across the grid and for the chemistry solvers to stabilize.

For the 36 km domain, initial and boundary conditions were extracted from the GEOS-Chem model as provided by Dr. B Henderson and his research team at the University of Florida (Henderson, 2014). GEOS-Chem is a global chemical transport model developed at Harvard. It is driven by assimilated meteorological observations from the Global Earth Observation System (GEOS) of the NASA Global Modelling and Assimilation Office (GMAO). The system has been applied to a wide range of atmospheric composition problems including greenhouse gases, oxidants, PM, mercury, and other species. The coupled ozone-NOX-VOC-PM version of GEOS-Chem is described in Park et al. (2004). The initial and boundary conditions were extracted and downscaled from GEOS-Chem for the selected time period with a one year spin-up period for GEOS-Chem. Where boundary and initial conditions were not available from GEOS-Chem for specific species (due to differences in the chemistry represented between the models), standard initial and boundary condition profiles were used. Boundary conditions were provided to CMAQ every 3 hours everyday, while initial conditions were only provided for the first time step of the first day of the five (5) day spin up period. For the inner, higher resolution domains, the boundary conditions are downscaled from the outer tier on an hourly basis. Similarly, the initial conditions are downscaled from the outer tier for the first time step of the first day of the five day spin up period.

3.0 MODELLING DOMAIN

This section provides descriptions of the modelling domains used for photochemical modelling.

3.1 Horizontal Modelling Domains

The horizontal CMAQ modelling domain consists of four nested grids, or Tiers, with increasing spatial resolution (Figure 3-1 and Figure 3-2) according to proximity to the Hamilton area. Using the nested grid approach with increasing resolution, the photochemical modelling is able to account for influences on a regional to national scale, while capturing the complex photochemistry and transformations occurring on a local scale, without limiting computation time and resources. The resolution and coverage of the four modelling Tiers are shown in Table 3-1.

Table 3-1: Air Quality Modelling Tiers

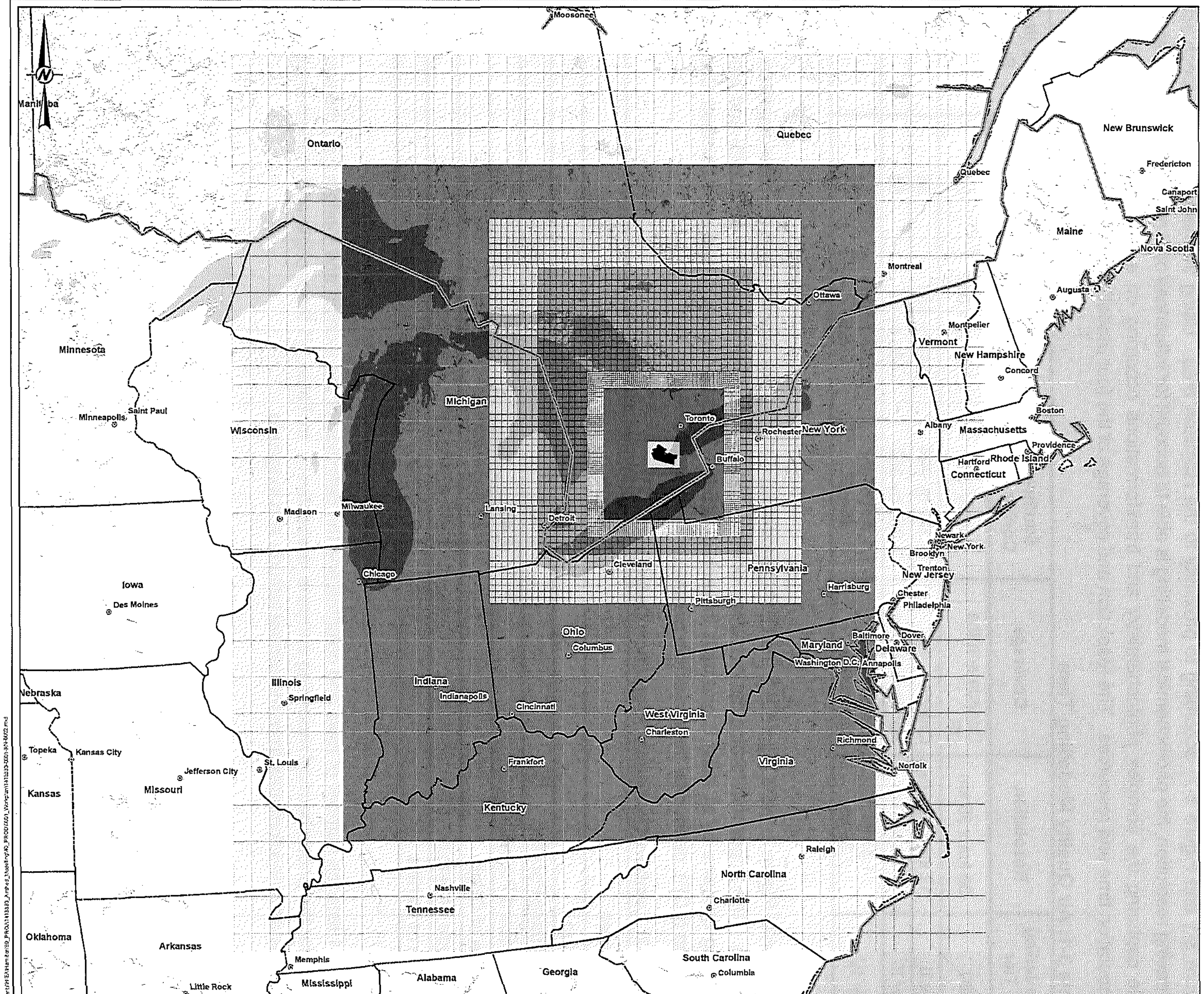
Modelling Tier	Resolution	Coverage	Southwest Corner (km)	Northeast Corner (km)	Columns (East-West)	Rows (North-South)
Tier I	36 km x 36 km	Canada and the US	738 by -270	-1,782 by 1,062	29	37
Tier II	12 km x 12 km	Ontario	1,122 by 294	1,542 by 858	36	47
Tier III	4 km x 4 km	Hamilton Region	1,250 by 362	1,486 by 62	59	65
Tier IV	1.33 km x 1.33 km	Hamilton Community	1,336.67 by 464.67	1,399.33 by 515.33	47	38

As shown in Figure 3-1 and Figure 3-2, the CMAQ modelling domains are aligned within the meteorological model domains. The larger meteorological modelling domains provide a buffer around the air quality and emissions modelling domains by at least 6 grid cells in each direction. These grids are based on a Lambert Conformal Projection (LCP), defined by the projection parameters listed in Table 3-2.

Table 3-2: Lambert Conformal Projection Definition

Parameter	Value
Projection	Lambert-Conformal
1st Standard Parallel	33°
2nd Standard Parallel	45°
Latitude of Origin	42.6031057°
Longitude of Origin	-81.4746529°
Sphere of Radius	6,370,997 metres

Table 3-1 lists the number of rows and columns and the definition of the x-origin and y-origin (i.e., the southwest corner) for the photochemical modelling domains, respectively. In Table 3-1 the x-origin and y-origin are defined as the distance in kilometres from the central latitude and longitude.



LEGEND
- City
- City of Hamilton
- State and Province Boundary
- Country Boundary
- Waterbody
- Tier IV 1 km CMAQ
- Tier IV 1 km WRF
- Tier III 4 km CMAQ
- Tier III 4 km WRF
- Tier II 12 km CMAQ
- Tier II 12 km WRF
- Tier I 36 km CMAQ
- Tier I 36 km WRF

0 200 400 600
Kilometres
1:7,500,000

REFERENCE(S)
BASE DATA FROM ESRI,PROJECTION: LAMBERT CONFORMAL CONIC.

CLIENT
HAMILTON INDUSTRIAL ENVIRONMENTAL ASSOCIATION

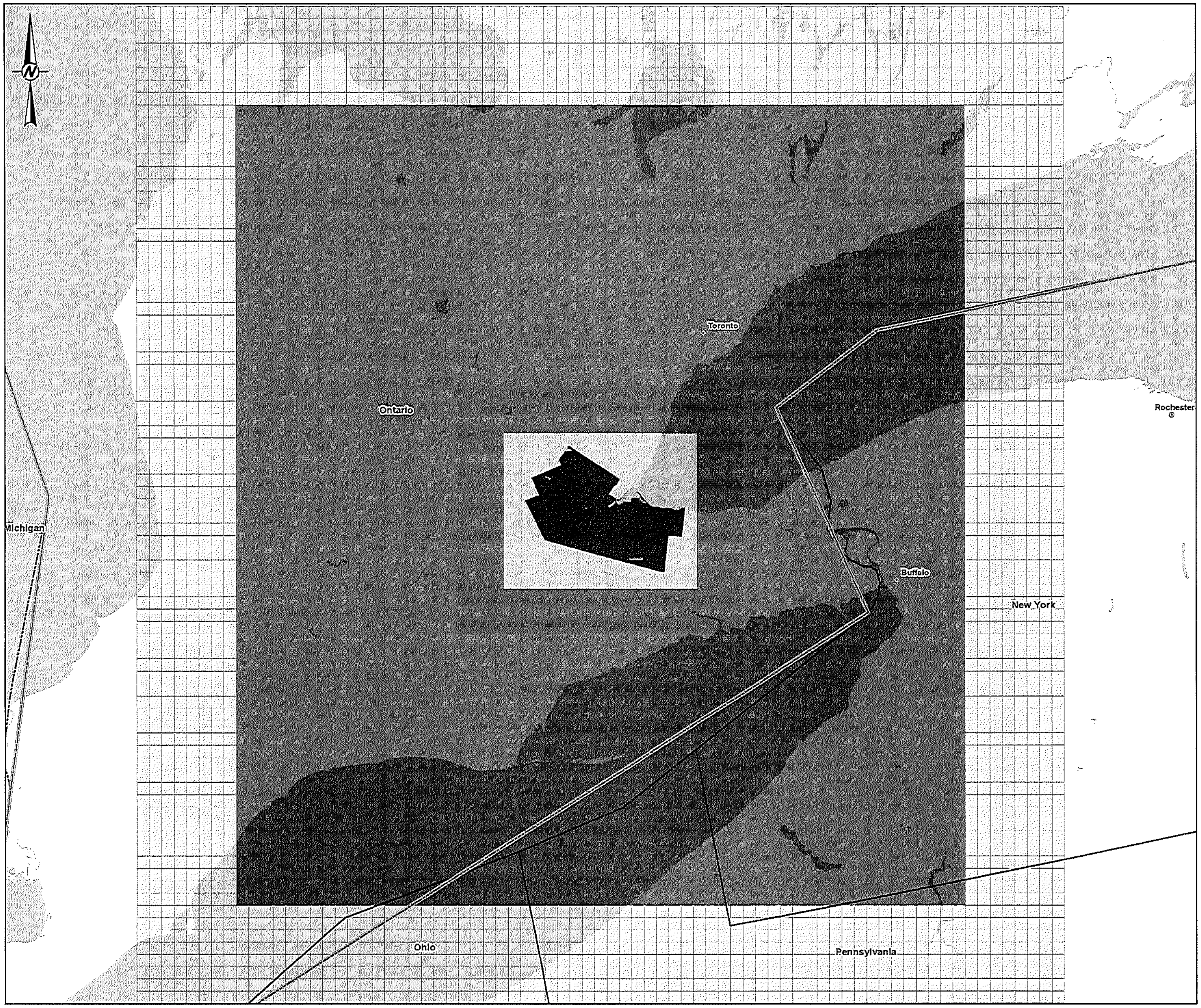
PROJECT
AIRSHED MODELLING TIERS

TITLE
MODELLING AND EMISSION GRIDS FOR HAMILTON AIRSHED MODELLING SYSTEM

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-03-09
DESIGNED	KD
PREPARED	KD
REVIEWED	JK
APPROVED	JLK

PROJECT NO.	CONTROL	REV.	FIGURE
1418883	0001	1.0	3-1



LEGEND

- City
- City of Hamilton
- State and Province Boundary
- Country Boundary
- Waterbody
- Tier IV 1 km CMAQ
- Tier IV 1 km WRF
- Tier III 4 km CMAQ
- Tier III 4 km WRF

REFERENCE(S)
BASE DATA FROM ESRI.PROJECTION: LAMBERT CONFORMAL CONIC.

CLIENT
HAMILTON INDUSTRIAL ENVIRONMENTAL ASSOCIATION

PROJECT
AIRSHED MODELLING TIERS

TITLE
TIER III AND IV MODELLING AND EMISSION GRIDS FOR HAMILTON AIRSHED MODELLING SYSTEM

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-03-09
DESIGNED	KD
PREPARED	KD
REVIEWED	JK
APPROVED	JLK

PROJECT NO.	CONTROL	REV.	FIGURE
1418883	0001	1.0	3-2

3.2 Vertical Modelling Domain

The CMAQ vertical structure is primarily defined by the vertical grid used in the meteorological modelling. The WRF model employs a terrain-following coordinate system defined by pressure, using multiple layers that extend from the surface to 50 mb (approximately 19 km above ground level). A layer-averaging scheme is adopted for the CMAQ simulations to reduce the air quality computational time. The effects of layer averaging were evaluated by WRAP and VISTAS and found to have a relatively minor effect on the model performance metrics when both 34 layer and 19 layer CMAQ model simulations were compared to ambient monitoring data (Morris et al., 2004a).

The vertical structures for both the meteorological and air quality domains are presented in Table 3-3. Note that the CMAQ model uses a terrain following "sigma" coordinate system so over elevated terrain the model heights are compressed.

Table 3-3: Comparison of Vertical Structures for Meteorology and Air Quality

Height (m)	WRF			CMAQ	
	Model Layer	Sigma	Depth of Layer (m)	Model Layer	Depth of Layer (m)
19314	0	50.00	2054	30	3785
17261	0.0267	75.72	1731		
15529	0.057	104.91	1631	29	4213
13898	0.0936	140.16	1346		
12552	0.1308	175.99	1236		
11316	0.1714	215.10	1151	28	3245
10165	0.2155	257.58	1079		
9086	0.263	303.33	1015		
8071	0.3137	352.17	954	27	2681
7117	0.3672	403.71	894		
6224	0.4229	457.36	833		
5390	0.4801	512.46	770	26	2105
4620	0.5378	568.04	703		
3917	0.5948	622.94	632		
3285	0.6498	675.92	559	26	559
2726	0.7015	725.72	486	25	486
2241	0.7489	771.38	415	24	415
1826	0.7913	812.22	348	23	348
1478	0.8282	847.76	286	22	286
1192	0.8595	877.91	232	21	232
960	0.8856	903.05	186	20	186
774	0.9069	923.57	147	19	147
628	0.924	940.04	115	18	115
513	0.9376	953.14	90	17	90
423	0.9483	963.45	70	16	70
353	0.9567	971.54	54	15	54
299	0.9632	977.80	42	14	42
257	0.9683	982.71	33	13	33
224	0.9723	986.57	25	12	25

MODEL PERFORMANCE EVALUATION

Height (m)	WRF			CMAQ	
	Model Layer	Sigma	Depth of Layer (m)	Model Layer	Depth of Layer (m)
199	0.9754	989.55	20	11	20
179	0.9778	991.87	20	10	20
159	0.9803	994.27	20	9	20
140	0.9827	996.59	20	8	20
119	0.9852	998.99	19	7	19
100	0.9876	1001.31	20	6	20
80	0.9901	1003.71	20	5	20
59	0.9926	1006.12	19	4	19
40	0.995	1008.43	20	3	20
20	0.9975	1010.84	20	2	20
0	1	1013.25	SURFACE	1	SURFACE

4.0 MODEL PERFORMANCE

Model Performance Evaluation (MPE) is the process of testing a model's ability to accurately estimate observed atmospheric properties over a range of synoptic and geophysical conditions. The purpose of the MPE is to demonstrate whether the Hamilton Airshed Modeling System performs with sufficient reliability to justify its use in tracing the sources influencing the airshed, determining potential health impacts, and developing emissions control strategies, among others.

MPE consists of two components: the operational and scientific evaluations. The *operational* evaluation entails an assessment of the model's ability to correctly estimate surface meteorological or air quality variables largely independent of whether the actual process descriptions in the model are accurate. The operational evaluation essentially tests whether the predicted surface meteorological and air quality fields are reasonable, consistent and agree adequately with routinely available observations. For Hamilton, the operational evaluations focused on the various model's reliability in reproducing average ground-level (a) wind speed, wind direction, temperature, precipitation (see associated report); (b) gas phase concentrations of O_3, NO_2, and SO_2; and (c) particulate concentrations of PM_{10} and $PM_{2.5}$ and (d) concentrations benzene and benzo(a)pyrene.

The *scientific* evaluation addresses the realism of the meteorological and air quality processes simulated by the Hamilton Airshed Modelling System through testing the model as an entire system as well as its component parts. The scientific evaluation seeks to determine whether the model's behavior, in the aggregate and in its component modules, is consistent with prevailing theory, knowledge of physical processes, and recent observations. As there is a significant amount of peer-reviewed literature that suggests the science underlying CMAQ is correct a scientific evaluation will not be performed.

In the absence of Canadian guidance on MPEs, the EPA recommendations on what should be reported in a MPE are used as guidance (Simon, Baker and Phillips, 2012). The following provides a summary of the guidance:

- The mean bias (MB), mean error or root mean square error (ME or RMSE), normalized mean bias (NMB) and/ or fractional bias (FB), normalized mean error (NME) and/or fractional error (FE) are reported as a minimum and calculated according to Table 4-1.
- Model evaluation statistics are calculated for the highest temporal resolution available, as well as the regulatory averaging times.
- Processing steps for the MPE, including how the predicted and observed data were paired and whether data are spatially/temporally averaged before the statistics are calculated.
- Modelled values are taken from the grid cell that contains the monitoring site.
- Both spatial displays and time series at monitoring sites are considered in the MPE.

The U.S. Regional Planning Organizations (RPOs) have established model performance goals and criteria for $PM_{2.5}$, PM_{10} and components of fine particle mass based on previous model performance for ozone and fine particles (e.g., Boylan and Russell, 2006; Morris et al., 2004a,b; 2009a,b). Table 4-2 summarizes EPA's model performance goals and criteria developed by the RPOs for PM to assist in interpreting the evaluating regional model performance for PM species.

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Table 4-1: Statistical Measures for Model Performance Evaluation

Statistical Measure	Formula	Comments
Root Mean Square Error (RMSE)	$\left[\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2\right]^{1/2}$	P_i = model prediction at time and location i O_i = observation at time and location i N =- number of paired values RMSE is reported as a concentration
Mean Bias (MB)	$\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)$	MB is reported as a concentration.
Normalized Mean Bias (NMB)	$\frac{\sum_{i=1}^{N}(P_i - O_i)}{\sum_{i=1}^{N} O_i}$	NMB is reported as a percentage
Normalized Mean Error (NME)	$\frac{\sum_{i=1}^{N}\lvert P_i - O_i\rvert}{\sum_{i=1}^{N} O_i}$	NME is reported as a percentage
Fractional Bias (FB)	$\frac{2}{N}\sum_{i=1}^{N}\left(\frac{P_i - O_i}{P_i + O_i}\right)$	FB is reported as a percentage and bounded by ±200%
Fractional Gross Error (FE)	$\frac{2}{N}\sum_{i=1}^{N}\left\lvert\frac{P_i - O_i}{P_i + O_i}\right\rvert$	FE is reported as a percentage (%) and bounded by 0% and 200%

Table 4-2: Model Performance Goals and Criteria for 24-Hour PM.

Fractional Bias (FB)	Fractional Error (FE)	Comment
≤±30%	≤50%	Goal for PM model performance, considered good performance[2]
≤±60%	≤75%	Criteria for PM model performance, considered average performance.[2]

4.1 Monitoring Station Data

Existing air quality in Hamilton has been monitored over the last number of years to a very high standard. The current monitoring network includes regulatory stations (i.e., MOECC, Environment Canada) as well as the Hamilton Air Monitoring Network (HAMN). Table 4-3, along with Figure 4-1 and FIGURE present the list of monitoring stations and relevant compounds of Interest which are used for the MPE. The monitoring stations collect additional parameters but were not used in the MPE.

Table 4-3: List of Air Monitoring Stations and Compounds of Interest in Hamilton During 2012

Station Information			Compounds of Interest						
Station Name	Station ID	Owner	SO_2	NO_2	O_3	$PM_{2.5}$	PM_{10}	Benzene	B(a)P
Brantford	61402	MOECC		✓	✓	✓			
Burlington	63001	MOECC		✓	✓	✓			
Hamilton Downtown	60512	MOECC	✓	✓	✓	✓		✓	✓
Hamilton Mountain	60513	MOECC	✓	✓	✓	✓			
Gertrude / Depew	STN29113	HAMN					✓	✓	✓
STN29153	STN29153	HAMN					✓		

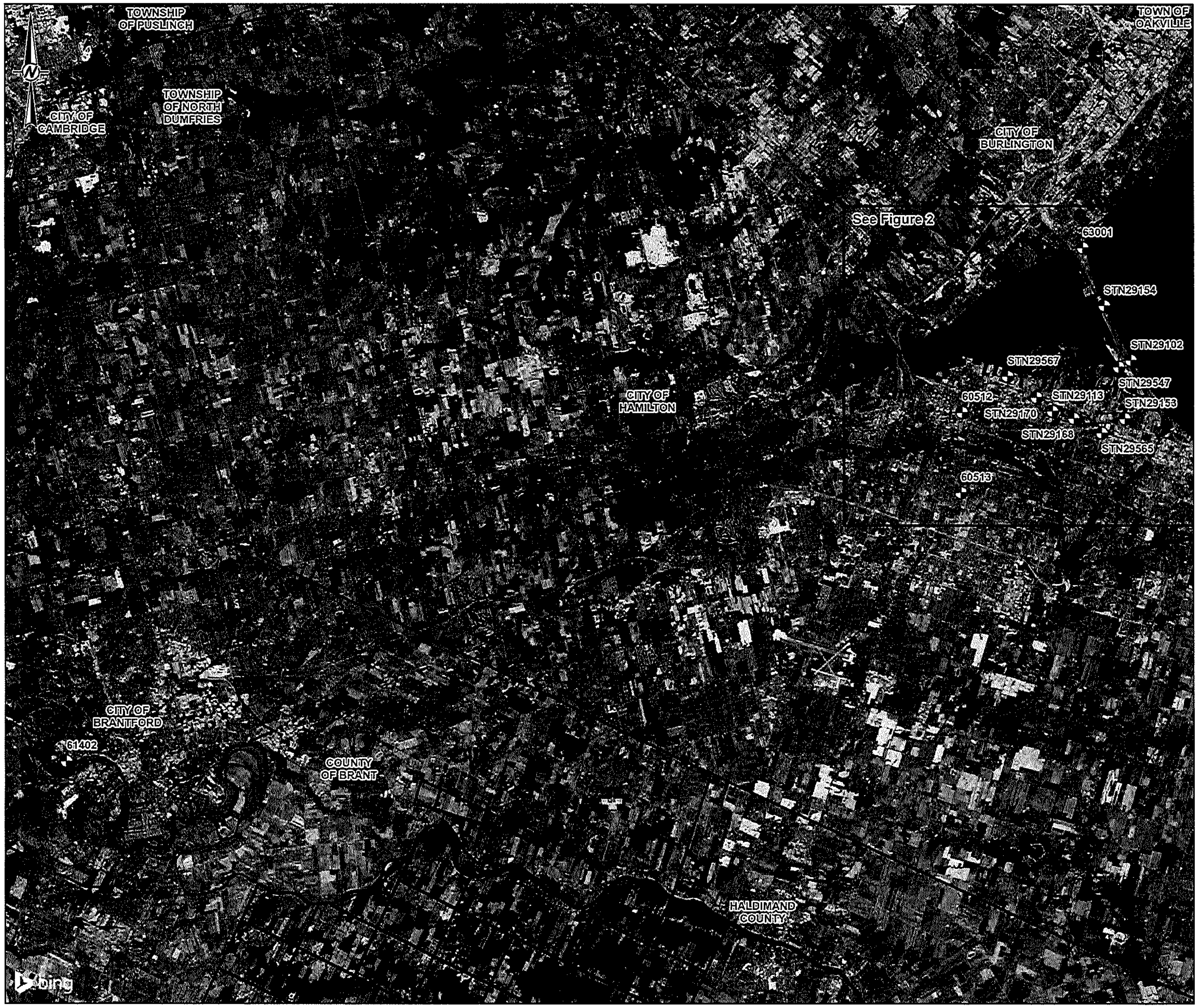
Station Information			Compounds of Interest						
STN29153	STN29153	HAMN					✓		
STN29154	STN29154	HAMN					✓		
STN29168	STN29168	HAMN					✓		
STN29170	STN29170	HAMN					✓		
STN29565	STN29565	HAMN					✓		
Niagara / Land	STN29567	HAMN	✓	✓			✓	✓	✓
Pier 25	STN29547	HAMN							✓
Beach Strip	STN29102	HAMN						✓	

4.2 Performance Results

4.2.1 Daily $PM_{2.5}$ Concentrations

The 24-hour $PM_{2.5}$ paired performance statistics for the Tier IV Hamilton airshed are summarized in Table 4-4, along with each monitoring station for the CMAQ 1.3 km domain. The FB metric indicates that the model overestimates the observed 24-hour $PM_{2.5}$ concentrations across the Tier IV domain by 36.2% which achieves the PM performance criteria (≤±60%). The average FE metric (64.3%) also satisfies the performance criteria (≤75%) but exceeds the performance goal (≤50%). The Quantile-Quantile (Q-Q) plot for the Tier IV are shown on Figure 4-3 and individual stations are provided on Figure 4-4. The individual station results are similar to each other as they all meet the performance criteria. The Q-Q plots show reasonability good correlations with model results being within a factor of two of observations.

Figure 4-5 presents the 2012 time series of daily modelled and observed $PM_{2.5}$ concentrations across the monitoring network. CMAQ over-predicts during winter time conditions (i.e., December, January and February) but does very well between March and November as shown by the matching peaks of the diagram.



LEGEND

Monitoring Stations

Municipal Boundary

Station Name	Station ID
Brantford	61402
Burlington	63001
Hamilton Downtown	60512
Hamilton Mountain	60513
Gertrude / Depew	STN29113
STN29153	STN29153
STN29154	STN29154
STN29168	STN29168
STN29170	STN29170
STN29565	STN29565
Niagara / Land	STN29567
Pier 25	STN29547
Beach Strip	STN29102

0 5,000 10,000
1:150,000 Metres

REFERENCE(S)
1. BASEDATA - MNRF LIO, OBTAINED 2017
2. IMAGERY - EARTHSTAR GEOGRAPHICS SIO © 2018 MICROSOFT CORPORATION
3. COORDINATE SYSTEM - NAD 1983 UTM ZONE 17N PROJECTION: TRANSVERSE MERCATOR
DATUM: NORTH AMERICAN 1983

CLIENT
HAMILTON INDUSTRIAL ENVIRONMENTAL ASSOCIATION

PROJECT
ADDITIONAL EFFORT TRACKING

TITLE
MONITORING STATION LOCATIONS

CONSULTANT

Golder Associates

YYYY-MM-DD	2018-01-08
DESIGNED	RA
PREPARED	RA
REVIEWED	JK
APPROVED	JLK

PROJECT NO.	CONTROL	REV.	FIGURE
1418883 (9999)	0005	A.	4-1

LEGEND

Monitoring Stations

Municipal Boundary

Station Name	Station ID
Brantford	61402
Burlington	63001
Hamilton Downtown	60512
Hamilton Mountain	60513
Gertrude / Depew	STN29113
STN29153	STN29153
STN29154	STN29154
STN29168	STN29168
STN29170	STN29170
STN29565	STN29565
Niagara / Land	STN29567
Pier 25	STN29547
Beach Strip	STN29102

0 1,000 2,000
1:40,000 Metres

REFERENCE(S)
1. BASEDATA - MNRF LIO, OBTAINED 2017
2. IMAGERY - EARTHSTAR GEOGRAPHICS SIO © 2018 MICROSOFT CORPORATION
3. COORDINATE SYSTEM - NAD 1983 UTM ZONE 17N PROJECTION: TRANSVERSE MERCATOR DATUM: NORTH AMERICAN 1983

CLIENT
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TITLE
MONITORING STATION LOCATIONS

CONSULTANT
Golder Associates

YYYY-MM-DD	2018-01-08
DESIGNED	RA
PREPARED	RA
REVIEWED	JK
APPROVED	JLK

PROJECT NO.	CONTROL	REV.	FIGURE
1418883 (9999)	0005	A.	4-2

Table 4-4: Performance Statistics for Paired Daily $PM_{2.5}$ Observations

Station Name	Statistics							
	Observed Mean (µg/m^3)	Model Mean (µg/m^3)	MB (µg/m^3)	RMSE (µg/m^3)	NMB	NME	FB	FE
Brantford	6.3	9.3	3.07	6.73	49.0%	77.7%	32.4%	61.0%
Burlington	5.8	9.5	3.74	5.08	64.5%	65.3%	35.2%	38.1%
Hamilton Downtown	8.4	12.2	3.76	6.38	44.6%	58.2%	43.5%	53.3%
Hamilton Mountain	6.5	9.8	3.31	6.02	50.9%	68.0%	41.1%	55.5%
All Tier IV Stations	**6.7**	**10.2**	**3.47**	**7.21**	**51.4%**	**78.9%**	**36.2%**	**64.3%**
Performance Goal							≤±30%	≤50%
Performance Criteria							≤±60%	≤75%

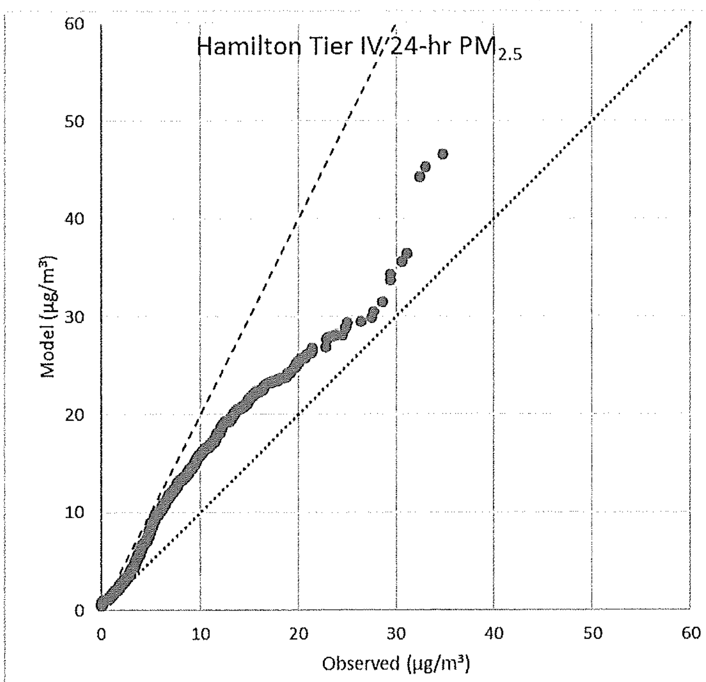

Figure 4-3: Unpaired Comparison of Modelled vs Observed $PM_{2.5}$ at All Hamilton Stations

MODEL PERFORMANCE EVALUATION

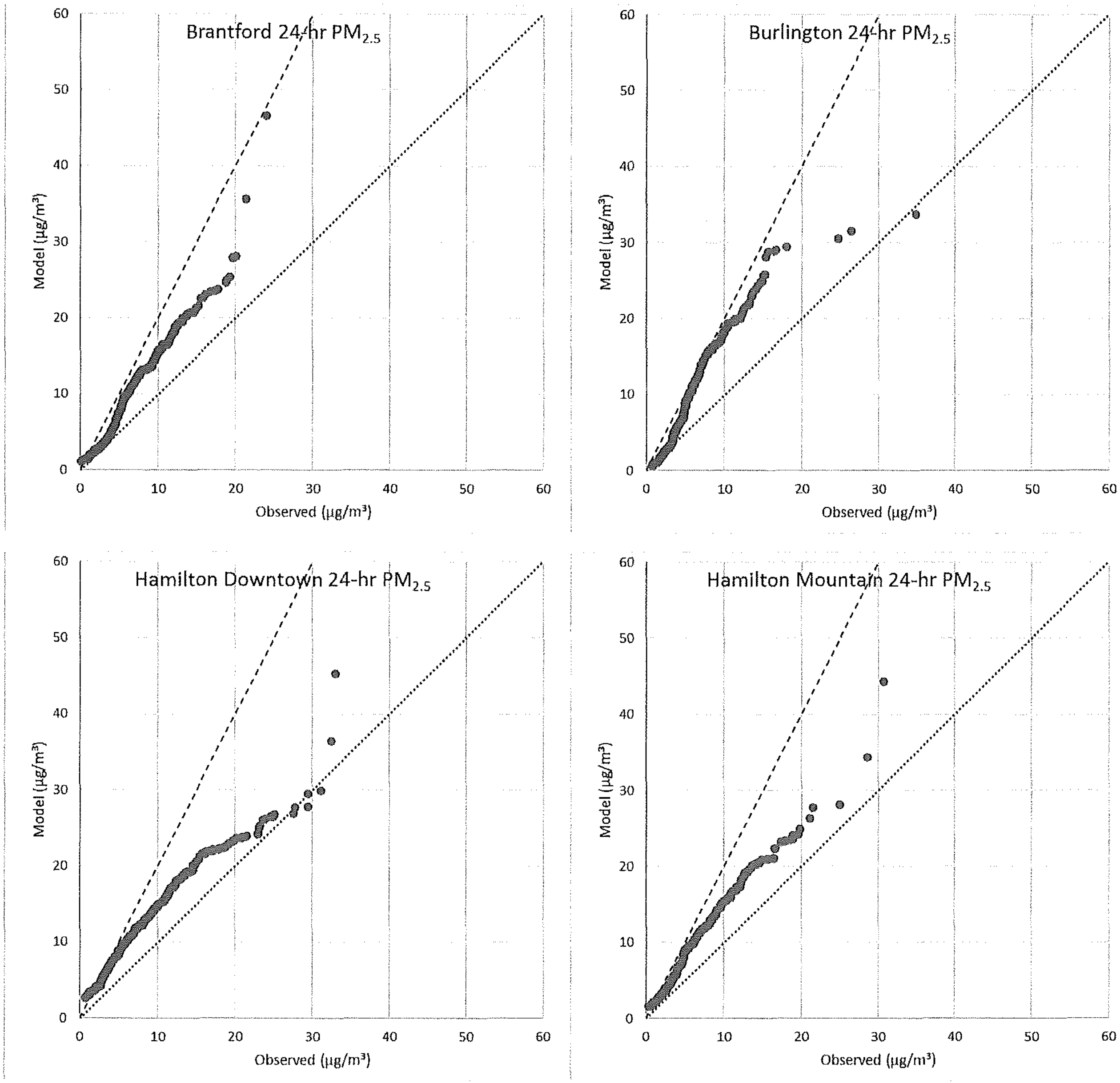

Figure 4-4: Unpaired Comparison of Modelled vs Observed $PM_{2.5}$ at Individual Stations

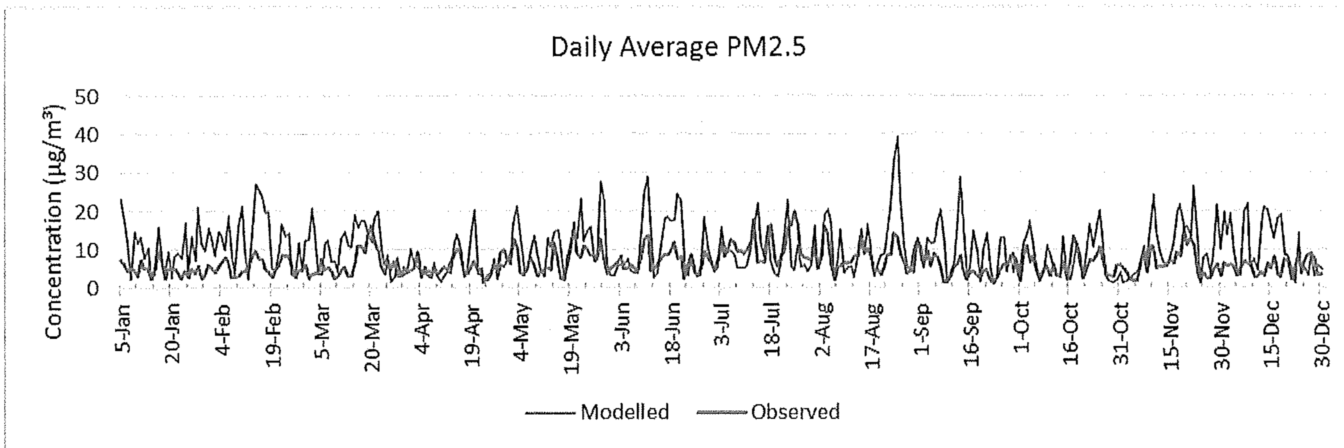

Figure 4-5: Time Series of Modelled vs Observed Daily Average $PM_{2.5}$ Concentrations

4.2.2 Daily PM_{10} Concentrations

The 24-hour PM_{10} paired performance statistics are summarized in Table 4-5, along with each monitoring station. Unlike the $PM_{2.5}$, the model under-predicts by 8.11 µg/m³ or -42% as shown by the FB metric across the Tier IV domain which achieves the PM performance criteria (≤±60%). The average FE metric (63.5%) also satisfies the performance criteria (≤75%) but exceeds the performance goal (≤50%). The Quantile-Quantile (Q-Q) plot for the Tier IV are shown on Figure 4-6 and individual stations are provided on Figure 4-7, respectively. The individual station results show mixed results. STN29153 has lowest FB/FE metrics with model results being less than 50% of observation. The Niagara/Land station has the best correlation and FB/FE metrics. The Q-Q plots show reasonability good correlations with model results below 60 µg/m³. There is a tendency to under-predict at the higher of the prediction which maybe the result of a local unknown source contributing to the observations.

The 2012 time series of daily modelled and observed PM_{10} concentrations across the monitoring network are presented on Figure 4-8. CMAQ under-predicts during the entire year but does show variability in the results as expected with observed values as there seems to be some correlation between peaks and troughs.

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Table 4-5: Performance Statistics for Paired Daily PM_{10} Observations

Station Name	Observed Mean (µg/m³)	Model Mean (µg/m³)	MB (µg/m³)	RMSE (µg/m³)	NMB	NME	FB	FE
	Statistics							
Gertrude / Depew	22.9	17.0	-5.81	17.01	-26.1%	50.8%	-23.4%	58.3%
Niagara / Land	22.0	24.6	2.69	11.86	12.2%	41.6%	11.5%	42.7%
STN29153	33.4	11.7	-20.42	27.17	-72.2%	73.7%	-87.5%	89.8%
STN29154	15.7	11.5	-4.26	9.78	-31.4%	49.1%	-42.7%	57.2%
STN29168	21.9	13.0	-8.14	15.50	-43.0%	60.5%	-46.9%	67.2%
STN29170	30.0	16.2	-13.34	22.65	-51.5%	60.3%	-52.2%	64.9%
STN29565	21.4	11.7	-8.66	14.65	-46.8%	58.6%	-54.0%	66.8%
Tier IV All Stations	**23.5**	**15.4**	**-8.11**	**17.68**	**-34.5%**	**51.6%**	**-41.6%**	**63.5%**
Performance Goal							≤±30%	≤50%
Performance Criteria							≤±60%	≤75%

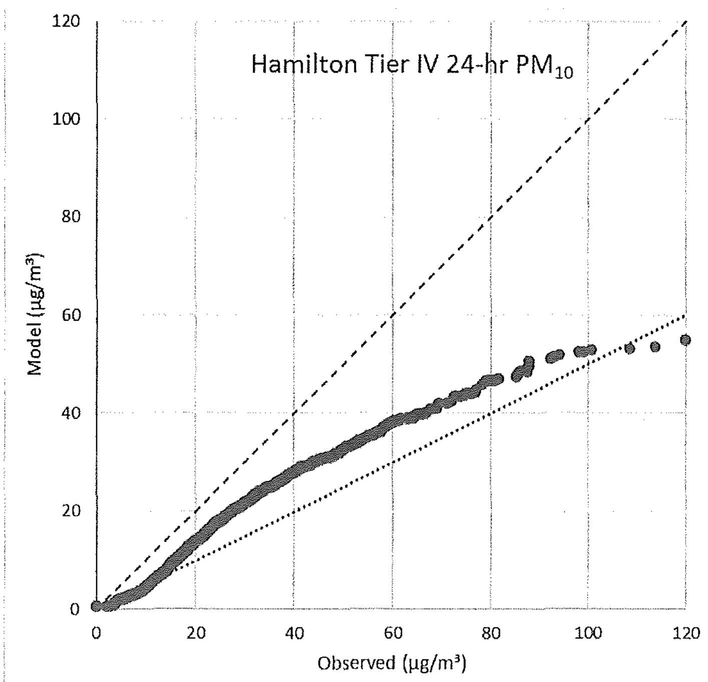
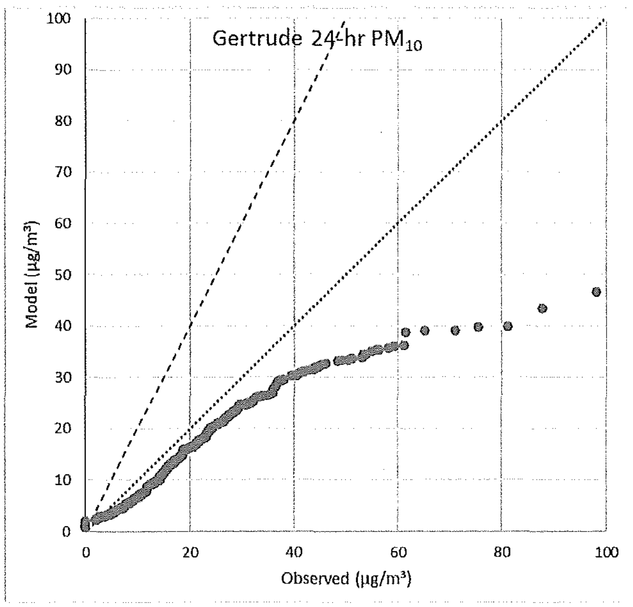
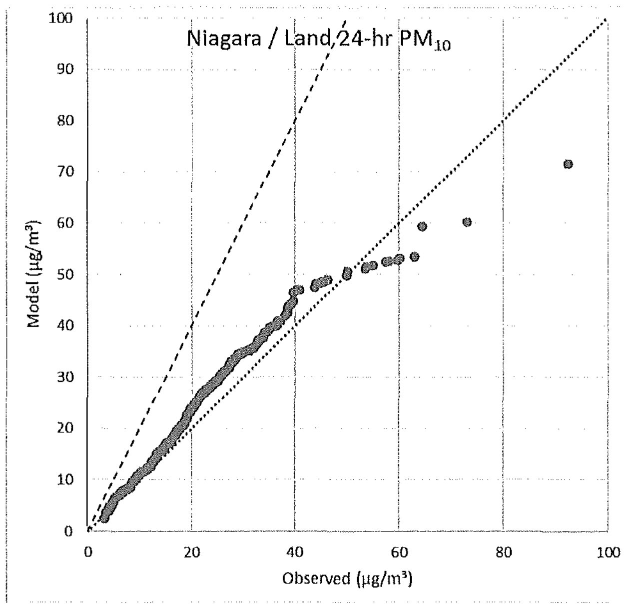
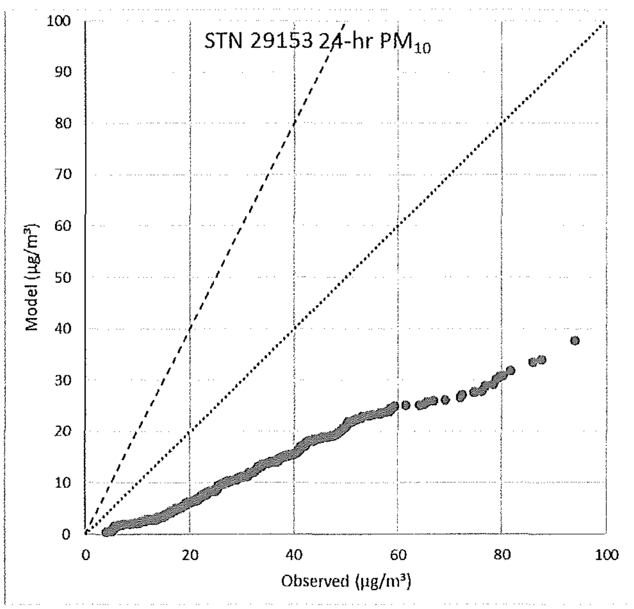


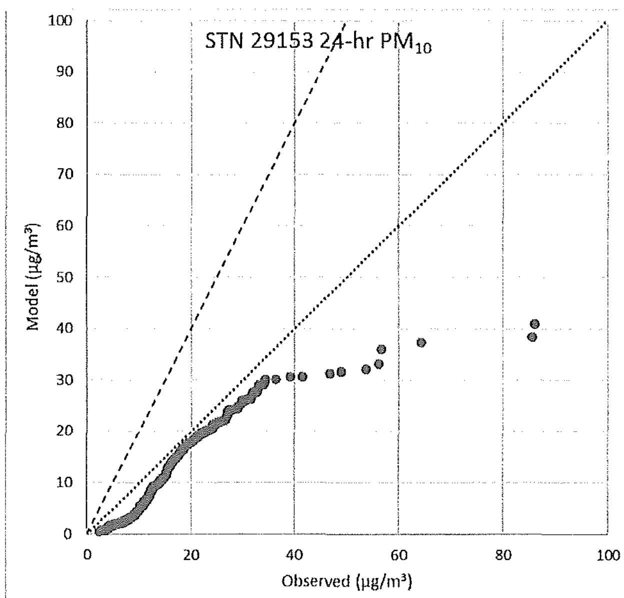
Figure 4-6: Unpaired Comparison of Modelled vs Observed PM_{10} at All Hamilton Stations

MODEL PERFORMANCE EVALUATION









MODEL PERFORMANCE EVALUATION

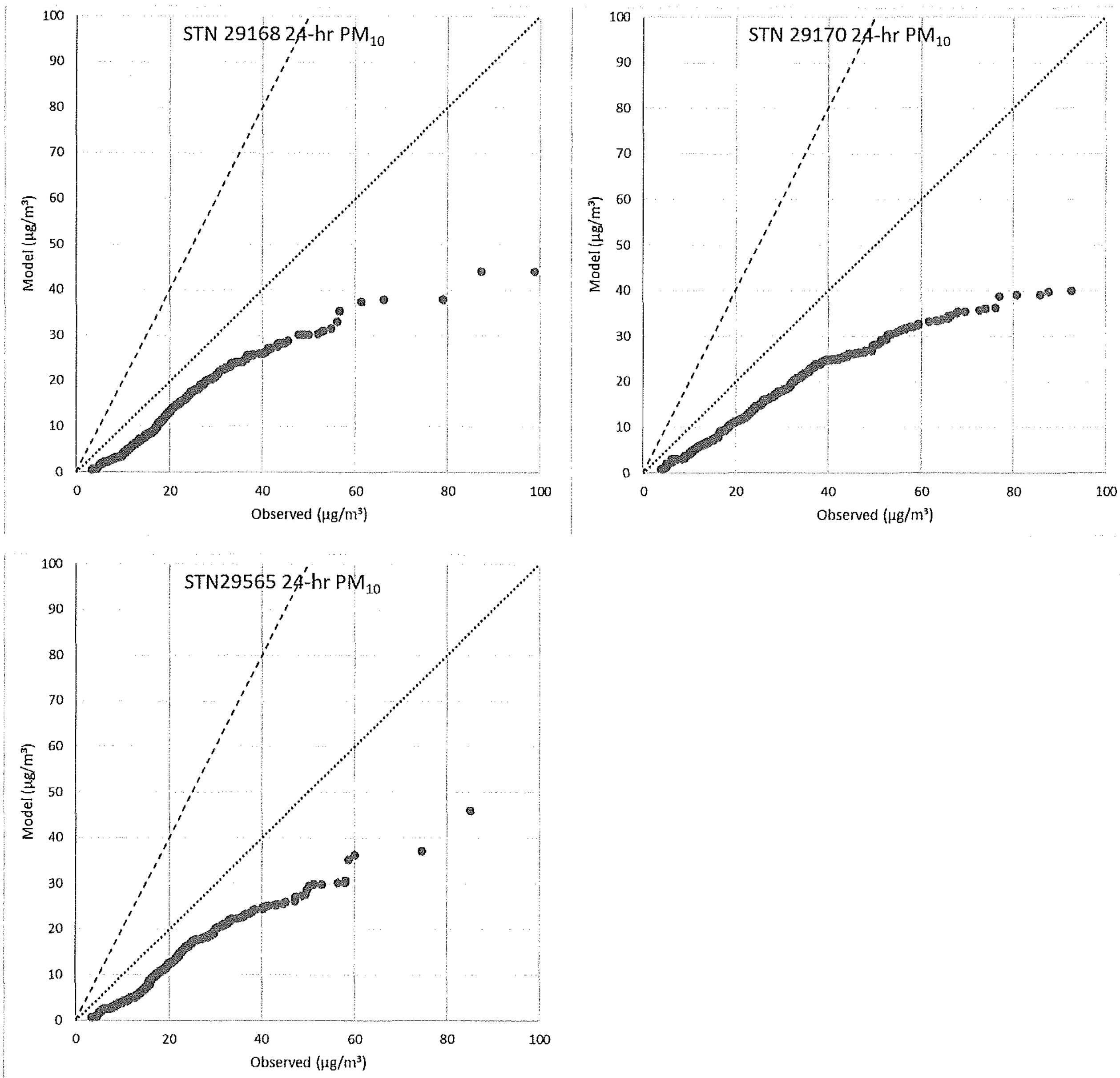


Figure 4-7: Unpaired Comparison of Modelled vs Observed PM10 at Individual Stations

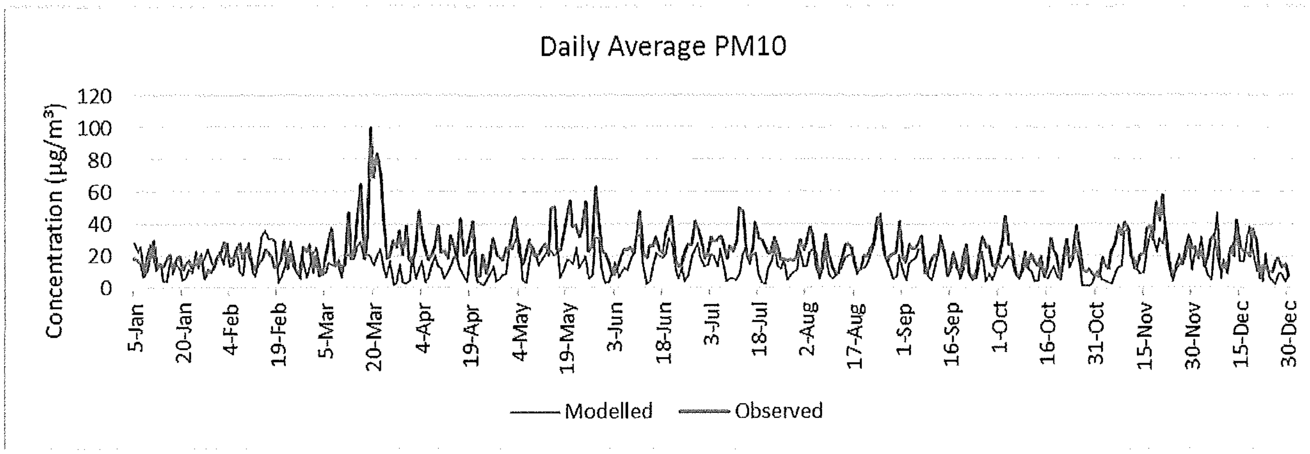


Figure 4-8: Time Series of Modelled vs Observed Daily Average PM_{10} Concentrations

4.2.3 Daily O_3 Concentrations

The 24-hour ozone paired performance statistics are summarized in Table 4-6, along with each monitoring station. The model has a slight under-prediction of 3.61 ppb (MB) or -29.2% as shown by the FB metric across the Tier IV domain. The Quantile-Quantile (Q-Q) plot for the Tier IV are shown on Figure 4-9 and individual stations are provided on Figure 4-10. The individual station results show strong results. Three of the four stations show moderate under predictions with Hamilton Mountain having a moderate over prediction. The Burlington station has the best correlation and FB/FE metrics. The Q-Q plots show good correlations with model results. There is a tendency to slightly over-predict at the higher of the end of the observations, but the overall results are very good.

The 2012 time series of daily modelled and observed ozone concentrations across the monitoring network are presented on Figure 4-11. Modelled and observed results both show peak ozone occurring in the summer time and decreasing to lows in the winter. The model simulations are strongly representative of the observed conditions.

Table 4-6: Performance Statistics for Paired Daily O_3 Observations

	Statistics (ppb)							
Station Name	**Observed Mean (ppb)**	**Model Mean (ppb)**	**MB (ppb)**	**RMSE (ppb)**	**NMB**	**NME**	**FB**	**FE**
Brantford	28.8	25.6	-3.13	12.06	-10.9%	35.1%	-24.8%	45.3%
Burlington	24.9	26.5	1.50	15.74	6.1%	48.7%	-8.9%	53.7%
Hamilton Downtown	25.8	21.0	-4.80	9.86	-18.6%	32.4%	-37.3%	50.1%
Hamilton Mountain	30.2	22.2	-8.06	11.36	-26.7%	32.7%	-45.8%	51.9%
Tier IV All Stations	**27.4**	**23.8**	**-3.61**	**12.45**	**-13.2%**	**36.9%**	**-29.2%**	**50.3%**
Performance Goal							≤±15%	≤30%

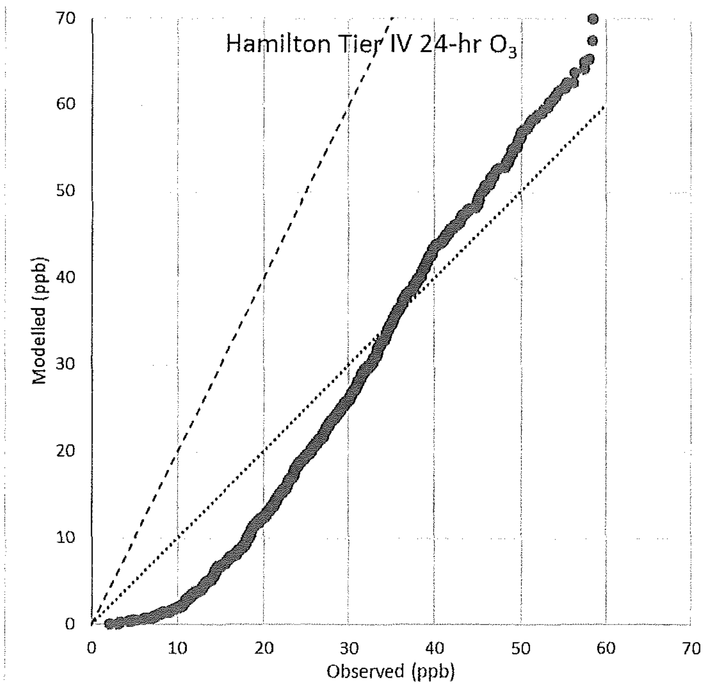


Figure 4-9: Unpaired Comparison of Modelled vs Observed O_3 at All Hamilton Stations

MODEL PERFORMANCE EVALUATION

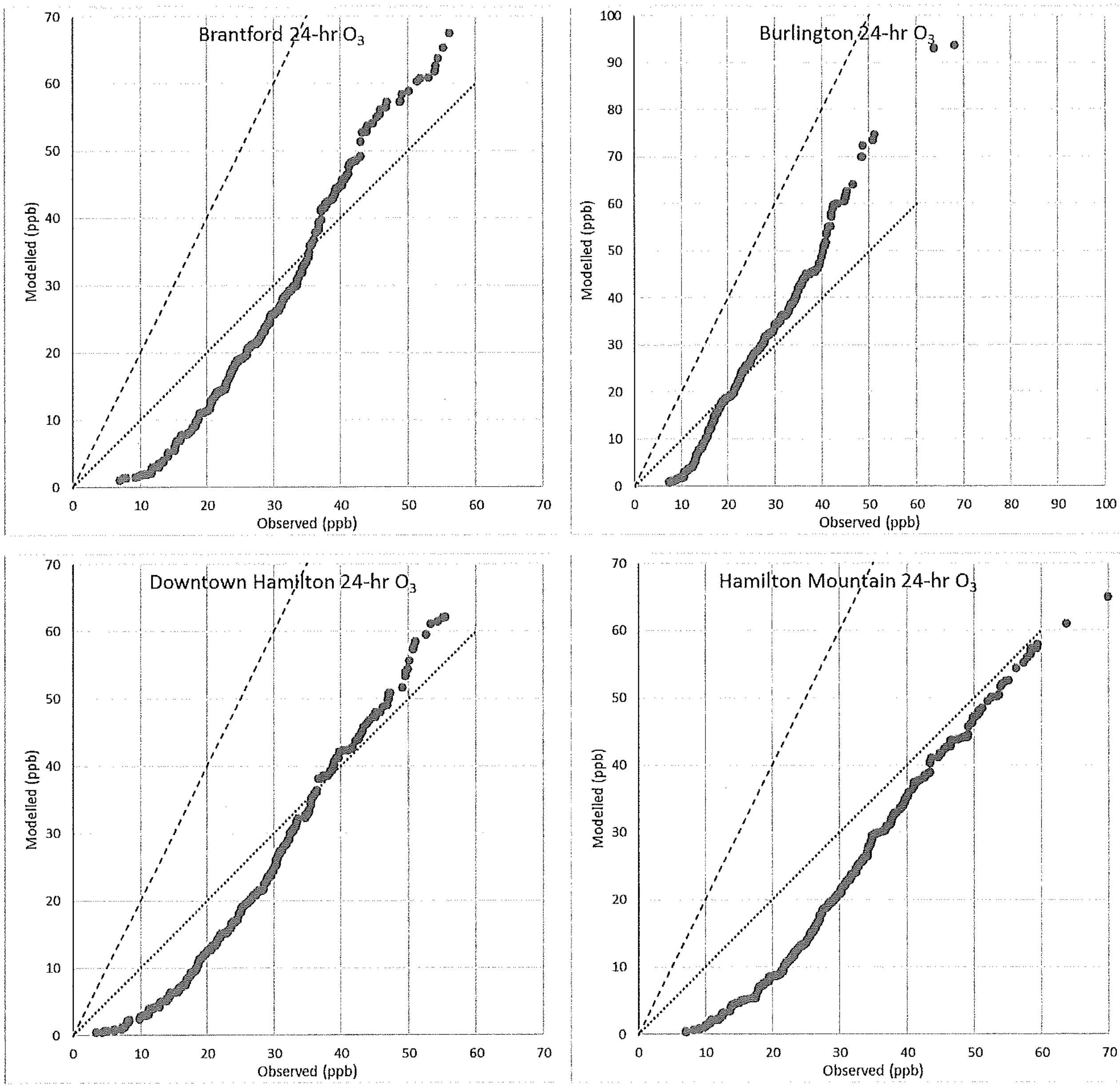


Figure 4-10: Unpaired Comparison of Modelled vs Observed O_3 at Individual Stations

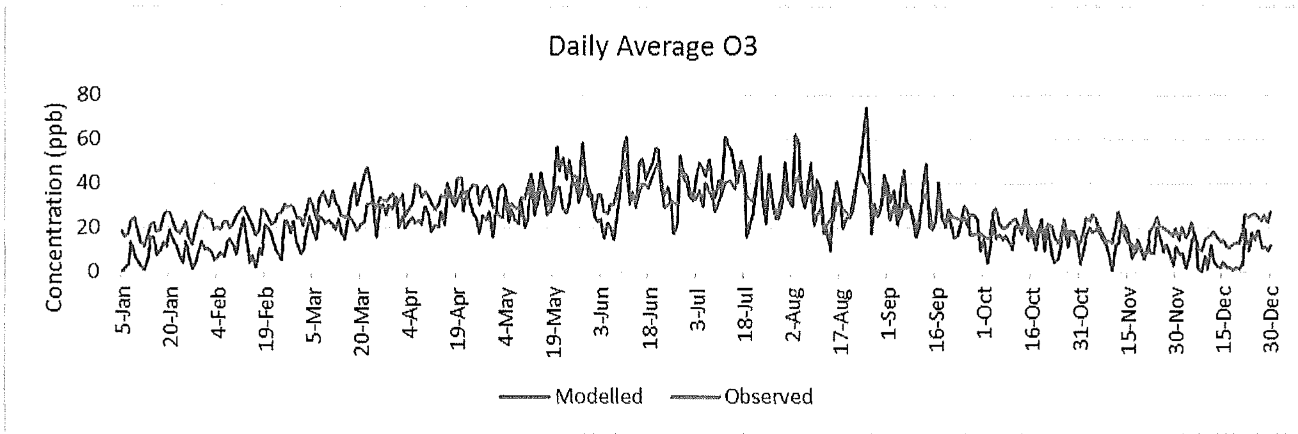


Figure 4-11: Time Series of Modelled vs Observed Daily Average Ozone Concentrations

4.2.4 Daily SO_2 Concentrations

The 24-hour sulphur dioxide paired performance statistics are summarized in Table 4-7, along with each monitoring station. The model has an over-prediction of 2.3 ppb (MB) or 53.5%% as shown by the FB metric across the Tier IV domain. The Quantile-Quantile (Q-Q) plot for the Tier IV are shown on Figure 4-12 and individual stations are provided on Figure 4-13. The individual station results show mixed results with Niagara / Land having the highest FB/FE results. The Q-Q plots show good correlations with model results and observations.

The time series for observed and modelled daily SO_2 concentrations are provided on Figure 4-14. The model tends to over-predict in the winter season but provides good simulations during the summer season. The modelled results provide reasonable correlations with the observed for the entire year.

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Table 4-7: Performance Statistics for Paired Daily SO_2 Observations

	Statistics							
Station Name	**Observed Mean (ppb)**	**Model Mean (ppb)**	**MB (ppb)**	**RMSE (ppb)**	**NMB**	**NME**	**FB**	**FE**
Hamilton Downtown	4.9	7.5	2.65	7.41	54.4%	112.7%	68.0%	97.4%
Hamilton Mountain	3.7	4.2	0.54	3.92	14.6%	68.3%	13.4%	59.8%
Niagara / Land	5.1	8.8	3.78	8.96	75.0%	140.6%	79.2%	110.7%
Tier IV All Stations	4.5	6.9	2.32	7.08	51.1%	110.8%	53.5%	89.2%

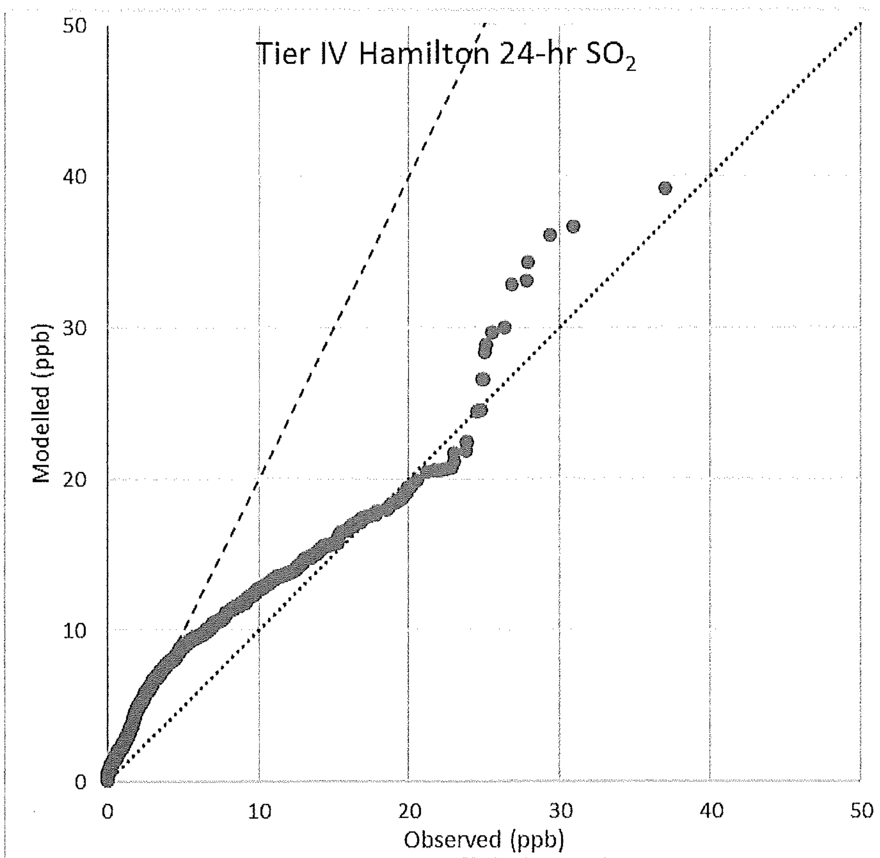

Figure 4-12: Unpaired Comparison of Modelled vs Observed SO_2 at All Hamilton Stations

MODEL PERFORMANCE EVALUATION

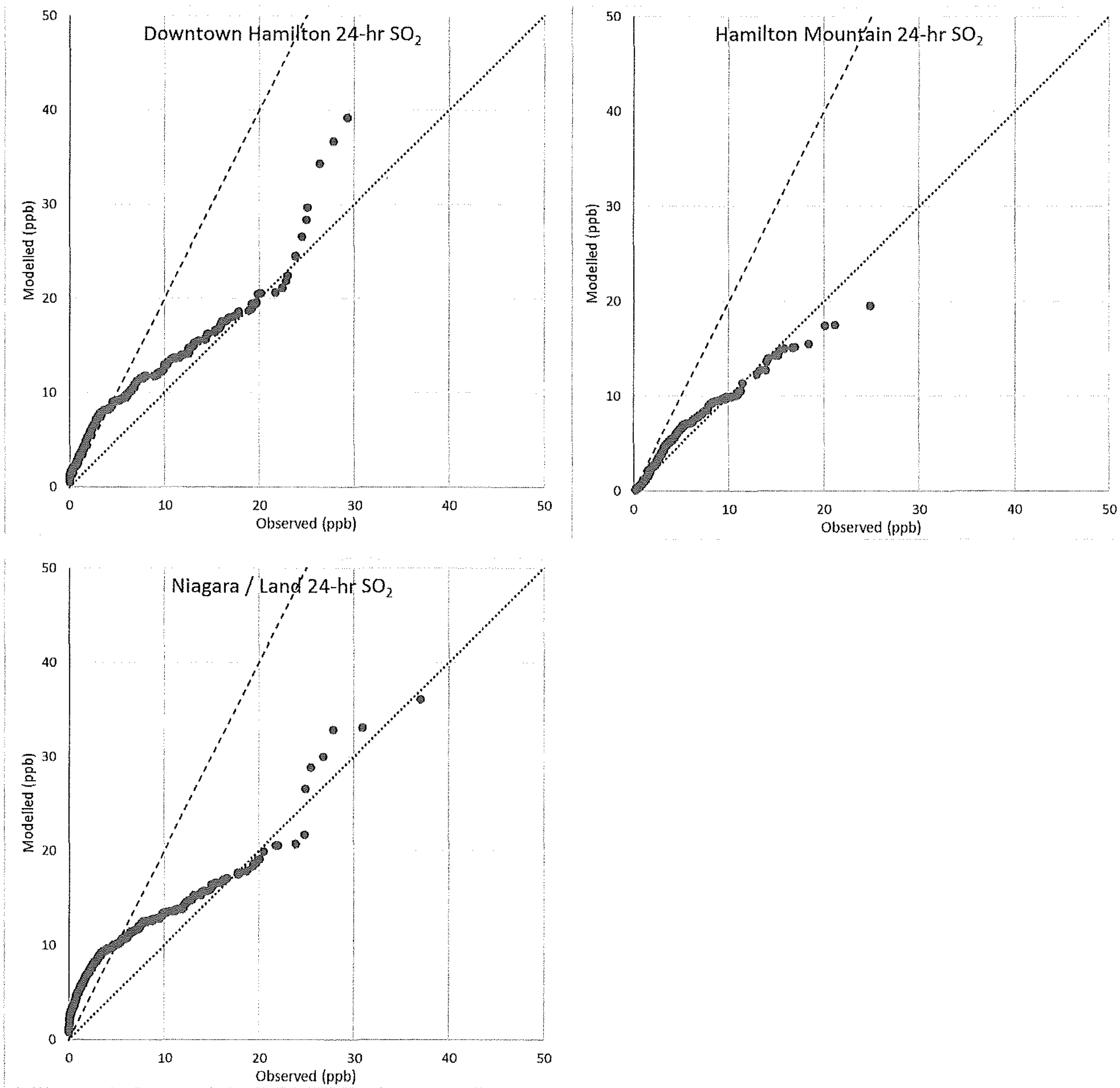

Figure 4-13: Unpaired Comparison of Modelled vs Observed SO_2 at Individual Stations

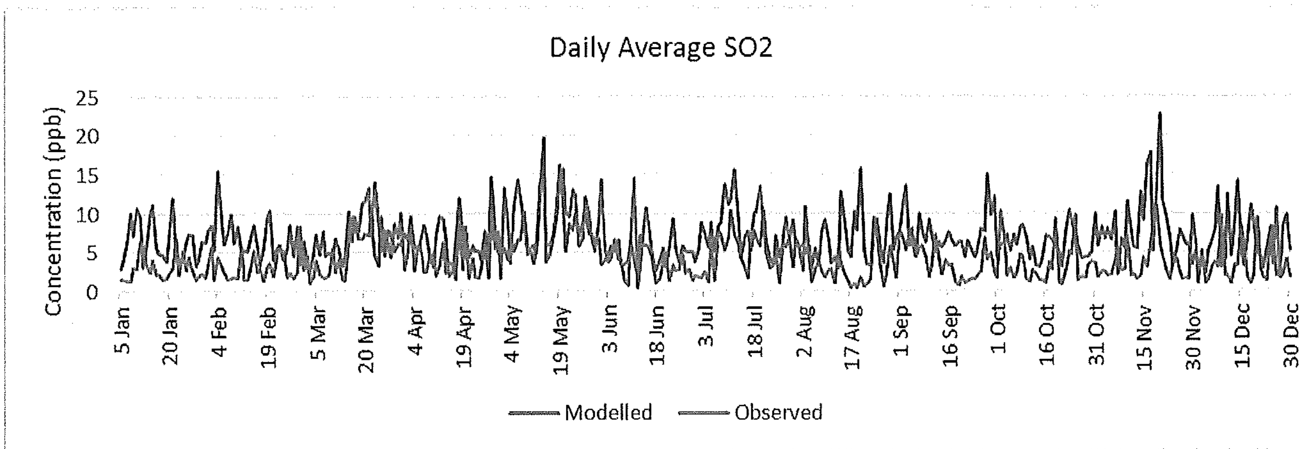

Figure 4-14: Time Series of Modelled vs Observed Daily Average SO_2 Concentrations

4.2.5 Daily NO_2 Concentrations

The 24-hour nitrogen dioxide paired performance statistics are summarized in Table 4-8, along with each monitoring station. The model has an over-prediction of 10 ppb (MB) or 67% as shown by the FB metric across the Tier IV domain The Quantile-Quantile (Q-Q) plot for the Tier IV are shown on Figure 4-15 and individual stations are provided in Figure 4-16. The individual station results show mixed results with Burlington having the best FB/FE results. The Q-Q plots show good correlations with model results and observations with model results within a factor of two of observations with the exception of Niagara / Land and Hamilton Mountain.

Time series of the daily NO_2 levels (observed and modelled) are presented on Figure 4-17 which illustrate that the modelled consistently over-predicts concentrations by about 10 ppb. The over-prediction is consistent through the year and is likely do to background (transboundary) levels influencing the results.

Table 4-8: Performance Statistics for Paired Daily NO_2 Observations

	Statistics (ppb)							
Station Name	**Observed Mean (ppb)**	**Model Mean (ppb)**	**MB (ppb)**	**RMSE (ppb)**	**NMB**	**NME**	**FB**	**FE**
Brantford	5.5	13.7	8.22	9.13	150.7%	151.8%	90.6%	91.1%
Burlington	13.6	17.8	4.23	12.30	31.2%	72.0%	16.5%	61.8%
Hamilton Downtown	11.9	22.8	10.85	12.85	91.1%	92.6%	67.0%	68.0%
Hamilton Mountain	8.7	19.9	11.23	12.27	129.5%	129.9%	85.2%	85.4%
Niagara / Land	11.9	28.1	16.20	19.50	136.3%	138.7%	76.2%	78.7%
Tier IV All Stations	**10.3**	**20.4**	**10.14**	**13.65**	**98.4%**	**110.3%**	**67.1%**	**77.0%**

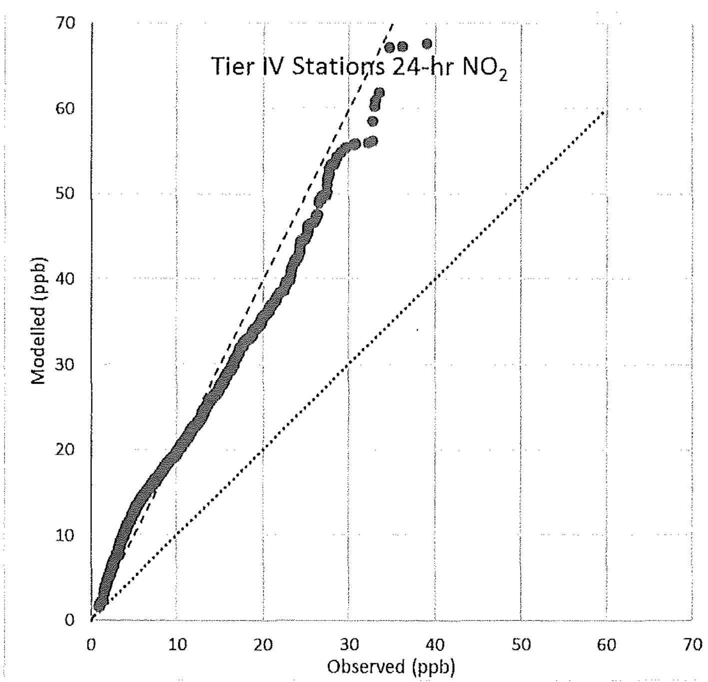

Figure 4-15: Unpaired Comparison of Modelled vs Observed NO_2 at All Hamilton Stations

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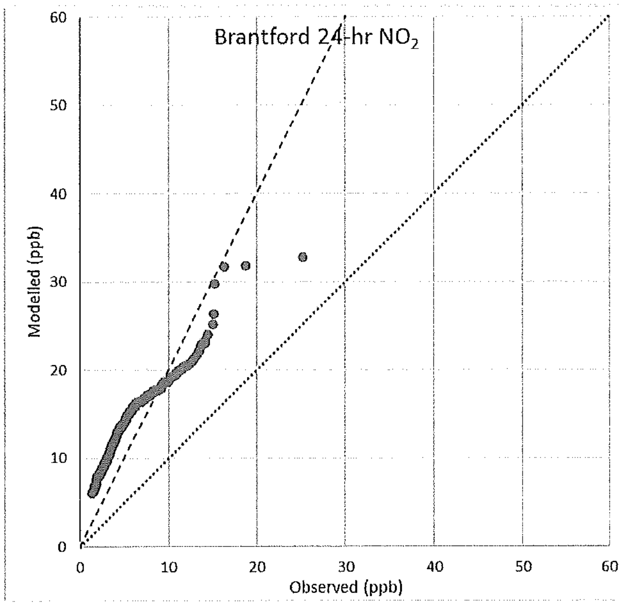
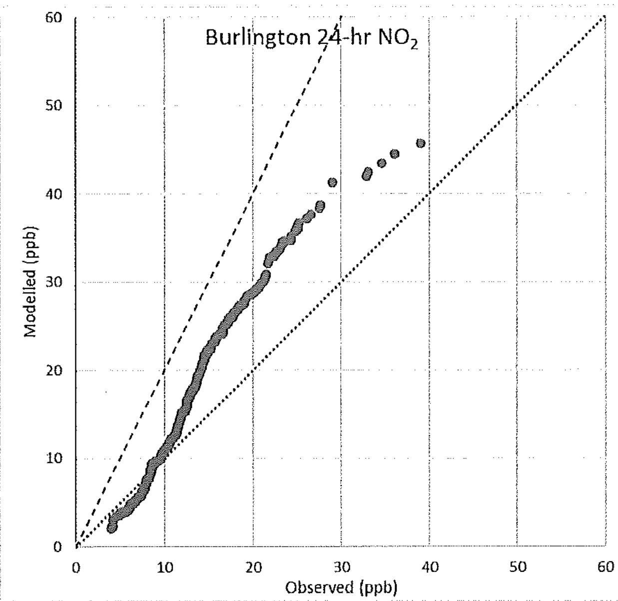
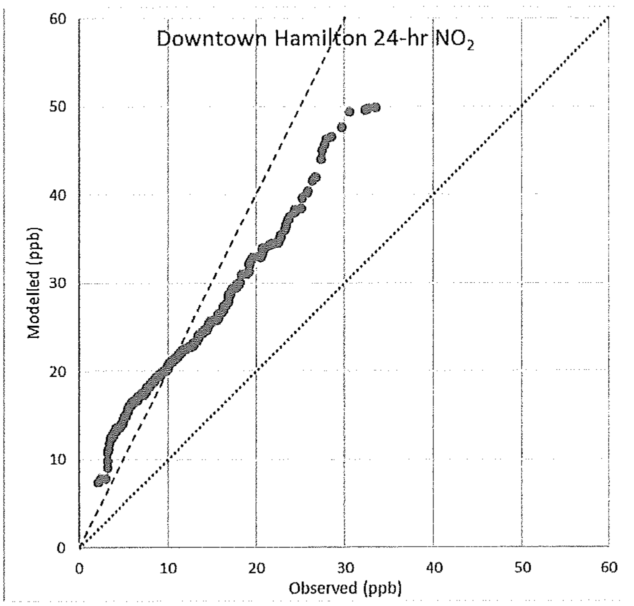
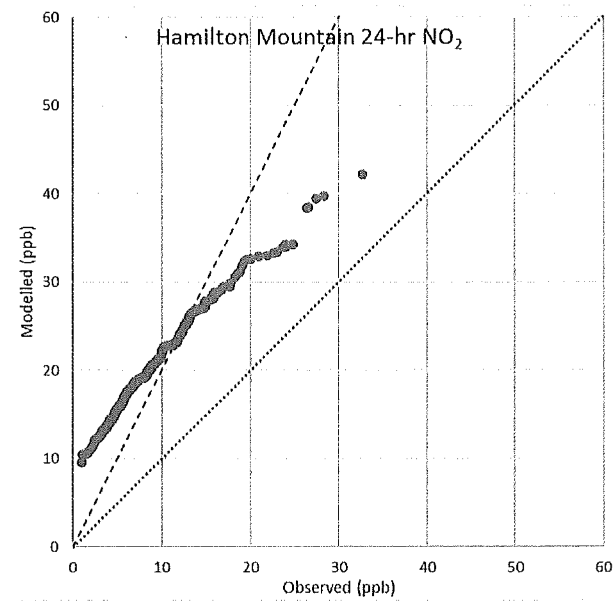
MODEL PERFORMANCE EVALUATION









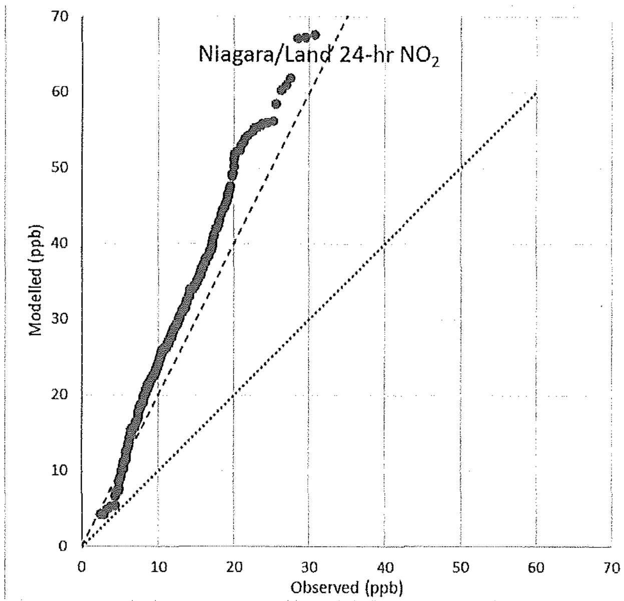


Figure 4-16: Unpaired Comparison of Modelled vs Observed NO_2 at Individual Stations

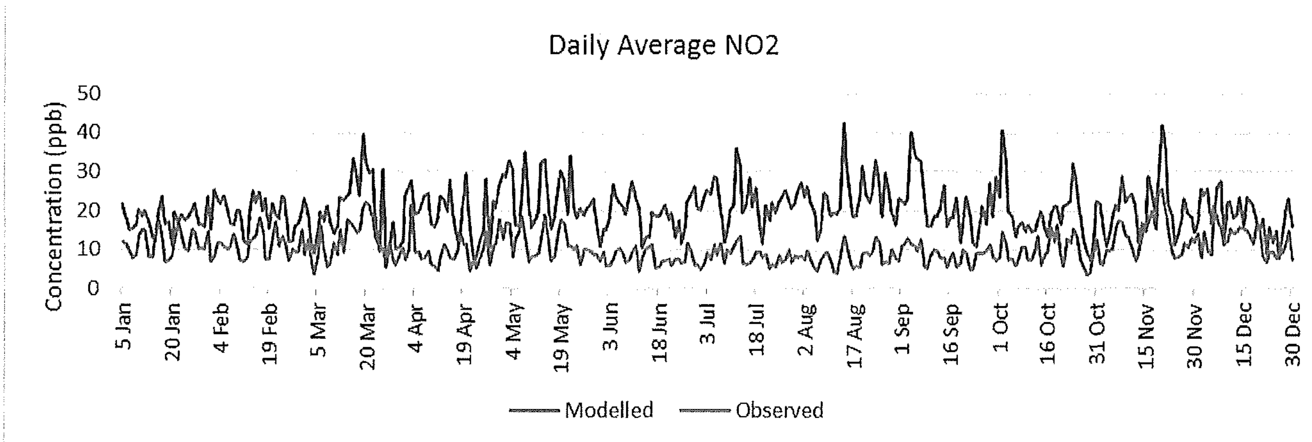


Figure 4-17: Time Series of Modelled vs Observed Daily Average NO_2 Concentrations

4.2.6 Daily Benzene Concentrations

The 24-hour benzene paired performance statistics are summarized in Table 4-9, along with each monitoring station. The model has an over-prediction of less than 1 µg/m³ (MB) or 57% as shown by the FB metric across the Tier IV domain The Quantile-Quantile (Q-Q) plot for the Tier IV are shown on Figure 4-18 and individual stations are provided on Figure 4-19. The individual station results show mixed results with three stations over-predicting and one under-predicting results. Generally, the model over-predicts by greater than a factor of two for observations below 3 µg/m³ and under two those above.

MODEL PERFORMANCE EVALUATION

The benzene time series of observed and modelled daily concentrations are provided on Figure 4-20. Benzene is measured on a six (6) day cycle at the stations. Generally, CMAQ over-predicts for all months with the exception of June and July where the model and observed values are closer together.

Table 4-9: Performance Statistics for Paired Daily Benzene Observations

	Statistics							
Station Name	**Observed Mean (µg/m³)**	**Model Mean (µg/m³)**	**MB (µg/m³)**	**RMSE (µg/m³)**	**NMB**	**NME**	**FB**	**FE**
Beach Strip	1.58	1.25	-0.33	0.85	-20.9%	42.3%	-20.5%	54.0%
Gertrude / Depew	3.30	2.54	-0.76	10.09	-23.1%	115.4%	49.9%	106.1%
Hamilton Downtown	0.99	1.91	0.92	1.66	93.4%	127.1%	83.3%	91.9%
Niagara / Land	1.77	4.67	2.90	3.89	163.7%	186.8%	93.3%	108.4%
Tier IV All Stations	**1.73**	**2.46**	**0.73**	**4.92**	**42.4%**	**118.9%**	**57.0%**	**90.1%**

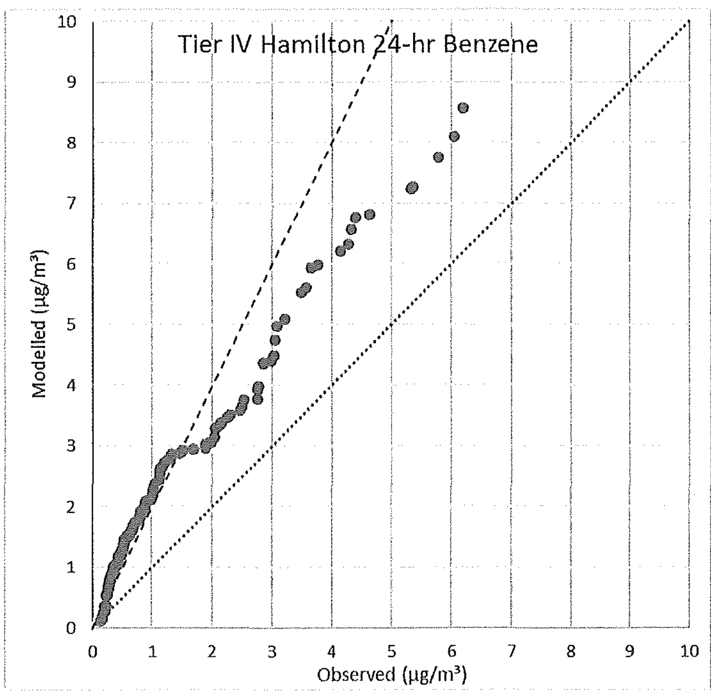


Figure 4-18: Unpaired Comparison of Modelled vs Observed Benzene at All Hamilton Stations

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MODEL PERFORMANCE EVALUATION

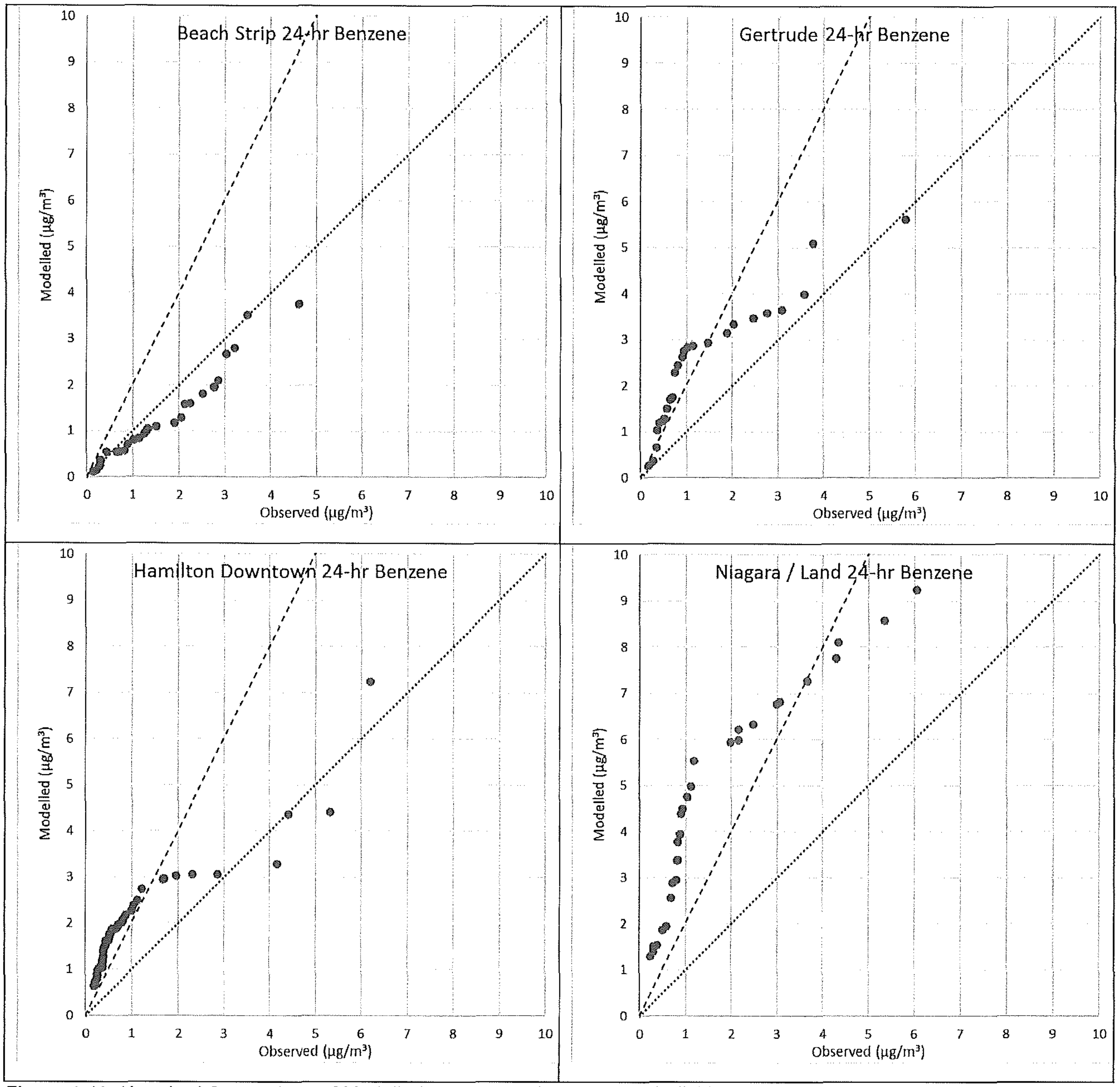

Figure 4-19: Unpaired Comparison of Modelled vs Observed Benzene at Individual Stations

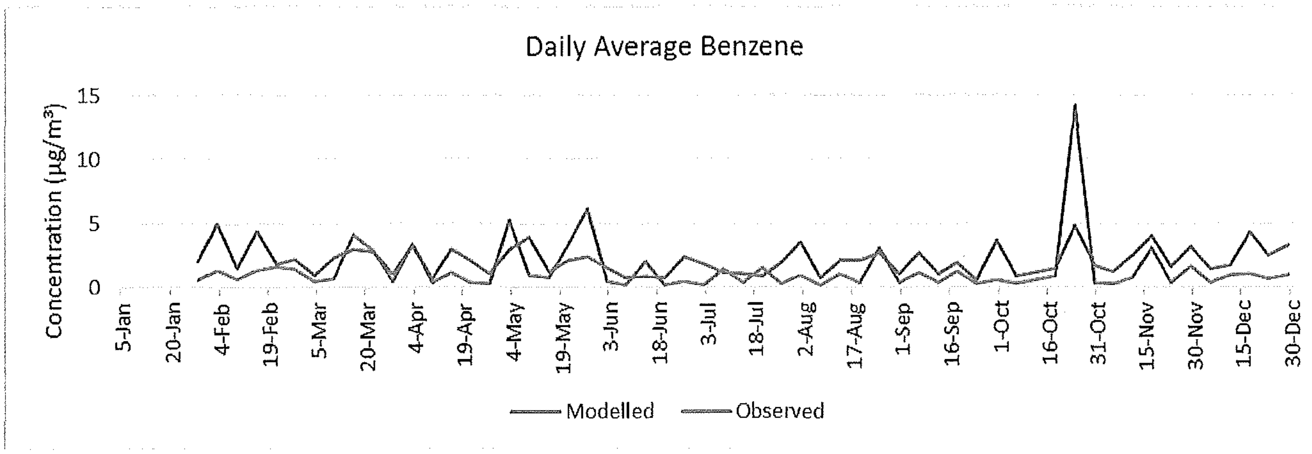

Figure 4-20: Time Series of Modelled vs Observed Daily Average Benzene Concentrations

4.2.7 Daily Benzo(a)pyrene Concentrations

The 24-hour benzo(a)pyrene performance statistics for the Hamilton airshed within Tier IV are provided in Table 4-10 along with the individual station statistics. The model has an over-prediction of 0.98 ng/m^3 (MB) or 59% as shown by the FB metric across the Tier IV domain. The Quantile-Quantile (Q-Q) plot for the Tier IV are shown on Figure 4-21 and individual stations are provided on Figure 4-22. The individual station results show mixed results with three stations over-predicting and one under-predicting results. Generally, the model over-predicts by greater than a factor of two for observations below 1 ng/m^3 and under two those above 1 ng/m^3.

Figure 4-23 presents the B(a)P time series of observed and modelled daily concentrations. B(a)P is measured on a six (6) day interval similar to benzene. B(a)P levels are over-predicted during winter and spring but reasonably well during summer and fall. Observed levels show a step-wise decrease in concentrations during mid-summer while the model shows a shallower decline in concentrations.

Table 4-10: Performance Statistics for Paired Daily Benzo(a)pyrene Observations

	Statistics							
Station Name	**Observed Mean (ng/m³)**	**Model Mean (ng/m³)**	**MB (ng/m³)**	**RMSE (ng/m³)**	**NMB**	**NME**	**FB**	**FE**
Gertrude / Depew	0.86	1.97	1.11	2.22	128.3%	209.5%	83.4%	132.1%
Hamilton Downtown	0.36	1.67	1.32	1.92	368.4%	374.6%	133.5%	135.1%
Niagara / Land	1.84	4.31	2.47	4.52	134.2%	212.4%	101.8%	136.0%
Pier 25	1.50	0.62	-0.89	1.47	-59.0%	65.3%	-54.7%	91.6%
Tier IV All Stations	**1.23**	**2.21**	**0.98**	**2.90**	**79.7%**	**170.4%**	**59.1%**	**122.5%**

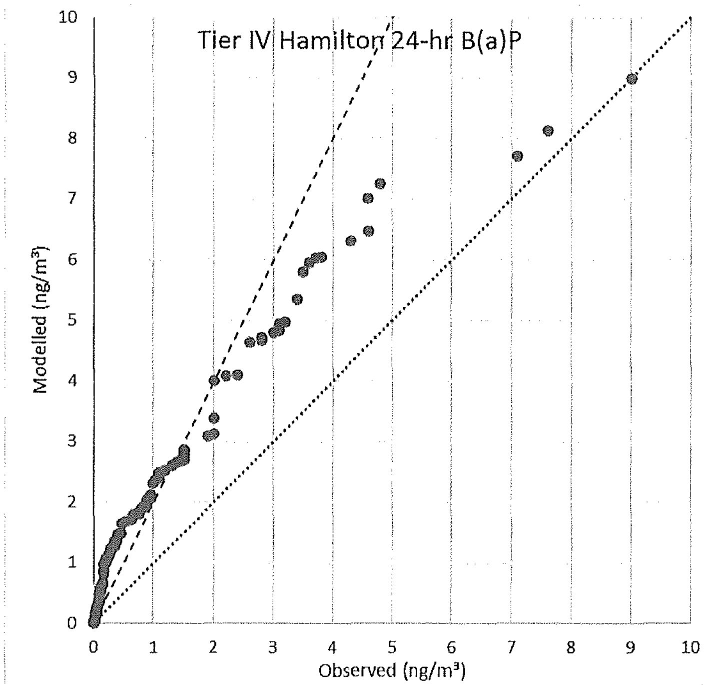

Figure 4-21: Unpaired Comparison of Modelled vs Observed Benzo(a)pyrene at All Hamilton Stations

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MODEL PERFORMANCE EVALUATION

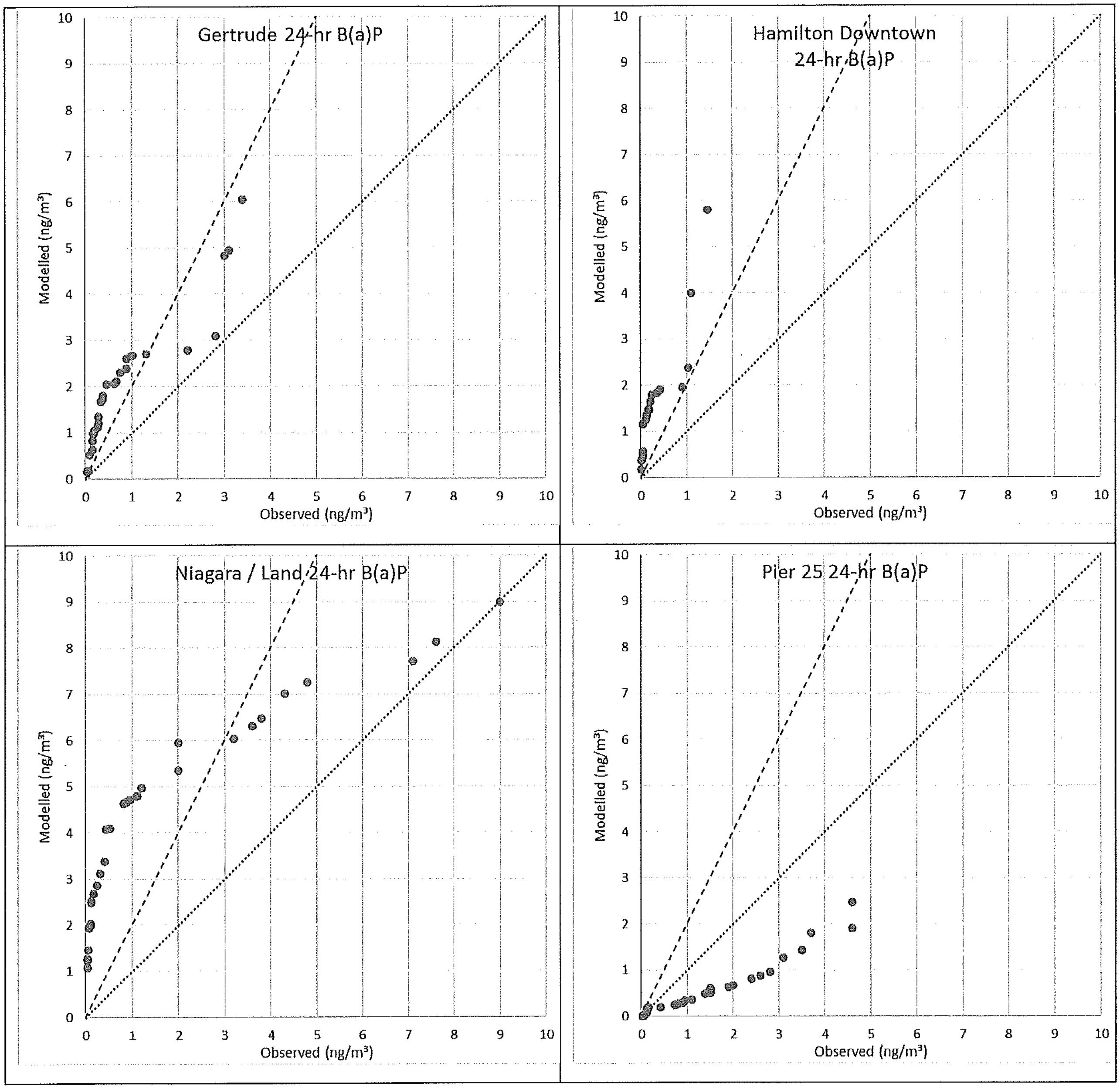

Figure 4-22: Unpaired Comparison of Modelled vs Observed Benzo(a)pyrene at Individual Stations

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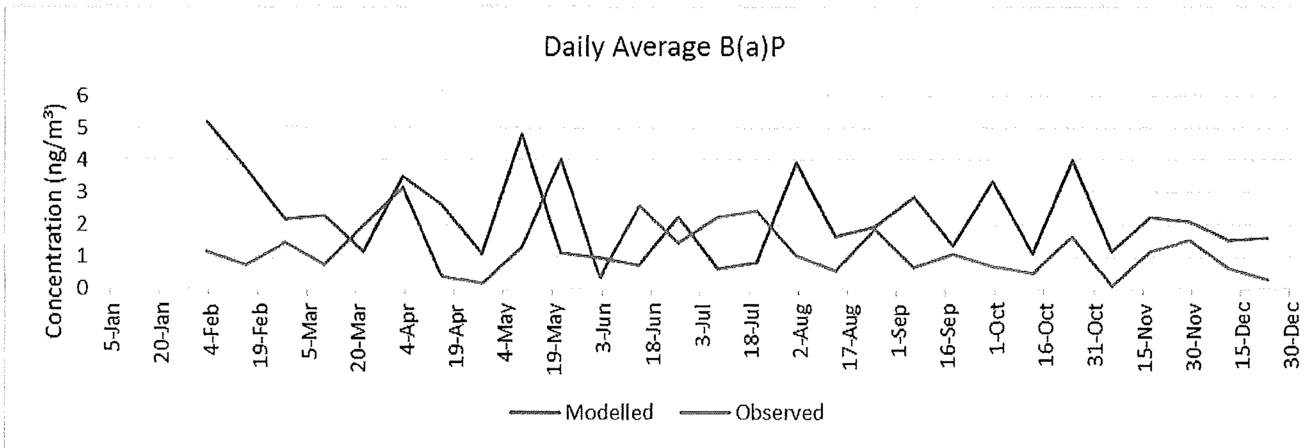

Figure 4-23: Time Series of Modelled vs Observed Daily Average Benzo(a)pyrene Concentrations

5.0 SUMMARY

A summary of the Hamilton Airshed Modelling System performance statistics are presented in Table 5-1. The modelling system provides good results given the complexity of the model and inputs. The modelling tends to over-predict concentrations with the exception PM_{10} where the model under-predicts based on the mean bias (MB). Model results are within a factor of two for all compounds (i.e., a FB ≤ 67%). The modelling system meets the objectives for PM and ozone model performance.

The under-prediction of PM_{10} is likely due to local sources generating fugitive dust that are unaccounted for in the current emissions inventory for Tier IV. These sources are likely track out from industrial sources, road construction activities and other local construction, which are very short duration and have not been quantified. The PM_{10} from these sources includes a coarse size fraction which tends to contribute locally within an airshed.

Table 5-1: Summary of 2012 Tier IV Performance Statistics for All Tier IV Monitoring Stations

		Statistics							
Compound	**Units**	**Observed Mean**	**Model Mean**	**MB**	**RMSE**	**NMB**	**NME**	**FB**	**FE**
$PM_{2.5}$	µg/m³	6.7	10.2	3.47	7.21	51.4%	78.9%	36.2%	64.3%
PM_{10}	µg/m³	23.5	15.4	-8.11	17.68	-34.5%	51.6%	-41.6%	63.5%
O_3	ppb	27.4	23.8	-3.61	12.45	-13.2%	36.9%	-29.2%	50.3%
SO_2	ppb	4.5	6.9	2.32	7.08	51.1%	110.8%	53.5%	89.2%
NO_2	ppb	10.3	20.4	10.14	13.65	98.4%	110.3%	67.1%	77.0%
Benzene	µg/m³	1.73	2.46	0.73	4.92	42.4%	118.9%	57.0%	90.1%
B(a)P	ng/m³	1.23	2.21	0.98	2.90	79.7%	170.4%	59.1%	122.5%
Performance Goal for PM								**≤ ±30%**	**≤ 50%**
Performance Criteria for PM								**≤ ±60%**	**≤ 75%**

While the time series for most compounds show an over-prediction, they also capture the daily values very well. From a seasonal perspective, the prediction of the daily variation is captured best during the summer months. The winter months show a larger tendency of over-prediction of daily values, except for ozone which shows a tendency to under-predict.

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Report Signature Page

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Golder Associates

HAMILTON AIRSHED MODELLING SYSTEM (HAMS)

April 16, 2018

Hamilton Board of Health

Matthew Lawson

Manager – Health Hazards

Healthy & Safe Communities Department

Public Health Services - Healthy Environments Division

Hamilton Airshed Modelling System (HAMS)

BACKGROUND

December 2013
- BOH approves development of an airshed model for Hamilton;

December 2014
- Funding agreement reached between City of Hamilton and Hamilton Industrial Environmental Association (HIEA) to procure airshed model;

January 2015
- Golder associates begin developing the Hamilton Airshed Modelling System (HAMS);
- Clean Air Hamilton advisory committee engaged by Golder re: model development (i.e., PHS, HIEA, MOECC, CAH, EH)

January 2018
- HAMS performance validation is successful;
- Project delivered on-budget;
- Accomplishes objective within the AQTF Action Plan (2013)

Hamilton Airshed Modelling System

Anthony Ciccone Ph.D., P. Eng. And Janya Kelly Ph.D.

16 April, 2018

CITY OF HAMILTON BOARD OF HEALTH

Acknowledgements

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

- Jim Wilkinson, Ph.D.
  - Technical review of modelling set-up and results
  - Technical expertise during model execution
- Barron Henderson, Ph.D.
  - Initial and Boundary conditions from GEOS-CHEM
- Environment and Climate Change Canada
  - SMOKE ready national emissions inventory for Canada
  - Technical expertise on processing emissions in SMOKE
- Stakeholder Advisory Committee (HIEA, Public Health, Community Stakeholders)
  - Providing direction and data

Project Objectives

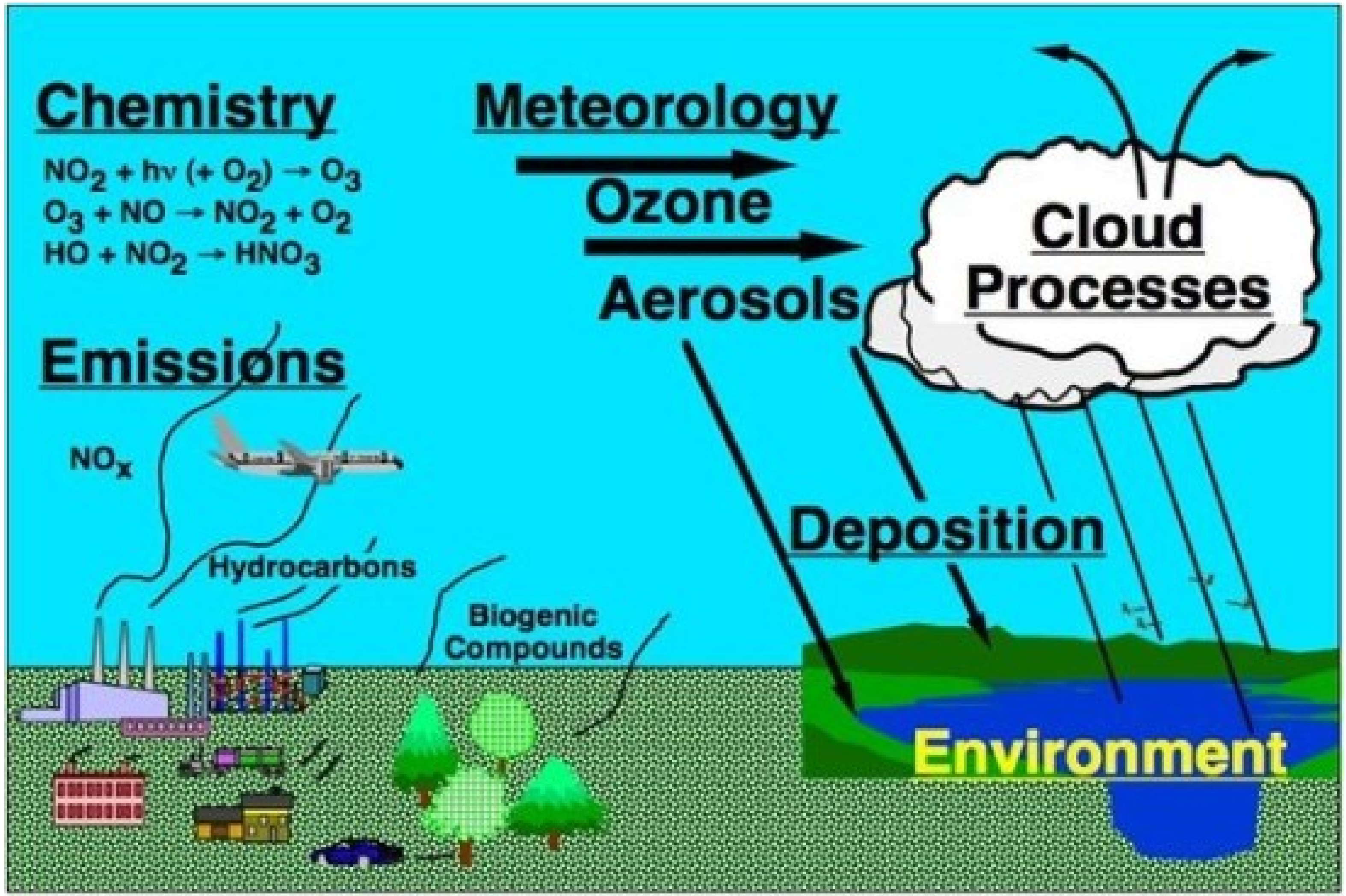
Challenges: The Hamilton Airshed Puzzle

- Who? What? Where? When? and How Much?
- 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?

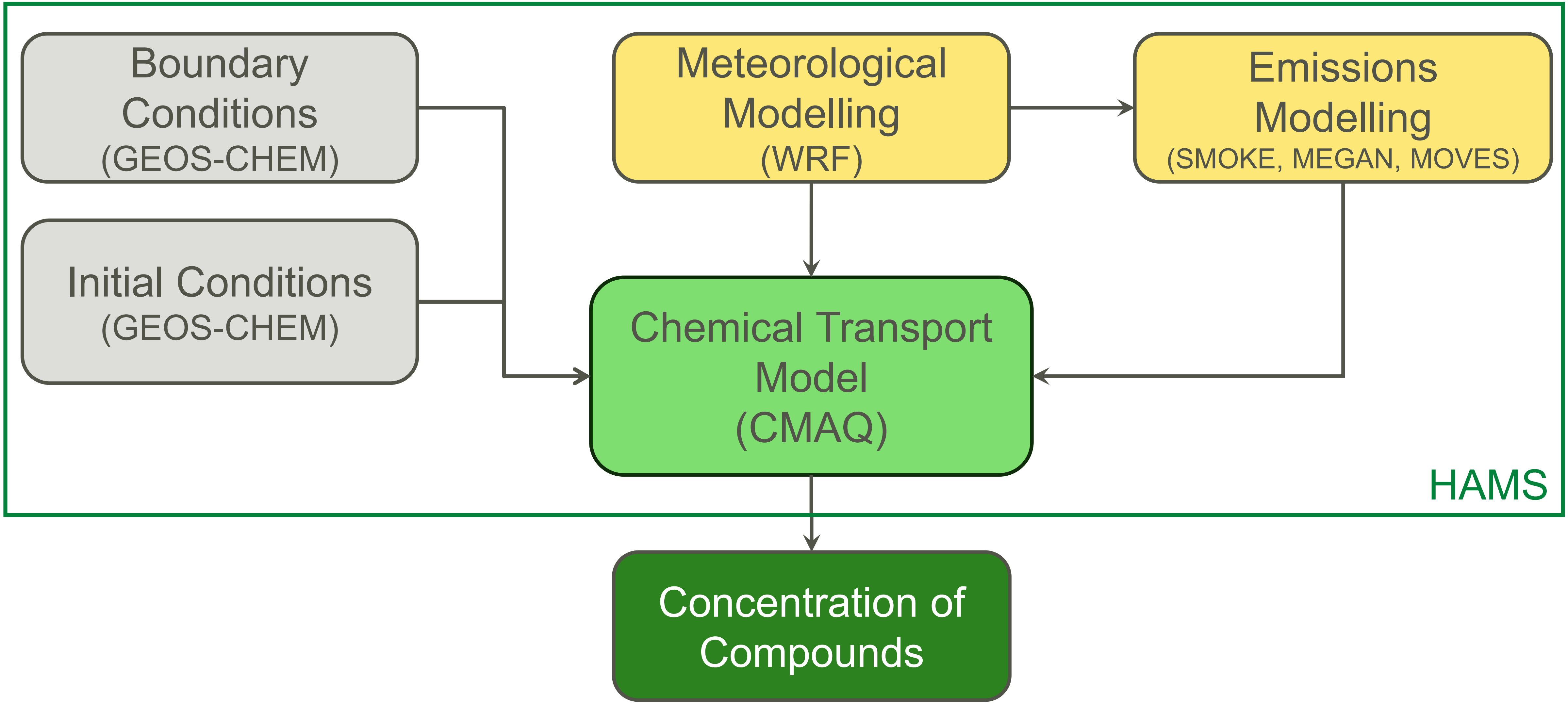
Solution: Hamilton Airshed Modelling System (HAMS)

- 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, etc)
- Handles complex meteorology (e.g. lake effects and escarpment)
- Considers atmospheric chemistry – important part of the puzzle
- Needs a Big computer

The Atmospheric Process

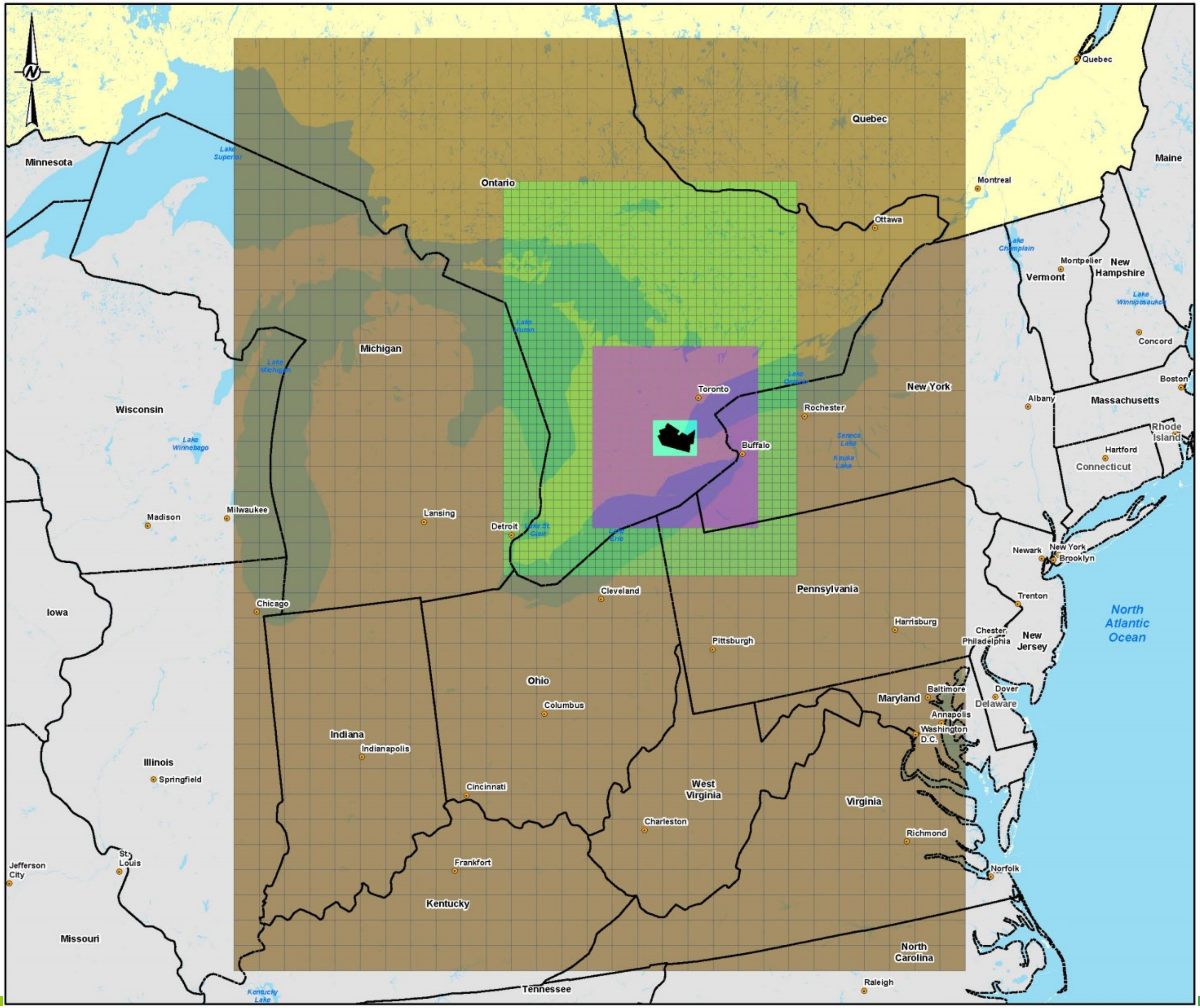


Hamilton Airshed Modelling System



Grid Density: All Tiers – Nested Grids

Tier	Area (km^2)	%
Tier I (36 km)	1,390,608	100%
Tier II (12 km)	243,648	17.5%
Tier III (4 km)	46,020	3.3%
Tier IV (1.33 km)	3,159	0.2%



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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*

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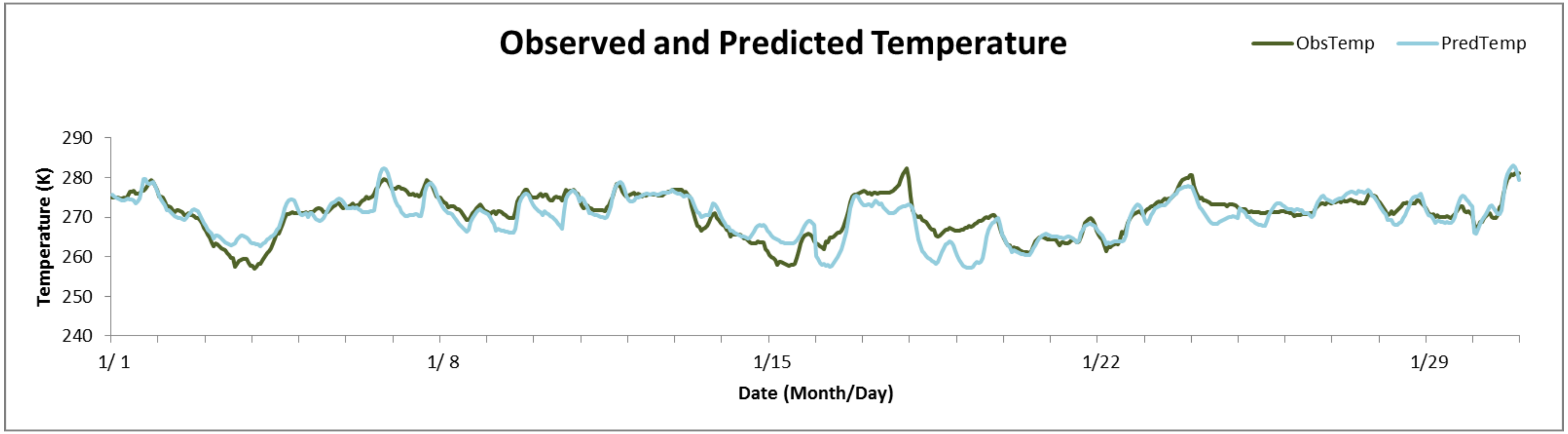
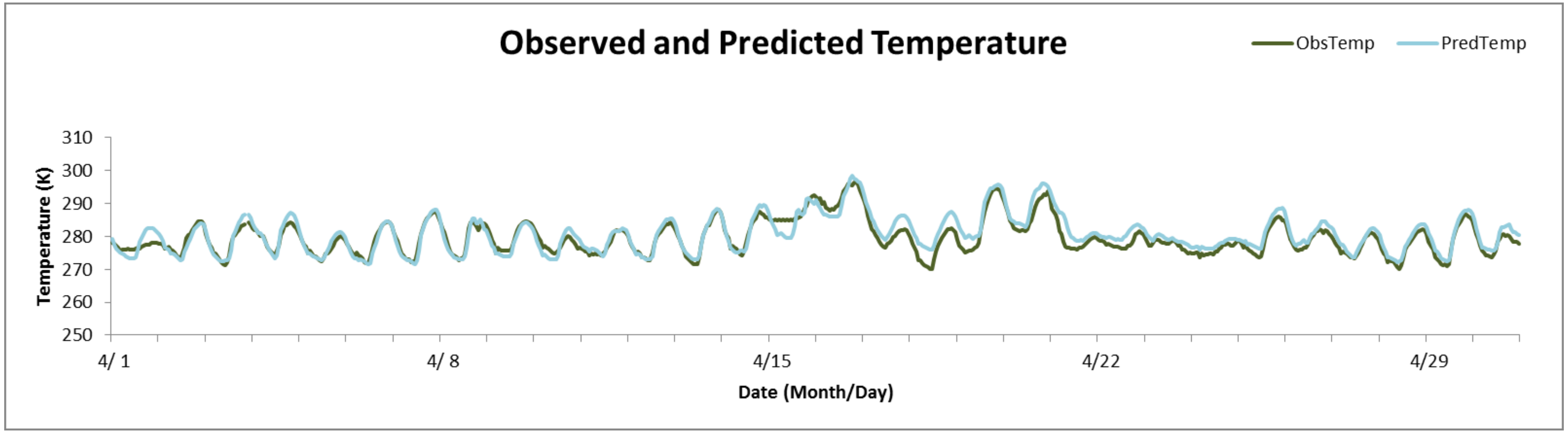
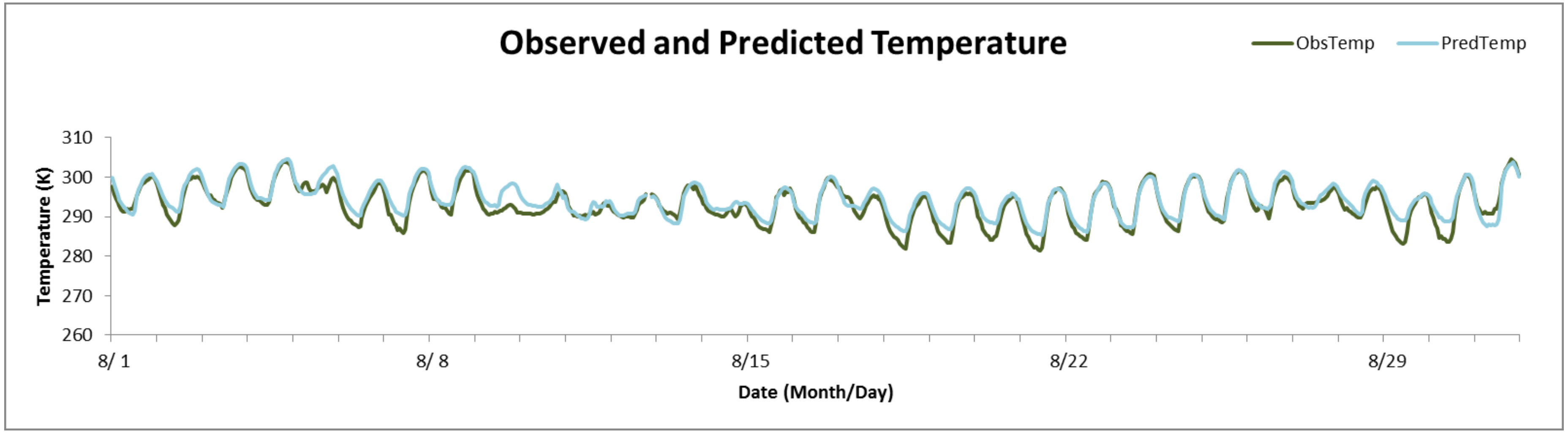
WRF – Meteorological Modelling Results

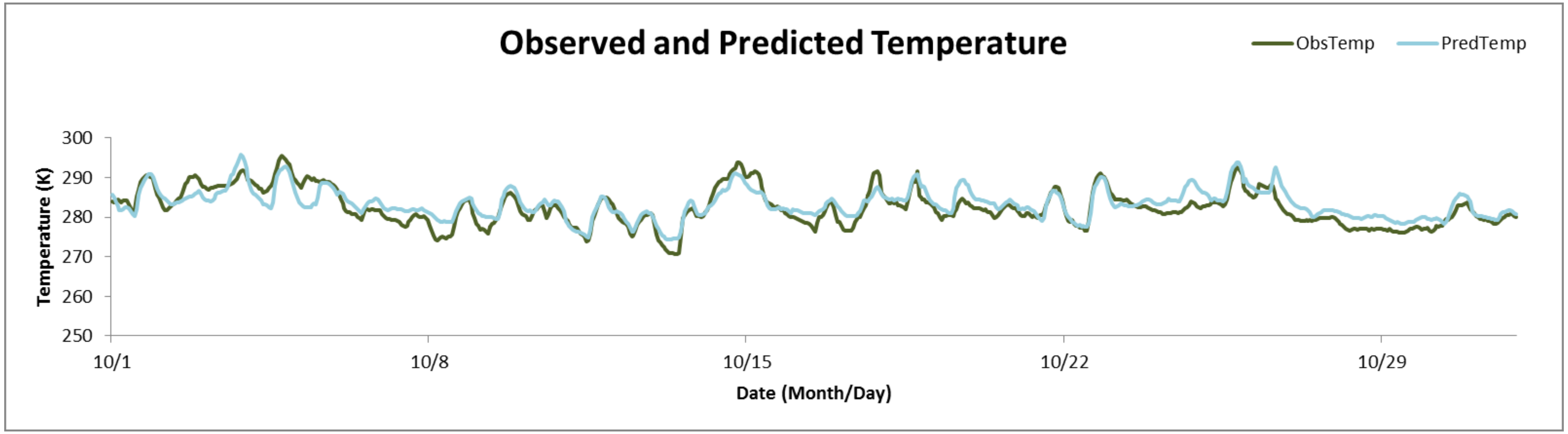
Tier IV Temperature: Winter and Spring



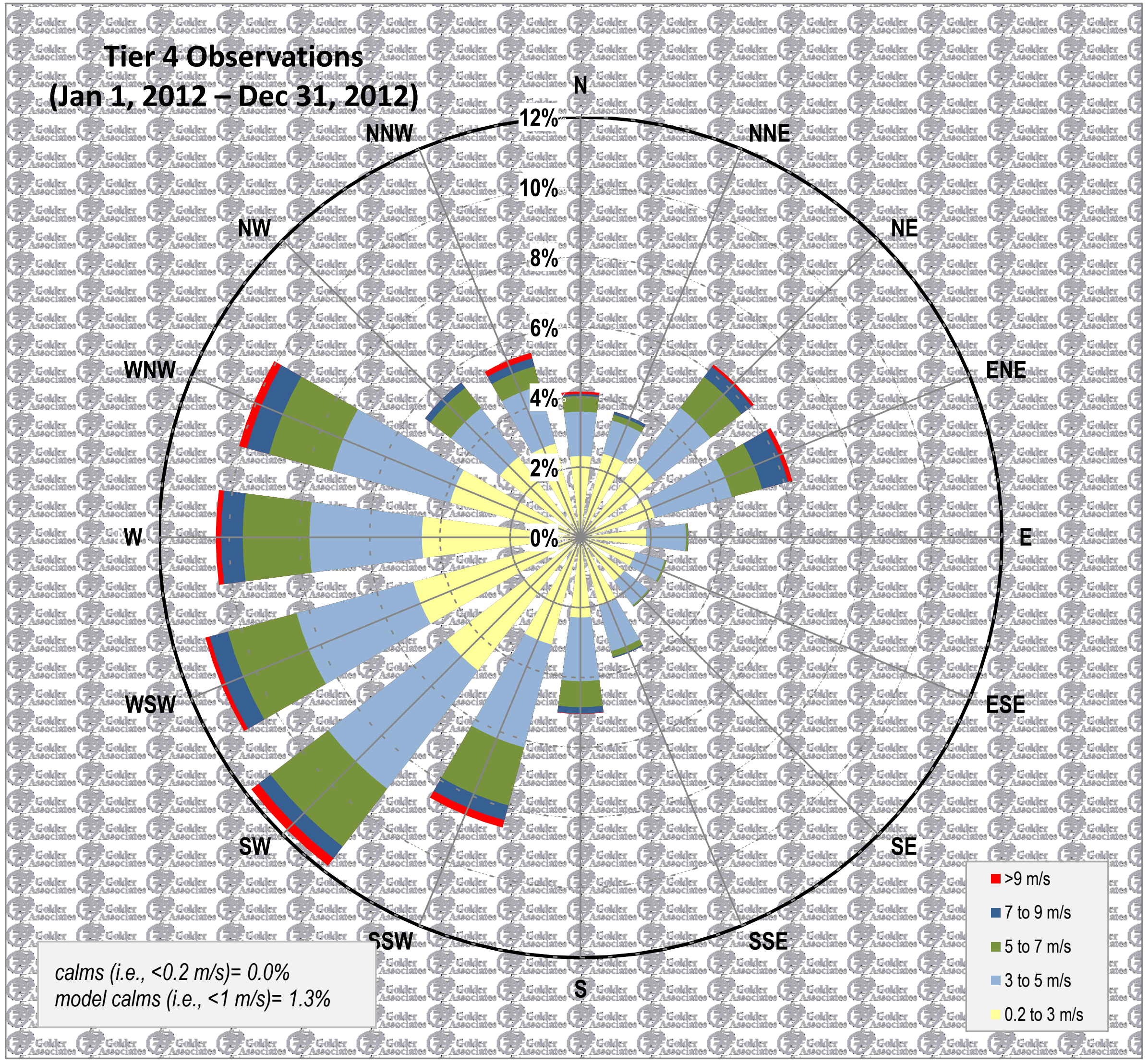


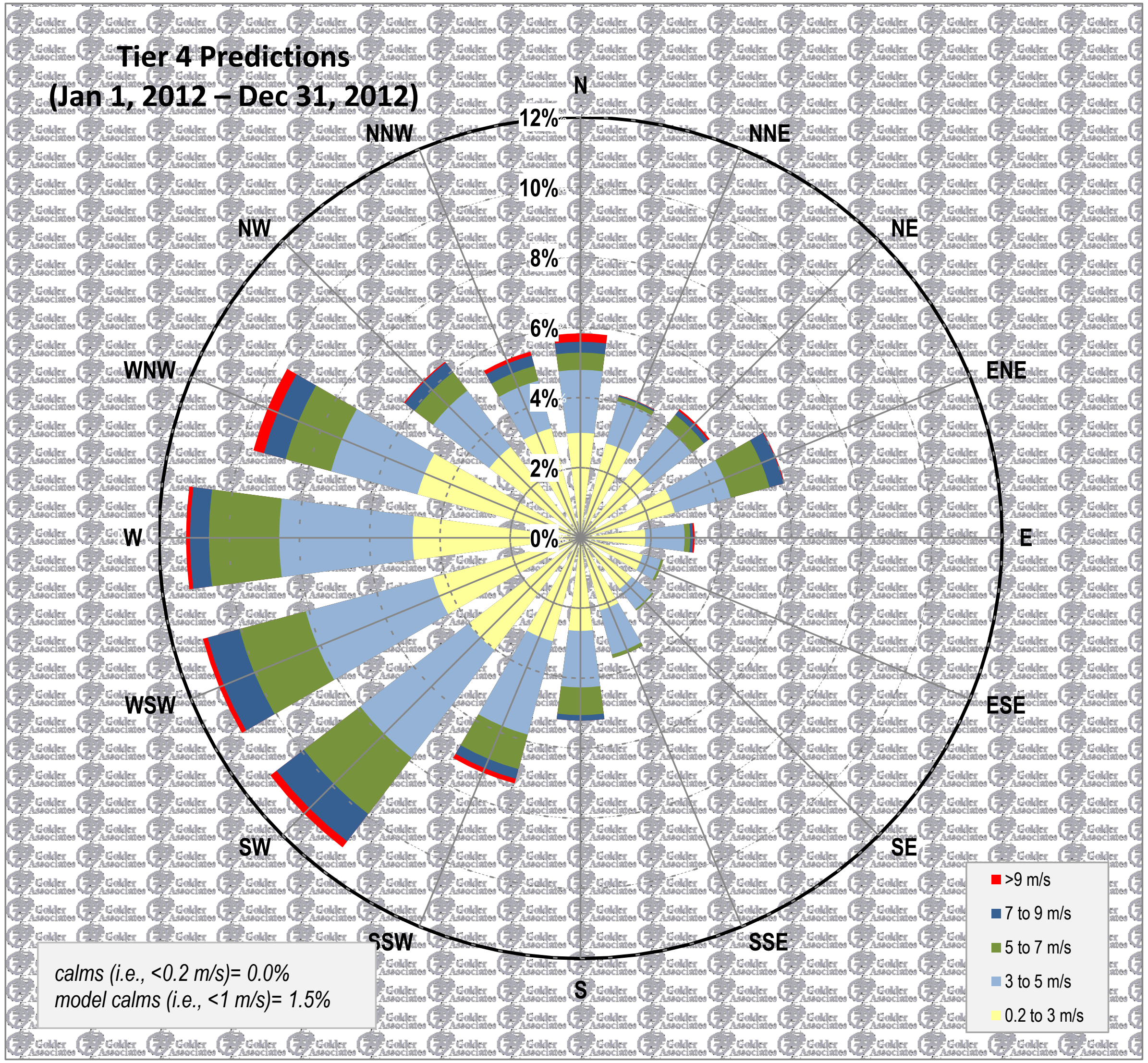
Tier IV Temperature: Summer and Fall





Tier IV Wind Rose Comparison





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Emissions Inventory Results

Emissions Inventory Sources

GRIDDED, HOURLY EMISSION ESTIMATES BY TIER

<table>
<tr><th rowspan="2">Emission Classification</th><th rowspan="2">Type</th><th rowspan="2">Definition</th><th colspan="2">Source</th></tr>
<tr><th>Tier I</th><th>Tiers II – IV</th></tr>
<tr><td rowspan="2">Industrial</td><td>Point (all tiers)</td><td>Elevated stacks from industrial activities</td><td rowspan="9">2006 Canadian National Emissions Inventory (NEI)
2011 US NEI</td><td>2012 NPRI, 2011 US NEI</td></tr>
<tr><td>Area</td><td>Industrial activities</td><td>2012 NPRI, 2011 US NEI</td></tr>
<tr><td rowspan="2">Commercial</td><td>Point (Tier I, US Only)</td><td rowspan="2">Natural gas usage, auto-body shops, dry cleaners, commercial solvents</td><td rowspan="2">2012, ChemTRAC (scaled by population), 2012 Stats Can population data, 2011 US NEI</td></tr>
<tr><td>Area</td></tr>
<tr><td>Residential</td><td>Area</td><td>Natural gas usage, other residential heating sources</td><td>2012 natural gas consumption, 2012 Stats Canada energy use, 2011 US NEI</td></tr>
<tr><td>On-Road</td><td>Area</td><td>On-road vehicles (trucks, cars, motorcycles)</td><td>2012 MOVES, 2012 MTO traffic data, 2011 US NEI</td></tr>
<tr><td rowspan="2">Non-Road</td><td>Point (Tier I, US Only)</td><td rowspan="2">Airport, marine, rail and lawn mowers,</td><td rowspan="2">2006 Canadian NEI, 2012 NRCAN data, 2011 US NEI</td></tr>
<tr><td>Area</td></tr>
<tr><td>Biogenic / Agricultural</td><td>Area</td><td>Natural, farmland etc activities</td><td>2012 MEGAN, 2006 Canadian NEI, 2011 US NEI</td><td>2012 MEGAN, 2012 NONROAD</td></tr>
</table>

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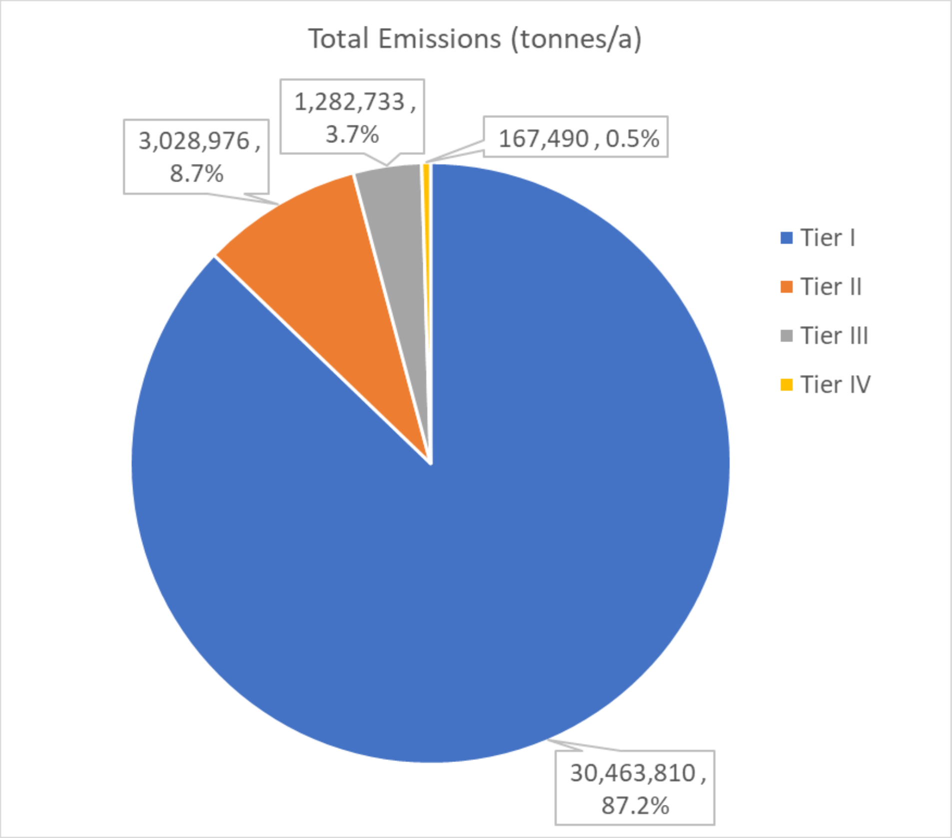
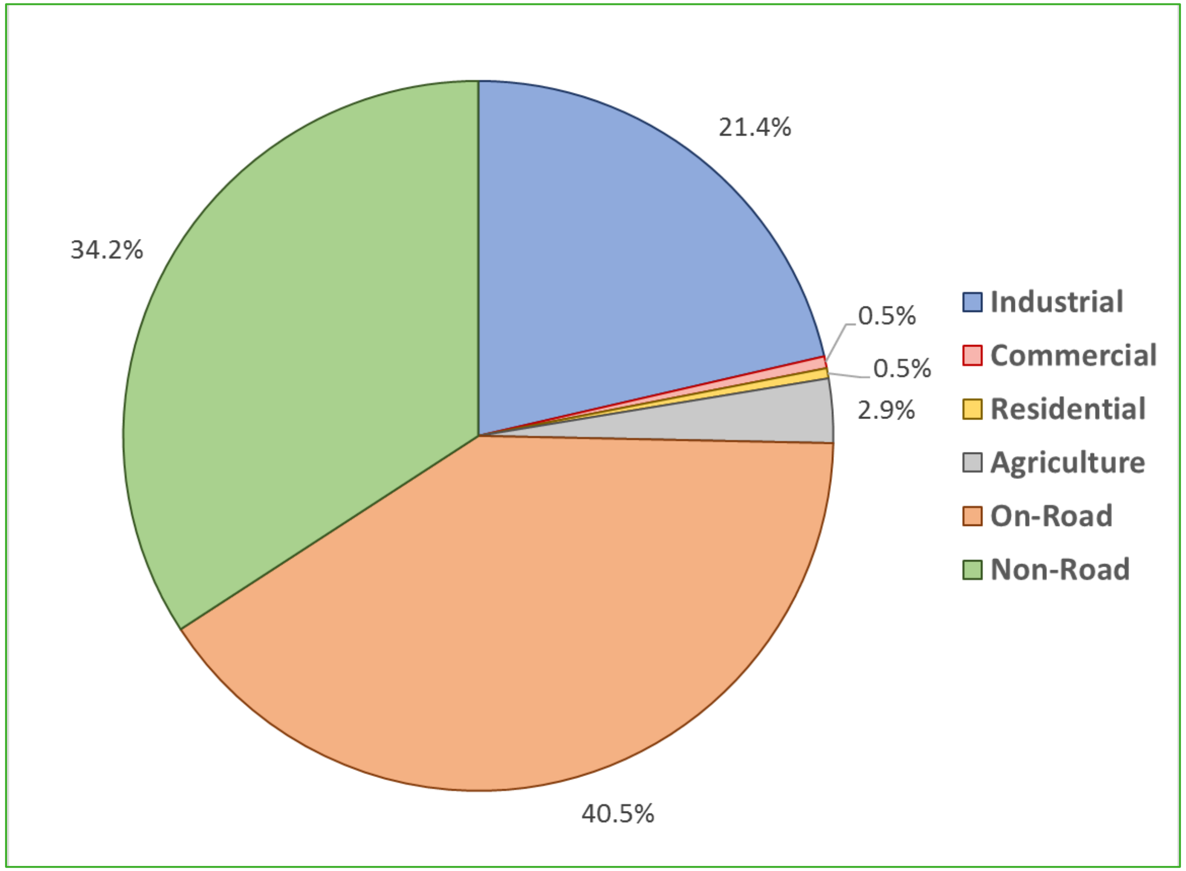
Total Emissions per Tier over the Computational Domain



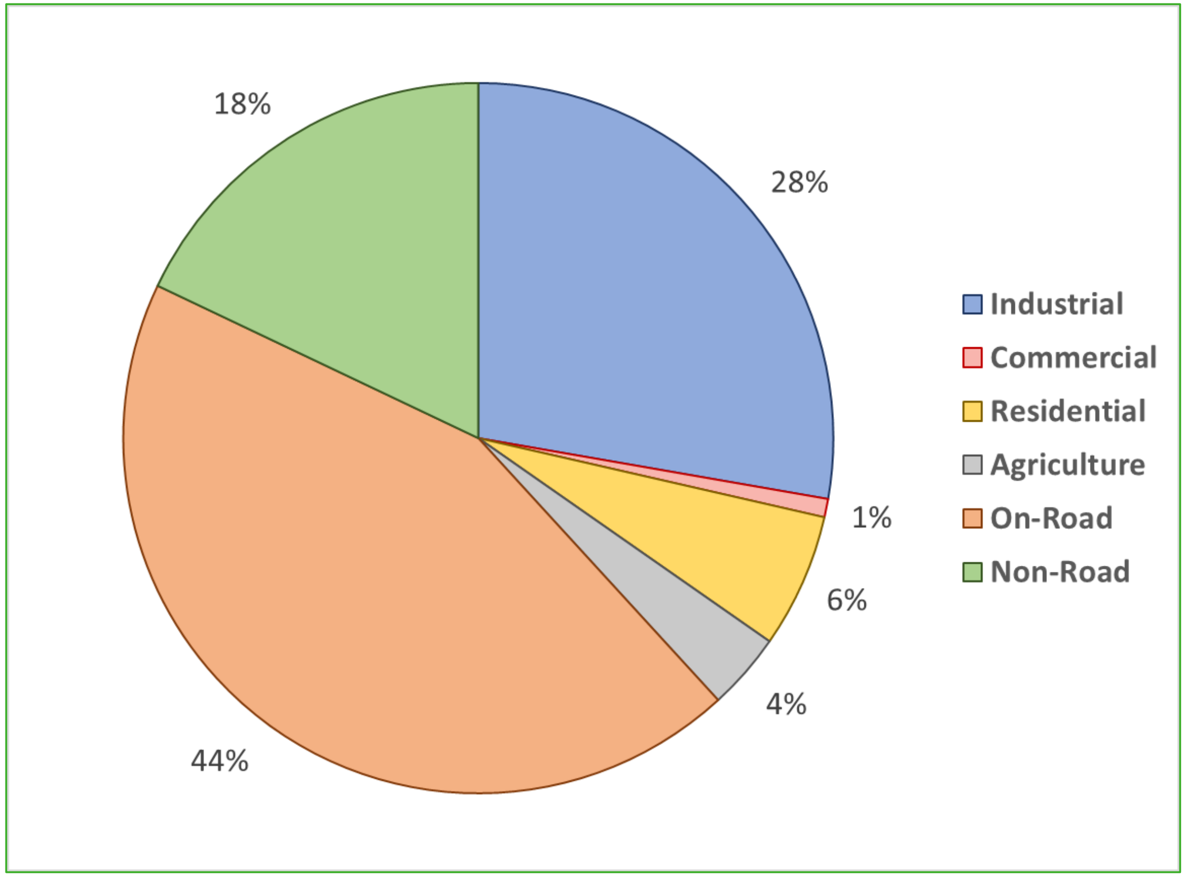
Tier	%	Tonne/km^2/yr
Tier I (36 km)	87.2%	21.91
Tier II (12 km)	8.7%	12.43
Tier III (4 km)	3.7%	27.87
Tier IV (1.33 km)	0.5%	53.02

Hamilton & Transboundary Sector Profiles

HAMILTON EMISSIONS

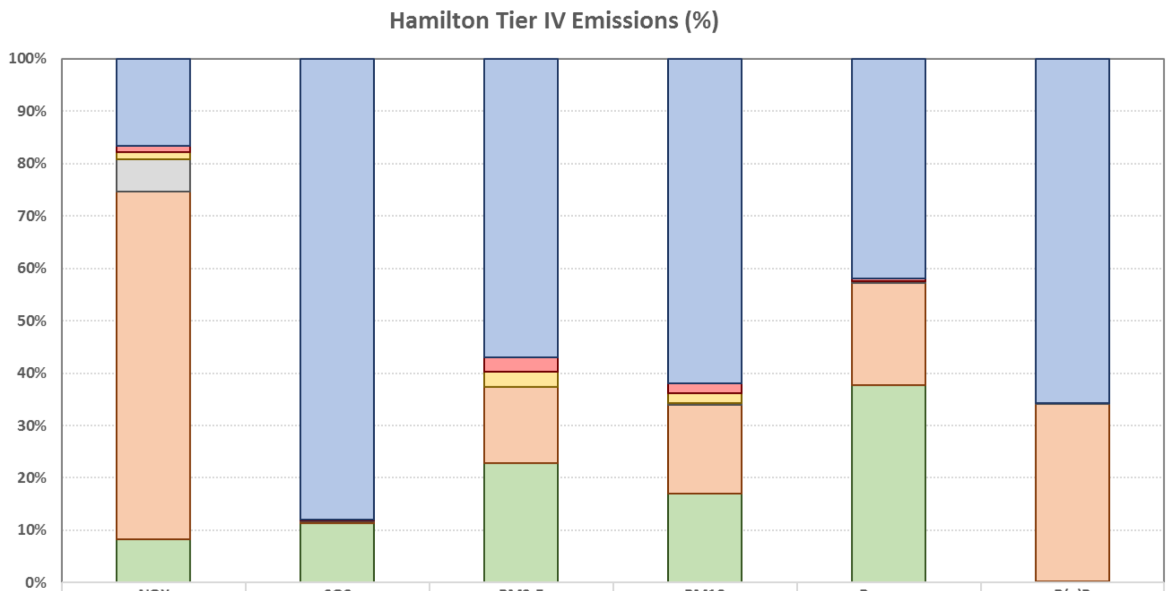


TRANSBOUNDARY EMISSIONS



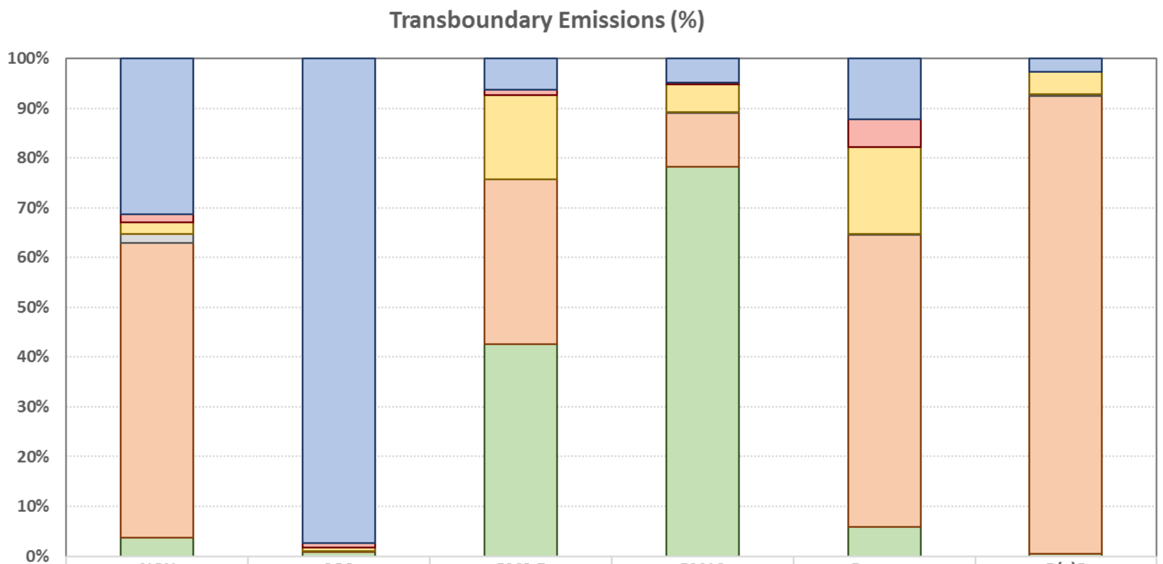
Hamilton & Transboundary Emissions Profiles

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%

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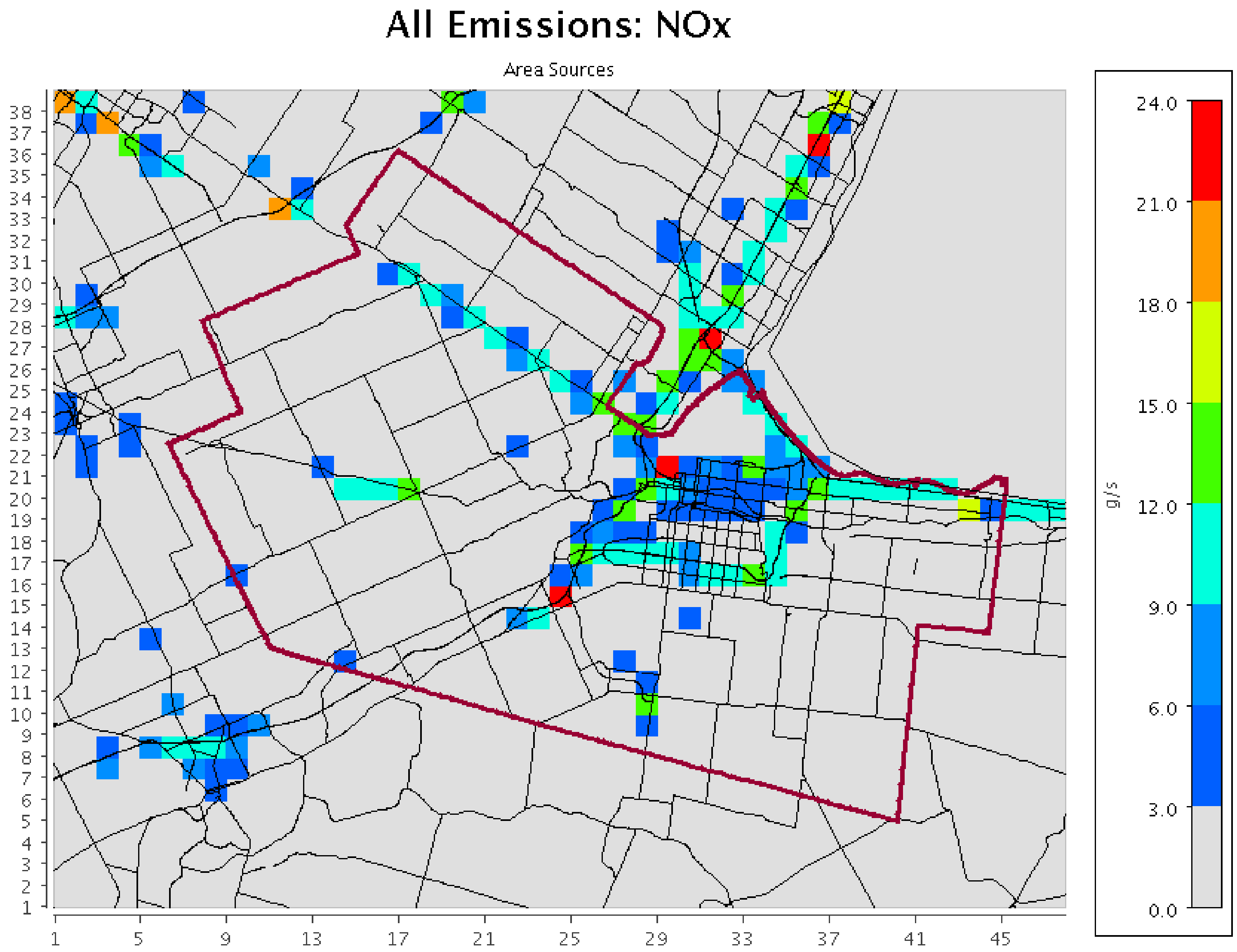
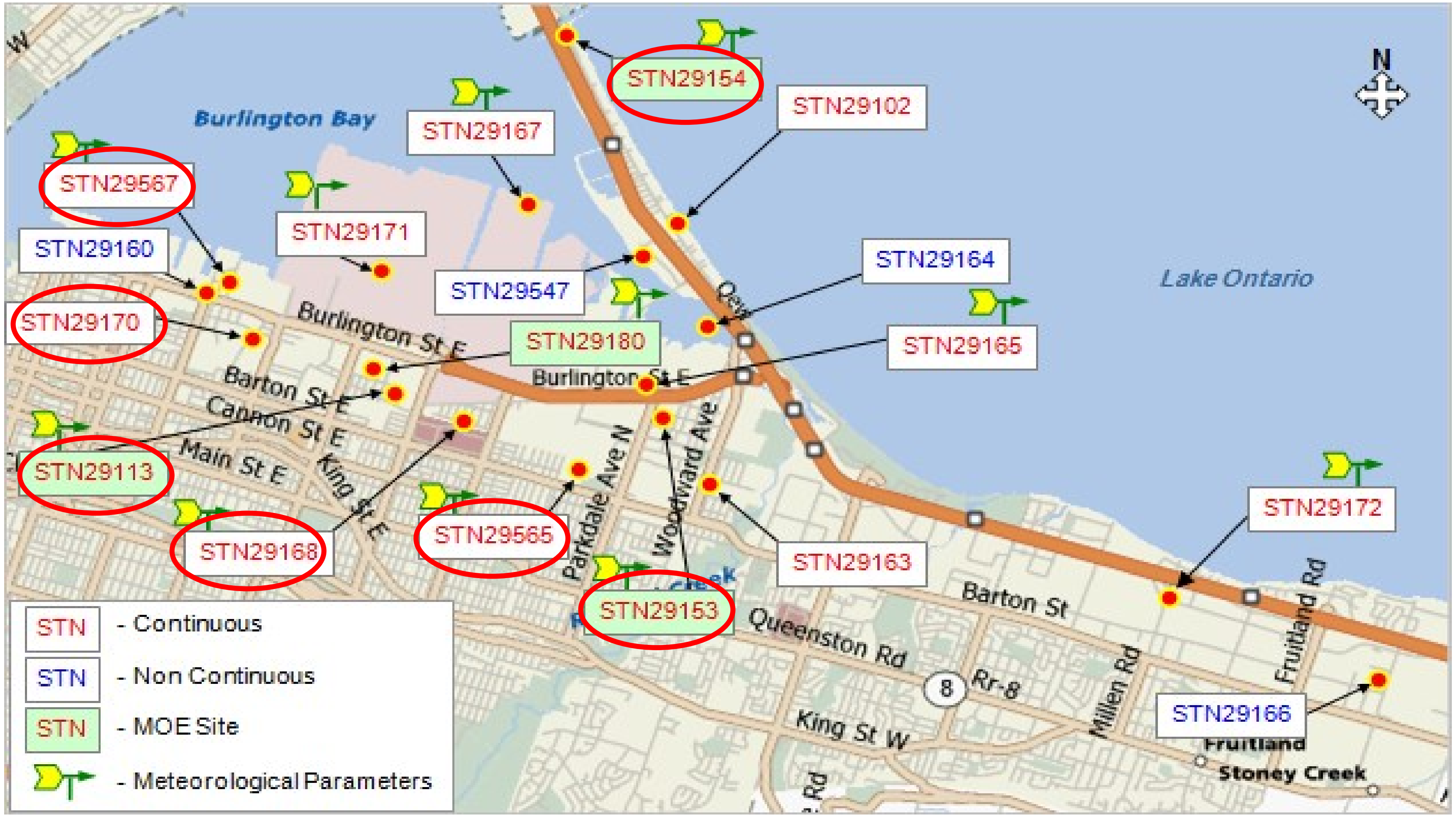
Tier IV: Geographical Distribution NO_x Emissions



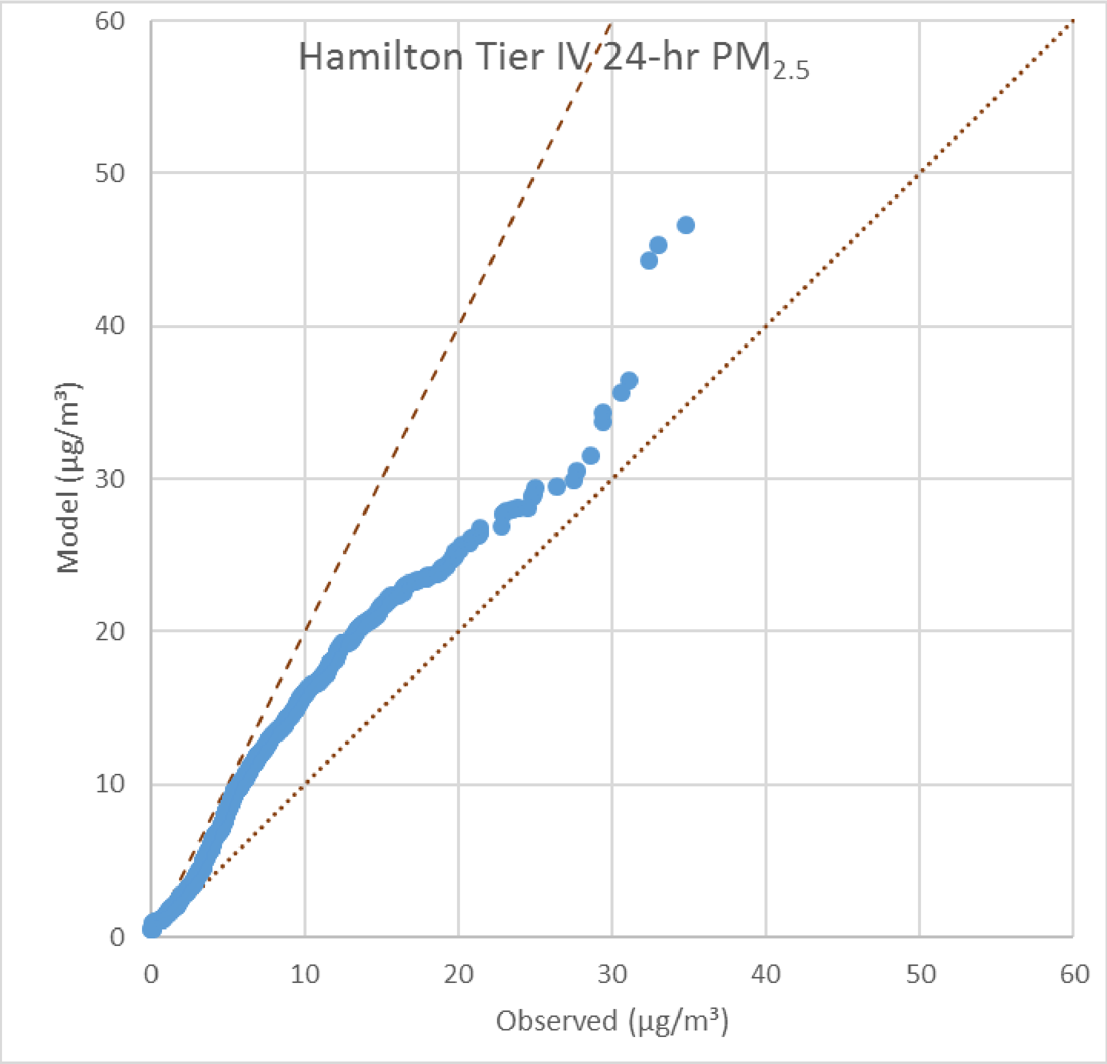
Air Quality Modelling Results: Model Performance

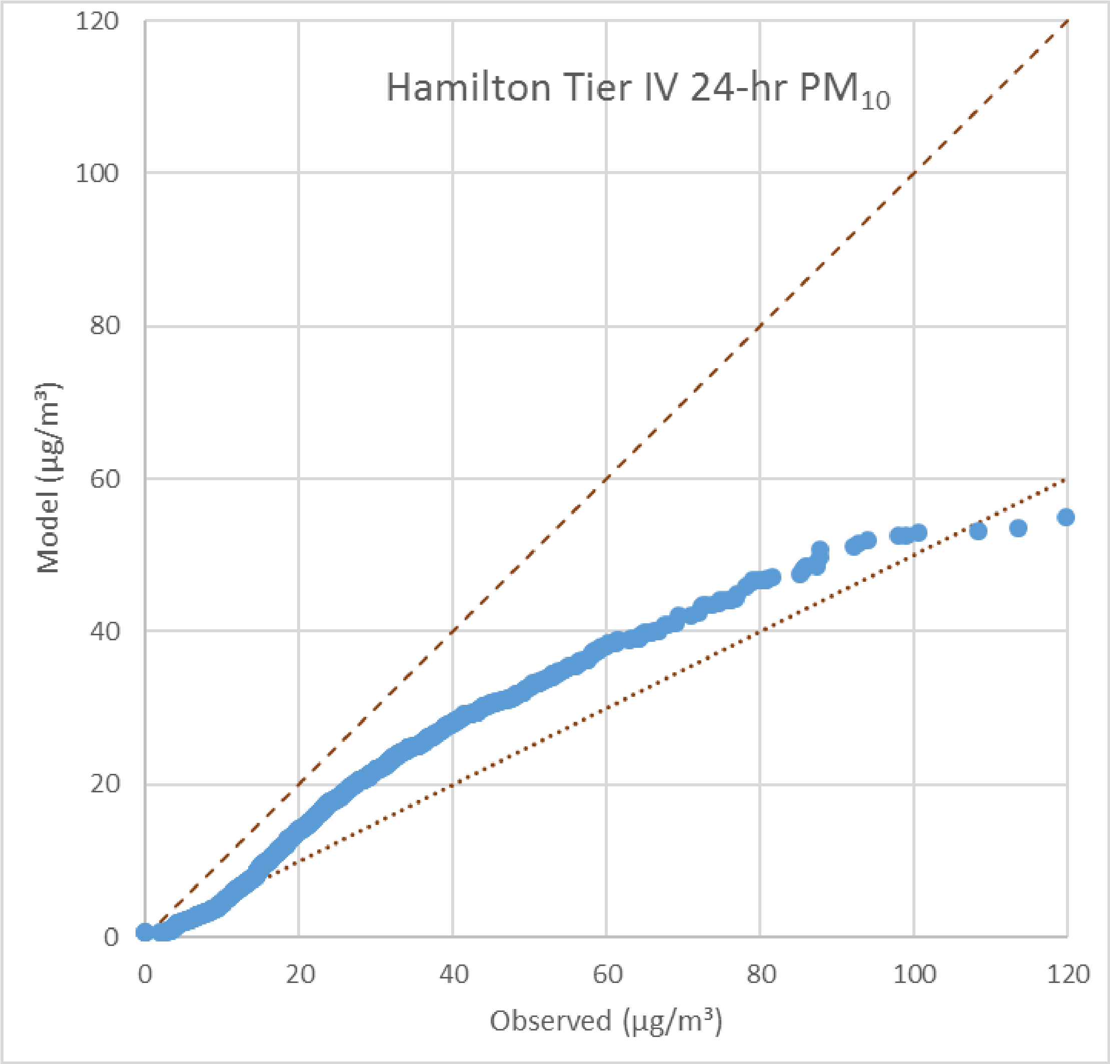
Source: https://en.wikipedia.org/wiki/File:HamiltonOntarioSkylineC.JPG, licensed under https://creativecommons.org/licenses/by-sa/3.0/

Air Quality Monitoring Station Map



Q:Q Plots: $PM_{2.5}$ and PM_{10}





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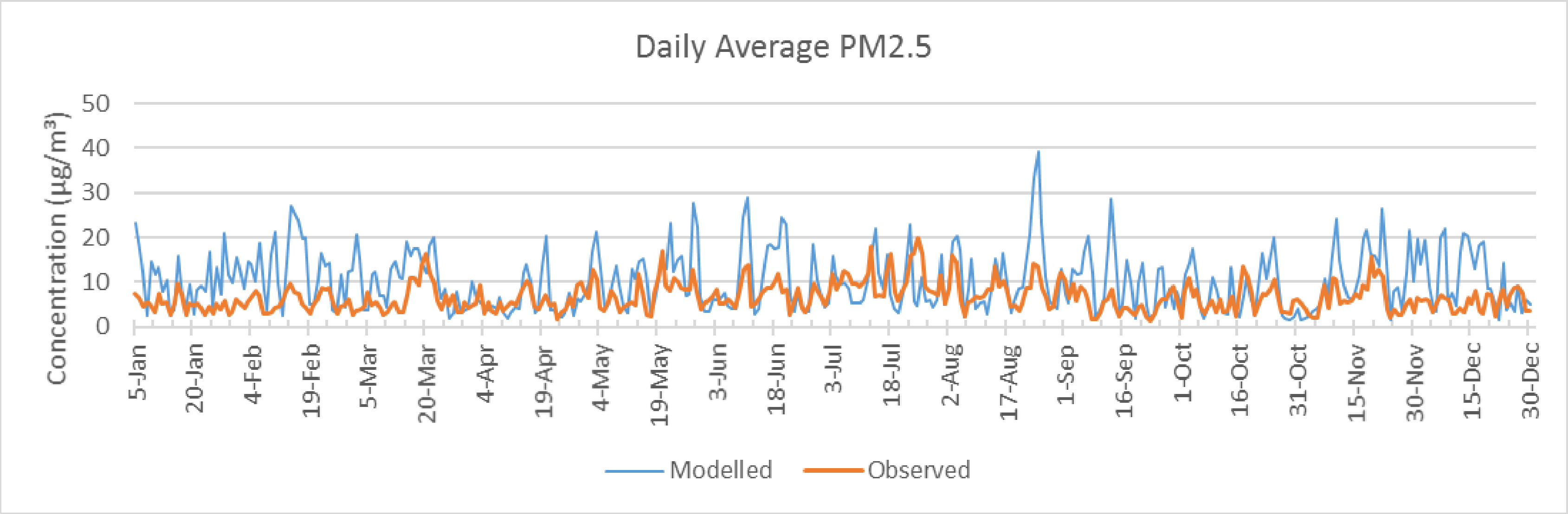
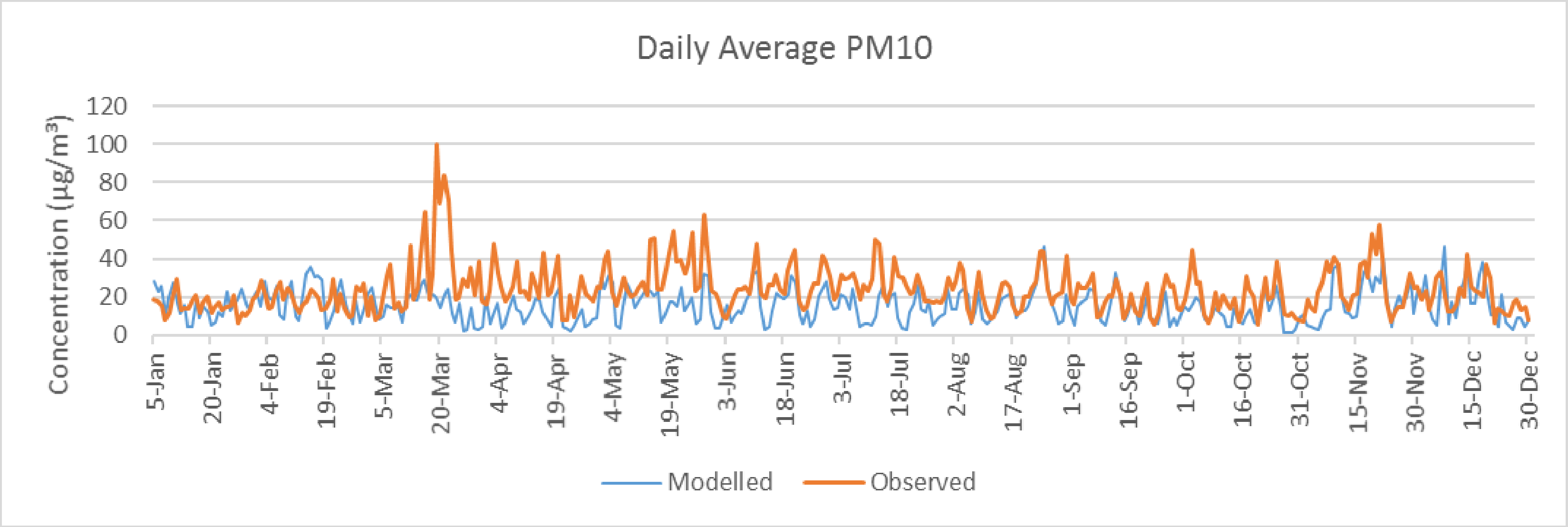
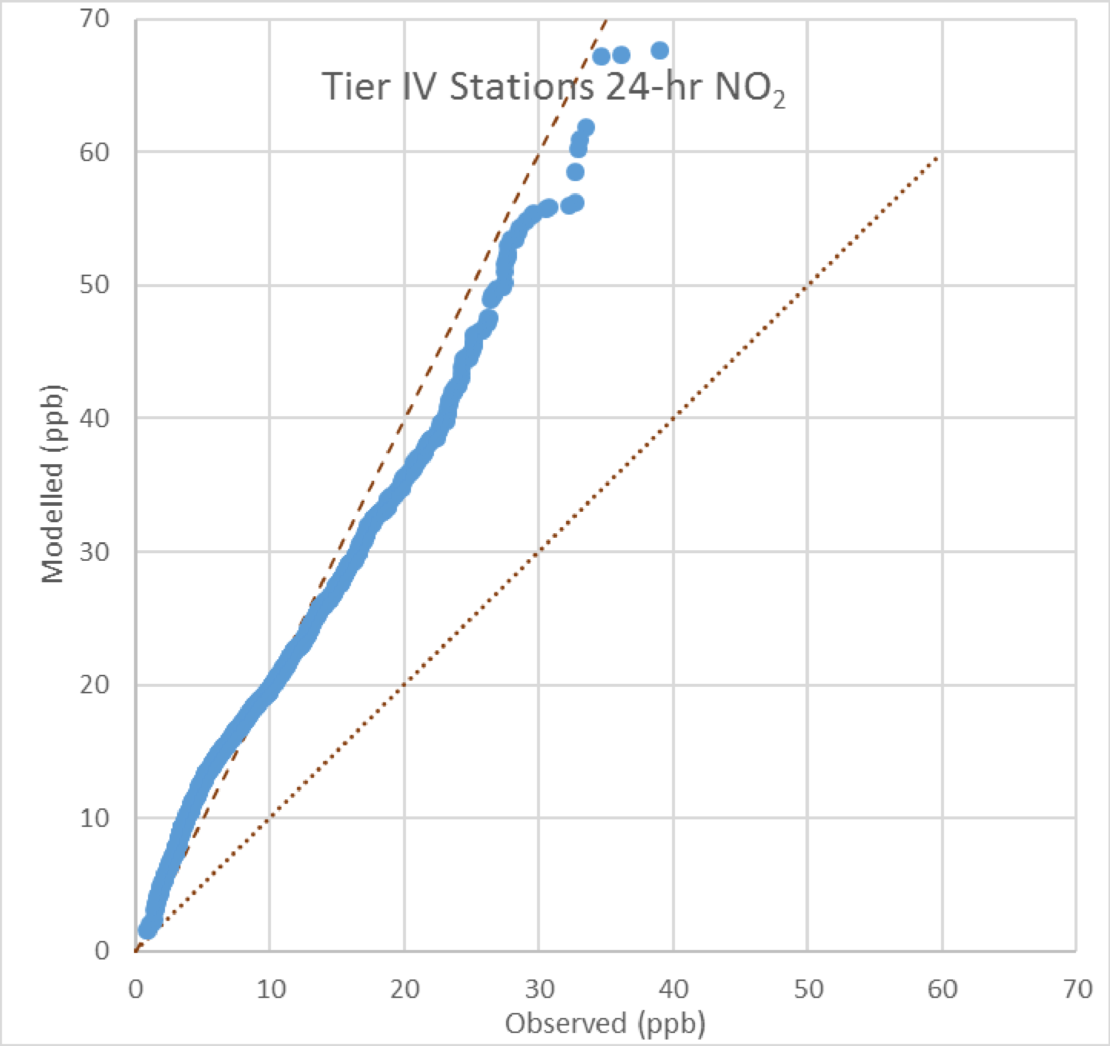
Time Series: $PM_{2.5}$ and PM_{10}

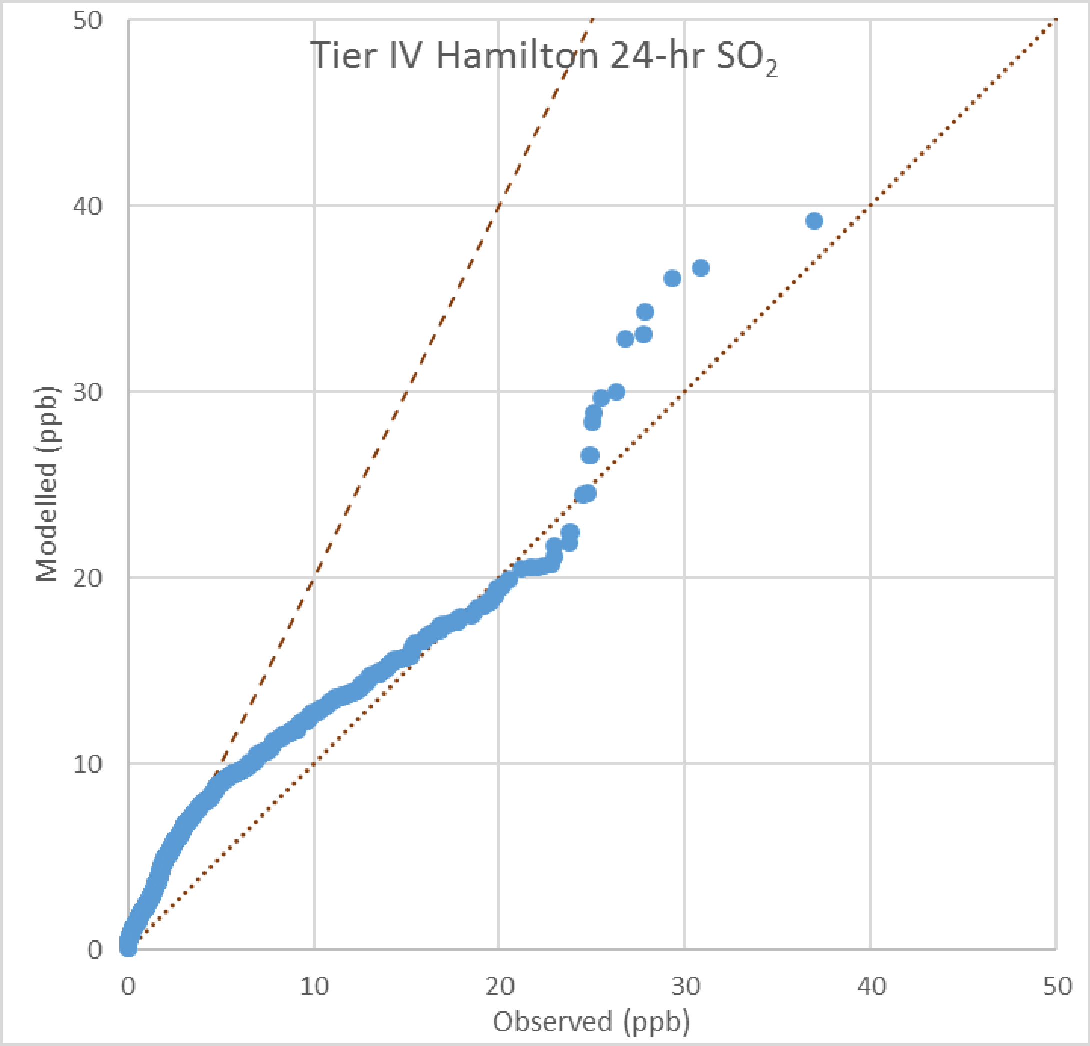




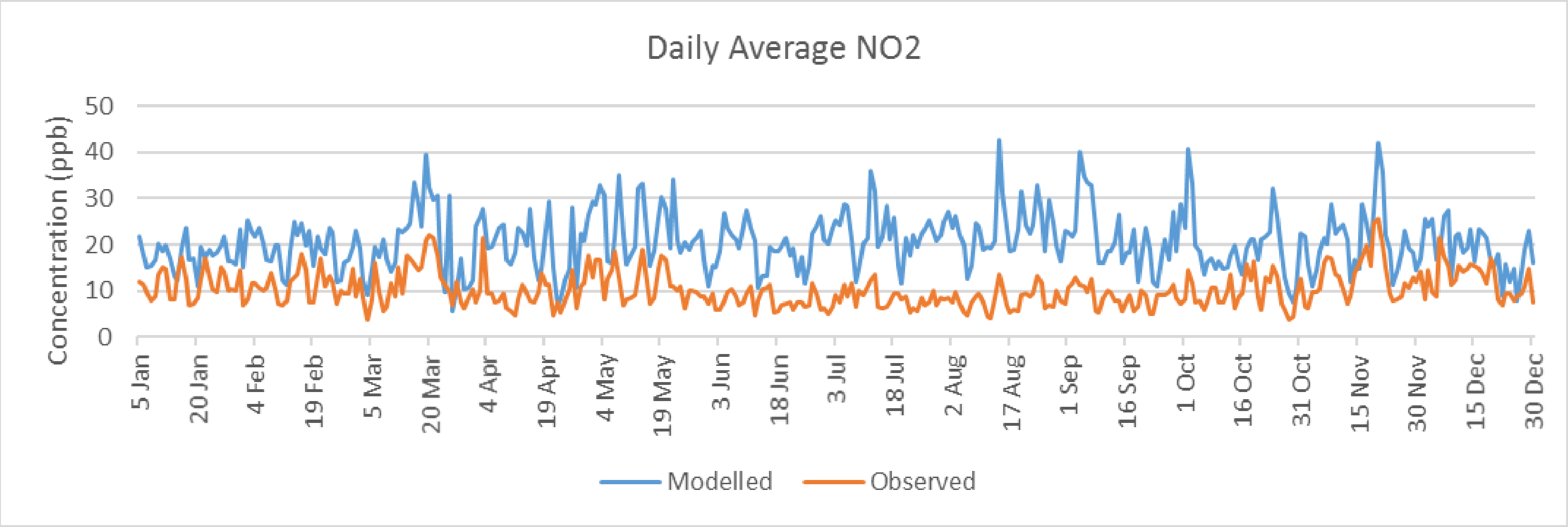
GOLDER

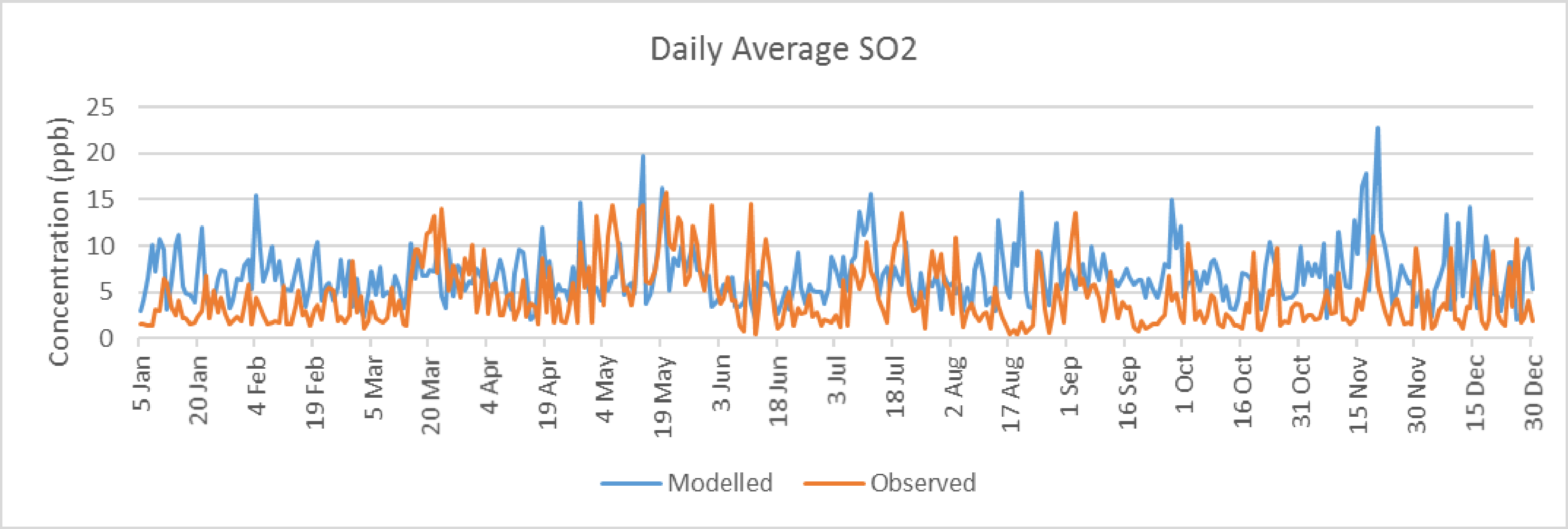
Q:Q Plots: NO_2 and SO_2



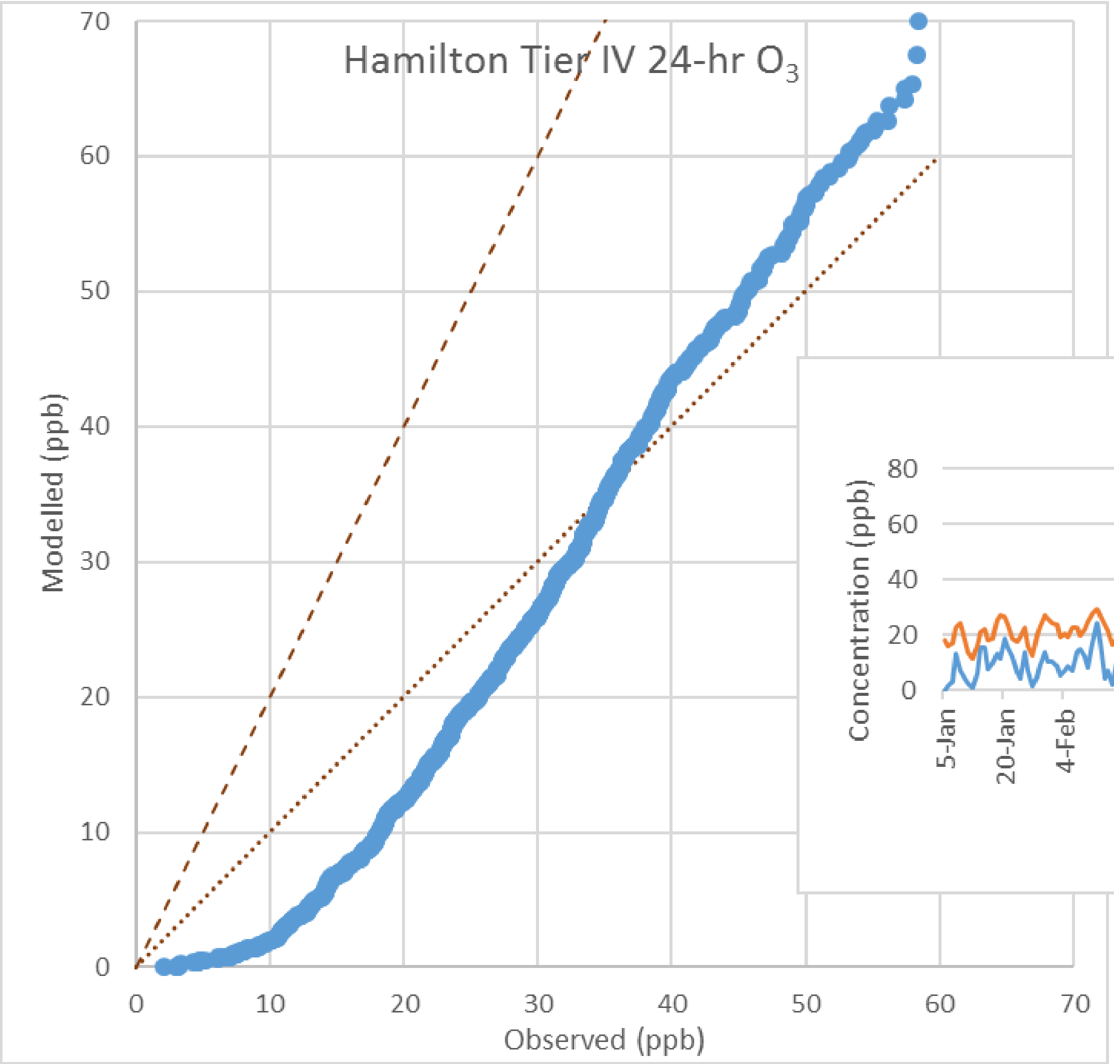


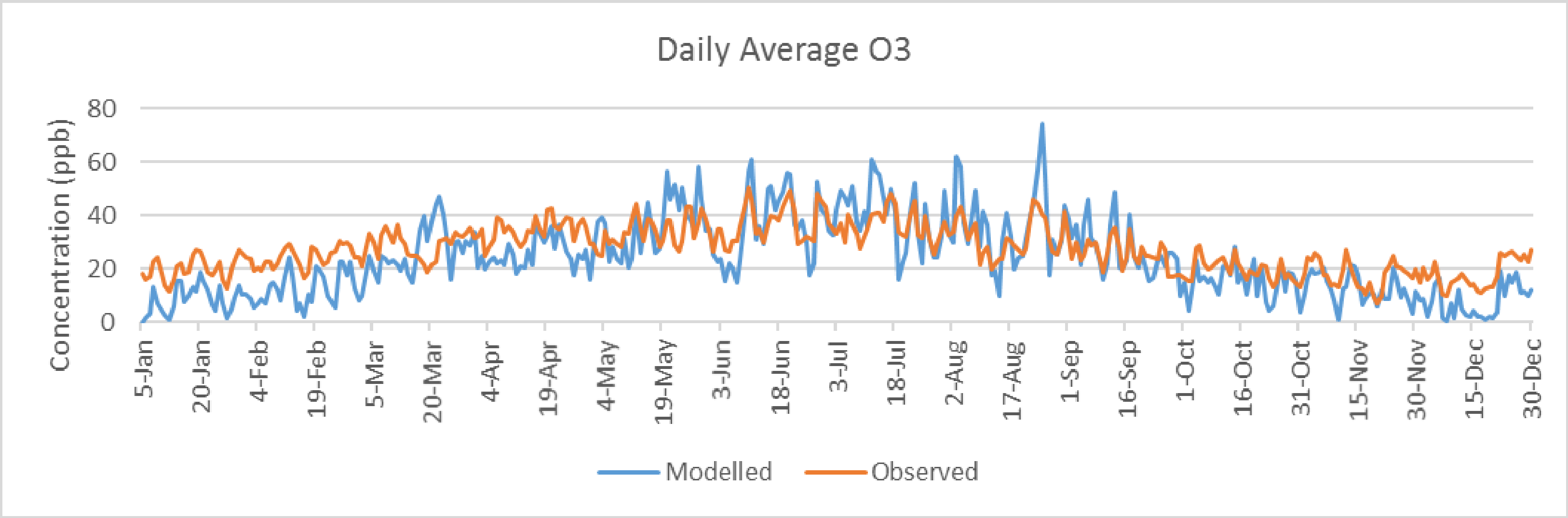
Time Series: NO_2 and SO_2



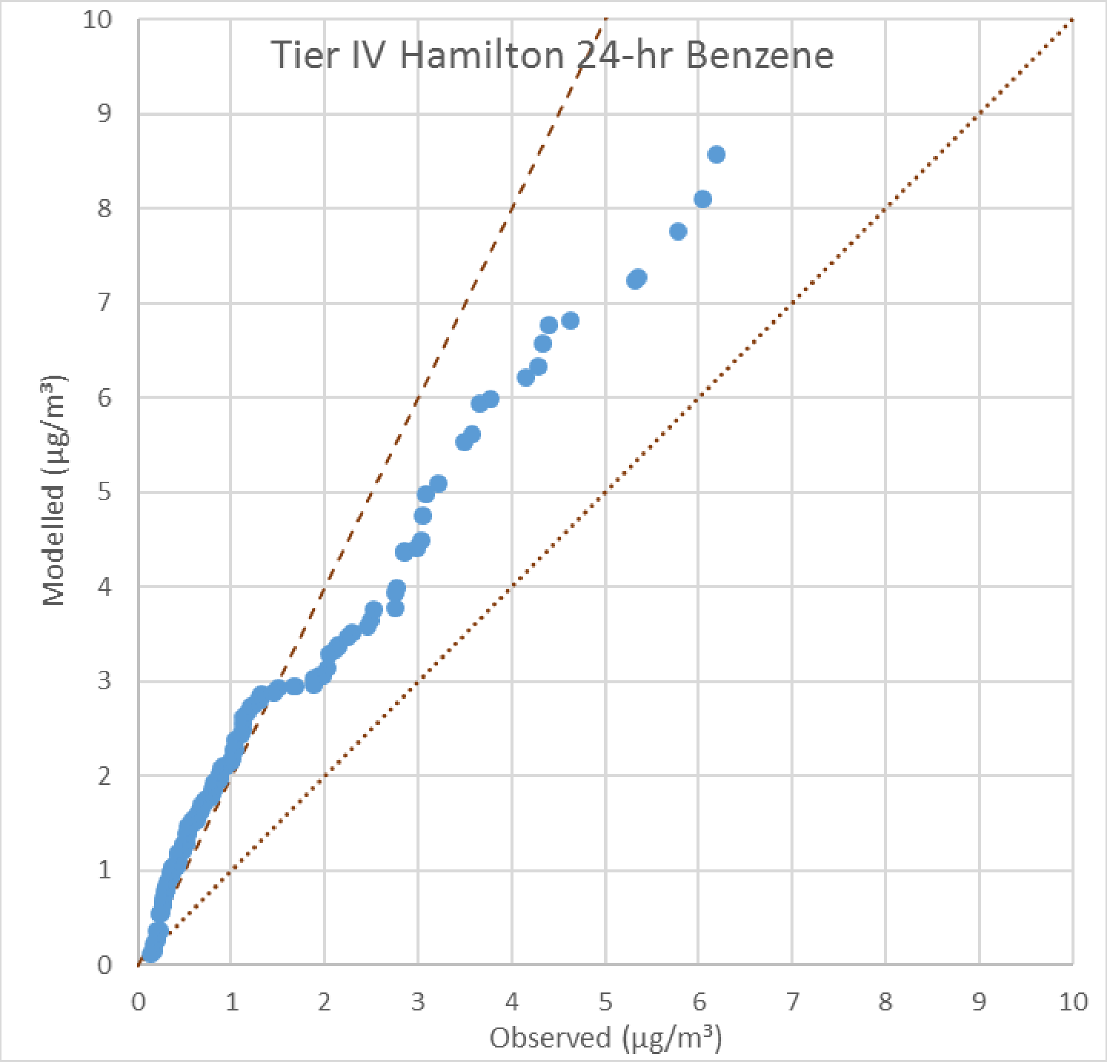


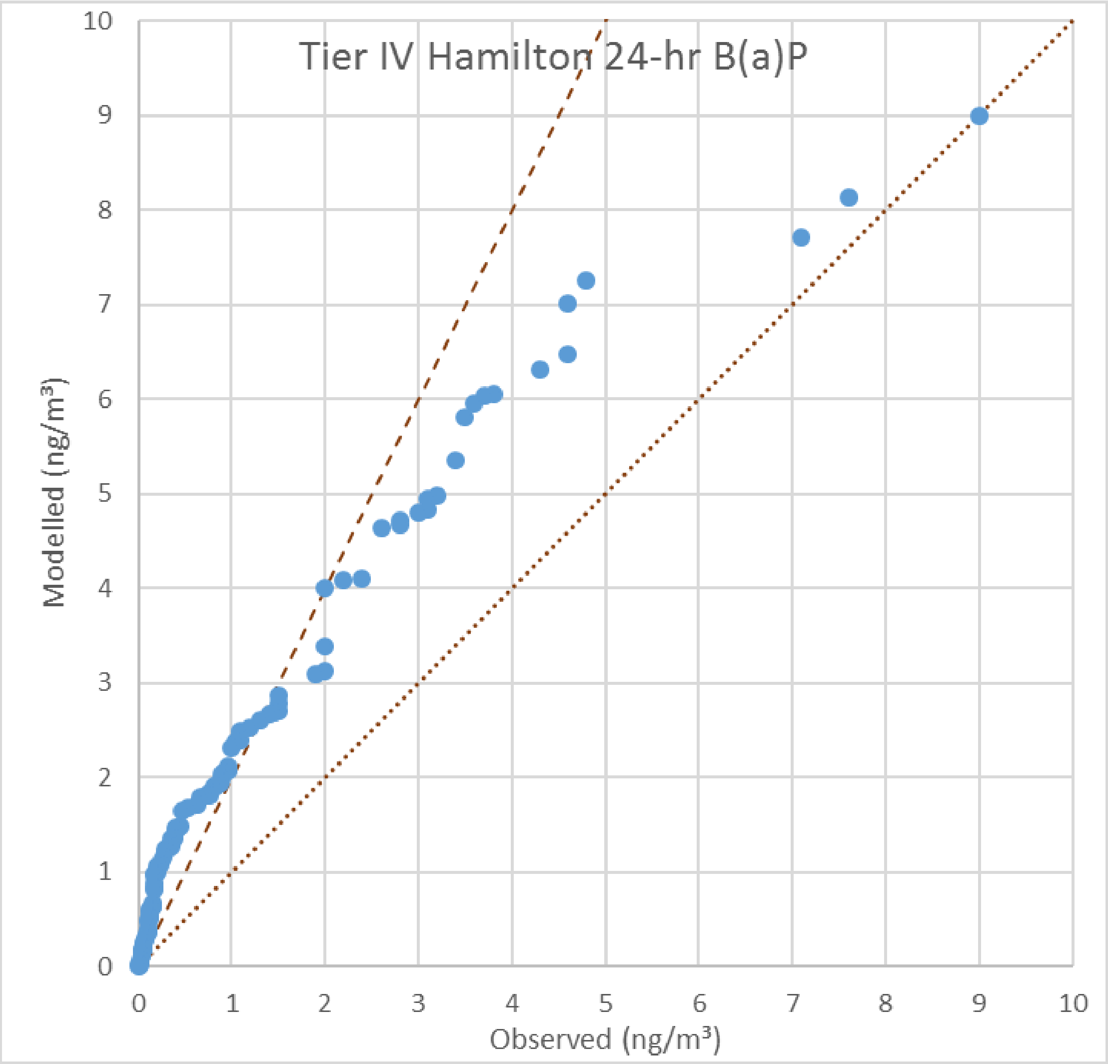
Q:Q and Time Series Plot: O_3





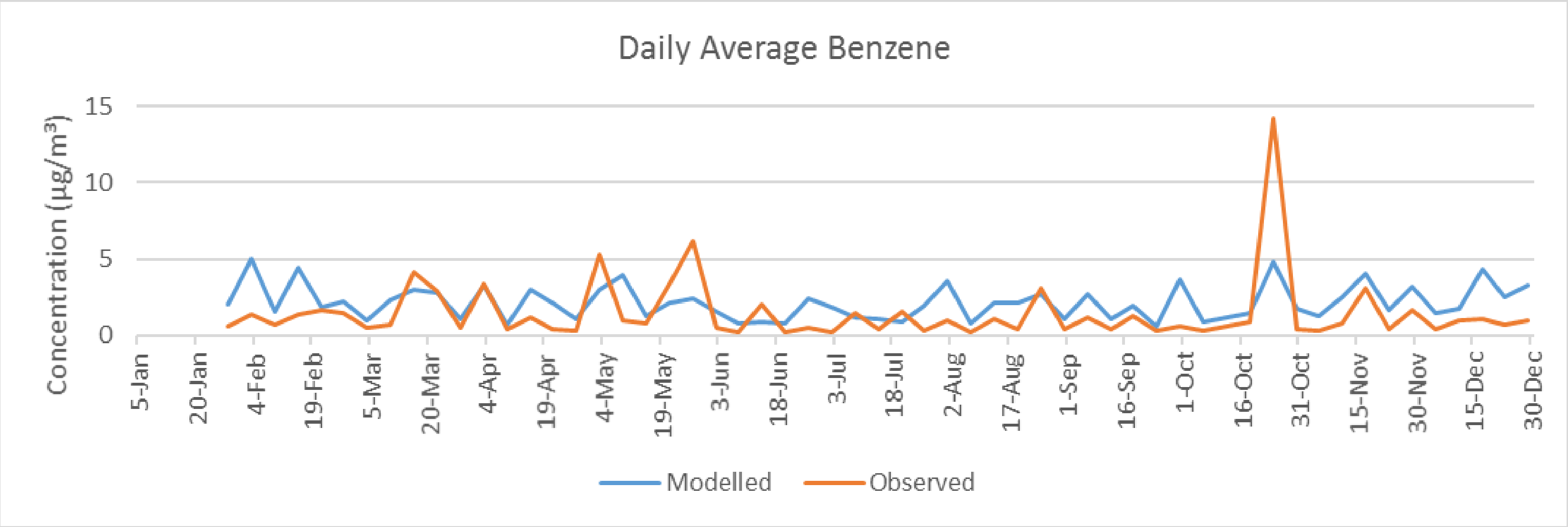
Q:Q Plots: Benzene and B(a)P

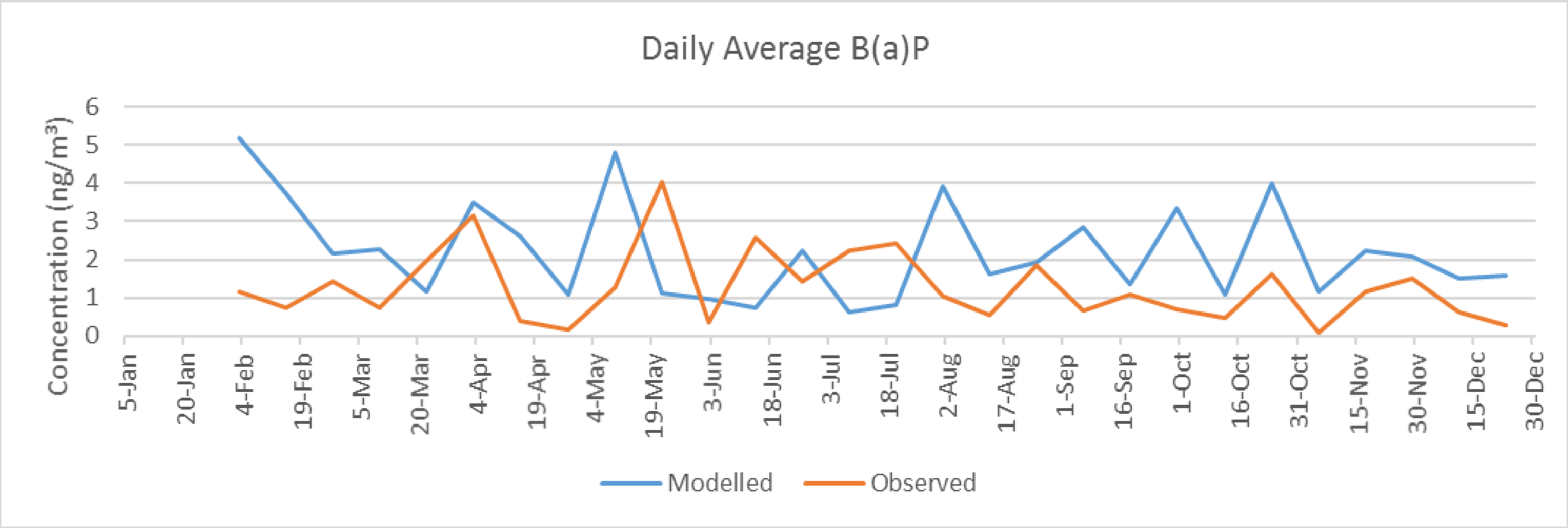




GOLDER

Time Series: Benzene and B(a)P





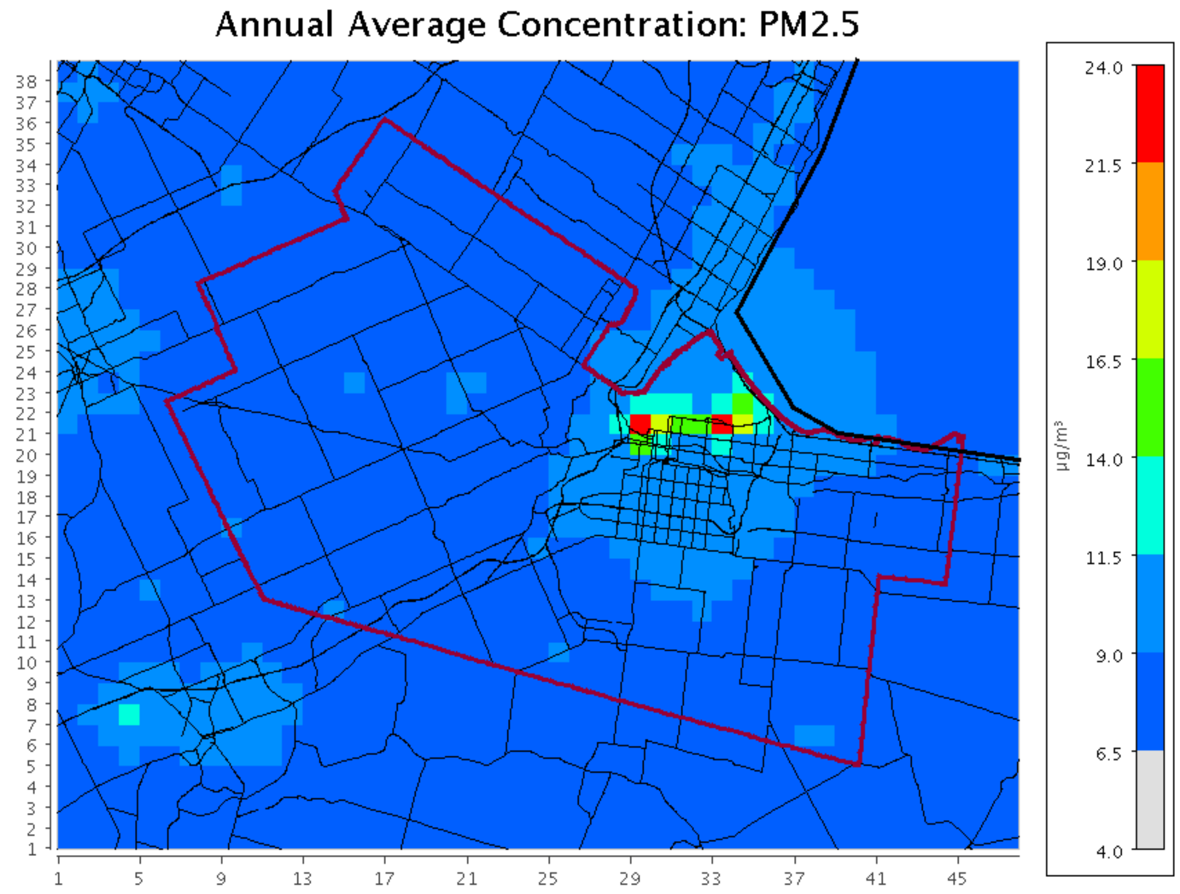
Air Quality Modelling Results

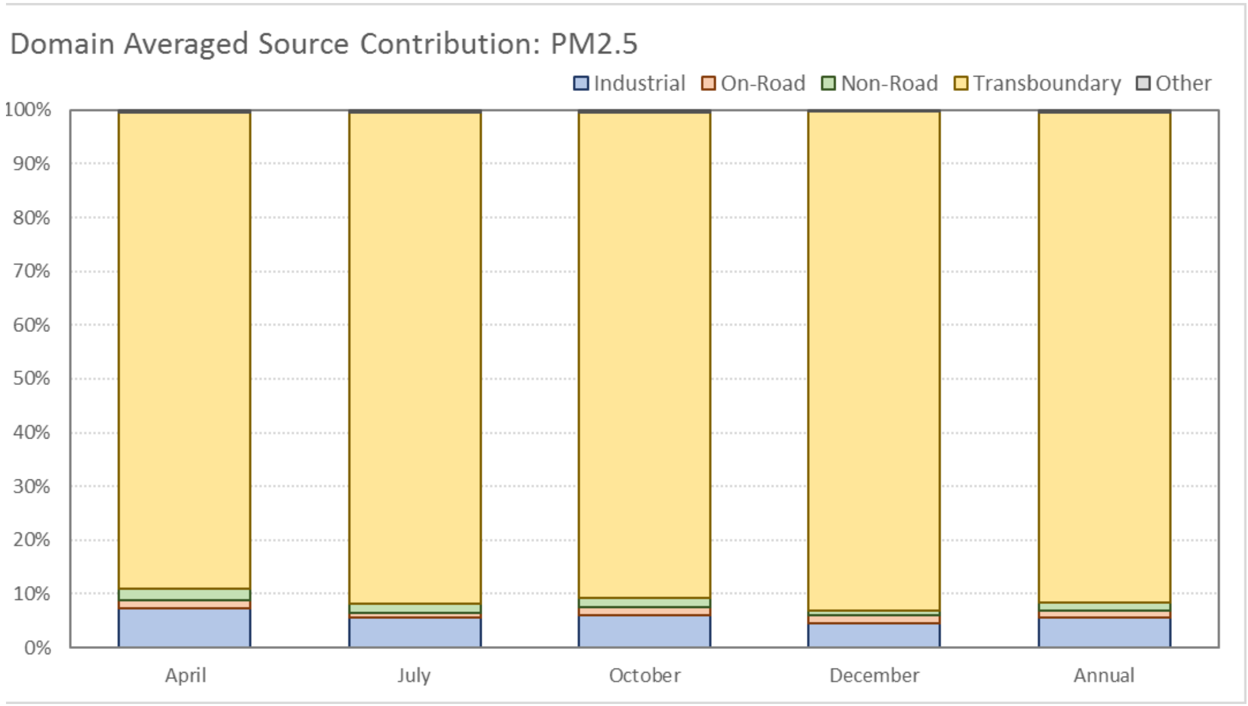
MODEL PERFORMANCE EVALUATION SUMMARY

- **Model results are conservative and reliable!**
- Particulate matter met performance criteria
  - PM_{10} is under-predicted likely due to unaccounted for fugitive dust source
  - Over prediction seems to occur in the winter months
- 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)
- Seasonal terms are captured

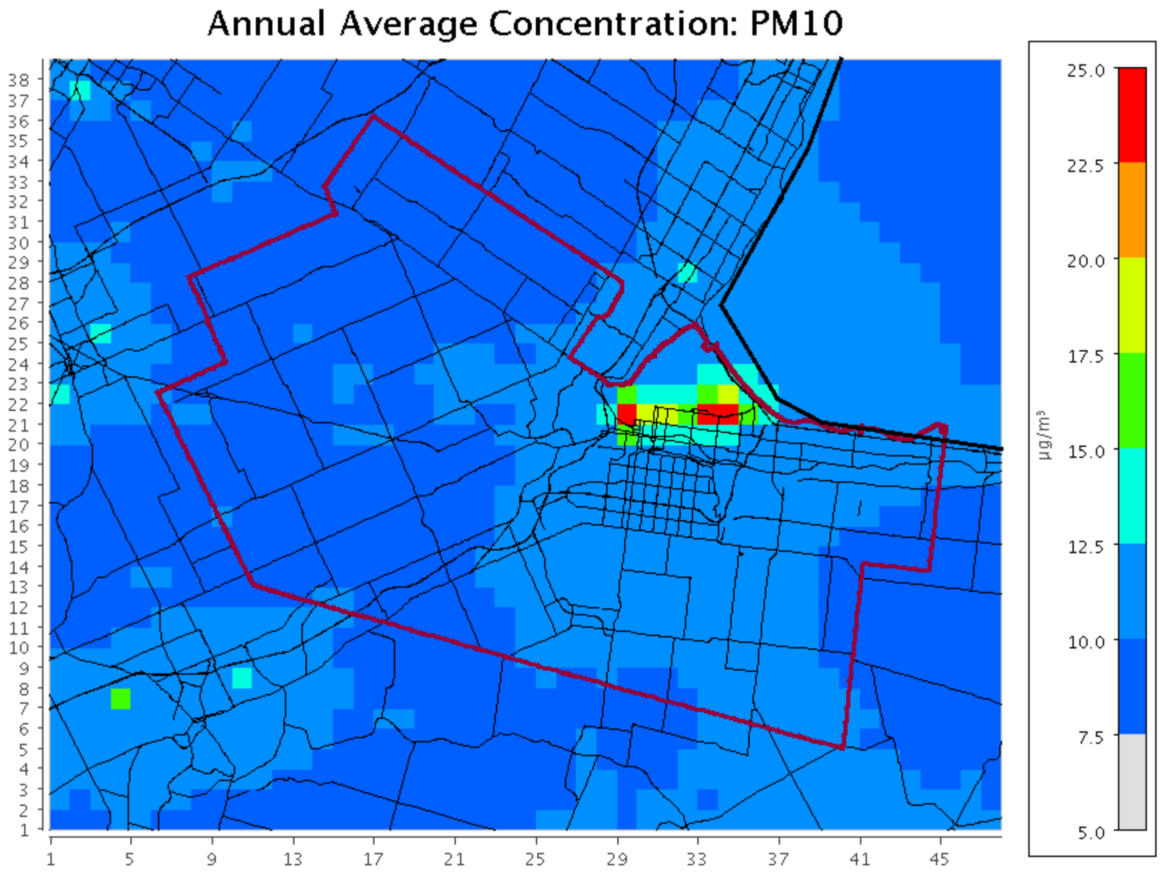
Air Quality Modelling Results: Aerial and Source Apportionment across Tier IV

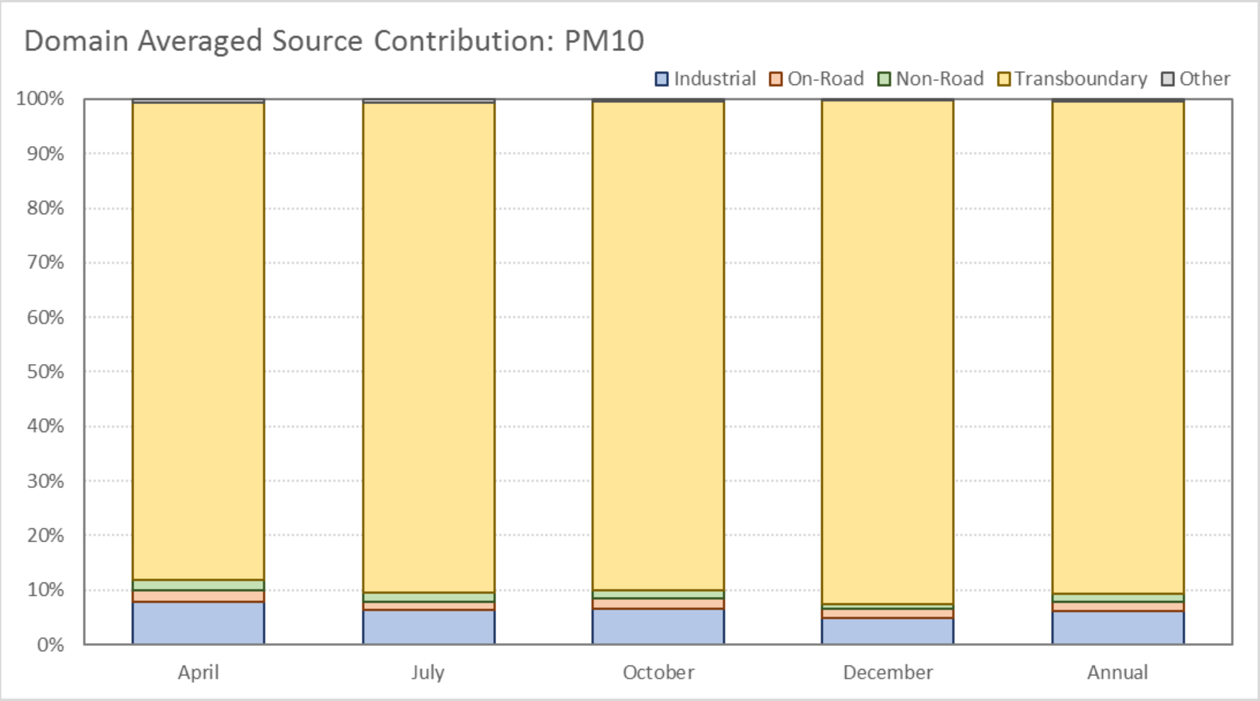
Air Quality Modelling Results: $PM_{2.5}$



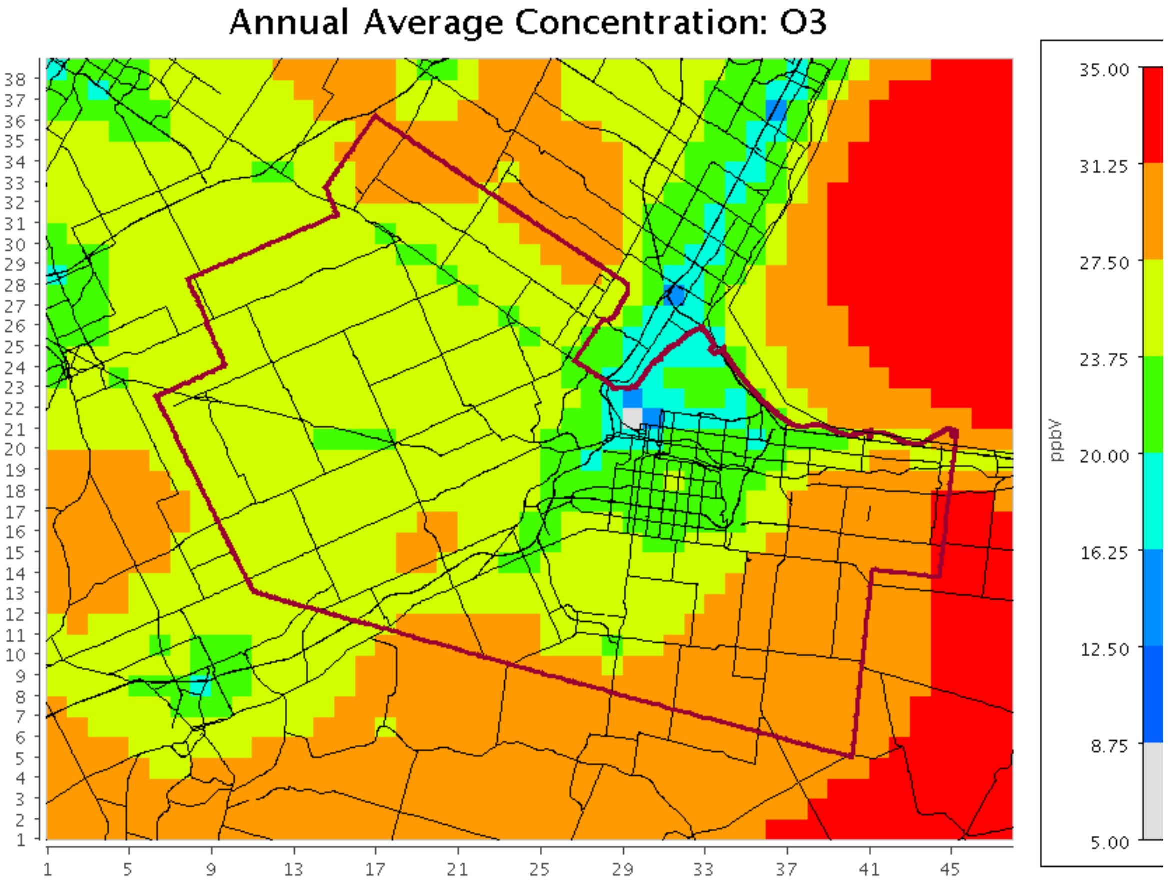


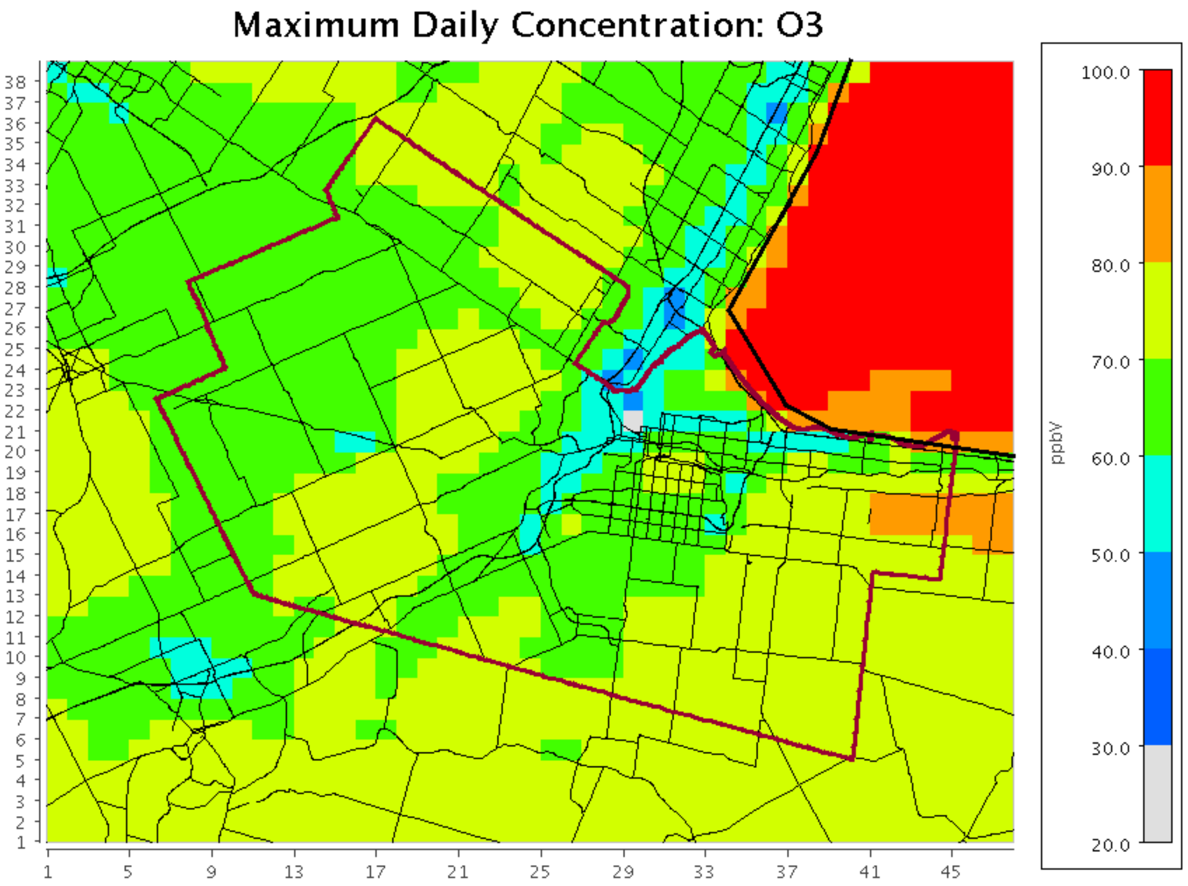
Air Quality Modelling Results: PM_{10}



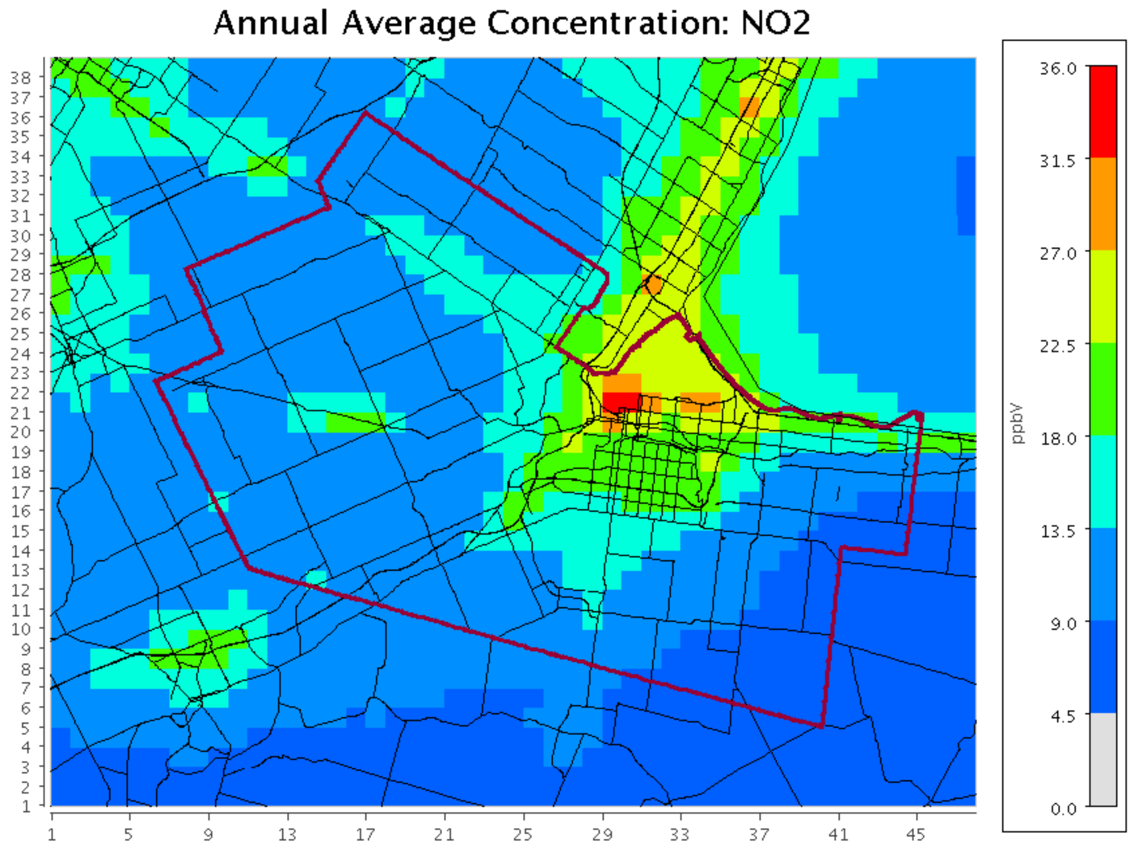


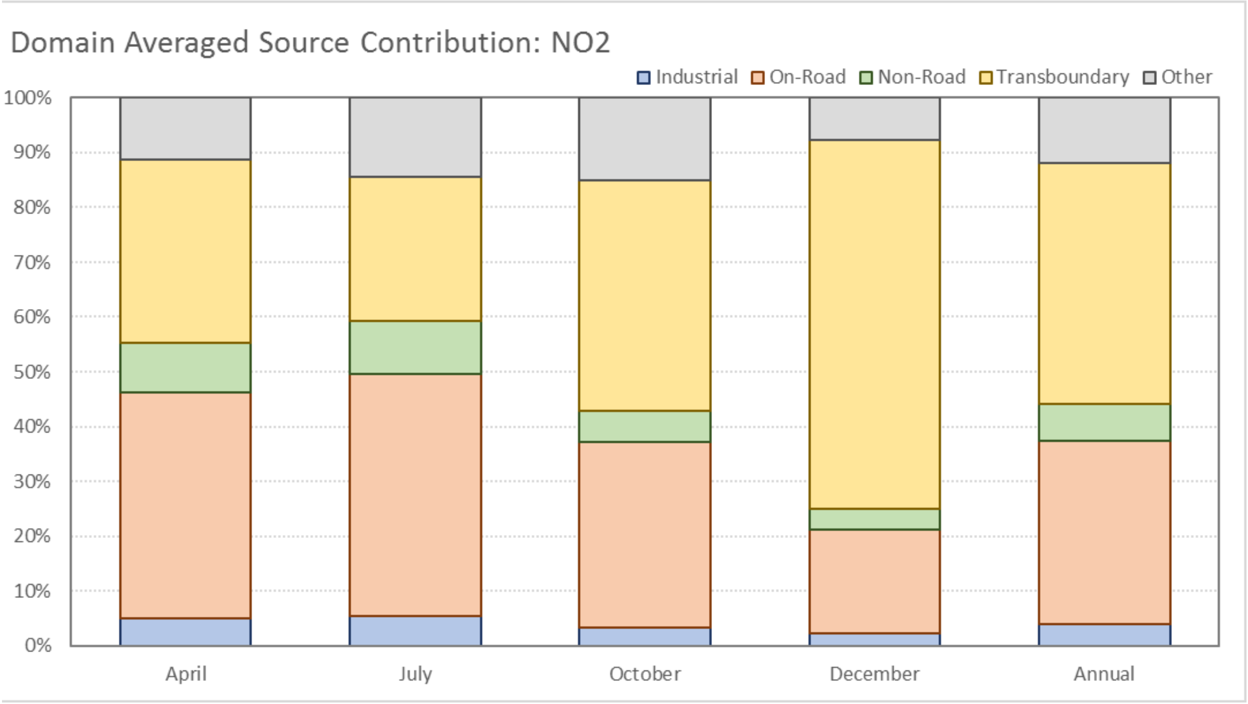
Air Quality Modelling Results: O_3



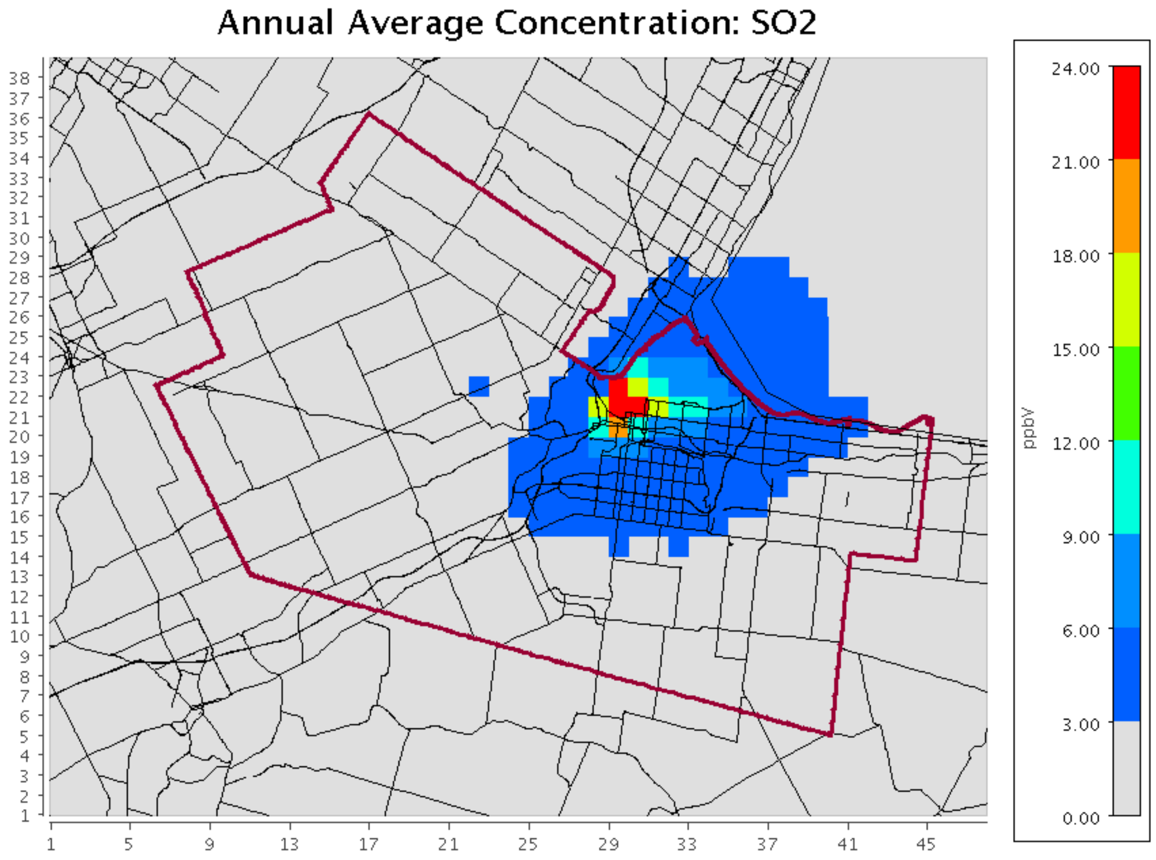


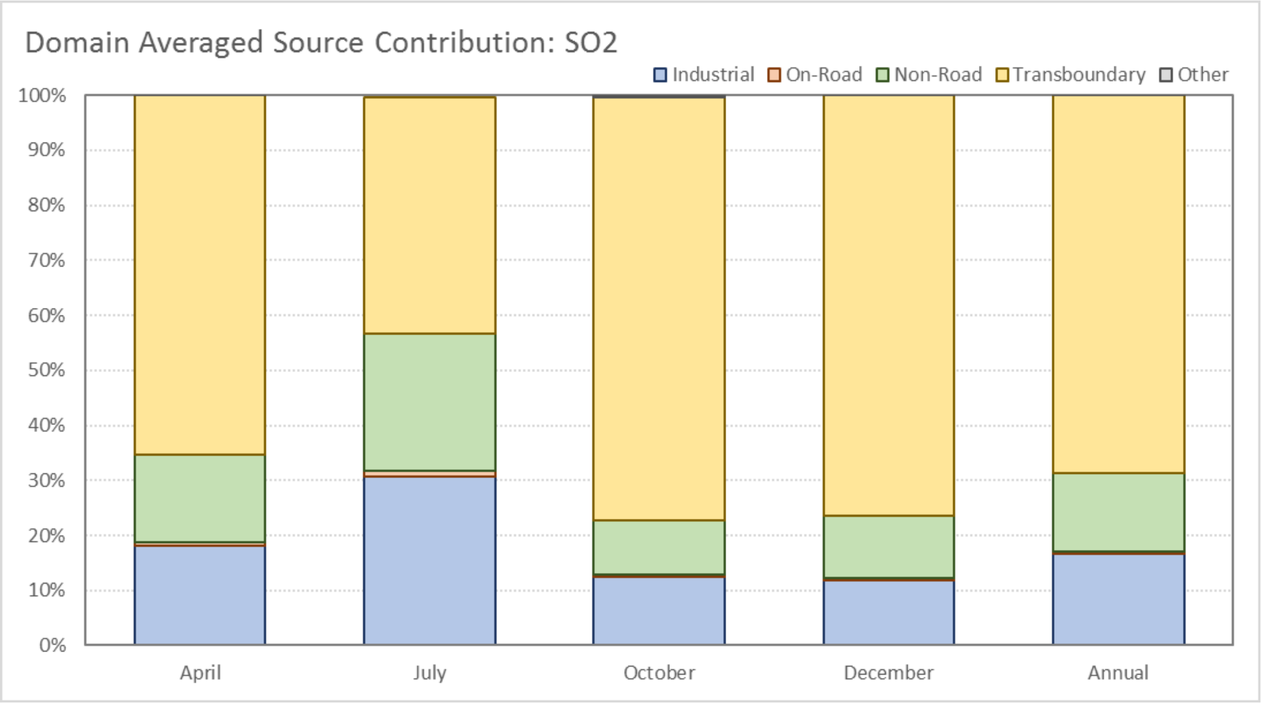
Air Quality Modelling Results: NO_2





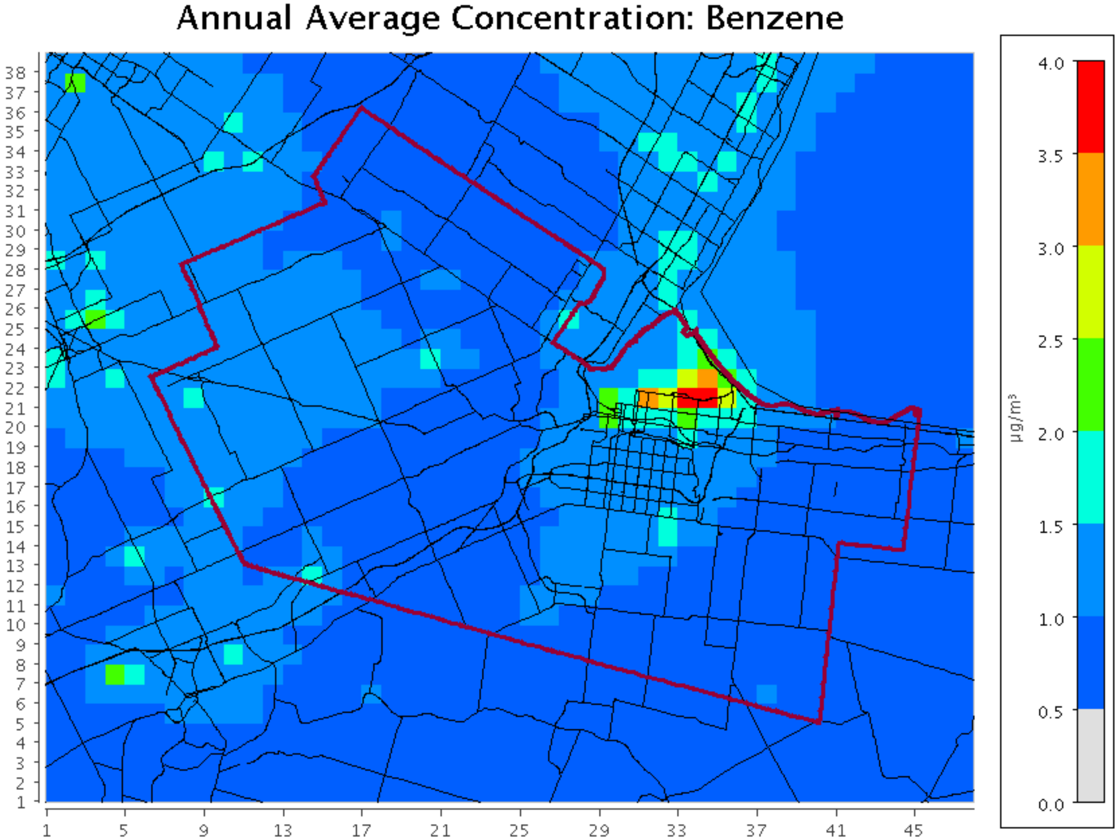
Air Quality Modelling Results: SO_2

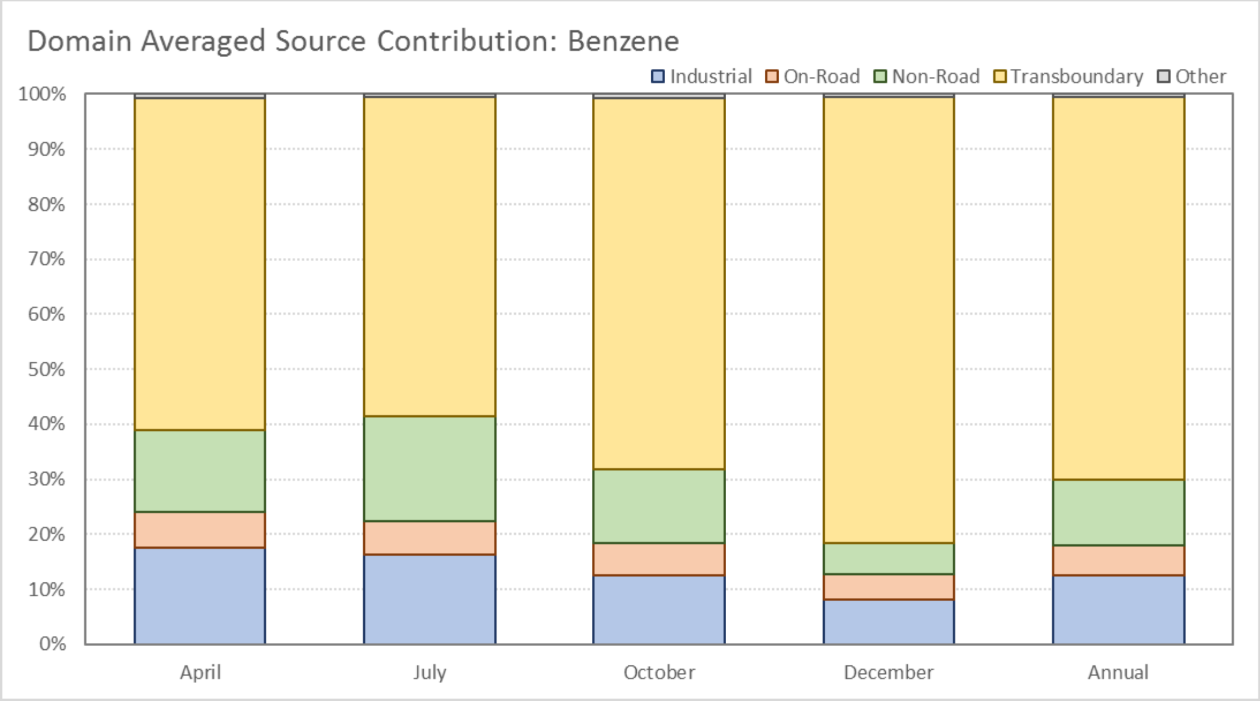




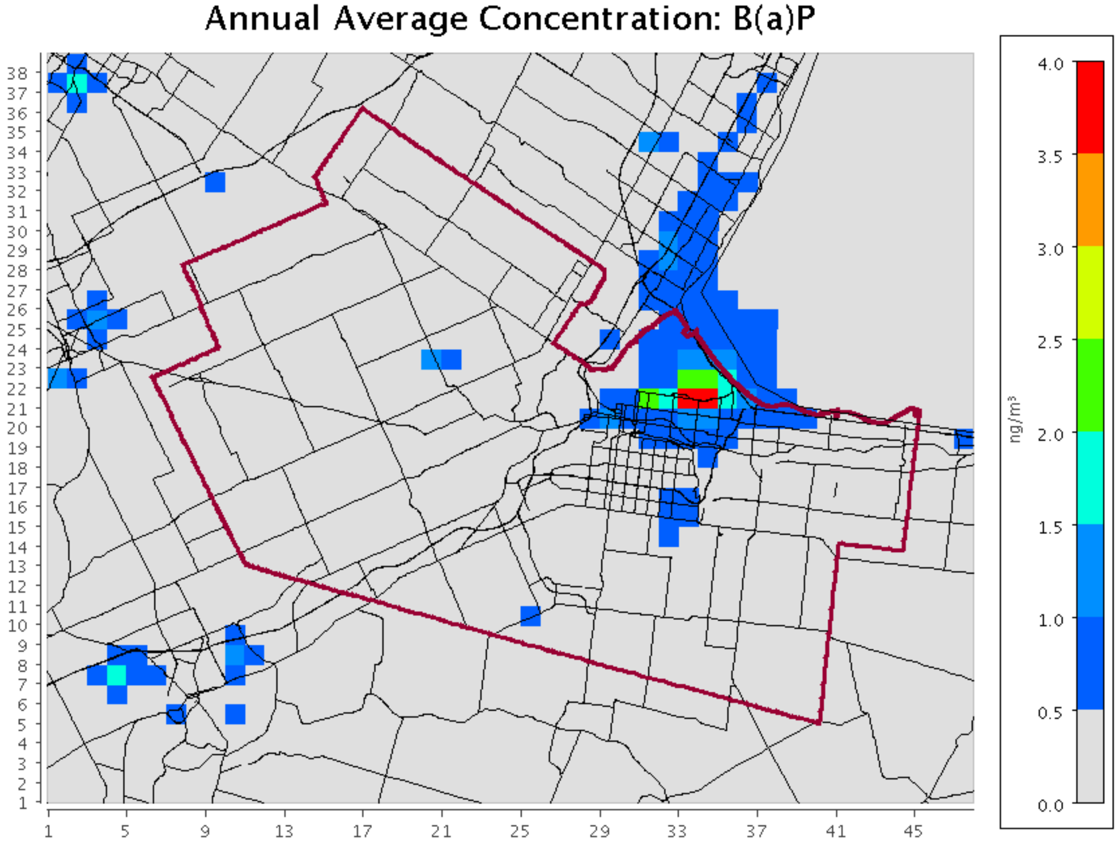
GOLDER

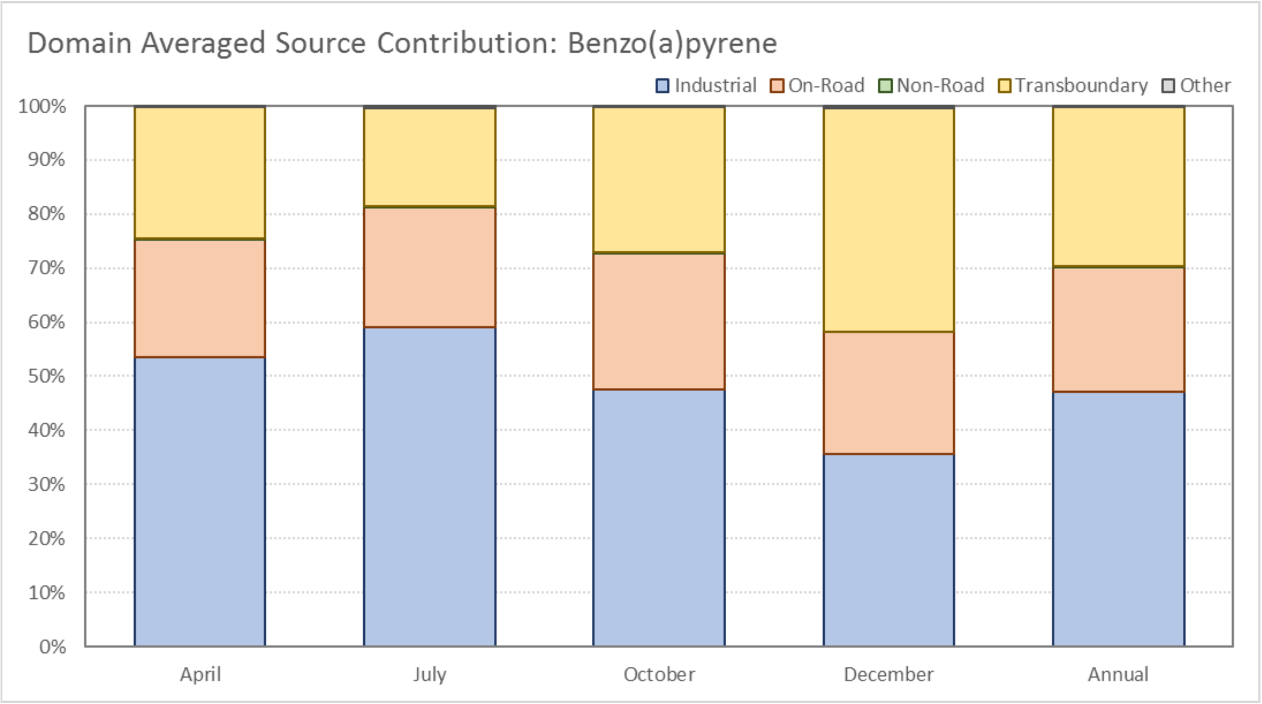
Air Quality Modelling Results: Benzene





Air Quality Modelling Results: B(a)P





Conclusions

Conclusions – Solving the Puzzle

WHAT HAVE WE LEARNED FROM THE HAMILTON AIRSHED MODELLING SYSTEM?

1. HAMS provides conservative and reliable results with a strong degree of confidence as results meet published benchmarks.
2. Source contribution profile varies according to geographic location (i.e. downtown vs mountain)
3. Transportation related activities are significant contributors to air quality levels (i.e., in and outside of the City)
4. Local industrial activities contribute less than 20% to air quality in the airshed except for B(a)P which is higher
5. Local industry and non-road sources contribute about ~15% to SO_2 levels

Conclusions - Continued

WHAT HAVE WE LEARNED FROM THE HAMILTON AIRSHED MODELLING SYSTEM?

6. $PM_{2.5}$ contribution (~75%) are from transboundary sources outside of Hamilton

7. PM_{10} is under-predicted in the industrial area due to unaccounted fugitive sources

8. Transportation sources have the highest contribution to NO_2 levels (~40%)

9. NO_2 levels are likely over-predicted due to transboundary sources outside of Hamilton

10. Source contribution varies seasonally with higher transboundary contribution in winter and more local source contribution in the summer (e.g. on-road emissions)

GOLDER

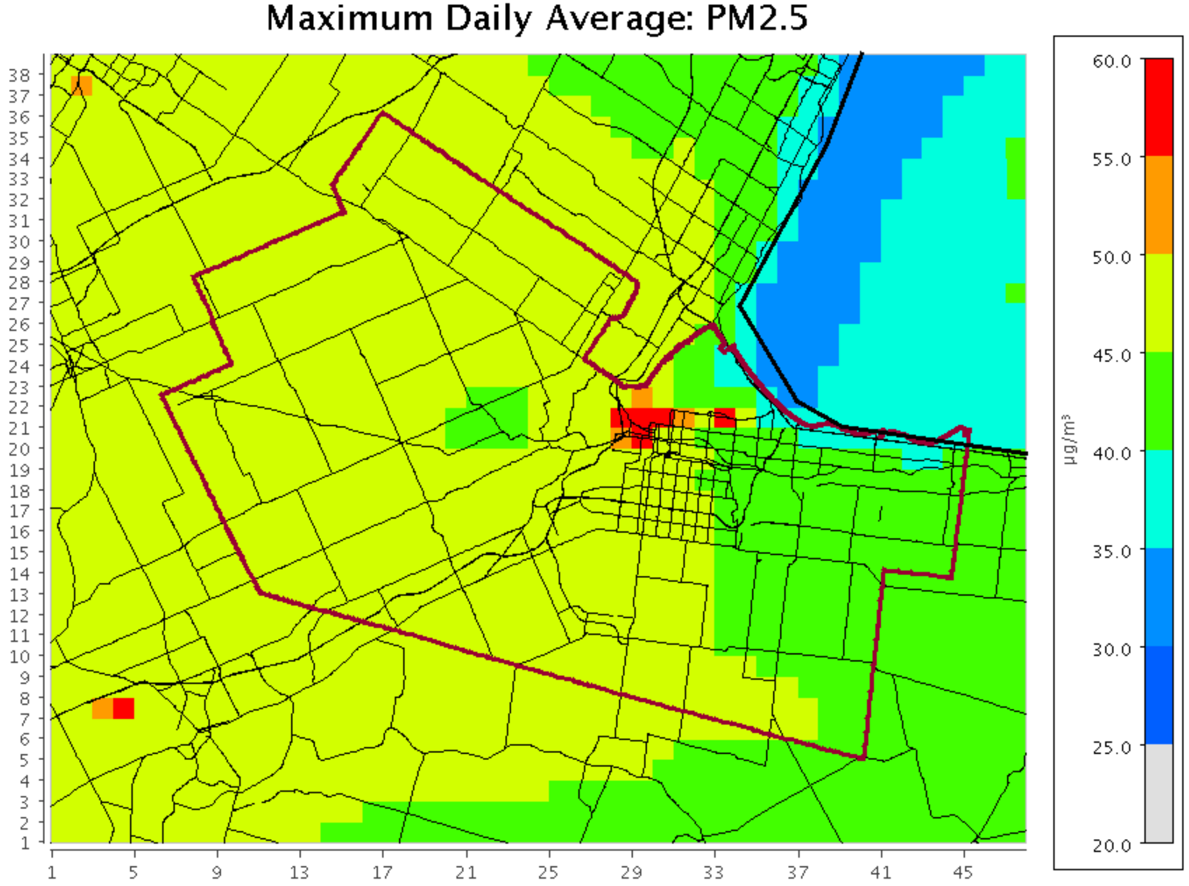
Thank you.

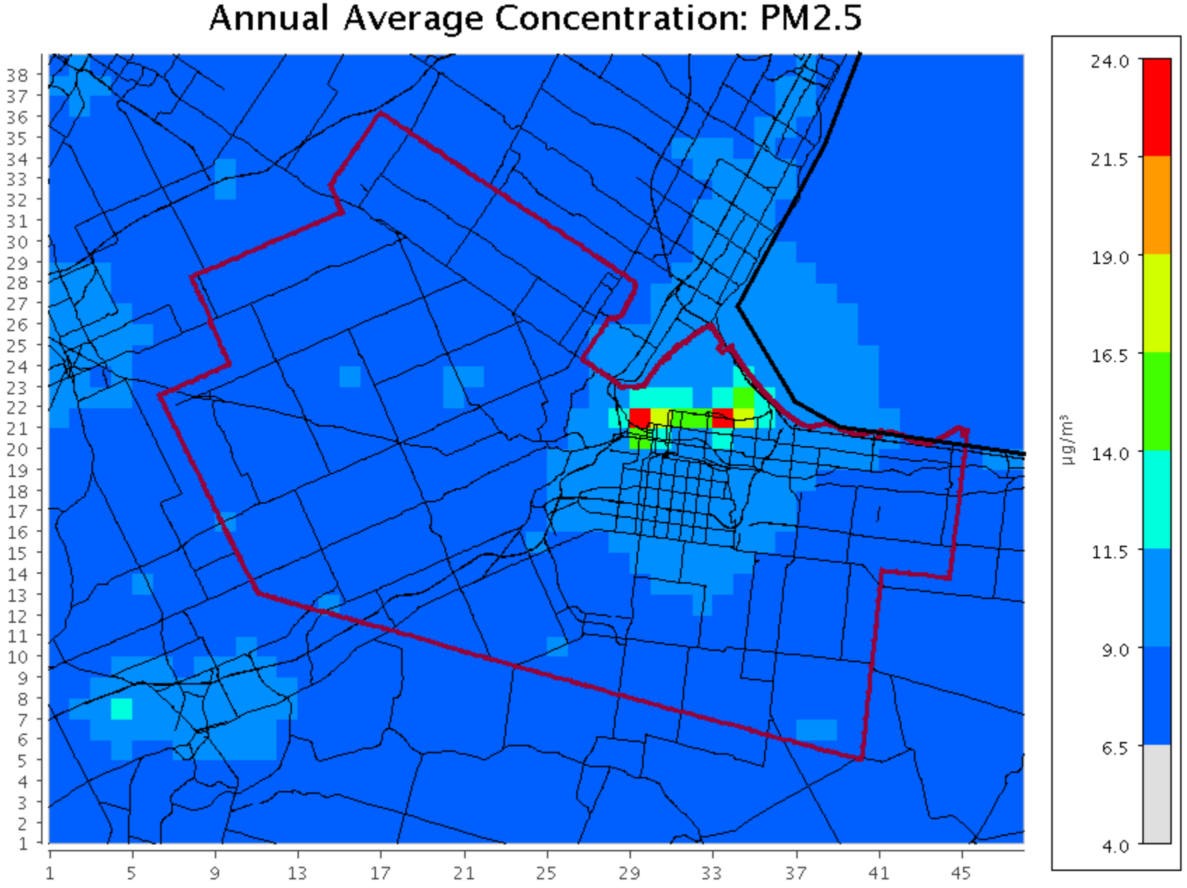
Anthony_Ciccone@Golder.com
Janya_Kelly@Golder.com

Additional Information: Maximum Daily and Annual Average Domain Plots

Source: https://en.wikipedia.org/wiki/File:HamiltonOntarioSkylineC.JPG, licensed under https://creativecommons.org/licenses/by-sa/3.0/

Air Quality Modelling Results: $PM_{2.5}$

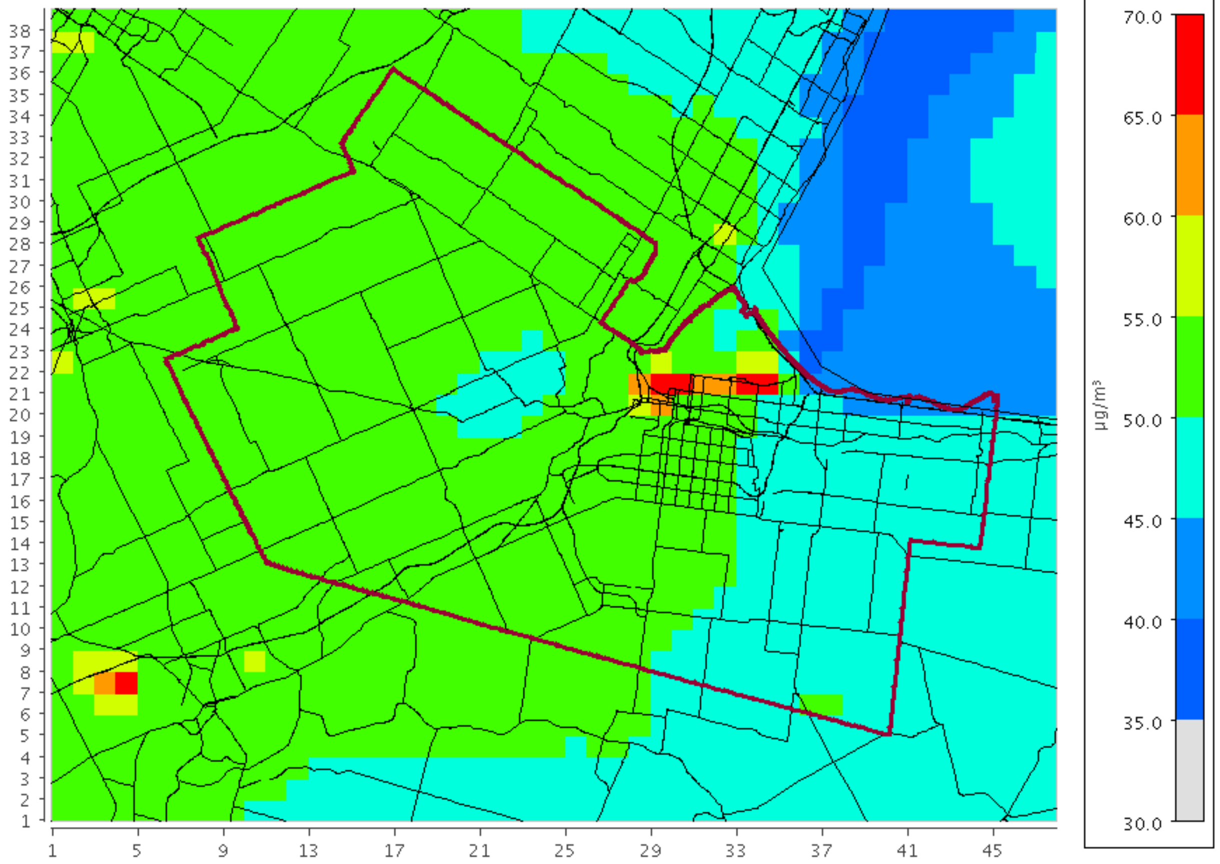




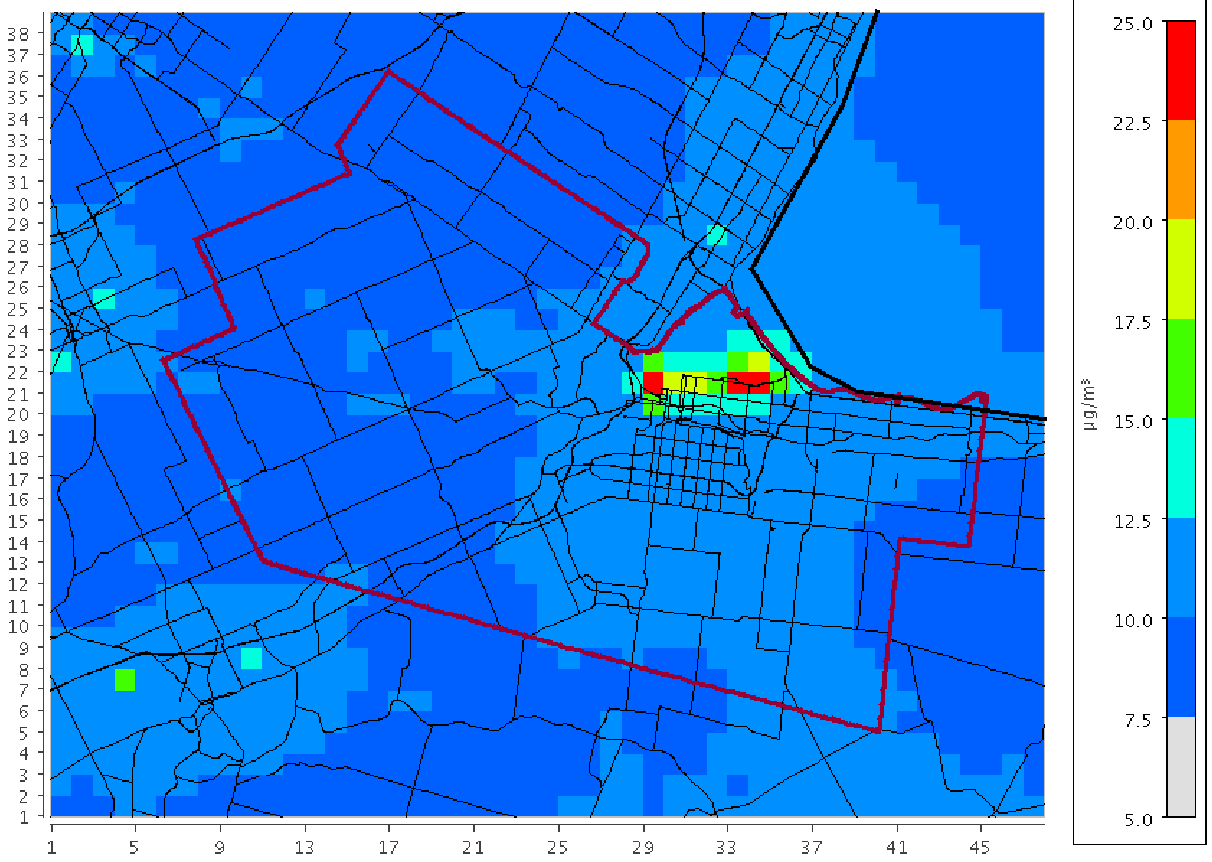
GOLDER

Air Quality Modelling Results: PM_{10}

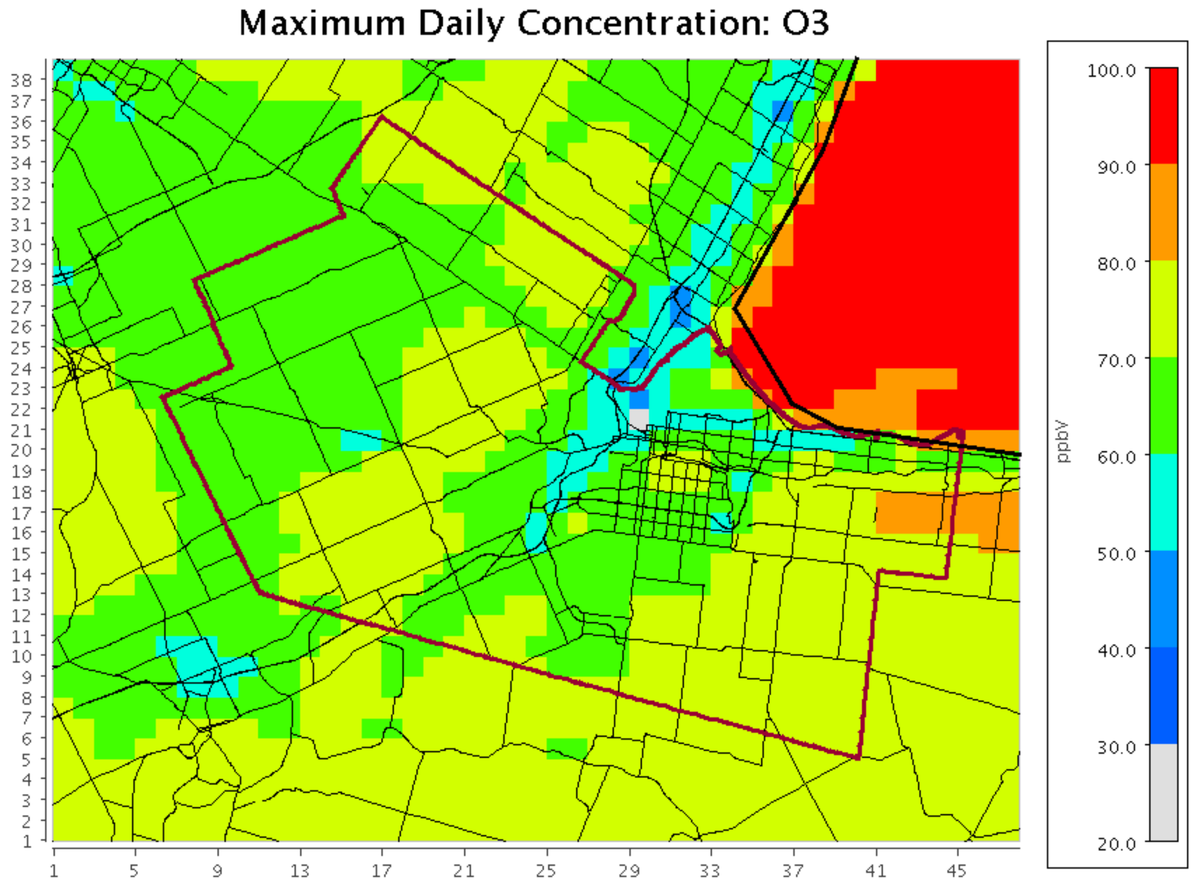
Maximum Daily Concentration: PM10

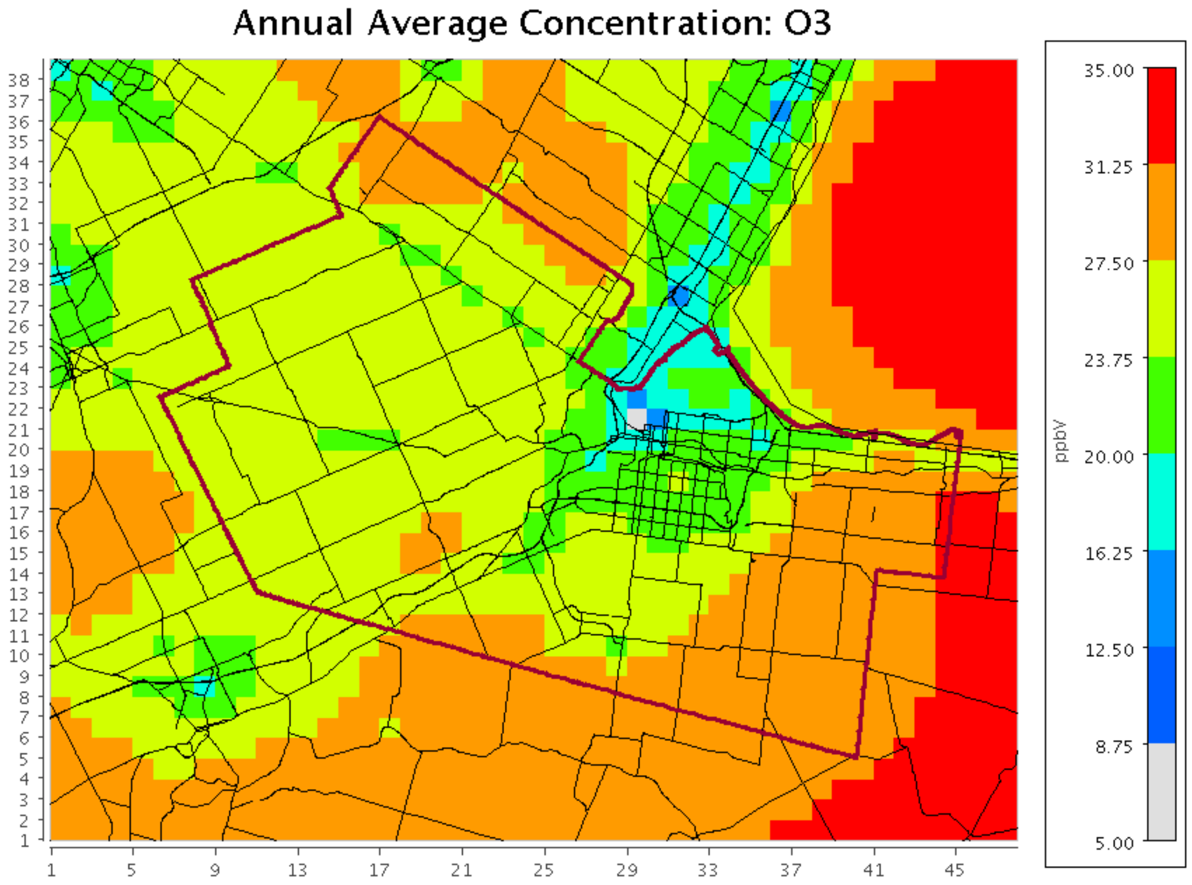


Annual Average Concentration: PM10

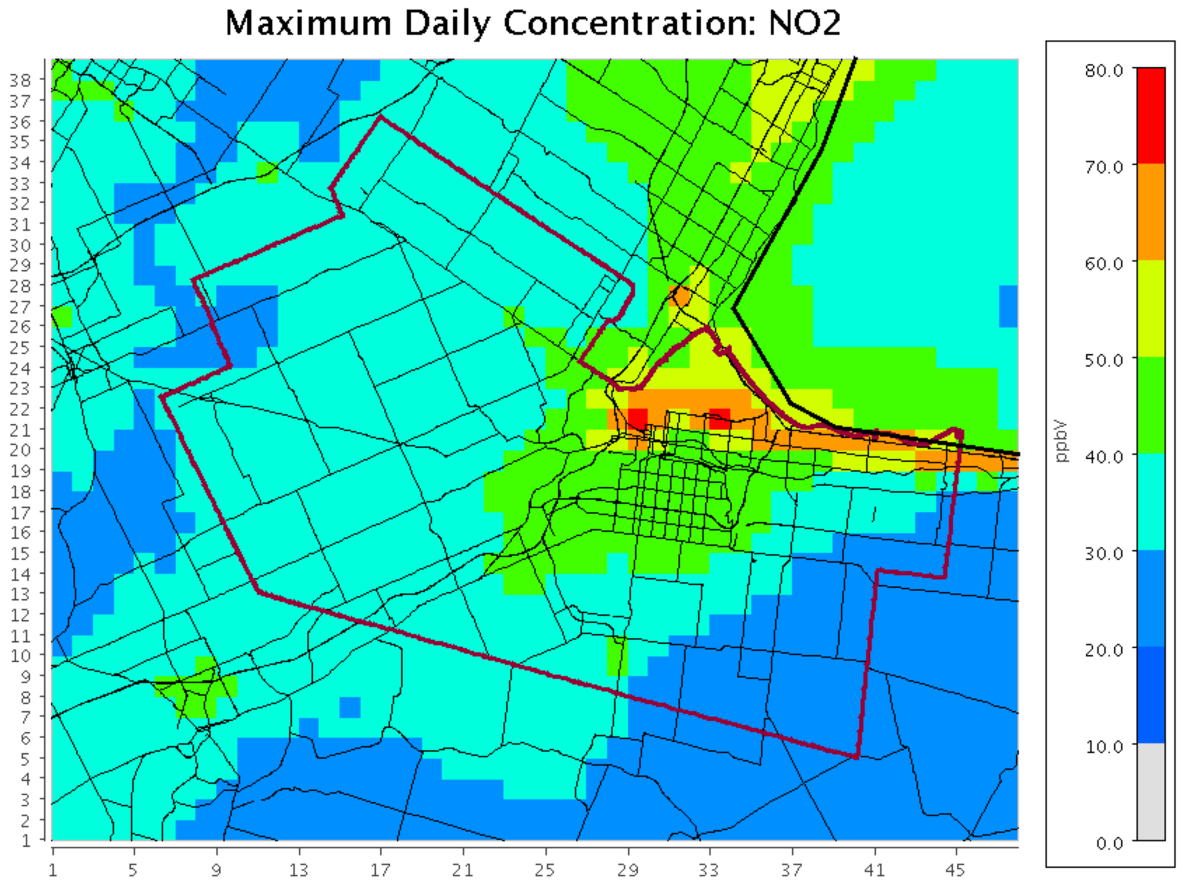


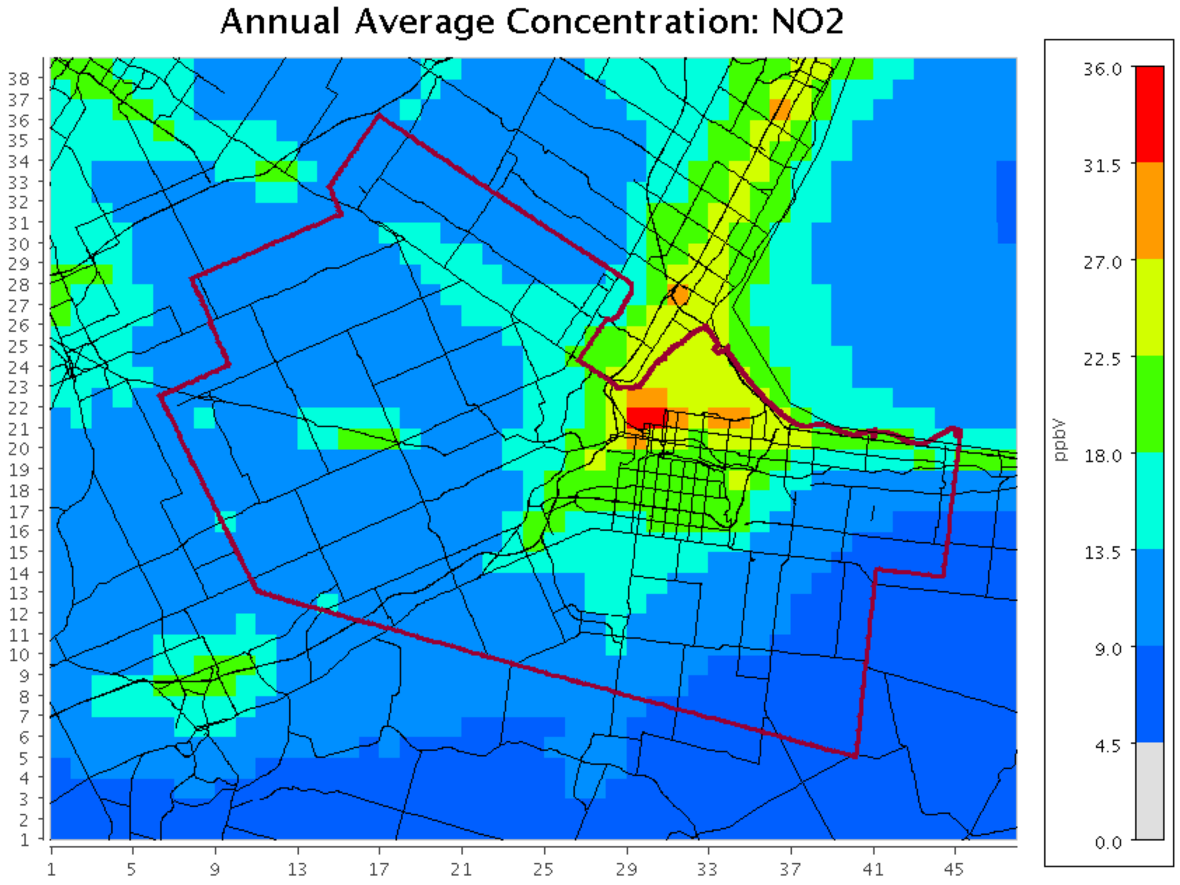
Air Quality Modelling Results: O_3



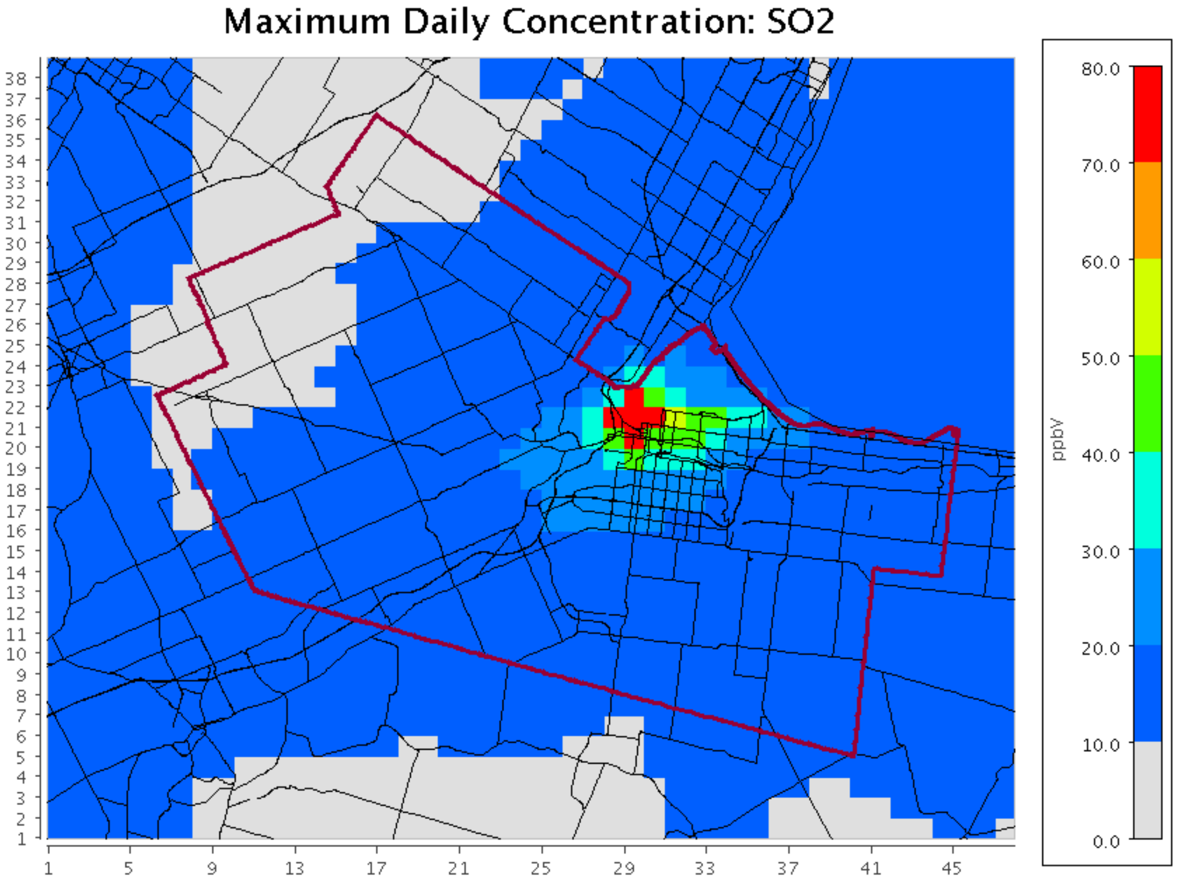


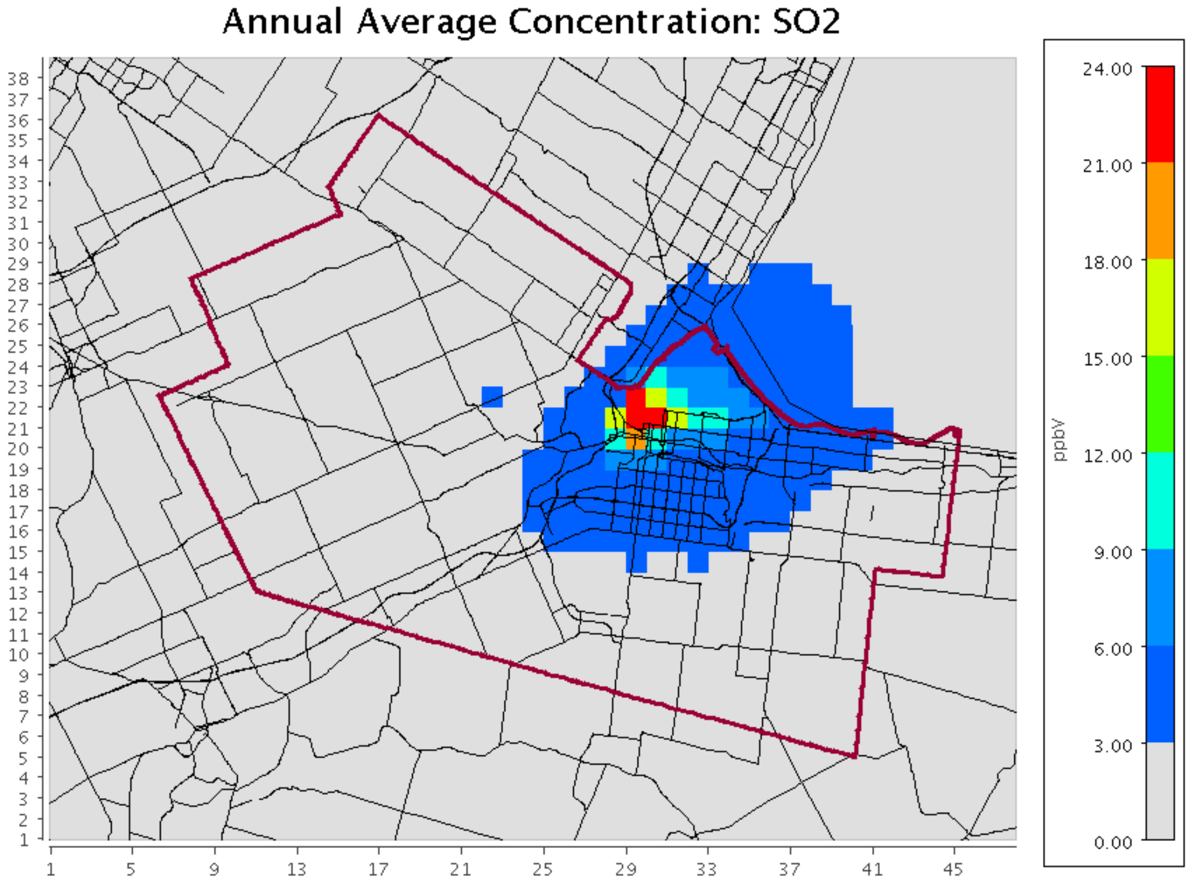
Air Quality Modelling Results: NO_2



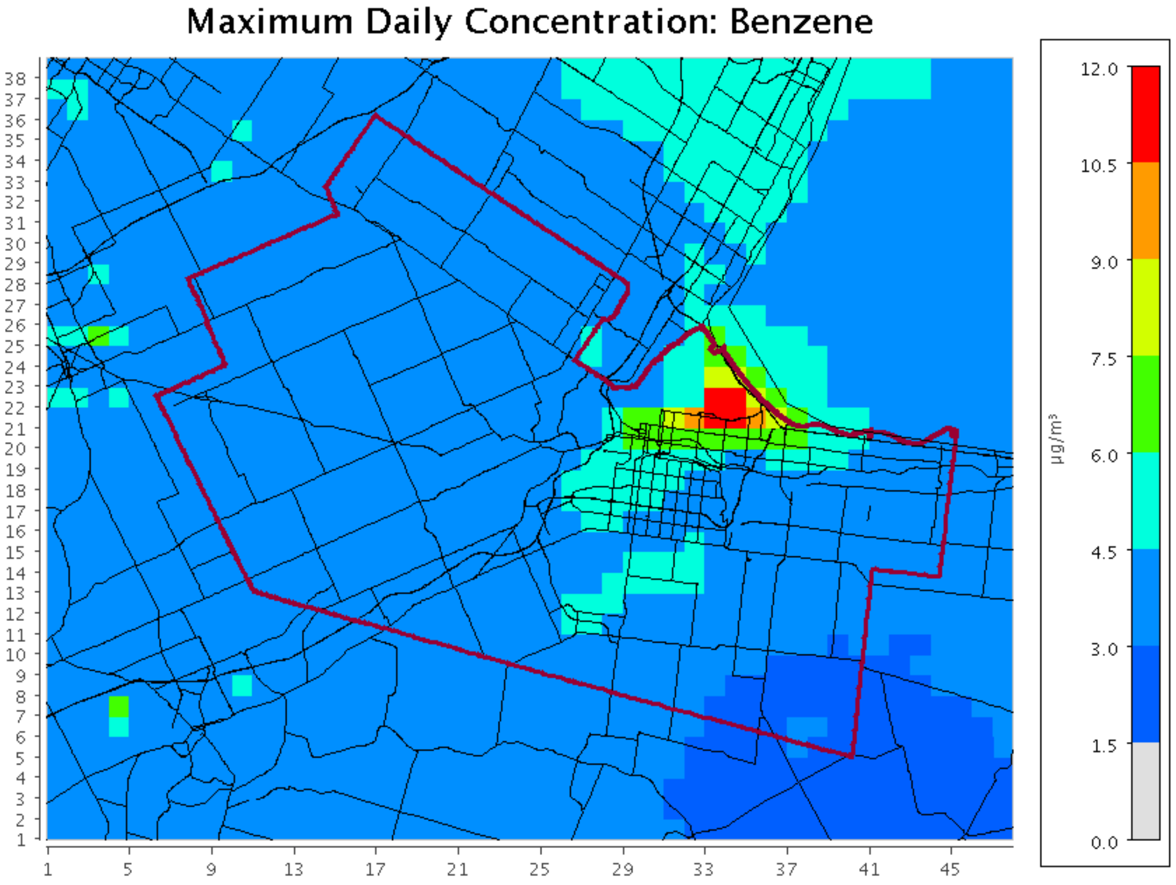


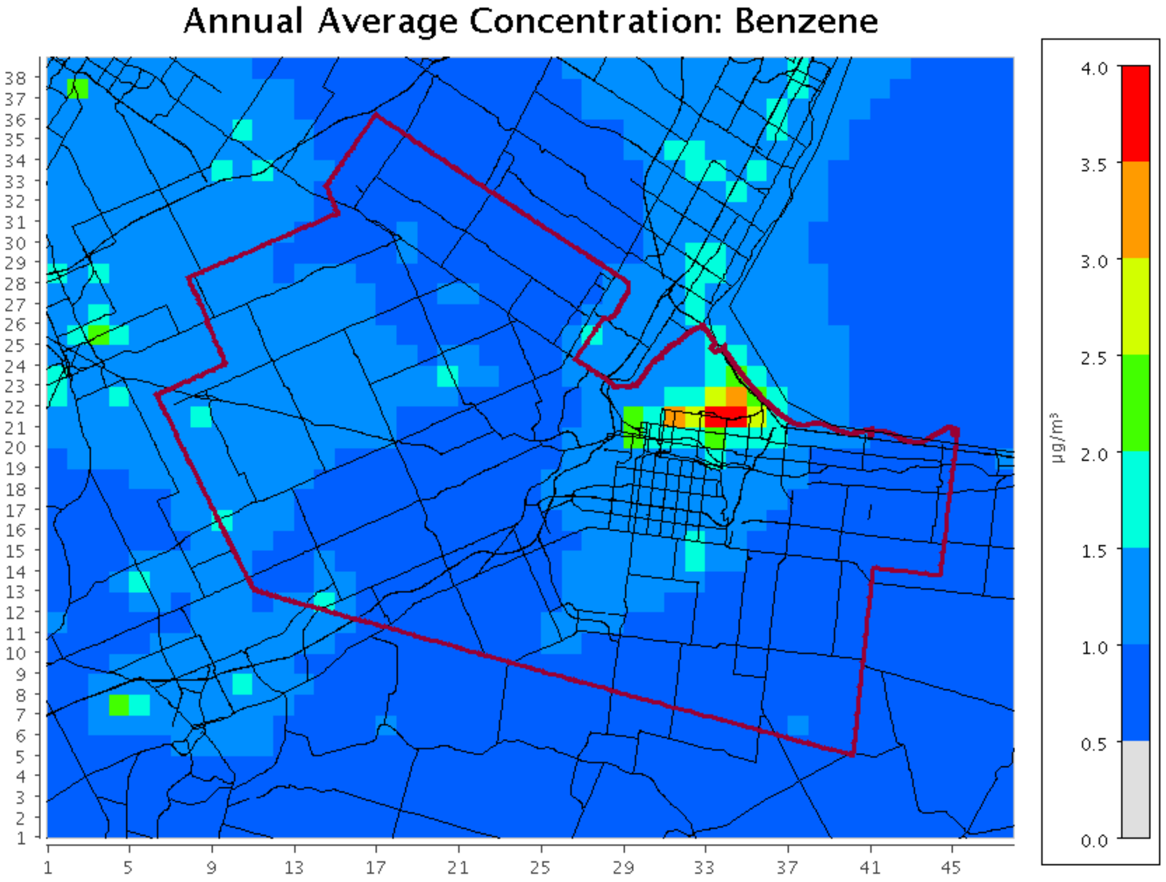
Air Quality Modelling Results: SO_2





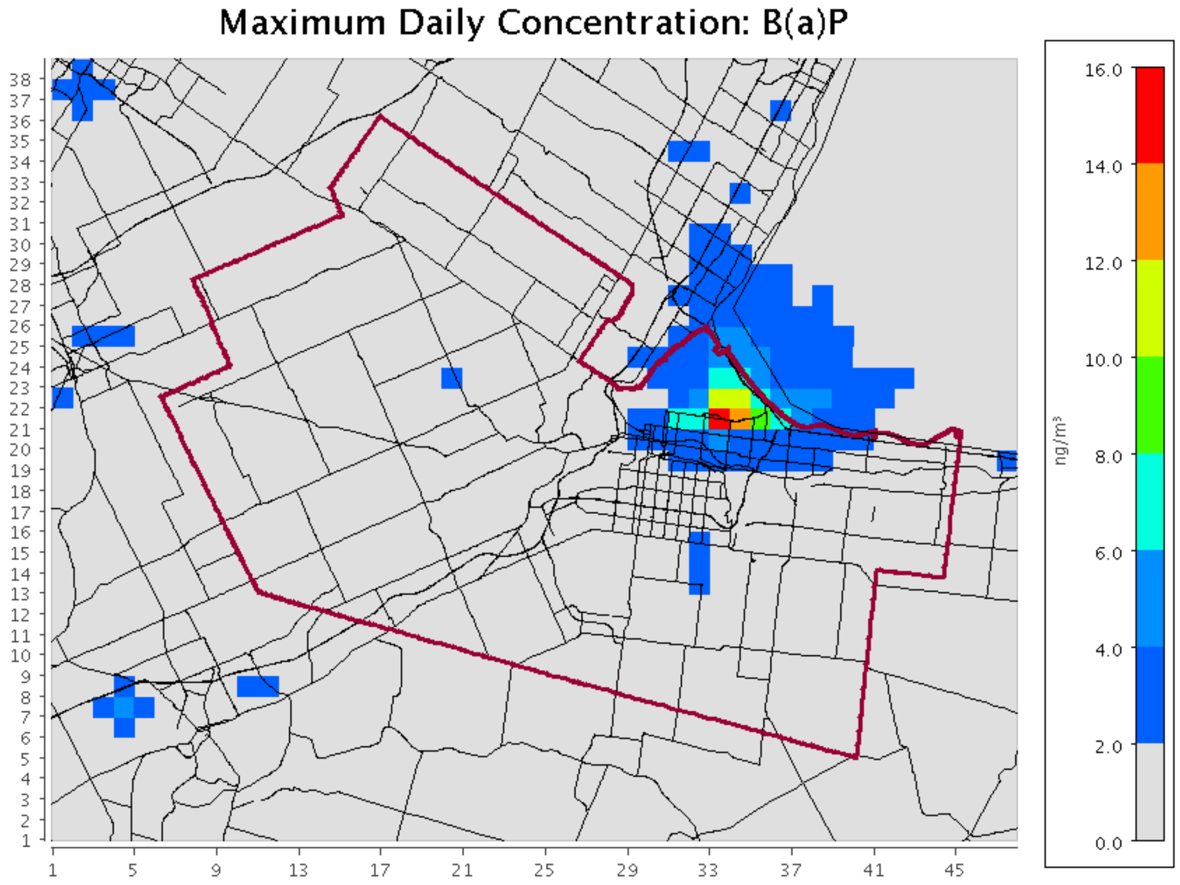
Air Quality Modelling Results: Benzene

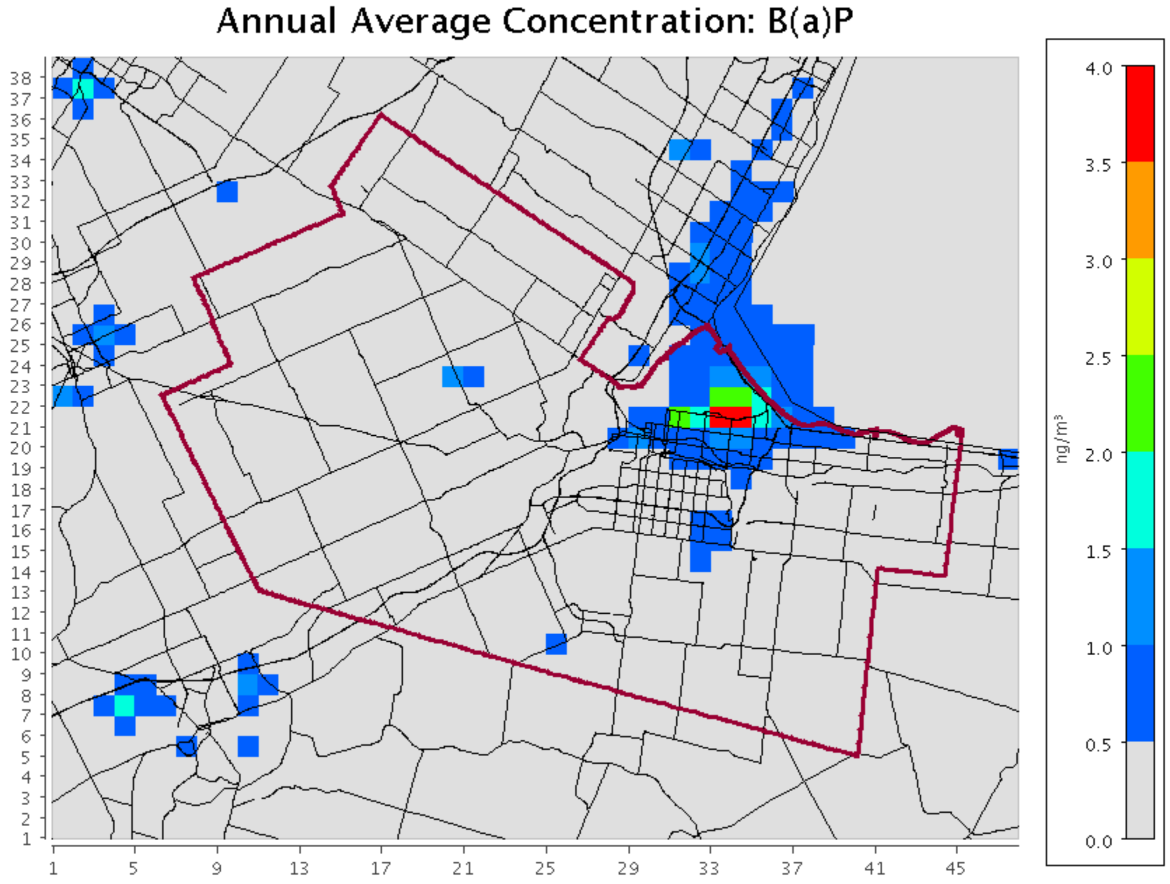




GOLDER

Air Quality Modelling Results: 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

GOLDER

Hamilton Airshed Modelling System (HAMS)

Recommendations

1. That staff work with Golder Associates to undertake sub-region analyses using the Hamilton Airshed Modelling System, and in consultation with key stakeholders and affected residents;

2. That staff examine the feasibility of using HAMS to estimate morbidity and mortality outcomes associated with air pollution and report back to Board of Health, if necessary;

3. That the Board of Health direct Public Health Services’ staff to work with City of Hamilton Planning staff to review the HAMS analysis and determine appropriate applications for planning directions and decisions and report back to Planning Committee in Q1 2019;

Hamilton Airshed Modelling System (HAMS)

Recommendations

4. That the Board of Health request the Ministry of Environment and Climate Change (MOECC) work with the City of Hamilton, other Ontario municipalities and levels of government regarding traffic-related air pollutants (TRAPs) to address transboundary transportation contributions impacting the City of Hamilton;

5. That the Board of Health advocate that the province of Ontario adopt the 24-hour Canadian Ambient Air Quality Standard for fine particulate matter (PM 2.5) of 28 micrograms per cubic metre of air (28 µg/m3) as air quality benchmarks for the maximum desirable concentration of particulate matter in the City of Hamilton; and

6. Support the Ministry of the Environment and Climate Change (MOECC) in their proposal for a new policy focusing on Cumulative Effects Assessment (CEA) in air approvals: "to more effectively consider cumulative impacts from multiple air pollution sources - both industrial and non-industrial" to address air quality issues in the City of Hamilton.

Ministry of Health and Long-Term Care

Child Visual Health and Vision Screening Protocol, 2018

Population and Public Health Division,
Ministry of Health and Long-Term Care

Effective: January 1, 2018 or upon date of release

Ontario

Preamble

The Ontario Public Health Standards: Requirements for Programs, Services, and Accountability (Standards) are published by the Minister of Health and Long-Term Care under the authority of section 7 of the *Health Protection and Promotion Act* (HPPA) to specify the mandatory health programs and services provided by boards of health.[1,2] The Standards identify the minimum expectations for public health programs and services. Boards of health are accountable for implementing the Standards including the protocols and guidelines that are referenced in the Standards. Protocols are program and topic-specific documents incorporated into the Standards which provide direction on how boards of health shall operationalize specific requirement(s) identified within the Standards.

Purpose

The purpose of this protocol is to provide direction to boards of health on child visual health and **vision screening**[*] services to be offered in the school setting.

Reference to the Standards

This section identifies the standard and requirement to which this protocol relates.

School Health

Requirement 7. The board of health shall provide, in collaboration with community partners, visual health supports and vision screening services in accordance with the *Child Visual Health and Vision Screening Protocol, 2018* (or as current).

Operational Roles and Responsibilities

Pre-Screen Notification

1) In preparation for the school vision screening, the board of health shall:
   a) Coordinate with schools to make prior arrangements regarding the screening dates, time and locations;
   b) Ensure that notification is provided to parents/guardians of children in Senior Kindergarten (SK) at least 10 business days before school vision screening is scheduled to take place. This notification shall include information on:
      i) The statutory authority under which vision screening is conducted;
      ii) The purpose of vision screening;
      iii) The screening processes, including clarification that vision screening is non-invasive;
      iv) Post-screening notification to parents/guardians;

[*] Terms marked in **bold** are defined in the Glossary.

v) The process parents/guardians should follow if they wish to opt out from vision screening; and
vi) A contact name and telephone number parents/guardians may call if they require additional information.

c) Confirm that pre-screen notifications have been sent to parents/guardians; and
d) Reschedule the screening if pre-screen notifications have not been sent to parents/guardians before vision screening is scheduled to take place.

Vision Screening

2) The board of health shall:
   a) Provide, or ensure the provision of vision screening by trained individual(s), as specified by the ministry, for SK students in all schools annually.
   b) Use vision screening tools, training, and methods as specified by the ministry for the purposes of identifying some risk factors for the following:
      i) **Amblyopia**;
      ii) Reduced **stereopsis** and/or **strabismus**;
      iii) **Refractive vision disorder**.
   c) Provide, or ensure the provision of vision screening at an alternate location as soon as reasonably possible, when requested by a parent/guardian and/or assist families in accessing an optometrist for a **comprehensive eye examination**.

Post-Screening Notification and Follow-Up

3) The board of health shall:
   a) Notify the parents/guardians of children who have been screened and identified in need of visual health services and/or treatment within two business days of completing the screening. This notification shall be by mail, telephone discussion, direct contact, or by electronic communication where available, and shall include issuing a Parent Notification Form-A (PNF-A). This form shall include a referral to an optometrist for a comprehensive eye exam.
      i) The board of health shall provide a reminder letter to all parents/guardians of children identified in need of visual health services and/or treatment within 20 business days of the date of screening, to book an appointment with an optometrist for a comprehensive eye examination.
   b) Notify the parents/guardians of all other children who have been screened. This notification shall be by mail, telephone discussion, direct contact, or by electronic communication where available, and shall include issuing a Parent Notification Form-B (PNF-B). This notification shall encourage parents/guardians to book an appointment with an optometrist for a comprehensive eye exam.

Visual Health Navigation

4) To support awareness of, access to, and utilization of visual health services, the board of health shall:

a) Support children and their families to improve their awareness about visual health, including the importance of early identification of vision disorders, through health promotion and targeted outreach to priority populations and/or communities;
b) Promote awareness of school-based vision screening, OHIP-covered comprehensive eye examinations, and available visual health services through health promotion and targeted outreach to priority populations and/or communities;
c) Utilize referral networks in order to assist families in accessing an optometrist to conduct a comprehensive eye examination;
d) Assist families with accessing appointments and treatment as needed; and
e) Increase awareness of available visual health services among community partners and providers.

Data Collection and Analysis

5) The board of health shall:
   a) Collect and record vision screening data as specified by the ministry as screening occurs or at the first opportunity post-screening; and
   b) Analyze and interpret vision screening data as specified by the ministry.

Glossary

Amblyopia: The medical term used when vision is reduced and not correctible to a normal level with optical devices. This condition is also sometimes called “lazy eye”. There are a variety of causes of amblyopia, including strabismus and anisometropia.”.[3-6]

Comprehensive Eye Examination/Periodic Oculo-Visual Assessment: As set out in the *Schedule of Benefits*, a comprehensive eye exam/periodic oculo-visual assessment is an assessment of the eye and vision system that includes: the diagnosis, treatment and prevention of disorders of refraction, sensory and oculomotor disorders and dysfunctions of the eye and vision system, and eye disease. This service includes all components required to perform the assessment (ordinarily a history of the presenting complaint, past medical history, visual acuity examination, ocular mobility examination, slit lamp examination of the anterior segment, ophthalmoscopy, tonometry) advice and/or instruction to the patient and provision of a written refractive prescription if required.[7]

Refractive Vision Disorder: A vision disorder in which the shape of the eye prevents a person from focusing well. The cause could be the length of the eyeball (longer or shorter), or changes in the curvature of the cornea or the lens. Common refractive errors are:

- Myopia, or nearsightedness: A disorder where there is clear vision close-up, but blurriness in the distance;
- Hyperopia, or farsightedness: A disorder in which distant objects can be seen clearly, but close ones do not come into proper focus;

- Presbyopia: A disorder where there is an inability to focus close-up as a result of aging;
- Anisometropia: A difference in refraction between the two eyes; and
- Astigmatism: A disorder caused by abnormality in the curvature of the cornea and/or the lens.[3-6]

Stereopsis: The ability to visually recognize depth based on differences in the images created on the two eyes. Stereoacuity is a measure of the smallest difference in the two images that can be resolved as a single image in depth.[6]

Strabismus: A disorder in which both eyes do not line up in the same direction, so they do not look at the same object at the same time. It is characterized by the misalignment of the visual axes of the eyes that affects **binocular vision** and depth perception. This results in one or both eyes turning inwards, outwards or upwards. The condition is more commonly known as "eye turn". A common form of strabismus is esotropia (the in-turning of one or both eyes).[3-6]

Vision Screening: A relatively short sequence of tests that can detect some potential risk factors of certain vision disorders. A vision screening cannot diagnose vision disorders nor is it a replacement for a comprehensive eye examination conducted by an optometrist. Vision screenings may indicate when a referral to an optometrist is necessary, but a comprehensive eye exam is a more fulsome assessment of the eye and vision system.[3-4,6]

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ISBN 978-1-4868-0771-0 (PDF) Queen's Printer of Ontario

Ministry of Health and Long-Term Care

Health Equity Guideline, 2018

Population and Public Health Division,
Ministry of Health and Long-Term Care

Effective: January 1, 2018 or upon date of release

Ontario

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1 Preamble

The Ontario Public Health Standards: Requirements for Programs, Services, and Accountability (Standards) are published by the Minister of Health and Long-Term Care under the authority of section 7 of the *Health Protection and Promotion Act* (HPPA) to specify the mandatory health programs and services provided by boards of health.[1,2] The Standards identify the minimum expectations for public health programs and services. Boards of health are accountable for implementing the Standards including the protocols and guidelines that are referenced in the Standards. Guidelines are program and topic-specific documents which provide direction on how boards of health shall approach specific requirement(s) identified within the Standards.

2 Purpose

This Guideline is intended to assist boards of health in implementing the requirements established in the Health Equity Standard within their processes for planning, implementation, and evaluation. It establishes the minimum expectations for strategies and approaches that boards of health shall consider. Content is organized as follows:

- Sections 1 Preamble, 2 Purpose, and 3 References to the Standards provide a brief orientation to this guideline.
- Section 4 Context provides a high-level introduction to health equity, and a brief overview of key concepts and frameworks to inform public health practice.
- Section 5 Roles and Responsibilities identifies core links between requirements for health equity and related requirements in the foundational and program standards.
- Section 6 Required Approaches outlines required approaches that boards of health shall consider in implementing the *Health Equity Standard*. This includes considerations for assessing and reporting on population health, modifying and orienting public health interventions, engaging in multi-sectoral collaboration, and advancing healthy public policies.

Approaches to board of health engagement with Indigenous communities and organizations share many common factors with a health equity approach. However, there are many different Indigenous communities across the province, including many different First Nation governments, each with their own histories, cultures, organizational approaches, and jurisdictional realities that need to be considered. These relationships must be fostered in a culturally safe way, building on trust, mutual respect, understanding, and reciprocity, and are well served by the provision of a separate guideline. Where appropriate, references will be made throughout this Guideline to related advice within the *Relationship with Indigenous Communities Guideline, 2018* (or as current), as well as other relevant protocols and guidelines under the Standards.

3 Reference to the Standards

This section identifies the standards and requirements to which this guideline relates.

Health Equity Standard

Requirement 1. The board of health shall assess and report on the health of local populations describing the existence and impact of health inequities and identifying effective local strategies that decrease health inequities in accordance with the *Health Equity Guideline, 2018* (or as current) and the *Population Health Assessment and Surveillance Protocol, 2018* (or as current).

Requirement 2. The board of health shall modify and orient public health interventions to decrease health inequities in accordance with the *Health Equity Guideline, 2018* (or as current), and by:

a) Engaging priority populations in order to understand their unique needs, histories, cultures, and capacities; and
b) Designing strategies to improve the health of the entire population while decreasing the health inequities experienced by priority populations.

Requirement 3. The board of health shall engage in multi-sectoral collaboration with municipalities, LHINs, and other relevant stakeholders in decreasing health inequities in accordance with the *Health Equity Guideline, 2018* (or as current). Engagement with Indigenous communities and organizations, as well as with First Nation communities striving to reconcile jurisdictional issues, shall include the fostering and creation of meaningful relationships, starting with engagement through to collaborative partnerships, in accordance with the *Relationship with Indigenous Communities Guideline, 2018* (or as current).

Requirement 4. The board of health shall lead, support, and participate with other stakeholders in health equity analysis, policy development, and advancing healthy public policies that decrease health inequities in accordance with the *Health Equity Guideline, 2018* (or as current).

4 Context

This section provides a high-level introduction to **health equity**,* along with an overview of key concepts and frameworks that boards of health shall consider to inform planning, implementation, and evaluation of health equity within public health practice. In order to support the establishment of a common understanding of health equity throughout Ontario's public health sector, additional terms and concepts are defined in the Glossary. Health equity must be grounded in an understanding of a particular **community's** values, identities, and lived experiences, as well as the economic, social, environmental, and

* Terms marked **in bold** are defined the Glossary.

political context, in order to be inclusive and responsive to diverse partners and community members.

Health equity means that all people can reach their full health potential without disadvantage due to social position or other socially determined circumstance, such as ability, age, culture, ethnicity, family status, gender, language, race, religion, sex, social class, or socioeconomic status.[3]

Systemic differences in health status exist across population groups, and these are often referred to as health inequities. **Health inequities** are health differences that are:

- Systematic, meaning that health differences are patterned, where health generally improves as socioeconomic status improves;
- Socially produced, and therefore could be avoided by ensuring that all people have the social and economic conditions that are needed for good health and **well-being**; and
- Unfair and/or unjust because opportunities for health and well-being are limited.[3]

Health is influenced by a broad range of factors, including social determinants that affect the conditions in which individuals and communities live, learn, work, and play. At the provincial level, health equity is linked to the following key **social determinants of health**:[4,5]

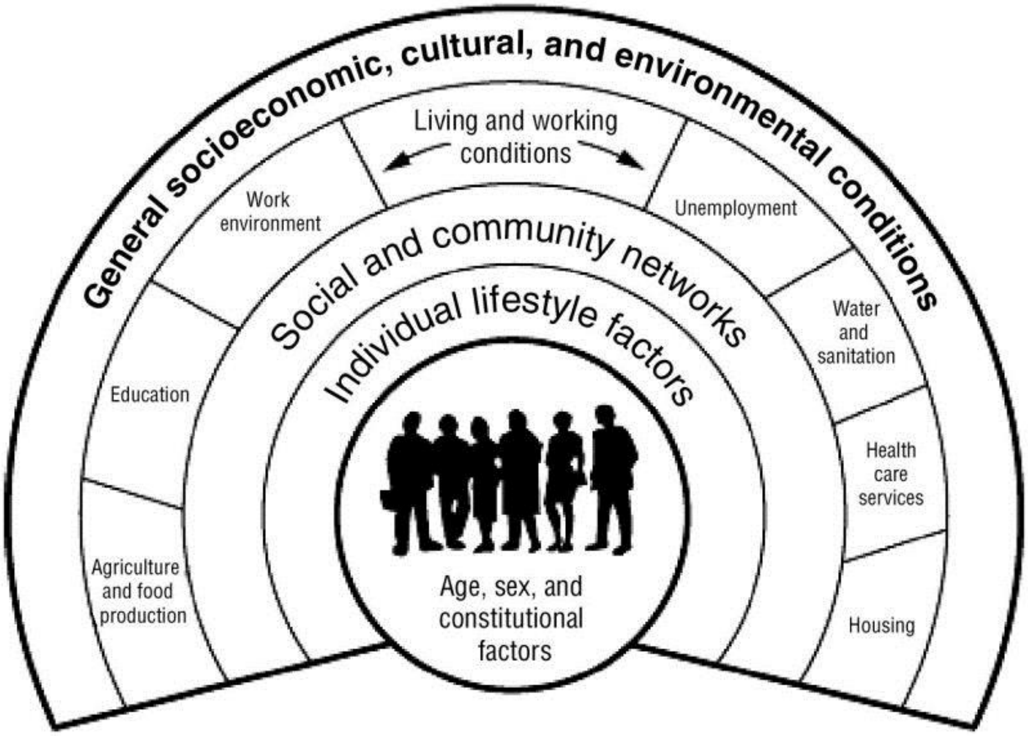
Table 1: Key Social Determinants of Health

- Access to health services
- Culture, race, and ethnicity
- Disability
- Early childhood development
- Education, literacy, and skills
- Employment, job security, and working conditions
- Food insecurity
- Gender identity and expression
- Housing
- Income and income distribution
- Indigenous status
- Personal health practices and **resiliency**
- Physical environments
- Sexual orientation and attraction
- Social inclusion/exclusion
- Social support networks

Individuals, communities, and populations may experience these factors differently based on social or economic conditions, putting some at a disadvantage and greater susceptibility to poor health outcomes. Reducing the negative impact of social determinants that contribute to health inequities is fundamental to the work of public health. The *Wider Determinants of Health Model* (Figure 1) below illustrates how various health-influencing factors are embedded within the broader aspects of society.[6]

Additional frameworks for consideration may be found in the Canadian Council on the Determinants of Health's "A Review of Frameworks on the Determinants of Health."[7]

Figure 1: Wider Determinants of Health Model



Used under terms of license[6]

Evidence-based “upstream" approaches to health—those that address people's access to the social determinants of health—are imperative to decreasing health inequities (see Table 2). A health equity approach applies to all levels, with interventions tailored to the needs and **assets** of locally-identified **priority populations**.

Table 2: Levels of Interventions[8]

Upstream Interventions	Midstream Interventions	Downstream Interventions
Seek to reform the fundamental social and economic structures that distribute wealth, power, opportunities, and decision-making. These changes generally happen at the macro policy level: national and transnational. ***They are about diminishing the causes-of-the-causes.***	Seek to reduce exposure to hazards by improving material working and living conditions, or to reduce risk by promoting healthy behaviours. These changes generally occur at the micro policy level: regional, local, community or organizational. ***They are about changing the causes.***	Seek to increase equitable access, at an individual level, to health and social services. These changes generally occur at the service or access to service level. ***They are about changing the effects of the causes.***

5 Roles and Responsibilities

Boards of health are required to engage in public health practice that results in decreased health inequities such that everyone has equal opportunities for optimal health and can attain their full health potential without disadvantage due to social position or other socially determined circumstances. As goals and outcomes related to health equity are established in a foundational standard, as well as within the overarching Policy Framework for the Standards, boards of health are responsible for applying a health equity approach systematically, as an integral part of all aspects of their work.

In addition to the specific requirements of the *Health Equity Standard*, which are addressed directly in Section 6 of this guideline, the foundational standards on *Population Health Assessment* and *Effective Public Health Practice* outline requirements that are relevant to the topic of health equity, including the following:

- Under the *Population Health Assessment Standard*, boards of health are required to assess and report on the health of local populations, which includes assessing health inequities and social determinants of health, priority populations and demographic indicators, **risk and protective factors**, and other information relevant to public and **population health**.
- Under the *Effective Public Health Practice Standard*, boards of health are required to employ public health practice that is transparent, responsive to current and emerging evidence, and which emphasizes continuous quality improvement. This requirement supports awareness among public health practitioners, policy-makers, community partners, and health care providers of the factors that determine the health of the population, which includes factors relating to health equity and the social determinants of health.

Additionally, board of health roles and responsibilities for health equity apply holistically to the planning, implementation, and evaluation of all public health services and **programs of public health interventions**. Various program standards articulate additional requirements relating to the overarching goal of reducing health inequities, and program/topic-specific guidance regarding required approaches is provided in corresponding protocols and guidelines.

6 Required Approaches

This section provides an overview of the approaches that boards of health shall consider, at minimum, when implementing the requirements established in the foundational *Health Equity Standard*. Board of health decision-making and prioritization regarding health equity shall be guided by the four principles established by the overarching Policy Framework: Need; Impact; Capacity; and Partnership, Collaboration, and Engagement.

As a foundational standard, health equity represents a cross-cutting vision and fundamental philosophy to guide public health practice in Ontario. It is recognized that the public health sector is one of many contributors to health equity, and action across multiple sectors is required in order to fully realize this vision.

In order to operationalize the four requirements under the *Health Equity Standard*, boards of health shall apply a health equity approach to continuously identify and address systemic and institutional factors affecting health equity, including the underlying causes. Boards of health shall apply a health equity approach within all aspects of their work, including processes for community inclusion and engagement, training, planning, implementation, and evaluation, by:

- Recognizing how the social determinants of health, and their root causes, influence the distribution of health and well-being across communities;[9]
- Seeking opportunities to address population diversity when planning, implementing, adapting, and evaluating public health programs and policies;[9]
- Enhancing capacity to apply **anti-racist**, **anti-oppressive**, and **culturally safe** approaches to public health practice;[9-12]
- Fostering organizational capacity for health equity action; [13]
- Planning and implementing public policy approaches to support health equity;
- Undertaking **community engagement** and inter-sectoral action strategies to address health inequities;
- Considering the use of performance management and quality improvement principles to continuously improve policies, processes, programs, and services that advance health equity; and
- Promoting the use of health equity tools for assessment, audit, program planning, and evaluation.

6.1 Assessing and Reporting

Requirement #1 of the *Health Equity Standard* requires boards of health to assess and report on the health of local populations[†] describing the existence and impact of health inequities and identifying effective local strategies that decrease health inequities.

In operationalizing this requirement, and in alignment with board of health requirements under the *Population Health Assessment Standard*, boards of health shall:

- Employ relevant assessment and surveillance tools for health equity, to identify and communicate the needs and assets of priority populations;
- Seek opportunities to conduct or participate in local or provincial evaluation studies, or research on new and existing public health programs and services developed and implemented for priority populations;
- Seek opportunities to engage priority populations in the design and implementation of assessment, surveillance, research, and evaluation processes, including the collection, maintenance, and disposition of data.

[†]For guidance on assessing and reporting on population health, refer to the *Population Health Assessment and Surveillance Protocol*, *2018* (or as current).

- Distribute and/or make available to the public, as appropriate, population health assessment and surveillance information products with respect to health equity, in accordance with the *Population Health Assessment and Surveillance Protocol, 2018* (or as current).

6.2 Modifying and Orienting Public Health Interventions

Requirement #2 of the *Health Equity Standard* requires boards of health to modify and orient public health interventions to decrease health inequities by:

a) Engaging priority populations in order to understand their unique needs, histories, cultures, and capacities; and
b) Designing strategies to improve the health of the entire population while decreasing the health inequities experienced by priority populations.

In operationalizing this requirement, boards of health shall consider alignment with related requirements under the *Effective Public Health Practice Standard*, as referenced above.

6.2.1 Engaging Priority Populations

In operationalizing the requirement to engage priority populations in order to understand their unique needs, histories, cultures, and capacities, boards of health shall consider the ways in which these communities experience the root causes of health inequities that affect the social determinants of health.

Informed by principles of anti-oppressive practice and cultural safety, boards of health shall develop and implement strategies to engage priority populations in the planning, implementation, and evaluation of public health programs and services, in order to advance health equity. The board of health shall employ community engagement frameworks and approaches that are informed by evidence and best practice, and are responsive to local needs and assets. In particular, community engagement strategies shall be guided by the following principles:

- Sustainable community engagement is supported and promoted by encouraging local communities to get involved in all stages of public health planning, implementation, and evaluation;
- Relationships are built on trust, commitment, leadership, and capacity across local communities, recognizing that relationship building is a continuous process that takes time;
- Decision-making groups include members of local communities who reflect the diversity of those communities; and
- The results of community engagement are reported back to the local communities concerned, as well as other partners.[13,15]

For guidance on required approaches to engaging First Nations and Indigenous communities, refer to the *Relationship with Indigenous Communities Guideline*, *2018* (or as current).

6.2.2 Designing Strategies to Improve the Health of the Entire Population while Decreasing Health Inequities

In operationalizing the requirement to design strategies to improve the health of the entire population while decreasing health inequities, boards of health shall:

- Apply the concept of proportionate universalism within all processes for planning, implementation, and evaluation. **Proportionate universalism** is an approach that can be used to address the **health gap** and **health gradient** by making health actions or interventions available to the whole population, but with a scale, intensity, and delivery that is proportionate to the level of need and disadvantage in specific populations. It balances **targeted** and **universal** population health perspectives and recognizes that programs, services, and policies must include a range of responses that address varying needs, assets, and the social determinants of health.[16,17] While some programs are universal (e.g., immunization), there will be groups within the general population that require additional resources and targeted actions to fully realize the intended health benefit.
- Employ the most appropriate tools, processes, and resources for health equity assessment within the local context, such as health impact assessments (HIA), equity focused health impact assessments (EFHIA), health equity impact assessments (HEIA), situational assessments, and health equity audits (HEA).

6.3 Engaging in Multi-Sectoral Collaboration

Requirement #3 of the *Health Equity Standard* requires boards of health to engage in multi-sectoral collaboration with municipalities, LHINs, and other relevant stakeholders in decreasing health inequities. As many factors and upstream interventions for addressing health equity and the social determinants of health lie outside the purview of the public health sector, it is particularly important that stakeholders and partners across multiple sectors be engaged to contribute to effective local strategies that decrease health inequities.

In operationalizing this requirement, and in alignment with the *Effective Public Health Practice Standard,* boards of health shall engage relevant partners in the health and non-health sectors. The board of health shall also consider effective stakeholder engagement strategies such as:

- Establishing and participating in collaborative partnerships and coalitions which address public health issues and social determinants with:
  - Key health sector partners, including but not limited to: LHIN(s), hospital administrators, long-term care facility administrators, community health centre administrators; and
  - Non-health sector partners, including but not limited to: community planning organizations, school boards, social housing authorities, labour organizations, grassroots and civic organizations, children and youth services, and local chambers of commerce.

- Establishing relationships with schools of public health and/or other related academic programs to promote collaborative research projects and knowledge exchange activities that advance the evidence and knowledge base for health equity; and
- Monitoring and evaluating these partnerships to determine their effectiveness and identify and address gaps.

Additional partner-specific considerations for addressing health equity are articulated in the relevant protocols and guidelines, such as the *Board of Health and Local Health Integration Network Engagement Guideline, 2018* (or as current) and the *Relationship with Indigenous Communities Guideline, 2018* (or as current).

6.4 Health Equity Analysis, Policy Development, and Advancing Healthy Public Policies

Requirement #4 of the *Health Equity Standard* requires boards of health to lead, support, and participate with other stakeholders in health equity analysis, policy development, and advancing healthy public policies that decrease health inequities.

In operationalizing this requirement, and in alignment with the *Effective Public Health Practice Standard,* boards of health shall engage in various forms of research, knowledge exchange, and communication modalities regarding factors that determine the health of the local population, including consideration of the following actions:

- Gathering and disseminating data;
- Developing health reports and policy statements that address social determinants of health and health inequities experienced by local priority populations;
- Providing the health and health equity context to the analysis of local issues;
- Participating in partnerships/coalitions organized to advance specific policy issues to decrease health inequities;
- Identifying organizational and community-level enablers and barriers to policy change; and
- Assessing and/or supporting the use of assessments and tools to evaluate the health impact of all policies with a health equity approach.

Additional guidance to support public health practice in advancing healthy public policies may be found in Public Health Ontario's "At a Glance: The Eight Steps to Developing a Healthy Public Policy," or the World Health Organization's "Health in All Policies: Helsinki Statement; Framework for Country Action."[18,19]

Glossary

Anti-colonialism/decolonization refers to a movement or approach that seeks to disrupt, dismantle, and unlearn colonialist structures and processes in support of Indigenous sovereignty and self-determination, which has been cited as the most important determinant of health among Indigenous peoples.[20,21]

Anti-oppressive practice refers to the strategies, theories, actions, and practices that seek to recognize the systems of privilege and oppression that exist in society, to actively mitigate their effects, and to equalize power imbalances over time.[9] This requires individuals and institutions to acknowledge and accept responsibility for their role in perpetuating oppression, whether intentionally or unconsciously.

Anti-racism is an active approach to identifying, challenging, and changing the systems, behaviours, and values that uphold racism at all levels of society. It "is intended to promote an equitable society in which people do not face discrimination on the basis of their actual or perceived race, however defined".[21]

Bias refers to ingrained ideas, prejudices, stereotypes, and assumptions that we are often unaware. These ideas influence our perceptions, expectations, judgments, and behaviours. All people have biases which are developed through socialization and personal experience.

Colonialism refers to "a process that includes geographic incursion, socio-cultural dislocation, the establishment of external political control and economic dispossession, the provision of low-level social services, and ultimately, the creation of ideological formulations around race and skin colour that position the colonizer at a higher evolutionary level that the colonized." "While neo-colonialism detrimentally influences the health of contemporary Indigenous peoples, historic, successively traumatic events continue to affect generations through what has been referred to as 'historic or cultural trauma'". Colonialism impacts the health of Indigenous peoples by producing social, political, and economic inequalities that 'trickle down' through the construction of unfavourable intermediate and proximal determinants.[20-23]

Community refers to "a group of people who have common characteristics or interests. Communities can be defined by: geographic location, race, ethnicity, age, occupation, a shared interest or affinity (such as religion and faith) or other common bonds, such as health need or disadvantage."[24]

Community assets "include not only buildings and facilities but also people, with their skills, knowledge, social networks, and relationships."[24]

Community engagement "is a process, not a program. It is the participation of members of a community in assessing, planning, implementing, and evaluating solutions to problems that affect them. As such, community engagement involves interpersonal trust, communication, and collaboration. Such engagement, or participation, should focus on, and result from, the needs, expectations, and desires of a community's members."[25]

Comprehensive health promotion approach applies diverse strategies and methods in an integrated manner—one of the preconditions for health promotion to be effective. Health promotion addresses the key action areas identified in the Ottawa Charter in an integrated and coherent way.

Cultural safety refers to “an environment which is safe for people: where there is no assault, challenge or denial of their identity, of who they are and what they need.” Cultural safety is conceptualized on a continuum that begins with unsafe practises, moving to cultural competence, and culminating in culturally safe practices that account for the role and consequence of power in relationships between providers and communities, and in which the needs and voices of communities take a prominent role.[11,12,26]

Health equity means that all people can reach their full health potential and are not disadvantaged from attaining it because of their race, ethnicity, religion, gender, age, social class, socioeconomic status or other socially determined circumstance.[3]

Health gap refers to the difference between those who are most and least healthy in a society.[27]

Health gradient refers to the consistent pattern formed by the health gap at every step of the socioeconomic spectrum, where those with higher status are healthier than those below them.[27]

Health inequity is a sub-set of health inequality and refers to differences in health associated with social disadvantages that are modifiable, and considered unfair.[3]

Intersectionality recognizes that individuals and communities must be related to as complex and heterogeneous, rather than one dimensional.[21] It acknowledges that identities and forms of oppression intersect to produce unique and often unpredictable experiences, as one form of oppression can be shaped by and influence another.[28] Additionally, one individual or community’s experiences of privilege and oppression can shift over time and in different contexts.

Oppression refers to institutionalized power that is historically formed over time. It allows certain groups to assume a dominant or privileged position over other groups and identities, either knowingly or unconsciously, and this dominance is maintained and continued at individual/interpersonal, cultural, and structural/institutional levels.[9,29,30]

Population health is the health of the population, measured by health status indicators. Population health is influenced by physical, biological, behavioural, social, cultural, economic, and other factors. The term is also used to refer to the prevailing health level of the population, or a specified subset of the population, or the level to which the population aspires. Population health describes the state of health, and public health is the range of practices, procedures, methods, institutions, and disciplines required to achieve it. The term also is used to describe the academic disciplines involved in studies of determinants and dynamics of health status of the population.[31]

Priority populations are those that are experiencing and/or at increased risk of poor health outcomes due to the burden of disease and/or factors for disease; the determinants of health, including the social determinants of health; and/or the intersection between them. They are identified by using local, provincial, and/or federal data sources; emerging trends and local context; community assessments; surveillance; and epidemiological and other research studies.

Privilege refers to unearned power that gives members of a dominant group economic, social, and political advantages.[29,30]

Program of public health interventions includes the suite of programs, services, and other interventions undertaken by a board of health to fulfill the requirements and contribute to achieving the goals and program outcomes outlined in the Standards.

Proportionate universalism is an approach that balances targeted and universal population health perspectives. This approach makes health actions or interventions available to the whole population, but with a scale, intensity and delivery that is proportionate to the level of need and disadvantage in particular populations.

Racialization refers to the social processes that construct racial categories as "real, different and unequal in ways that matter to economic, political and social life".[32] Racialization is often based on perceived differences in anatomical, cultural, ethnic, genetic, geographical, historical, linguistic, religious, and/or social characteristics and affiliations.

Racism refers to a set of individual, cultural, and institutional beliefs and practices that seeks to construct social differences between groups of people in order to subordinate and oppress one group for the benefit of another.[33-35]

Resiliency refers to the ability of an individual or community to effectively manage or cope with adversity or stress in ways that are not only effective, but increase their ability to respond to future adversity and enable them to thrive.[36]

Risk and protective factors are variables that can be present at the individual, interpersonal, community, and societal levels and that impact mental health and resiliency.[37] **Protective Factors** are determinants that affect health in a positive way. They help with maintaining good health, and can assist in effective management of health conditions.[38] **Risk Factors** are determinants that affect health in a negative way. They can increase the likelihood of developing chronic diseases, or hinder in the management of existing conditions.[38]

Social determinants of health are the interrelated social, political and economic factors that create the conditions in which people live, learn, work and play. The intersection of the social determinants of health causes these conditions to shift and change over time and across the life span, impacting the health of individuals, groups and communities in different ways.[39]

Targeted approaches use selection criteria, such as income, neighbourhood, health, or employment status, to target eligibility and access to programs and services to priority sub-groups within the broader population.[27]

Universal approaches are programs and services that are available to the whole population.[27]

Well-being refers to “the presence of the highest possible quality of life in its full breadth of expression focused on but not necessarily exclusive to: good living standards, robust health, a sustainable environment, vital communities, an educated populace, balanced time use, high levels of democratic participation, and access to and participation in leisure and culture.”[40]

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Ministry of Health and Long-Term Care

Healthy Environments and Climate Change Guideline, 2018

Population and Public Health Division,
Ministry of Health and Long-Term Care

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Ontario

Preamble

The Ontario Public Health Standards: Requirements for Programs, Services, and Accountability (Standards) are published by the Minister of Health and Long-Term Care under the authority of section 7 of the *Health Protection and Promotion Act* (HPPA) to specify the mandatory health programs and services provided by boards of health.[1,2] The Standards identify the minimum expectations for public health programs and services. Boards of health are accountable for implementing the Standards including the protocols and guidelines that are referenced in the Standards. Guidelines are program and topic-specific documents which provide direction on how boards of health shall approach specific requirement(s) identified within the Standards.

Purpose

The Healthy Environments and Climate Change Guideline is intended to assist boards of health to develop approaches for promoting healthy built and natural environments to enhance population health and mitigate environmental health risks. The guideline presents existing and new population-based activities to address the health impacts of environmental health issues, which includes climate change and environmental exposures of public health significance.

The guideline supports the development of strategies that raise public awareness and reduce environmental health risks, allowing for evidence- informed program delivery to address the needs of priority populations within local communities.

The objective of this guideline is to identify approaches for boards of health that must be used or considered to achieve the following:

- Enhance public health capacity to address risk factors in the environment, including the impacts of climate change, using population-based activities. (e.g. Vulnerability Assessments).
- Identify and enable mitigation of risk factors related to environmental exposures that can contribute to the burden of illness.
- Facilitate upstream, preventative strategies for advancing healthy built and natural environment initiatives using standard provincial approaches.
- Align existing public health initiatives across boards of health to ensure optimum delivery from both the Healthy Environments and Chronic Disease Prevention Standards.

The following approaches are required for use by boards of health, as outlined in this guideline:

- Engaging Municipalities in Healthy Environment Strategies
- Climate Change Adaptation
- Environmental Exposures

Reference to the Standards

Population Health Assessment

Requirement 2: The board of health shall interpret and use surveillance data to communicate information on risks to relevant audiences in accordance with the *Healthy Environments and Climate Change Guideline, 2018* (or as current); the *Infectious Diseases Protocol, 2018* (or as current); and the *Population Health Assessment and Surveillance Protocol, 2018* (or as current).

Healthy Environments

Requirement 1: The board of health shall:

a) Conduct surveillance of environmental factors in the community;
b) Conduct epidemiological analysis of surveillance data, including monitoring of trends over time, emerging trends, and priority populations; and
c) Use information obtained to inform healthy environments programs and services in accordance with the *Health Hazard Response Protocol, 2018* (or as current); the *Healthy Environments and Climate Change Guideline, 2018* (or as current); the *Infectious Diseases Protocol, 2018* (or as current); and the *Population Health Assessment and Surveillance Protocol, 2018* (or as current).

Requirement 3: The board of health shall assess health impacts related to climate change in accordance with the *Healthy Environments and Climate Change Guideline, 2018* (or as current).

Requirement 4: The board of health shall engage in community and multi-sectoral collaboration with municipal and other relevant partners to promote healthy built and natural environments in accordance with the *Healthy Environments and Climate Change Guideline, 2018* (or as current).

Requirement 5: The board of health shall collaborate with community partners to develop effective strategies to reduce exposure to health hazards and promote healthy built and natural environments in accordance with the *Health Hazard Response Protocol, 2018* (or as current) and the *Healthy Environments and Climate Change Guideline, 2018* (or as current).

Requirement 7: The board of health shall, as part of its strategy to reduce exposure to health hazards and promote healthy natural and built environments, effectively communicate with the public by:

a) Adapting and/or supplementing national/provincial health communications strategies where local assessment has identified a need;
b) Developing and implementing regional/local communications strategies where local assessment has identified a need; and
c) Addressing the following topics based on an assessment of local needs:
    i) Built and natural environments;
    ii) Climate change;

iii) Exposure to hazardous environmental contaminants and biological agents;
iv) Exposure to radiation, including UV light and radon;
v) Extreme weather;
vi) Indoor air pollutants;
vii) Outdoor air pollutants; and
viii) Other emerging environmental exposures

in accordance with the *Healthy Environments and Climate Change Guideline, 2018* (or as current).

Required Approaches

Engaging Municipalities in Healthy Environment Strategies

1) Boards of health shall develop and maintain working relationships with local municipalities to integrate population health approaches through the actions outlined below.
   a) Boards of health shall participate in local processes for developing, updating or reviewing municipal bylaws and standards as authorized by municipalities under the *Ontario Municipal Act* to support changes which are intended to improve health outcomes and address the impacts of the social determinants of health.[3] Policy and bylaws that may be considered for review include, but are not limited to:
      i) Property standards;
      ii) Housing conditions;
      iii) Temperature control in rental housing;
      iv) Pest and vermin control;
      v) Restrictions on open fires in residential areas; and
      vi) Restrictions on wood burning stoves.
   b) Boards of health shall collaborate with municipalities under the *Ontario Planning Act* to address local impacts of climate change and reduce exposure to environmental health hazards in the community.[4] Collaboration activities may include reviewing and providing comments to local planning authorities on regional and local official plans not less than every 5 years as part of the local planning cycle. Aspects to consider for review include, but are not limited to:
      i) Land use compatibility (e.g., air quality impacts, $PM_{2.5}$,protection of ground water);
      ii) Climate change impacts (e.g., integrating green space and shade policy options to adapt to rising extreme heat events, and flood protection); and
      iii) Other local or emerging environmental health concerns.

Climate Change Adaptation

1) Boards of health shall consider the use of the *Ontario Climate Change and Health Toolkit, 2016* or other equivalent tool when assessing the health vulnerability status of their communities.[5] Assessments should address rising temperatures, vector-borne illness, food and waterborne illness, forest fires, and air pollution.
2) Boards of health shall monitor the impacts of climate change within their jurisdiction to inform local vulnerability plans using indicators such as:
   a) Number of heat and cold alerts for the summer and winter seasons respectively;
   b) Number of Smog Air Health Advisories (SAHA) per year;
   c) Number of extreme weather events requiring public health emergency interventions per year;
   d) Surveillance data for vector-borne illness rates (e.g. West Nile Virus, Lyme disease);
   e) Syndromic surveillance data (e.g. hospital admissions coinciding with extreme heat, extreme cold, poor air quality events etc.); and
   f) Number of climate change adaptation measures implemented.
3) Boards of health shall engage in actions to mitigate heat health impacts using tools such as the *Harmonized Heat Warning and Information System for Ontario*, *2016* (or as current).[6]

Environmental Exposures

1) Boards of health shall consider planning and implementing public awareness initiatives to address environmental exposures of:
   a) Solar Ultra Violet Radiation;
   b) Radon; and
   c) Other region-specific environmental exposure(s).
2) Boards of health shall use best available evidence and resources, which could include the complementary resources referenced in this document, to develop and implement mitigation strategies for radon exposures.
3) Boards of health shall use tools and evidence-based approaches to address the public health impact(s) resulting from poor air quality and enable the public to take precautions through the promotion of tools such as the *Air Quality Health Index (AQHI)*.

Glossary

Adaptation: The process societies go through in order to prepare for and cope with an uncertain future. Adapting to climate change entails taking measures to reduce the negative effects of climate change – or to take advantage of the positive effects.

Intervention: An activity or set of activities aimed at modifying a process, course of action or sequence of events in order to change one or several of their characteristics, such as performance or expected outcome. A public health intervention would be a programme or policy designed to reduce the burden of illness and prevent or reduce risk exposures.[3]

Priority Population: Priority populations are identified by surveillance, epidemiological, or other research studies. They are those populations that are at risk and for which public health interventions may be reasonably considered to have a substantial impact at the population level.

Syndromic Surveillance: Syndromic surveillance monitors in real time or as close to it as possible, information from electronic data collected for other purposes – such as emergency department visits – to detect emerging patterns of disease outbreaks sooner than with traditional public health methods.[7]

Vulnerability: It is the propensity or predisposition to be adversely affected. Vulnerability can arise because of individual susceptibility, geographic location, socioeconomic factors, and a wide range of other factors that determine an individual or community's susceptibility to harm and ability to cope with an event. For example, certain individuals can be vulnerable to extreme heat events because of where they live (parts of cities may warm more than others), characteristics of their dwelling (such as whether there is cross ventilation) that influence inside temperature, socioeconomic status, age, fitness, and a range of other factors that determine their susceptibility to high ambient temperatures.[2]

Complementary Resources

1. **Ontario Climate Change and Health Toolkit**
   - **Ontario Climate Change and Health Vulnerability and Adaptation Assessment Guidelines: Technical Document**
     http://www.health.gov.on.ca/en/common/ministry/publications/reports/climate_change_toolkit/climate_change_toolkit.aspx
   - **Ontario Climate Change and Health Vulnerability and Adaptation Assessment Guidelines: Workbook**
   - http://www.health.gov.on.ca/en/common/ministry/publications/reports/climate_change_toolkit/climate_change_toolkit.aspx
   - **Ontario Climate Change and Health Modelling Study: Report**
     http://www.health.gov.on.ca/en/common/ministry/publications/reports/climate_change_toolkit.aspx
2. **Harmonized Heat Warning Information System**
   - http://www.health.gov.on.ca/en/common/ministry/publications/reports/heat_warning_information_system/heat_warning_information_system.aspx
3. **Air Quality Health Index (AQHI)**
   - http://www.ec.gc.ca/cas-aqhi/default.asp?lang=En&n=CB0ADB16-1
4. **Radon Mitigation Resources, Examples & Tools**
   - **Government of Canada Radon Guideline**
     https://www.canada.ca/en/health-canada/services/environmental-workplace-health/radiation/radon/government-canada-radon-guideline.html
   - **Health Canada: National & International Resource Bank**
     http://www.hc-sc.gc.ca/ewh-semt/radiation/radon/resource-ressources-eng.php#a3
   - **The Lung Association: Radon Awareness**
     https://www.on.lung.ca/take-action
5. **Policies addressing UV Radiation**
   - **Shade Policy and Guidelines for the City of Toronto: Implementation, Dissemination, and Next Steps**
   - **York Region Public Health: Shade- A Planning Guide**
     http://www.york.ca/wps/portal/yorkhome/health/yr/cancer/sunsafety/sunsafetyresources/sunsafetyresources
6. **Healthy Community Design: Policy Statements for Official Plans**
   http://www.simcoemuskokahealth.org/JFY/OurCommunity/healthyplaces/Healthydesign.aspx

7. **Public Health and Land Use Planning Guide**
   http://www.opha.on.ca/What-We-Do/Resources.aspx
8. **Public Health and Environmental Assessments**
   http://www.opha.on.ca/What-We-Do/Resources.aspx

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Ministry of Health and Long-Term Care

Institutional/Facility Outbreak Management Protocol, 2018

Population and Public Health Division,
Ministry of Health and Long-Term Care

Effective: January 1, 2018 or upon date of release

Ontario

Preamble

The Ontario Public Health Standards: Requirements for Programs, Services, and Accountability (Standards) are published by the Minister of Health and Long-Term Care under the authority of section 7 of the *Health Protection and Promotion Act* (HPPA) to specify the mandatory health programs and services provided by boards of health.[1,2] The Standards identify the minimum expectations for public health programs and services. Boards of health are accountable for implementing the Standards including the protocols and guidelines that are referenced in the Standards. Protocols are program and topic-specific documents incorporated into the Standards which provide direction on how boards of health shall operationalize specific requirement(s) identified within the Standards.

Purpose

The purpose of this protocol is to provide direction to boards of health with respect to the prevention, detection, and management of infectious disease outbreaks of public health importance, including but not limited to respiratory infection and gastroenteritis outbreaks in institutions (as defined in section 21(1) of the HPPA)[2] and facilities, such as hospitals, long-term care homes, child care settings and other institutional/facility settings.

With respect to retirement homes, the Ministry of Health and Long-Term Care (the “ministry”) does not regulate retirement homes. A retirement home is not expressly listed as an “institution” for purposes of section 21(1) of the HPPA.[2] Boards of health, however, often do consider retirement homes to fall under the definition of an institution, as “any other place of a similar nature” under section 21(1) of the HPPA and is a reasonable interpretation of this definition.[2] Premises that meet the definition of retirement home in the *Retirement Homes Act, 2010* are required to consult at least once a year with the medical officer of health or designate on how to reduce outbreaks and develop their surveillance protocol,[3] and to report outbreaks under that Act’s regulation (O. Reg.166/11, section 27.)[4]

If required, further confirmation that the board of health’s activities for preventing and managing outbreaks in this protocol may be applied in retirement homes, the Retirement Homes Regulatory Authority should be consulted or, where applicable, legal counsel. Under the *Infectious Diseases Protocol, 2018* (or as current), boards of health shall provide public health investigation and management of confirmed or suspected local outbreaks of public health importance, which may include the management of outbreaks in retirement homes.[5]

Reference to the Standards

This section identifies the standard and requirements to which this protocol relates.

Infectious and Communicable Diseases Prevention and Control Standard

Requirement 11. The board of health shall provide public health management of cases, contacts, and outbreaks to minimize the public health risk in accordance with the *Infectious Diseases Protocol, 2018* (or as current);[5] the *Institutional/Facility Outbreak Management Protocol, 2018* (or as current); the *Rabies Prevention and Control Protocol, 2018* (or as current); the *Sexual Health and Sexually Transmitted/Blood-Borne Infections Prevention and Control Protocol, 2018* (or as current); and the *Tuberculosis Prevention and Control Protocol, 2018* (or as current).

Requirement 16. The board of health shall participate on committees, advisory bodies, or networks that address infection prevention and control practices[*] and policies of, but not limited to, hospitals and long-term care homes in accordance with the *Institutional/Facility Outbreak Management Protocol, 2018* (or as current).

Requirement 20. The board of health shall ensure 24/7 availability to receive reports of and respond to:

a) Infectious diseases of public health importance in accordance with the *Health Protection and Promotion Act*;[2] the *Mandatory Blood Testing Act, 2006*; the *Infectious Diseases Protocol, 2018* (or as current);[5] and the *Institutional/ Facility Outbreak Management Protocol, 2018* (or as current).

Operational Roles and Responsibilities

General

1) The board of health shall develop and maintain written policies and procedures in preparation for responding to infectious disease outbreaks in institutional/facility settings, including, but not limited to, respiratory infection and gastroenteritis outbreaks. This shall include coordination and assistance in the management of such outbreaks in single or multiple institutions/facilities.
2) The board of health shall assist institutions/facilities with outbreak management preparation, addressing the following components at a minimum:
    a) Establishing a surveillance mechanism for determining baseline data for infectious diseases;
    b) Early identification of outbreaks;
    c) Education as needed for preventing and managing an outbreak;

[*]Infection prevention and control practices that may be addressed could include having current evidence-informed infection prevention and control policies and conducting regular staff education sessions to communicate and enhance awareness about the content of the policies.

d) Outbreak management measures;
e) Communication within and outside institutions/facilities when appropriate;
f) Communication with regulatory bodies and the public when appropriate;
g) Interagency cooperation and timely information sharing with all who need to know about the occurrence of an outbreak; and
h) Staff exclusion policy.

3) The board of health shall apply current communicable disease policies and procedures as outlined in the *Infectious Diseases Protocol, 2018* (or as current).[5]

4) The board of health shall assist, as appropriate, institutions/facilities in the review and revision, as needed, of their existing infection prevention and control policies and procedures and shall provide public health recommendations for outbreak prevention, detection and management.

5) The board of health shall assist institutions in establishing and reviewing written outbreak response plans at a minimum of every two years.

Detection, Investigation, and Identification

1) The board of health shall inform institutions/facilities that they should notify the medical officer of health of all infectious diseases of public health importance. Note: there is no duty to report infectious diseases unless they are diseases of public health significance† under the HPPA.[2]

2) The board of health shall inform institutions/facilities regarding their duty to report to the medical officer of health upon forming the opinion that a respiratory infection or gastroenteritis outbreak exists that is a disease of public health significance† under the HPPA.[2]

3) The board of health shall work with, as appropriate, institutions/facilities in developing a mutually agreed-upon early outbreak detection surveillance system that includes establishing baseline data in order to accurately assess a probable or confirmed outbreak.

4) The board of health shall assist institutions/facilities in developing an effective communication plan between the board of health and institutions/facilities to ensure the board of health receives outbreak notification and outbreak information from institutions/facilities.

5) The board of health shall provide to institutions/facilities current epidemiological information on local occurrences of infectious diseases of public health significance†, as it becomes available, to assist in the prevention, detection, control, and management of outbreaks.

   For further information on 1-5, please refer to *Recommendations for the Control of Gastroenteritis Outbreaks in Long-Term Care Homes, 2018* (or as current), the

† Replaces reportable diseases, subject to approval

Provincial Infectious Diseases Advisory Committee (PIDAC) Best Practice Annex B: ***Best Practices for Prevention of Transmission of Acute Respiratory Infections in all Health Care Settings***, and *Recommendations for the Control of Respiratory Infection Outbreaks in Long-Term Care Homes, 2018* (or as current).[6-8]

Notification: Reporting from Source to Boards of Health

1) The board of health shall have an on-call system for receiving and responding to notifications of infectious disease outbreaks of public health importance including, but not limited to, respiratory infection and/or gastroenteritis outbreaks, on a 24 hours per day, 7 days per week (24/7) basis.
2) The board of health shall provide assistance regarding infectious disease outbreak assessment within 24 hours of receiving notification of an outbreak. Refer to the *Infectious Diseases Protocol, 2018* (or as current) for additional information.[5]
3) The board of health shall obtain the epidemiological information necessary to assess, evaluate, and control the outbreak.
4) The board of health shall assist in ensuring the collection of any environmental, clinical or other samples as appropriate to assess, evaluate, confirm and control an outbreak.

Management

1) The board of health shall assist institutions/facilities in the management of infectious disease outbreaks of public health importance, including but not limited to respiratory infection and gastroenteritis outbreaks. However, it is ultimately the responsibility of the institution/facility to manage the outbreak.
2) The board of health shall assist, as necessary, in confirming the existence of an outbreak and with declaring an outbreak. An outbreak can be declared by the institution/facility or by the medical officer of health or designate.
3) The board of health shall perform the following actions when assisting in the management of outbreaks:
   a) Review and/or establish a case definition in collaboration with the institution/facility, utilize standardized case definitions from best-practice guidelines if available and appropriate;
   b) Determine the population at risk;
   c) Assist in active case finding through consultation;
   d) Assess the status of the outbreak daily, or as previously arranged; and
   e) Review and discuss line listings provided by the institution/facility, including populations at risk and number of cases.

4) The board of health shall recommend and assist as needed with the implementation of appropriate infection prevention and control practices, with a focus on Routine Practices and applicable/appropriate Additional Precautions, as required.[9]
5) The board of health shall participate in outbreak management team meetings with appropriate representatives from the institution/facility when appropriate.
6) The board of health shall assist institutions/facilities with developing and implementing a risk communications plan to address stakeholders affected by an outbreak.
7) The board of health, while monitoring outbreaks on an ongoing basis, shall suggest modification(s) of outbreak control measures as required, including ongoing surveillance of populations at risk. For further direction regarding the surveillance of outbreaks please refer to the *Infectious Diseases Protocol, 2018* (or as current) and the *Population Health Assessment and Surveillance Protocol, 2018* (or as current).[5,10]
8) The board of health shall declare whether an outbreak is over, in consultation with the institution/facility.
    a) The board of health shall use the most current available epidemiological data and best practices/guidance documents to determine when an outbreak can be declared over; and
    b) The medical officer of health or designate retains the final authority to determine if an outbreak is over.
9) The board of health shall review the response to outbreaks with institutions/facilities after they have been declared over. The board of health shall evaluate the management and impact of outbreaks and assist in identifying strategies for improvement in their management and in formulating preventive measures going forward.
10) The board of health shall inspect institutions as follows:
    a) For respiratory infection outbreaks, the board of health shall assess and, where epidemiological evidence supports it, inspect and evaluate infection prevention and control practices at the institution.
        i) If a legionella outbreak is suspected, further investigations should be carried out to identify the potential sources and appropriate mitigating strategies based on current provincial or national assessment guidelines.
    b) For gastroenteritis outbreaks, the board of health shall assess the need for an additional inspection of food preparation and handling within the institution.
        i) If meals are prepared in a food premises outside of the institution, the food premises shall be inspected by the board of health;
        ii) If meals are prepared in a food premises located outside the health unit where the outbreak has occurred, the board of health in which the premises is located shall be contacted and shall inspect the premises and report back to the originating board of health in a timely manner; and

iii) In the case of a gastroenteritis disease outbreak, if it is suspected that the spread is primarily person-to-person, inspection of food preparation premises may not be required.

c) For *Clostridium difficile* infection (CDI) outbreaks, the board of health shall assess and, where epidemiological evidence supports it, inspect and evaluate infection prevention and control practices at the institution/facility, including antimicrobial stewardship programs. Provincial assistance, such as the Ontario Agency for Health Protection and Promotion's (Public Health Ontario [PHO]) Infection Control Resource Team (ICRT), may be requested when local resources for outbreak control are exhausted.
   i) For further information on c), please refer to the Roles and *Responsibilities of Hospitals and Public Health Units for Clostridium difficile Infection Reporting and Outbreak Management, 2014* (or as current) and the PIDAC *Annex C: Testing, Surveillance and Management of Clostridium difficile, 2013* (or as current).[11,12]
   ii) For outbreaks other than respiratory infection or gastroenteritis, including hospital acquired infections (HAI), the board of health shall assess the benefit of inspection based on collaboration with the facility, and local epidemiological and surveillance data.

11) The board of health shall respond to food safety and environmental issues in outbreak settings in accordance with the requirements of the *Food Safety Protocol, 2018* (or as current) and the *Health Hazard Response Protocol, 2018* (or as current).[13,14]

For further information on infection prevention and control best practices for outbreak management refer to the relevant PIDAC Best Practices documents.[15]

Data Collection, Reporting, and Information Transfer: Boards of Health to Ministry of Health and Long-Term Care and Other Stakeholders

1) The board of health shall report outbreak data on diseases of public health significance[‡] to the ministry and to PHO, using the integrated Public Health Information System (iPHIS), or any other method specified by the ministry, within one business day of receiving notification of an outbreak or of assessing that an outbreak is occurring but has not been reported by the institution/facility.
   a) The board of health shall update the outbreak file and enter data as required using iPHIS or any other method specified by the ministry.
   b) The board of health shall communicate as soon as possible with the ministry and PHO about any occurrences involving evidence of increased virulence based on unusual clinical presentation or outcomes and/or the possibility of multi-jurisdiction

‡ Replaces reportable diseases, subject to approval

involvement, or suspicion of a novel or emerging infectious disease as per national and or international health alerts. Associated data shall also be entered using iPHIS or any other method specified by the ministry.

c) The board of health shall enter final summary outbreak data using iPHIS, or any other method specified by the ministry, no later than 15 business days after the outbreak is declared over.
d) The board of health shall assist the institution/facility to summarize the outbreak and highlight areas for improved/enhanced response activities in the future.

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Ministry of Health and Long-Term Care

Mental Health Promotion Guideline, 2018

Population and Public Health Division,
Ministry of Health and Long-Term Care

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1. Preamble

The Ontario Public Health Standards: Requirements for Programs, Services, and Accountability (Standards) are published by the Minister of Health and Long-Term Care under the authority of section 7 of the *Health Protection and Promotion Act* (HPPA) to specify the mandatory health programs and services provided by boards of health.[1,2] The Standards identify the minimum expectations for public health programs and services. Boards of health are accountable for implementing the Standards including the protocols and guidelines that are referenced in the Standards. Guidelines are program and topic-specific documents which provide direction on how boards of health shall approach specific requirement(s) identified within the Standards.

2. Purpose

This Guideline is intended to assist boards of health in considering **mental health promotion**[*] within their processes for planning, implementing, and evaluating **programs of public health interventions**, according to the requirements of the Standards. It establishes the minimum expectations for strategies and approaches that boards of health shall consider. Content is organized as follows:

- Overview, Purpose, and References to the Standards provide a brief orientation to this Guideline and specific references to mental health promotion and related subjects in the Standards.
- Context provides a high-level introduction to mental health promotion as an area of consideration for public health in Ontario, and a brief overview of key concepts and frameworks to inform planning, implementation, and evaluation.
- Roles and Responsibilities identifies the core functions that boards of health shall consider in addressing their responsibilities for mental health promotion under the Standards, including the application of the Foundational Standards.
- Required Approaches provides additional considerations and guidance to support boards of health in implementing their roles and responsibilities. This includes considerations for embedding mental health promotion strategies and approaches across programs and services; offering mental health promotion programs and services across the life course; implementing whole-population and community-based interventions, and engaging in multi-sectoral collaboration.

Problems associated with mental health, mental illness and substance use share many common **risk and protective factors**, and promotion and prevention efforts employ similar approaches and considerations for interventions. Boards of health should consider mental health and substance use together when conducting population health assessments and developing programs and services. Nevertheless, there are important distinctions and unique considerations that are well served by the provision of a

[*] Terms marked in **bold** are defined in the Glossary.

separate Guideline to address substance use. Where appropriate, this Guideline makes references to related or companion guidance within the *Substance Use Prevention and Harm Reduction Guideline, 2018* (or as current), as well as other relevant Protocols and Guidelines under the Standards.

3. Reference to the Standards

This section identifies the standard and requirements to which this protocol relates.

Chronic Disease Prevention and Well-Being

Requirement 2. The board of health shall develop and implement a program of public health interventions using a comprehensive health promotion approach that addresses chronic disease risk and protective factors to reduce the burden of illness from chronic diseases in the health unit population.

a) The program of public health interventions shall be informed by:
   i) An assessment of the risk and protective factors for, and distribution of, chronic diseases;
   ii) Consultation and collaboration with local stakeholders in the health, education, municipal, non-governmental, and other relevant sectors;
   iii) An assessment of existing programs and services within the area of jurisdiction of the board of health to build on community assets and minimize duplication;
   iv) Consideration of the following topics based on an assessment of local needs:
      - Built environment;
      - Healthy eating behaviours;
      - Healthy sexuality;
      - Mental health promotion;
      - Oral health;
      - Physical activity and sedentary behaviour;
      - Sleep;
      - Substance[†] use; and
      - UV exposure.
   v) Evidence of effectiveness of the interventions employed.
b) The program of public health interventions shall be implemented in accordance with relevant guidelines, including the *Chronic Disease Prevention Guideline, 2018* (or as current); the *Health Equity Guideline, 2018* (or as current); the *Mental Health Promotion Guideline, 2018* (or as current); and the *Substance Use Prevention and Harm Reduction Guideline, 2018* (or as current).[‡]

[†]Substance includes tobacco, e-cigarettes, alcohol, cannabis, opioids, illicit, other substances and emerging products.

[‡]The *Substance Use Prevention and Harm Reduction Guideline, 2018* (or as current) provides guidance on alcohol, cannabis, opioids, and illicit substances.

Healthy Growth and Development

Requirement 2. The board of health shall develop and implement a program of public health interventions using a comprehensive health promotion approach to support healthy growth and development in the health unit population.

a) The program of public health interventions shall be informed by:
   i) An assessment of risk and protective factors that influence healthy growth and development.
   ii) An assessment of existing programs and services within the area of jurisdiction of the board of health to build on community assets and minimize duplication.
   iii) Consultation and collaboration with local stakeholders in the health, education, municipal, non-governmental, social, and other relevant sectors with specific attention to:
      - School boards, principals, educators, parent groups, student leaders, and students;
      - Child care providers and organizations that provide child care services such as Community Hubs and Family Centres;
      - Health care providers and LHINs;
      - Social service providers; and
      - Municipalities.
   iv) Consideration of the following topics based on an assessment of local needs:
      - Breastfeeding;
      - Growth and development;
      - Healthy pregnancies;
      - Healthy sexuality;
      - Mental health promotion;
      - Oral Health;
      - Preconception health;
      - Pregnancy counselling;
      - Preparation for parenting;
      - Positive parenting; and
      - Visual health.
   v) Evidence of the effectiveness of the interventions.

b) The program of public health interventions shall be implemented in accordance with relevant guidelines, including the *Health Equity Guideline, 2018* (or as current); the *Healthy Growth and Development Guideline, 2018* (or as current); and the *Mental Health Promotion Guideline, 2018* (or as current).

School Health

Requirement 3. The board of health shall develop and implement a program of public health interventions using a comprehensive health promotion approach to improve the health of school-aged children and youth.

a) The program of public health interventions shall be informed by:
   i) An assessment of the local population, including the identification of priority populations in schools, as well as school communities at risk for increased health inequities and negative health outcomes;
   ii) Consultation and collaboration with school boards, principals, educators, parent groups, student leaders, and students;
   iii) A review of other relevant programs and services delivered by the board of health; and
   iv) Evidence of the effectiveness of the interventions employed.
b) The program of public health interventions shall be implemented in accordance with relevant guidelines, including the *Chronic Disease Prevention Guideline, 2018* (or as current); the *Health Equity Guideline, 2018* (or as current); the *Injury Prevention Guideline, 2018* (or as current); the *Healthy Growth and Development Guideline, 2018* (or as current); the *Mental Health Promotion Guideline, 2018* (or as current); and the *Substance Use Prevention and Harm Reduction Guideline, 2018* (or as current).

Requirement 4. The board of health shall offer support to school boards and schools to assist with the implementation of health-related curricula and health needs in schools, based on need and considering, but not limited to:
a) Concussions and injury prevention;
b) Healthy eating behaviours and food safety;
c) Healthy sexuality;
d) Immunization;
e) Infectious disease prevention (e.g., tick awareness, rabies prevention, and hand hygiene);
f) Life promotion, suicide risk and prevention;
g) Mental health promotion;
h) Oral health;
i) Physical activity and sedentary behaviour;
j) Road and off-road safety;
k) Substance[§] use and harm reduction;
l) UV exposure;
m) Violence and bullying; and
n) Visual Health.

Substance Use and Injury Prevention

Requirement 2. The board of health shall develop and implement a program of public health interventions using a comprehensive health promotion approach that addresses risk and protective factors to reduce the burden of preventable injuries and substance use in the health unit population.

[§]Substance includes tobacco, e-cigarettes, alcohol, cannabis, opioids, illicit, other substances and emerging products.

a) The program of public health interventions shall be informed by:
   i) An assessment of the risk and protective factors for, and distribution of, injuries and substance use;
   ii) Consultation and collaboration with local stakeholders in the health, education, municipal, non-governmental, and other relevant sectors, including LHINs;
   iii) An assessment of existing programs and services within the area of jurisdiction of the board of health to build on community assets and minimize duplication;
   iv) Consideration of the following topics based on an assessment of local needs:
      - Comprehensive tobacco control;[**]
      - Concussions;
      - Falls;
      - Life promotion, suicide risk and prevention;
      - Mental health promotion;
      - Off-road safety;
      - Road safety;
      - Substance use; and
      - Violence.
   v) Evidence of the effectiveness of the interventions employed.
b) The program of public health interventions shall be implemented in accordance with relevant guidelines, including the *Health Equity Guideline, 2018* (or as current); the *Injury Prevention Guideline, 2018* (or as current); the *Mental Health Promotion Guideline, 2018* (or as current); and the *Substance Use Prevention and Harm Reduction Guideline, 2018* (or as current).

4. Context

This section provides a high-level introduction to mental health promotion as an area of consideration for public health in Ontario, along with an overview of key concepts and frameworks that boards of health shall consider to inform planning, implementation, and evaluation of mental health promotion within public health programs and services. In order to support the establishment of a common understanding of mental health and mental illness throughout Ontario's public health sector, additional terms and concepts are defined in the Glossary. However, mental health promotion must be grounded in an understanding of a particular sector or community's values and concepts relating to mental health and well-being, in order to be inclusive and responsive to diverse partners and community members. As the World Health Organization notes, "although the

[**] Comprehensive tobacco control includes: preventing the initiation of tobacco; promoting quitting among young people and adults; eliminating exposure to environmental tobacco smoke; and identifying and eliminating disparities related to tobacco use and its societal outcomes among different population groups.

qualities included in the concept of mental health may be universal, their expression differs individually, culturally, and in relation to different contexts.”[3]

4.1 Mental Health Promotion and Public Health

Mental health promotion is the process of enhancing the capacity of individuals and communities to increase control over their lives and improve their **mental health**. By working to increase self-esteem, coping skills, social connectedness and well-being, mental health promotion empowers people and communities to interact with their environments in ways that enhance emotional and spiritual strength. It is an approach that fosters individual and community **resilience** and promotes socially supportive environments.[4]

The majority of Ontarians (70%) aged 12 and older rate their mental health as very good or excellent. However, there have been notable increases in Ontarians who perceive their mental health as fair or poor (7%)[5] as well as those who have experienced **mental health problems** or illness. Among Ontario adults in 2015,

- 26% reported moderate to serious psychological distress;
- 10% reported frequent mental distress (14 or more days) in the past 30 days;
- 10% reported using prescribed antianxiety medication; and
- 9% reported using prescribed antidepressants.[6]

The mental health and **well-being** of Ontarians is heavily influenced by the social, economic, and physical environments where people live, learn, work, and play. Risk and protective factors affecting mental health and **mental illness** differ across regions of the province, and certain populations are at a higher risk of mental health problems or illness because of greater exposure to discrimination or disadvantage. These disadvantages are often based on race, ethnicity, religion, age, sex, gender, sexual orientation, language, ability, family status, socioeconomic status, or other socially-determined circumstance. As Ontario is one of Canada's most diverse provinces, all public health efforts to promote mental health and prevent mental illness require a strong attention to principles of **health equity**, so that all people can reach their full health potential.

Promoting the mental health and well-being of Ontarians requires a collaborative, **proportionate universalism** approach, involving stakeholders across various sectors, including public health. It also requires that mental and physical health be considered together, not independently, as “there is no health without mental health.”[3] Mental health and resilience are protective factors for physical health, recovery from physical illness, reducing harmful behaviours such as problematic use of substances, and unhealthy eating.[7] Considering mental and physical health holistically and simultaneously is an integral part of public health’s mandate to reduce health inequities and improve and protect the overall health and well-being of the population of Ontario.

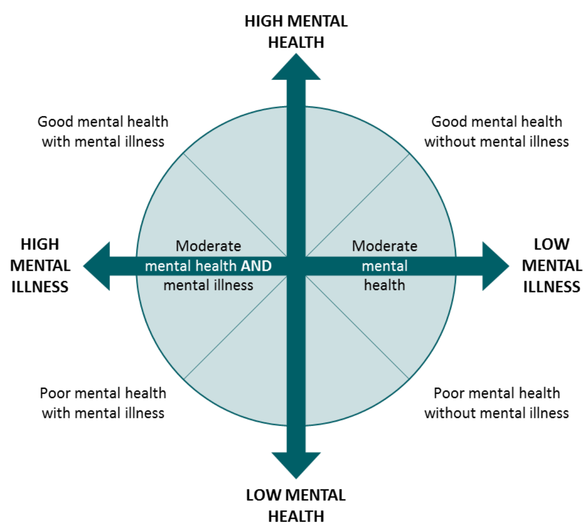
Overall, the impact of mental health, mental illness, and addictions in Ontario on life expectancy, quality of life, and health care utilization is more than 1.5 times that of all cancers and more than 7 times that of all infectious diseases.[8] Efforts to reduce the burden of **chronic diseases** in Ontario must include efforts to reduce the burden of mental illness and addictions through upstream interventions that promote positive mental health, resiliency, and well-being across the lifespan.

4.2 Two Continua Model of Mental Health and Mental Illness

Mental health is a positive concept and more than the absence of mental illness. The Public Health Agency of Canada defines it as “the capacity of each and all of us to feel, think, and act in ways that enhance our ability to enjoy life and deal with the challenges we face. It is a positive sense of emotional and spiritual well-being that respects the importance of culture, equity, social justice, interconnections and personal dignity.”[4] Mental health may be used interchangeably with mental well-being, particularly outside of the health sector.

Mental illness refers to conditions where our thinking, mood, and behaviours severely and negatively impact how we function in our lives. Mental illnesses are affected by “a complex mix of social, economic, psychological, biological, and genetic factors,”[9] and may take many forms, including mood disorders, schizophrenia, anxiety disorders, personality disorders, eating disorders, and addictions such as substance dependence and gambling.[4]

Figure 1: The Two Continua Model of Mental Health and Mental Illness[10]



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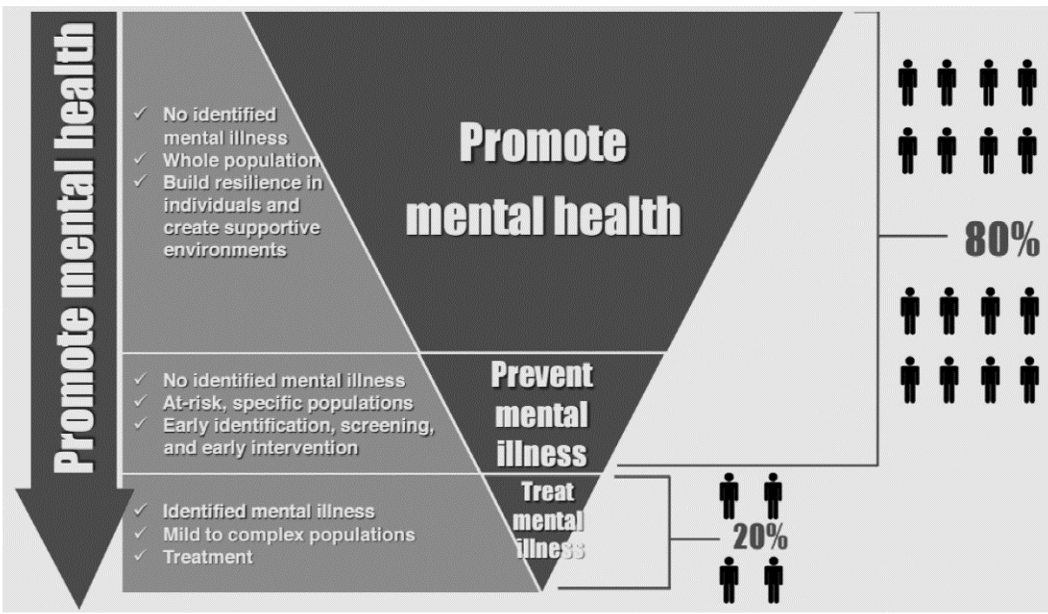
Mental health and mental illness are distinct but related concepts that need to be considered and addressed differently. The *Two Continua Model of Mental Health and Mental Illness*[10] (Figure 1) illustrates how they intersect and co-exist in individuals and populations. People with mental illness can experience good mental health that allows them to be resilient and thrive. Conversely, people without a mental illness can experience mental health problems and struggle to cope.[11] An individual or community's response to issues that arise will be influenced by their access to resources, social connectedness, and overall resiliency.[12]

4.3 Comprehensive Approach to Population Mental Health

Figure 2: The Tiered Population Mental Health Approach[13]



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A comprehensive approach to population mental health is comprised of three tiers of action (Figure 2), including 1) **promoting mental health**, 2) **preventing mental illness**, and 3) **treating mental illness**.[13] These three tiers may overlap, as promotion and prevention can be woven into treatment to enhance client outcomes by addressing risk and protective factors that support recovery and resiliency. Prevention may also include early identification and intervention initiatives that are appropriate for, and specifically target, people displaying the early signs and symptoms, or first episode, of mental illness or addiction.[14] Promotion, prevention, and treatment are interdependent tiers of an integrated system that requires coordination across multiple sectors with various stakeholders and partners working together.

Within an integrated health system, boards of health are an important contributor to a comprehensive approach to population mental health. In order to maximize the reach and impact of public health, their role centers on promoting mental health and preventing mental illness, extending as far as early identification and referrals. It is not anticipated that boards of health will engage directly in the delivery of early intervention or treatment services for mental illness. However, this may be appropriate in rare cases, such as where the discontinuation of historical programs might critically disrupt relationships with partners and stakeholders or create a significant gap in local services.

Mental health promotion:

- Focuses on the enhancement of well-being rather than on illness;
- Addresses the population as a whole, including people experiencing risk conditions, in the context of everyday life;
- Takes action on the determinants of health;
- Broadens the focus to include protective factors, rather than simply focusing on risk factors and conditions;
- Includes a wide range of strategies such as communication, education, and policy development;
- Acknowledges and reinforces the competencies of the population;
- Encompasses the health and social sectors; and
- Uses strategies that foster supportive environments and individual resilience while demonstrating respect for culture, equity, social justice, interconnections, and personal dignity.[15]

5. Roles and Responsibilities

5.1 Standards, Protocols, and Guidelines

Mental health promotion is a required consideration within four program standards. Board of health roles and responsibilities relating to mental health promotion should be read in conjunction with the corresponding standards (see Reference to the Standards section), and related protocols, guidelines, and reference documents, including the following:

- *Chronic Disease Prevention Guideline, 2018* (or as current);
- *Health Equity Guideline, 2018* (or as current);
- *Healthy Growth and Development Guideline, 2018* (or as current);
- *Injury Prevention Guideline, 2018* (or as current);
- *School Health Guideline, 2018* (or as current); and
- *Substance Use Prevention and Harm Reduction Guideline, 2018* (or as current).

5.2 Foundational Standards

Boards of health shall consider the application of the Foundational Standards to the topic of mental health promotion. Whether embedding mental health promotion and mental illness prevention into public health programs and services, or developing new initiatives on a **universal** or **targeted** basis, boards of health shall consider implications for population health assessment, health equity, and effective public health practice.

5.2.1 Population Health Assessment

Under the Standards, boards of health are responsible for assessing local needs and existing programs and services within the area of jurisdiction to build on community assets and minimize duplication.[††] Surveillance efforts shall include consideration of relevant tools, such as the *Positive Mental Health Surveillance Indicator Framework* developed by the Public Health Agency of Canada, which identify a core set of indicators that include positive mental health outcomes and determinants at the individual, family and community level.[16]

For additional guidance, refer to the *Population Health Assessment and Surveillance Protocol*, *2018* (or as current).

5.2.2 Health Equity

The *Foundational Standard for Health Equity* articulates specific program requirements and outcomes that boards of health shall fulfill in relation to health equity. In particular, boards of health shall identify and engage **priority populations** and implement strategies to reduce health inequities.

Considerations relating to priority populations and mental health promotion are outlined in the Required Approaches section of this Guideline. For additional guidance, refer to the *Health Equity Guideline, 2018* (or as current), the *Population Health Assessment and Surveillance Protocol*, *2018* (or as current), and the *Relationships with Indigenous Communities Guideline, 2018* (or as current).

5.2.3 Effective Public Health Practice

Under the *Foundational Standard for Effective Public Health Practice*, boards of health are required to employ public health practice that is transparent, responsive to current and emerging evidence, and emphasizes continuous quality improvement. This requirement supports awareness among public health practitioners, policy-makers, community partners, health care providers, and the public of the factors that determine the health of the population.

The Required Approaches section of this Guideline outlines considerations and required approaches relating to public health practice that effectively considers mental health alongside physical health as an integral component of overall well-being, including leadership, planning, workforce development, and mental health literacy.

6. Required Approaches

This section provides an overview of the approaches that boards of health shall consider, at minimum, when implementing requirements for considering mental health promotion to inform programs of public health interventions under the program

[††] Refer to the *Population Health Assessment and Surveillance Protocol*, *2018* (or as current) for related guidance.

standards on Chronic Disease Prevention and Well-Being, Healthy Growth and Development, Substance Use and Injury Prevention, and School Health. All board of health decision-making and prioritization regarding mental health promotion activities shall be guided by the four principles established by the Policy Framework outlined in the Standards: Need; Impact; Capacity; and Partnership, Collaboration, and Engagement.

Informed by situational assessments and a proportionate universalism approach, boards of health shall consider the following:

- Embedding mental health promotion strategies and approaches across public health programs and services (see Section 6.1);
- Seeking opportunities to offer mental health promotion programs and services across the life course (see Section 6.2); and
- Seeking opportunities to implement whole-population and community-based interventions, particularly for cross-cutting issues (see Section 6.3).[‡‡]

In operationalizing these approaches, and in alignment with board of health requirements under the *Effective Public Health Practice Standard,* boards of health shall consider the following:

- Strengthening effective leadership for mental health is one of four priorities established in the World Health Organization's *Mental Health Action Plan 2013 – 2020*.[17] Public health leaders share responsibility for considered mental and physical health equally and holistically within public health planning, and for developing and sustaining mental health promotion strategies, approaches, and interventions as a core feature of an integrated health system.
- The ability of the public health workforce to recognise and address mental and physical health equally and holistically is critical to the goals of the Standards, and to the delivery of effective public health practice. Boards of health shall consider strategies to develop core skills and capabilities within the public health workforce to deliver sustainable improvements in mental health promotion, mental illness prevention, early identification, and referrals.
- The degree to which public health practitioners may benefit from mental health literacy will depend on their core functions and the populations they routinely interact with; however, it is a necessary foundation for effective public health practice that promotes mental health and decreases stigma related to mental health problems and accessing mental health services. Mental health literacy encompasses four components:[18]
    - Understanding how to obtain and maintain positive mental health;
    - Understanding mental health problems and forms of treatment;
    - Decreasing stigma related to mental health problems; and

[‡‡] Examples of interventions may be found on the *Canadian Best Practices Portal*: cbpp-pcpe.phac-aspc.gc.ca.

- Enhancing help-seeking efficacy (knowing when and where to seek help and developing competencies designed to improve one's mental health care and self-management capabilities).

6.1 Embedding Mental Health Promotion Strategies and Approaches across Programs and Services

Boards of health shall consider embedding mental health promotion strategies and approaches across public health programs and services, in accordance with the requirements established in the relevant program standards. This includes consideration of the strategies and approaches listed below, as core components of a **comprehensive health promotion approach**. These strategies and approaches can also inform the development of universal or targeted programs and services that are specific to mental health promotion:

- Focus on health promotion;
- Address the **social determinants** of mental health;
- Address risk and protective factors for mental health and mental illness;
- Reduce stigma and increase mental health literacy for individuals and communities;
- Embed trauma-awareness into public health practice;
- Focus on strengths at the individual, community, and population level; and
- Engage with priority populations, communities, partners, and stakeholders.

6.1.1 Priority Populations

In operationalizing these strategies and approaches, and in alignment with board of health requirements under the *Standards*, boards of health shall employ multiple sources of information to identify priority populations. In some cases, there is sufficient data to demonstrate disparities in health outcomes at the provincial level. Concerning mental health promotion, there is sufficient evidence to demonstrate significant health inequities among the following population groups, which boards of health shall consider:[§§]

- Indigenous peoples and communities;[***]
- Francophones;
- Immigrant, refugee, ethno-cultural and racialized groups (IRER);

[§§] Additional priority populations may be identified through local needs assessments. Refer to the *Health Equity Guideline, 2018* (or as current) for related guidance.

[***] The *Relationship with Indigenous Communities Guideline, 2018* (or as current) provides guidance on engaging the different Indigenous and First Nation communities that may be represented within a board of health's area of jurisdiction in a way that is meaningful for them.

- Lesbian, gay, bisexual, transgender, queer, questioning, and Two Spirit (LGBTQ2S+) populations;
- People with disabilities;
- People experiencing low-income or income insecurity;
- People who are underhoused or homeless; and
- People experiencing mental health problems, mental illness, substance use problems, and/or addiction.[†††]

Experiences of discrimination, exclusion, and mistreatment may be heightened for individuals who identify with multiple priority populations. Intersecting forms of prejudice and discrimination towards these individuals can affect the social determinants of mental health, compounding risk factors and/or reducing protective factors in unanticipated ways.[19] This can lead to diminished quality of life while increasing the chances of individuals experiencing mental health problems or illness.[7] For these reasons, the experiences of individuals with intersecting marginalized identities require particular consideration in mental health promotion programs and services.

Evidence pertaining to priority populations can be obtained through surveillance, epidemiological, or other research studies. It may also be identified through local data sources, including community assessments.[1] However, the social determinants of mental health, particularly social exclusion and discrimination, may also contribute to the under-representation or omission of priority populations within common data sets. Boards of health shall employ multiple sources of information, including an assessment of the social determinants of health and strong engagement with community groups and organizations, to identify priority populations and collect evidence at the local level. It should not be inferred that the absence of data regarding a particular population indicates an absence of need.

6.2 Offering Mental Health Promotion Programs and Services across the Life Course

Informed by the strategies and approaches identified in Required Approaches, boards of health shall consider seeking opportunities to develop and deliver mental health promotion and mental illness prevention programs and services on a universal or targeted basis, to advance the goals established in the relevant program standards.

In order to achieve meaningful outcomes, these interventions must be applied in a range of settings (e.g., the home, child care centres, schools, workplaces, the community, etc.)[20] and be relevant throughout the life course, as the determinants of mental health and well-being influence people differently at different stages of life.[21] In particular, evidence shows that initiatives that focus on giving "every child the best

[†††] Refer to the *Substance Use Prevention and Harm Reduction Guideline*, *2018* (or as current) for related guidance.

possible start" will yield the greatest impacts.[22] For example, programs that target infants, children, adolescents, and their caregivers have the most potential to produce significant net cost benefits.[23]

Early years are a critical period due to rapid brain development. This phase lays the foundation for physical and mental health outcomes in later years. Adverse childhood experiences, such as poor attachment to parents, child abuse, family conflict, and neglect, have been clearly linked to risk for mental illness and addiction later in life. Meanwhile, strong attachment to a caregiver, and programs that support parents to develop positive parenting practices, can serve as protective factors for a child's mental health. [22] Investing in mental health early and often helps to buffer individuals from harms that may trigger or exacerbate mental health problems later on and support recovery if issues do emerge. Every $1 invested in early childhood is equivalent to $3 spent on school-aged children and $8 on young adults.[24]

Upstream investments in mental health promotion, mental illness prevention, and early identification across the lifespan can mitigate and reduce potential expenses in various systems like healthcare, education, justice and beyond. As such, they are an integral part of Ontario's overall approach to chronic disease prevention, healthy growth and development, school health, substance use, and injury prevention.

6.3 Implementing Whole-Population and Community-Based Interventions

Although effective mental health promotion efforts are well situated within a life course perspective, "whole system" strategies are also needed to support a universally proportionate approach.[25,26] Accordingly, boards of health shall consider seeking opportunities to implement whole-population and community-based interventions, to advance the goals established in the Standards and promote well-being. Such interventions may be particularly appropriate for cross-cutting issues that boards of health are also required to consider under the Standards, such as life promotion, suicide risk and prevention; substance use; violence and bullying; and built environments. Integral to these efforts is a focus on community engagement, education, skill building, empowerment, and resiliency, [27-30] as well as the development of robust social support systems.[31,32]

6.4 Engaging in Multi-Sectoral Collaboration

In considering mental health promotion, and in alignment with the *Effective Public Health Practice Standard* and related program standards, boards of health shall foster relationships with community researchers, academic partners, and other appropriate organizations, and shall develop and implement programs of public health interventions that are informed by consultation and collaboration with local stakeholders, including the health, education, municipal, non-governmental, social, and other relevant sectors. Mental health and well-being are affected by many factors—both inside and outside the purview of the health system—and stakeholders and partners across multiple sectors contribute to a comprehensive population mental health approach:

- In Ontario, the health sector includes, but is not limited to: primary care, public health units, Local Health Integration Networks, acute care settings (e.g., hospitals), mental health and addiction services, community-based services, and programs/services administered by other government ministries (e.g., Ministry of Children and Youth Services, Ministry of Education, Ministry of Advanced Education and Skills Development, Ministry of Community Safety and Correctional Services, Ministry of Citizenship and Immigration).
- Other sectors that are involved in supporting the mental health and well-being of the population include, but are not limited to: municipal and social services, housing, refugee and settlement organizations, child and youth services, education, justice, human rights, and non-governmental/non-profit organizations.

The public health sector is one of many contributors to mental health promotion, and other sectors may have mandates that are mutually reinforcing. A board of health's comprehensive situational assessment should include a scan of existing programs and services within the area of jurisdiction to identify gaps as well as opportunities to build partnerships and relationships that increase the reach and effect of mental health promotion strategies, approaches, and interventions.

Glossary

Chronic diseases of public health importance include, but are not limited to, obesity, cardiovascular diseases, respiratory disease, cancer, diabetes, intermediate health states (such as metabolic syndrome and prediabetes), hypertension, dementia, mental illness, and addictions.

Comprehensive health promotion approach applies diverse strategies and methods in an integrated manner—one of the preconditions for health promotion to be effective. Health promotion addresses the key action areas identified in the Ottawa Charter in an integrated and coherent way.[33]

Cultural safety refers to an environment which is safe for people: where there is no assault, challenge or denial of their identity, of who they are and what they need. Cultural safety is conceptualized on a continuum that begins with unsafe practises, moving to cultural competence, and culminating in culturally safe practices.[34]

Health equity means that all people can reach their full health potential and are not disadvantaged from attaining it because of their race, ethnicity, religion, gender, age, social class, socioeconomic status or other socially determined circumstance.[1]

Mental health is a positive concept and more than the absence of mental illness. The Public Health Agency of Canada defines it as “the capacity of each and all of us to feel, think, and act in ways that enhance our ability to enjoy life and deal with the challenges we face. It is a positive sense of emotional and spiritual well-being that respects the importance of culture, equity, social justice, interconnections and personal dignity.”[4] Mental health may be used interchangeably with mental well-being, particularly outside of the health sector.

Mental health problems are the psychological changes that happen over time, affecting a person’s ability to function and manage life. It is normal for a person to experience emotions such as sadness or feeling worried as a result of various life stressors; however, they become mental health problems if they affect daily functioning over an extended period of time. Mental health problems can affect everyone across the entire lifespan.[35]

Mental health promotion is the process of enhancing the capacity of individuals and communities to increase control over their lives and improve their mental health.[15] Beyond a focus on risk factors, it is an approach that aims to improve the health of individuals, families, communities, and society by influencing the complex interactions between social and economic factors, the physical environment, and individual behaviours and conditions across the lifespan (i.e., the social determinants of health).[36]

Mental illness refers to conditions where our thinking, mood, and behaviours severely and negatively impact how we function in our lives. Mental illnesses are affected by “a complex mix of social, economic, psychological, biological, and genetic factors,”[9] and may take many forms, including mood disorders, schizophrenia, anxiety disorders, personality disorders, eating disorders, and addictions such as substance dependence and gambling.[4]

Mental illness prevention focuses on reducing risk factors for mental illness and enhancing protective factors. Prevention aims to address risk and protective factors before the onset of illness. However, prevention can also address risk and protective factors once symptoms of mental illness emerge to reduce their severity.[37]

Population health is the health of the population, measured by health status indicators. Population health is influenced by physical, biological, behavioural, social, cultural, economic, and other factors. The term is also used to refer to the prevailing health level of the population, or a specified subset of the population, or the level to which the population aspires. Population health describes the state of health, and public health is the range of practices, procedures, methods, institutions, and disciplines required to achieve it. The term also is used to describe the academic disciplines involved in studies of determinants and dynamics of health status of the population.[38]

Priority populations are those that are experiencing and/or at increased risk of poor health outcomes due to the burden of disease and/or factors for disease; the determinants of health, including the social determinants of health; and/or the intersection between them. They are identified by using local, provincial, and/or federal data sources; emerging trends and local context; community assessments; surveillance; and epidemiological and other research studies.

Program of public health interventions includes the suite of programs, services, and other interventions undertaken by a board of health to fulfill the requirements and contribute to achieving the goals and program outcomes outlined in the Standards.

Proportionate universalism is an approach that balances targeted and universal population health perspectives. This approach makes health actions or interventions available to the whole population, but with a scale, intensity and delivery that is proportionate to the level of need and disadvantage in particular populations.

Resiliency refers to the ability of an individual or community to effectively manage or cope with adversity or stress in ways that are not only effective, but increase their ability to respond to future adversity and enable them to thrive.[12]

Risk and protective factors are variables that can be present at the individual, interpersonal, community, and societal levels and that impact mental health and resiliency.[39] **Protective Factors** are determinants that affect health in a positive way. They help with maintaining good health, and can assist in effective management of health conditions.[40] **Risk Factors** are determinants that affect health in a negative way. They can increase the likelihood of developing chronic diseases, or hinder in the management of existing conditions.[40]

Social determinants of health: The interrelated social, political and economic factors that create the conditions in which people live, learn, work and play. The intersection of the social determinants of health causes these conditions to shift and change over time and across the life span, impacting the health of individuals, groups and communities in different ways.[41]

Targeted approaches use selection criteria, such as income, neighbourhood, health or employment status, to target eligibility and access to programs and services to priority sub-groups within the broader population.[42]

Universal approaches are programs and services that are available to the whole population.[42]

Well-being refers to "the presence of the highest possible quality of life in its full breadth of expression focused on but not necessarily exclusive to: good living standards, robust health, a sustainable environment, vital communities, an educated populace, balanced time use, high levels of democratic participation, and access to and participation in leisure and culture."[43]

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Ministry of Health and Long-Term Care

Operational Approaches for Food Safety Guideline, 2018

Population and Public Health Division,
Ministry of Health and Long-Term Care

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Ontario

Table of Contents

Preamble

The Ontario Public Health Standards: Requirements for Programs, Services, and Accountability (Standards) are published by the Minister of Health and Long-Term Care under the authority of section 7 of the *Health Protection and Promotion Act* (HPPA) to specify the mandatory health programs and services provided by boards of health.[1,2] The Standards identify the minimum expectations for public health programs and services. Boards of health are accountable for implementing the Standards including the protocols and guidelines that are referenced in the Standards. Guidelines are program and topic-specific documents which provide direction on how boards of health shall approach specific requirement(s) identified within the Standards.

Purpose

The purpose of this Guideline is to provide direction on how boards of health must approach/apply requirements outlined in the Food Safety Standard and *Food Safety Protocol, 2018* to achieve consistency for specific program requirements.[3]

Reference to the Standards

This section identifies the standards and requirements to which this guideline relates.

Food Safety

Requirement 1. The board of health shall:

a) Conduct surveillance of suspected and confirmed food-borne illnesses, food premises, and food for public consumption;
b) Conduct epidemiological analysis of surveillance data including monitoring of trends over time, emerging trends, and priority populations; and
c) Respond by adapting programs and services

in accordance with the *Food Safety Protocol, 2018* (or as current); the *Operational Approaches for Food Safety Guideline, 2018* (or as current); and the *Population Health Assessment and Surveillance Protocol, 2018* (or as current).

Requirement 2. The board of health shall ensure food handlers in food premises have access to training in safe food-handling practices and principles in accordance with the *Food Safety Protocol, 2018* (or as current) and the *Operational Approaches for Food Safety Guideline, 2018* (or as current).

Requirement 3. The board of health shall increase public awareness of food-borne illnesses and safe food-handling practices and principles in accordance with the *Food Safety Protocol, 2018* (or as current) and the *Operational Approaches for Food Safety Guideline, 2018* (or as current) by:

a) Adapting and/or supplementing national/provincial food safety communications strategies where local assessment has identified a need; and/or

b) Developing and implementing regional/local communications strategies where local assessment has identified a need.

Requirement 4. The board of health shall provide all the components of the Food Safety Program in accordance with the *Food Safety Protocol, 2018* (or as current) and the *Operational Approaches for Food Safety Guideline, 2018* (or as current).

Requirement 5. The board of health shall ensure 24/7 availability to receive reports of and respond to:
a) Suspected and confirmed food-borne illnesses or outbreaks;
b) Unsafe food-handling practices, food recalls, adulteration, and consumer complaints; and
c) Food-related issues arising from floods, fires, power outages, or other situations that may affect food safety in accordance with the *Health Protection and Promotion Act*; the *Food Safety Protocol, 2018* (or as current); the *Infectious Diseases Protocol, 2018* (or as current); and the *Operational Approaches for Food Safety Guideline, 2018* (or as current).

1. Provincial Food Handler Training Plan

This section outlines how the Provincial Food Handler Training Plan shall be implemented by boards of health by providing minimum requirements for:

a) Food handler training programs delivered by boards of health, or on behalf of Boards of health;
b) Standardized food handler training examinations;
c) Provincial Food Handler Certification Card and template; and
d) Acceptance of certifications awarded by non-public health unit providers recognized by the Ministry of Health and Long-Term Care.

1.1 Food Handler Training Program Requirements

All boards of health must meet the Ministry of Health and Long-Term Care Food Handler Training Program Requirements – Public Health Units (Appendix A).

Boards of health that offer food handler training through an agent of the board of health (ex. community college) shall ensure the course meets the Food Handler Training Program Requirements – Public Health Units (Appendix A). Agents of the board of health may not issue the Provincial Food Handler Certification Card.

Online Training
Online courses may be used to support local public health programming. In order to be eligible to meet the Food Handler Training Program Requirements – Public Health Units (Appendix A), online courses must meet all requirements, with the exception of a maximum class size.

1.2 Provincial Standardized Food Handler Training Examinations

All boards of health will have access to a minimum of three (3) Provincial Standardized Food Handler Training Examinations. Examinations and answer keys can be accessed through the web portal, as communicated by the Ministry of Health and Long-Term Care.

Boards of health may choose to use the Provincial Standardized Food Handler Training Examinations, or may continue to use their own examinations that meet the Food Handler Training Program Requirements – Public Health Units (Appendix A).

Recertification
Recertification may be obtained by successfully passing the examination. Although not required, it is recommended that the candidate retake the course or take a refresher course prior to challenging the examination.

Challenge examinations
Boards of health who may wish to allow individuals to challenge the food handler training exam to obtain certification shall develop criteria to assess the candidate's general food handling competency. Criteria may include number of years of experience in the food industry, type of settings where the candidate has been employed and previous related training, including certification from jurisdictions outside of Ontario.

Online courses
Examinations for online courses can be written in-person and facilitated by the board of health or proctored by webcam. This may include examinations that are proctored by an individual not employed by the board of health. The administration of the examination for online courses must meet the requirements outlined in the Food Handler Training Program Requirements – Public Health Units (Appendix A).

1.3 Provincial Food Handler Certification Card

Boards of health shall issue the Provincial Food Handler Certification Card to all candidates who demonstrate they have completed training by receiving a minimum score of 70% on food handler training examinations administered by a board of health. The Provincial Food Handler Certification Card may be issued to successful candidates of courses offered by, or exams administered by, an agent of the board of health. However, boards of health must directly issue the Provincial Food Handler Certification Card. Agents of the board of health may not issue the card.

The template for the Provincial Food Handler Certification Card can be accessed through the web portal, as communicated by the Ministry of Health and Long-Term Care.

The Provincial Food Handler Certification Card template may not be modified by boards of health. The Provincial Food Handler Certification Card must be printed on white card stock and as per the template, which includes predetermined size (89 × 51 mm [3.5 × 2 in]) and colour.

In addition to the Provincial Food Handler Certification Card, boards of health may choose to also issue certificates (215.9 mm x 279.4 mm [8.5 × 11 in]) to successful candidates, using the Ministry of Health and Long-Term Care-provided certificate template, or a template developed by the board of health.

1.4 Recognition of Non-Board of Health Food Handler Training Certifications

Non-public health unit providers (commercial/private entities, educational institutions, organizations, associations, etc.) of food handler training certifications who offer food handler training and certification may apply to the Ministry of Health and Long-Term Care to be evaluated against a provincial standard for food handler training certification programs, in order to be recognized as equivalent providers.

Boards of health shall accept food handler certification awarded by non-board of health providers recognized by the Ministry of Health and Long-Term Care as valid and equivalent to the provincial food handler training program.

2. Risk Categorization of Food Premises

This section outlines how boards of health are to assign risk categories for food premises using a standard approach by:

a) Outlining the scope and standard approach to the risk categorization of food premises that shall be used by the boards of health;
b) Providing definitions of key terms used in the process to ensure consistent application; and
c) Providing minimum requirements for the use of the accompanying Risk Categorization of Food Premises Template

The purpose of Ontario's risk categorization of food premises approach is to prevent or reduce food-borne illness attributed to food premises and to support efficient allocation of board of health resources. Because food premises do not all present the same potential risk of causing food-borne illness, a standard approach to risk categorization (high, moderate, or low) is necessary to ensure that resources are appropriately focused on the premises that pose the highest levels of risk. Levels of risk are attributable to a number of factors including:

- **Profile factors** such as those that consider the type of operation, population served, and the complexity and extent of food handling; and
- **Performance factors** such as those that are attributable to the operators' performance and commitment to food safety practices (i.e., compliance with regulations, commitment to training of food handlers, and the extent to which they incorporate food safety plans into their operations).

2.1 Risk Categorization of Food Premises Process

Boards of health shall incorporate the risk categorization approach and requirements outlined in this guideline into their operational practices which will consist of:

- Developing and implementing a plan to review and update standard operating procedures, categorization forms, templates, or tools (either paper based or electronic) to incorporate the risk categorization approach;
- Provide training to all public health unit staff that have a direct or supporting role in conducting, reporting, or monitoring the risk categorization process; and
- Developing and implementing a reporting system of outcomes from the risk categorization process that may be used for monitoring trends and changes to risk categories, as well as providing summary data on profile and performance factors that may be used for evaluation purposes.

Assigning Risk Categories

All boards of health must use the risk categorization of food premises approach in their annual on-site risk assessment of each food premises, and the annual assignment of risk categories must be completed during the first inspection of each calendar year.

With the exception of new premises that begin operation within a given year, for planning purposes and to ensure reporting requirements are met, food premises that have been assessed as high risk in the previous calendar year should be inspected between January 1st and April 30th or as soon as possible within the calendar year. This process should provide a consistent baseline to assess changes to the proportion of high and moderate risk categories in future years.

Boards of health are required to either use the template provided (Appendix B) or integrate the content, including the profile and performance factors and assigned weightings, into their existing IT system. Although paper versions of the template may also be used, boards of health must ensure that the data is available for reporting and evaluation purposes.

When available, inspection results from the previous 12 months shall be used to inform the annual risk categorization in terms of performance factors. Improvement in performance factors over time should improve food safety practices and reduce the potential of food-borne illness.

Risk Categories

A risk category of high, moderate, or low will be assigned for each food premises based on the total calculated score using the Risk Categorization of Food Premises Template (Appendix B). The minimum frequency of inspection for each risk category is based on the requirements outlined in section 1(c) of the *Food Safety Protocol, 2018*.[3]

Table 1: Risk Category and Frequency of Inspection

Risk Category	Score	Frequency of Inspection
High	55-230	Not less than once every four months
Moderate	20-54	Not less than once every six months.
Low	0-19	Not less than once every twelve months

Definitions

Food premises: A premises where food or milk is manufactured, processed, prepared, stored, handled, displayed, distributed, transported, sold or offered for sale, but does not include a room actually used as a dwelling in a private residence.

High risk premises: An establishment which represents a high likelihood of occurrence of a food-borne illness outbreak.

Moderate risk premises: An establishment which represents a moderate likelihood of occurrence of a food-borne illness outbreak.

Low risk premises: An establishment which represents a low likelihood of occurrence of a food-borne illness outbreak.

The factors and associated weights are established to provide a consistent province wide approach to the risk categorization of food premises. Therefore, the design and use of the process must not be changed or modified in the determination of risk categories. Boards of health may however, expand the use of the template to include other information that may be required for local operational and evaluation purposes (e.g., disclosure programs, compliance with bylaws, private water supply, food handler certification, etc.).

2.2 Factors in Determining Risk Categories

Ontario's risk categorization of food premises approach utilizes profile and performance factors that contribute to the assignment of risk categories. Each factor is weighted in such a way that gives priority to risks that contribute to foodborne illness. The approach of establishing risk categories will be applied to all year round and seasonal food premises with fixed locations.

The Ontario risk categorization of food premises approach should not be applied to individual transient and temporary food premises, including those operating at temporary special events. This includes temporary special event halls that do not have their own dedicated food operator and are mostly rented out for special events or celebrations (e.g., churches, community halls, etc.). In this case, as described in the *Food Safety*

Protocol, 2018 under Section 1 (d),[3] boards of health shall establish and implement procedures to monitor or inspect transient and temporary food premises, including those operating at temporary special events. Boards of health may however, use the established principles of the approach to assist in the development of operational priorities to address these types of food premises.

Food Premises with Multiple Operations

In some cases, food premises may have multiple types of operations within the same facility or include satellite locations supplied by a central kitchen. In order to assess, plan, and manage resources and work effort for these types of premises, Boards of health may subdivide distinct operations into “units”. Recognizing that the use of units to further describe these facilities is an important tool for managing inventories of food premises, the application of the risk categorization of food premises approach will be based on the following principles:

- One risk categorization will be applied to the entire food premises, based on the most complex aspect of the operation. Each “unit” will not receive a separate risk category.
- All areas of food premises will be included during routine inspections outlined in Section 1 (c) of the *Food Safety Protocol, 2018*.[3] Re-inspections for compliance, complaints and inspections carried out for other purposes will focus on the particular issue being investigated.

The following examples are provided to clarify the application of the risk categorization approach to food premises with multiple operations:

- A hospital with one main kitchen and ten serveries operating under the same owner would receive one risk categorization, which shall be based on the main kitchen, as it is the most complex operation. The main kitchen and its ten serveries would be considered one premise, and if the risk category is “high”, it would apply to the main and all serving kitchens. Public health inspectors (PHIs) would include most, if not all serveries during their routine inspection based on the identification of critical control points (CCPs) beyond the main kitchen.
- Multifunctional supermarkets with multiple specialty departments (e.g., delis, butcher shops, bakeries, seafood counters, etc.) operating within one location under the same owner would undergo one risk categorization assessment. For example, a supermarket may have a bakery, deli counter, and hot food counter (where chicken is cooked from raw, sandwiches are made to order, and pasta salads are made from scratch) in addition to the retail grocery area. In this case, the risk categorization would be based on the hot food counter, which is the operation with the most complex food handling, and the determined risk category would then apply to all other operations within the supermarket. Other distinct food businesses within the establishment operated by a different owner would be subject to a separate risk categorization (e.g., a sushi outlet operating as a sub-contractor within the supermarket).

Profile Factors
These factors describe operational attributes of the food premises that may not change over time and are significant considerations to assigning risk categories.

Population Served

Priority populations: Those that are experiencing and/or at increased risk of poor health outcomes due to the burden of disease and/or factors for disease; the determinants of health, including the social determinants of health; and/or the intersection between them. They are identified using local, provincial and/or federal data sources; emerging trends and local context; community assessments; surveillance; and epidemiological and other research studies.

Preparation and Serving

Potentially hazardous foods: means food in a form or state that is capable of supporting the growth of infectious or toxigenic micro-organisms and which requires time and temperature control to limit such growth.

Preparation steps: The number of steps or amount of food handling involved in the preparation of food (e.g., assembling, cooking, cooling, reheating, hot holding, etc.). The weight of the scores reflects that the likelihood of contamination increases with the number of steps that are involved.

- **Extensive food handling (3+ preparation steps):** Foods that are extensively handled during preparation can increase the potential of microbial growth and cross-contamination. Extensive handling/preparation would include a number of steps before service such as cooking, hot holding, cooling, and reheating of foods.
- **Limited food handling (1-2 preparation steps):** This category is for foods that require only one or two preparation steps, such as assembling and/or reheating (e.g., preparation of sandwiches/submarines for sale directly to the consumer, cutting fruit and vegetables, slicing deli meats, etc.).
- **Prepackaged:** There is no food preparation involved.

Catering: Food retail or food service establishment primarily providing catering services off-site where foods are prepared/cooked in the facility kitchen and then delivered to a function off site for further processing, including hot and cold holding, are shown to be at higher risk of being implicated in food-borne illness.

Full-service banquet hall: Premises with on-site preparation, used for holding special events or celebrations. Operating hours are usually off normal business hours. Premises has full kitchen and/or receives delivery of meals, and the facility is not usually available for hire. Full-service banquet halls often produce a high volume of food in a limited amount of time. An increase in volume includes additional food handling and an increased risk for temperature abuse, potentially resulting in food-borne illness.

- Due to the transient nature in the operation of temporary special event halls (e.g., church basements, community centres, etc.), they shall be treated as temporary and transient food premises, and the Ontario risk categorization of food premises approach should not be applied to them. It is recommended that boards of health inspect these premises no less than once per year.

Performance Factors
These factors are metrics that may be observed over time and can be used as indicators of food safety practices by operators. Performance factors provide a specific opportunity for PHIs to work with food premises operators to improve their overall performance, resulting in improved food safety practices and reducing the number of follow up inspections to ensure compliance. The performance factors used in the risk categorization of food premises include: the identification, monitoring and documentation of CCPs through a food safety management plan; food-borne illness or outbreak management; compliance history including the consideration of both existing and repeated infractions of regulation; and food handler training and safe food handling practices.

Compliance

Infraction: Any violation, contravention, or failure to meet legal requirements of the *Ontario Food Premises Regulation* within a food establishment.[4] Observed infractions of the regulation may be either critical or non-critical, and include those that are corrected at time of inspection.

- **Critical infraction:** An infraction which has the potential to pose an immediate public health risk and/or lead to a food-borne illness (e.g., improper hot/cold holding temperatures, etc.).
    - **Observed critical infraction(s) at one inspection**: The observation of critical infraction(s) during only one inspection within the past 12 months.
    - **Observed critical infraction(s) at two or more inspections**: The observation of critical infraction(s) during two or more inspections within the past 12 months. These infractions may be the same critical infraction or different critical infractions.
- **Non-critical infraction:** An infraction which does not pose an immediate health risk in and by itself, is not likely to lead to a food-borne illness, and/or does not directly relate to food handling practices (e.g., structural deficiency of floors or walls, etc.
    - **Observed non-critical infraction(s) at one inspection**: The observation of non-critical infraction(s) during only one inspection within the past 12 months.
    - **Observed non-critical infraction (s) at two or more inspections**: The observation of non-critical infraction(s) during two or more inspections within the past 12 months. These infractions may be the same non-critical infraction or different non-critical infractions.

Food-borne Illness/Outbreaks

Confirmed as source of food-borne illness/outbreak: A laboratory-confirmed or epidemiologically-linked food-borne illness or outbreak, attributed to improper food handling practices at the food premises.

- **Outbreak:** An incident in which two or more persons experience similar illness after a common source exposure. An outbreak is identified through laboratory surveillance or an increase in illness that is unusual in terms of time and/or place. An outbreak is confirmed through laboratory and/or epidemiological evidence.
- **Laboratory evidence:** Evidence shown by the isolation/identification of the same pathogen, toxin, or contaminant from cases of human illness and the suspect food.
- **Epidemiological evidence:** In the absence of other types of evidence, epidemiological evidence must show a statistically significant association between human illness and consumption of specific food(s).

Food Safety Management Plan

Food safety management plan (e.g., Hazard Analysis and Critical Control Point) **:** A documented, systematic approach, applied by the food premises operator or a third party quality assurance company, to identify and assess hazards and risks associated with a food operation and defining the means of their control.

Demonstrated evidence of CCP monitoring: Evidence includes observations by a PHI that food premises operators have incorporated operational processes or tools to identify and monitor CCPs without a formal food safety management plan. Processes and tools may include signage at CCPs for hot holding, refrigeration temperatures, and hand-washing, food handlers observed using thermometers, etc. to demonstrate active understanding of critical control points.

Food Safety Knowledge and Training

Food handler: Any person employed in a food premises, including the operator, who handles or comes in contact with any utensil or with food during its preparation, processing, packaging, service, storage, or transportation.

Certified food handler: A food handler who has successfully completed a course from a recognized food handler training provider (i.e., board of health or other recognized provider), with proven documentation from within the previous five years.

3. Supporting Food Recalls

This section includes requirements supporting Section 2 (e) of the *Food Safety Protocol, 2018* (or as current) on board of health responsibilities for supporting food recall notifications.[3] Boards of health may be requested for assistance with food recalls by the Ministry of Health and Long-Term Care or Chief Medical Officer of Health.

- In the event that the board of health increases its activities beyond the scope of the recall the board of health must notify the Ministry of Health and Long-Term Care, who in turn will notify the Canadian Food Inspection Agency's (CFIA's) Area Recall Coordinator.
- Boards of health must immediately notify the CFIA's Area Recall Coordinator when a recalled product involving the CFIA is found.
- Boards of health must monitor for recalled food, in the marketplace, particularly for Class 1 recalls, as part of regular inspections of food premises.
- Boards of health shall educate operators of institutions that serve priority populations (such as hospitals, long-term care facilities, and child care centres) to ensure they are aware of CFIA's web-based Food Recalls and Allergy Alerts so that they are able to take appropriate action.

4. Special Events Risk Assessment

Further to Section 1(d) of the *Food Safety Protocol, 2018* (or as current) that requires boards of health to monitor or inspect operators of temporary special events,[3] boards of health must develop a plan to manage and assess special events in order to determine appropriate public health action that includes education and/or inspection.

Boards of health shall determine whether a special event and/or individual food vendors are exempted from Ontario Regulation – *Food Premises*.[4]

If the special event and/or individual food vendor is not exempted from Ontario Regulation – *Food Premises*, the following factors should be considered, at a minimum in assessing further public health action:[4]

- The type of food being served
- Complexity of food processing and preparation
- The length of the event (e.g., number of days)
- Expected number of attendees
- Expected number of food vendors
- Previously linked to a foodborne illness/outbreak
- If special event is serviced by municipal water or power
- If the participating food vendors are routinely inspected food premises

5. Farmers' Market Exemption Assessment

Ontario Regulation– *Food Premises* exempts certain farmers' markets from being subject to compliance with the regulation.[4] As a result, boards of health must use a consistent approach to assess and recognize exempted farmers' markets.

Boards of health shall request initial verification from each farmers' market operator or agent of the farmers' market, to assess whether an exemption applies. This assessment should be based on the anticipated peak of the farmers' market operation and based on the best available information (such as an inventory of vendors with addresses) provided by the market operator and/or on-site assessment.

Boards of health shall exempt a farmers' market from Ontario Regulation – *Food Premises*,[4] if greater than 50% of the vendors are producers of farm products who are primarily selling or offering for sale their own products intended for use as food. When considering the greater than 50% rule, all vendors including non-food vendors/stalls should be considered as part of the farmers' market.[5]

Farmers' market operators that do not demonstrate the majority of vendors are producers of farm products who are primarily selling or offering for sale their own products intended for use as food will be subject to the Ontario Regulation – *Food Premises*.[4]

Once initial verification is complete, operators of exempted farmers' markets will be requested to maintain an inventory of vendors on-site or have access available to the inventory for the public health inspector to monitor the ongoing application of the exemption.

Additional assessments and/or inspections should be carried out as necessary to ensure compliance with the HPPA including recommendations from PHIs, suspected food-borne illnesses/outbreaks, consumer complaints and food recall action.

6. References

1. Ontario. Ministry of Health and Long-Term Care. Ontario public health Standards: requirements for programs, services, and accountability, 2018. Toronto, ON: Queen's Printer for Ontario; 2018. Available from: http://www.health.gov.on.ca/en/pro/programs/publichealth/oph_standards/default.aspx
2. *Health Protection and Promotion Act*, RSO 1990, c H.7. Available from: https://www.ontario.ca/laws/statute/90h07
3. Ontario. Ministry of Health and Long-Term Care. Food safety protocol, 2018. Toronto, ON: Queen's Printer for Ontario; 2018. Available from: http://www.health.gov.on.ca/en/pro/programs/publichealth/oph_standards/protocolsguidelines.aspx
4. *Food Premises*, RRO 1990, Reg 562. Available from: https://www.ontario.ca/laws/regulation/900562
5. Association of Supervisors of Public Health Inspectors of Ontario (ASPHIO). Common approaches for farmers' markets and exempted special events: a guide for public health units. Toronto, ON: ASPHIO; 2012.

7. Appendices

Appendix A: Food Handler Training Program Requirements

Food Handler Training Program Requirements

Public Health Units

Materials and Content
Please select one of the following options. ☐ The Provincial Food Handler Training Manual is being used, as provided. ☐ The Provincial Food Handler Training Manual is being used in part, to ensure the minimum course content below is covered. ☐ The health unit is using its own training manual, which includes the following minimum course content: • Role of the board of health • Public health legislation and regulations • Causes of foodborne illness and outbreaks (microbiological, physical, and chemical) • Outline of food safety management principles (including HACCP-based principles) • Safe handling, preparation, and storage (including basic microbiology, safe food supplies, adverse reactions to food, safe food preparation/storage) • Food handler hygiene • Food premises sanitation, design, and maintenance • Prevention of food allergies, incidents and response

Availability, Communication and Promotion
In-class and/or online food handler training program(s) are available through the public health unit. Program(s) may be delivered directly by the public health unit and/or by an agent of the public health unit (ex. community college).
The availability of food handler training program(s) is promoted through the public health unit website.
Information on the public health unit website includes:
• Description of program(s) (duration, format, timeframe to receive results)
• Registration information (cost, how to register, refund policy)
• Delivery options
• Certification / recertification requirements

• Contact information to obtain further details/information
• Link to Ministry of Health and Long-Term Care list of commercial providers recognized by the ministry

Delivery
Course material is available in both English and French
Maximum class size of up to 25 students per instructor
Course is designed to be completed in 6-8 hours, including exam
A manual and/or workbook(s) is provided to each student
Online Program (Optional)
• Designed to be completed within one day (6-8 hours)
• Communication is available to students for support with course content, delivery and technical assistance (i.e. phone number, email)
• Course is delivered using a variety of formats (i.e. text, audio, graphics, etc.) to support various learning styles.
Exam:
• Closed-book
• Minimum of 50 questions
• Pass rate of 70%
• Questions pre-tested to ensure learning objectives are met
• Question bank with sufficient number of potential questions, to ensure randomization
• Security and integrity of exams maintained, through measures such as counting and matching examinations to attendees, proper identification of attendees, protecting the examinations from loss or other confidentiality breaches.
• Proctored exams
• Accommodation and alternative testing is available for students
Certification:
• A certification card is issued within 15-20 business days of successful completion of course and exam to demonstrate students have completed training
• Certification card includes, at a minimum, name of successful candidate, date of issue, date of expiry, issuing public health unit
• Certification expires five years after date of issue
• Inventory of public health unit course participants is maintained, including name of participant, date of course, exam result, and date of expiry

Table 1: Guiding Principles

Guiding Principles
All food handler training programs offered by public health units or by agents of public health units must: • Use clear language • Be inclusive of cultural, disability, and gender differences • Provide accurate and current content

Appendix B: Risk Categorization of Food Premises Template

1. Does this food premises primarily serve clients of the following settings?	
Hospital, long-term care home, retirement home	60
Child-care setting (i.e., day nursery, nursery school)	35
Child-care settings (i.e., before and after school program)	0
Not applicable	0
2. To what extent is food prepared and served? (Select ONE of the following)	
Extensive food handling (3+ preparation steps)	35
Limited food handling (1-2 preparation steps)	20
Prepackaged	0
3. Is this premises a full-service banquet hall or does it primarily cater off-site?	
Full-service banquet hall and/or primarily serves catered meals off-site	30
Not applicable	0
4. What is the level of compliance over the past 12 months with Ontario Food Premises Regulation? (Select ALL that apply)	
Critical infraction(s) (select ONE of the following three options):	
Observed critical infraction(s) at one inspection	10
Observed critical infraction(s) at two or more inspections	25
No observed critical infractions at this or previous inspections	0
Non-critical infraction(s) (select ONE of the following three options):	
Observed non-critical infraction(s) at one inspection	5
Observed non-critical infraction(s) at two or more inspections	10
No observed non-critical infractions at this or previous inspections	0
Other (IF applicable):	
Insufficient history (new premises or no previous inspections – EXCLUDING premises that serve only prepackaged foods)	20
5. Food-borne illness/outbreak over the past 12 months	
Premises confirmed as the source of food-borne illness/outbreak, attributed to improper food handling practices	50
Not applicable	0
6. Is there a food safety management plan (HACCP)? *(Select ONE of the following)*	
Documented food safety management or written HACCP plan in place; principles and procedures are applied; plan is audited for effectiveness	-5
Demonstrated evidence of critical control point (CCP) monitoring	-5
No food safety management plan/HACCP program documented (food safety plan is warranted)	10
Not applicable to this premises (food safety plan is not warranted)	0

Food safety knowledge & training, at the time of inspection ***(Select ALL that apply)***	
One or more certified food handler(s) on site	-5
Food handler(s) demonstrate safe food handling practices	-5
Food handler(s) do not demonstrate safe food handling practices	10
Not applicable to this premises (food handling does not occur on site)	0
RISK CATEGORIZATION & TOTAL SCORE	

High: ≥55	Moderate: 20-54	Low: ≤19

Ontario

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Ministry of Health and Long-Term Care

Oral Health Protocol, 2018

Population and Public Health Division,
Ministry of Health and Long-Term Care

Effective: January 1, 2018 or upon date of release

Preamble

The Ontario Public Health Standards: Requirements for Programs, Services, and Accountability (Standards) are published by the Minister of Health and Long-Term Care under the authority of section 7 of the *Health Protection and Promotion Act* (HPPA) to specify the mandatory health programs and services provided by boards of health.[1,2] The Standards identify the minimum expectations for public health programs and services. Boards of health are accountable for implementing the Standards including the protocols and guidelines that are referenced in the Standards. Protocols are program and topic-specific documents incorporated into the Standards which provide direction on how boards of health shall operationalize specific requirement(s) identified within the Standards.

Purpose

This protocol has been developed to provide direction to boards of health on oral health services to be offered, including:

- **Oral screening**[*], **assessment** and **surveillance**; and
- Services to be offered through the Healthy Smiles Ontario (HSO) Program to children meeting the clinical and financial eligibility requirements of the Program.

Reference to the Standards

The following section identifies the standards and requirements to which this protocol relates.

School Health

Requirement 5: The board of health shall conduct surveillance, oral screening, and report data and information in accordance with the *Oral Health Protocol, 2018* (or as current) and the *Population Health Assessment and Surveillance Protocol, 2018* (or as current).

Requirement 6: The board of health shall provide the Healthy Smiles Ontario (HSO) Program in accordance with the *Oral Health Protocol, 2018* (or as current).

[*] Terms marked in **bold** are defined in the Glossary.

Operational Roles and Responsibilities

Pre-Screen Notification

1) In preparation for school oral screening, the board of health shall:
   a) Coordinate with schools to make prior arrangements regarding the screening dates, time and locations;
   b) Ensure that notification is provided to parents/guardians at least 10 business days before oral screening is scheduled to take place. This notification shall include information on:
      i) The statutory authority under which oral screening is conducted;
      ii) The purpose of oral screening;
      iii) The screening processes, including clarification that oral screening is non-invasive;
      iv) Post-screening notification to parents/guardians;
      v) The process parents/guardians should follow if they wish to opt out from oral screening; and
      vi) A contact name and telephone number parents/guardians may call if they require additional information.
   c) Confirm that pre-screen notifications have been sent to parents/guardians; and
   d) Reschedule the screening if pre-screen notifications have not been sent to parents/guardians before oral screening is scheduled to take place.

Oral Screening

School Risk Level Determination and School Screening

2) The board of health shall:
   a) Calculate the screening intensity level of the school by using Grade 2 screening results for the current school year. Record decay findings in the primary and secondary dentitions (**d + D**) to determine the school's risk and screening intensity level.
      i) Where it is not possible to use the current year, the board of health shall use the previous school year's screening results.
      ii) For schools that do not have Grade 2, the board of health shall determine screening intensity levels using:
         I) Feeder schools (where known);
         II) Appropriate population health assessment information; and/or
         III) Deprivation indices.
   b) Apply the following definitions:
      i) High screening intensity schools are those in which a Grade 2 census screening reveals that ≥14 per cent of students exhibit a "d + D" of two or more;

ii) Medium screening intensity schools are those in which a Grade 2 census screening reveals that ≥9.5 per cent, but <14 per cent of students exhibit a "d + D" of two or more; and
iii) Low screening intensity schools are those in which a Grade 2 census screening reveals <9.5 per cent of students exhibit a "d + D" of two or more.

c) Boards of health shall offer oral screening in all schools annually to students in the following grades:
    i) JK, SK, and Grade 2 in low screening intensity schools;
    ii) JK, SK, Grade 2 and 7 in medium screening intensity schools; and
    iii) JK, SK, Grade 2, 4, and 7 in high screening intensity schools

Screening at Non-School Locations

3) The board of health shall:
    a) Offer oral screening, within five business days, at an alternate location when requested by a parent/guardian or for operational reasons, it is determined that an alternate location is more appropriate.

Surveillance

4) The board of health shall:
    a) Record the number of decayed teeth (d + D), missing teeth (**m + M**) and filled teeth (**f + F**) for all SK students annually as specified by the ministry.

Healthy Smiles Ontario (HSO) Program Eligibility Assessment

Preventive Services Only Stream (HSO-PSO)

Assessment of Clinical Eligibility

5) The board of health shall:
    a) Assess and confirm clinical eligibility for HSO-PSO according to the criteria for each of the following services:
        i) Professionally Applied Topical Fluoride (PATF) and Pit and Fissure Sealants (PFS)
        Where one or more of the following criteria apply:
            I) History of decay;
            II) Current decay - including incipient **caries**/white spot lesions;
            III) Water fluoride concentration is less than 0.6 ppm;
            IV) Diet - frequent consumption of cariogenic and/or acidic foods/beverages;
            V) Inadequate oral hygiene practices;
            VI) Tooth morphology of the permanent first and second molars (for pit and fissure sealants);

VII) Physical disability that impacts oral health and/or the ability to perform oral hygiene; or
VIII) Medical/dental condition that contributes to higher risk of oral disease.

ii) Scaling
I) Presence of calculus; and/or
II) Evidence of gingival inflammation.

iii) Atraumatic restorative treatment/Interim stabilization therapy
I) When access to a permanent restoration is not immediate or practical;
II) When there are no medical contraindications;
III) When the client consents to the treatment; and
IV) When any of the following apply:
- There is a reasonable risk of further damage to the tooth structure;
- The pulp is not exposed;
- The client is in discomfort or is experiencing difficulty eating;
- The discomfort is due to recent **trauma**, fracture or lost dental restoration;
- The client has not received any medical/dental advice that would contraindicate placing a temporary restoration; or
- It is in the client's best interest to proceed.

b) Track children identified as eligible for preventive oral health services using methods specified by the ministry.

Assessment of Program and Financial Eligibility

6) The board of health shall:
a) Assess and confirm program and financial eligibility for HSO-PSO including completion of a HSO-PSO Parent Notification Form according to the following criteria:
i) Financial hardship criteria:
I) The child/youth or family's income is equivalent to a level at which they would be in receipt of the Ontario Child Benefit, **and**
II) The child/youth or family would suffer "financial hardship" if providing the preventive services would result in any one of the following:
- Inability to pay rent/mortgage;
- Inability to pay household bills;
- Inability to buy groceries for the family; or
- The child/youth or family will be required to seek help from a food bank in order to provide food.

ii) Program Criteria:
I) 17 years of age or under, and
II) A resident of Ontario.

Emergency and Essential Services Stream (HSO-EESS)

Assessment of Clinical Eligibility

7) The board of health shall:
   a) Assess and confirm clinical eligibility for HSO-EESS according to the following criteria:
      i) Emergency: The patient presents with **pain**, **infection**, **haemorrhage**, trauma, or **pathology** that requires immediate clinical treatment.
      ii) Essential: The patient presents with lost restorations, caries into the dentine (refer to definition in Glossary), **periodontal conditions**, or pathology that, without treatment, will lead to haemorrhage, pain or infection requiring immediate clinical treatment.

Assessment of Program and Financial Eligibility

8) The board of health shall:
   a) Assess and confirm program and financial eligibility for HSO-EESS including completion of a HSO-EESS Application Form or a HSO-EESS Parent Notification Form according to the following criteria:
      i) Financial hardship criteria:
         I) The child/youth or family's income is equivalent to a level at which they would be in receipt of the Ontario Child Benefit, **or**
         II) The child/youth or family would suffer "financial hardship" if providing the necessary dental care would result in any one of the following:
            - Inability to pay rent/mortgage;
            - Inability to pay household bills;
            - Inability to buy groceries for the family; or
            - The child/youth or family will be required to seek help from a food bank in order to provide food.
      ii) Program Criteria:
         I) 17 years of age or under, and
         II) A resident of Ontario.

Post-Screening Notification and Follow-Up

Preventive Services Only Stream (HSO-PSO)

9) The board of health shall:
   a) Notify the parents/guardians of children who are screened and identified in need of preventive services within five business days of completing screening, or as soon as reasonably possible. This notification shall be by mail, telephone discussion, direct contact, or by electronic communication where available, and shall include issuing a HSO-PSO Parent Notification Form (PNF).

Emergency and Essential Services Stream (HSO-EESS)

10) The board of health shall:
   a) Notify parents/guardians of all children who are screened and identified in need of emergency and/or essential oral health services within two business days of completing screening. This notification shall be by mail, telephone discussion or direct contact, or by electronic communication where available, and shall include issuing the first Parent Notification Form (PNF1).
   b) Mail a second PNF (PNF2) or have a telephone discussion with the child’s parent or guardian if there is no response to the PNF1 within 20 business days of the date of issue of the PNF1.
   c) Issue a third PNF (PNF3) with proof of delivery or have a telephone discussion with the child’s parent/guardian if there is no response to the PNF2 within 20 business days of the date of issue of the PNF2. As part of this notification, PHUs should advise the parent/guardian that there may be a referral to the local Children’s Aid Society (CAS) should they fail to respond to the PNF3.
   d) If there is no response to the PNF3 within 20 business days of the date of issue, the oral health staff member who performed the original oral screening shall report any suspicion that a child is suffering from abuse and/or neglect and may be in need of protection to the local CAS, in accordance with the *Child, Youth and Family Services Act, 2017*.[3]
   e) All reasonable efforts shall be made to re-screen the child to assess their dental condition prior to making a referral to CAS.
   f) In cases where the oral health staff member who performed the original oral screening is unable to make the referral, a designate shall make the referral and document, in the child’s file, the reason that a delegate was used.
   g) Within four months (16 weeks) of the date of enrolment into HSO-EESS, assess the status of treatment. Where no treatment has been initiated a staff member can have a phone discussion with the parent/guardian.
   h) If the parent/guardian cannot be reached or there is any suspicion that a child is suffering from abuse and/or neglect and may be in need of protection from the local CAS, the staff person who conducted the oral screening may expedite referring a child to the local CAS in accordance with the *Child, Youth and Family Services Act, 2017*.[3]
   i) Consider follow-up complete when:
      i) The child has been enrolled into HSO and treatment has been initiated;
      ii) An HSO-EESS PNF has been returned with the parent/guardian declaration of ability to pay for necessary dental treatment and dental provider confirmation that treatment has been initiated;
      iii) The child has been re-screened by board of health staff and deemed non-clinically eligible for HSO-EESS;
      iv) The child has moved out of the board of health catchment area; or has been referred to another board of health; or the child has moved out of Ontario;

v) The child has been referred to the local CAS; or
vi) The child is deceased.

All Other Screened Children (i.e., not clinically eligible for HSO-PSO or HSO-EESS)

11) The board of health shall:
   a) Notify the parents/guardians of all other children who are screened. This notification shall be by mail, telephone discussion, direct contact, or by electronic communication where available. This notification shall include:
      i) The results of the screening;
      ii) Information about the importance of good oral health;
      iii) Information about the Core Stream of the HSO Program; and
      iv) The public health unit's contact information.

Service Delivery

12) Where board of health clinics are in operation, the board of health shall:
   a) Provide oral health services for HSO-enrolled clients in accordance with the current HSO Schedule of Dental Services and Fees.

Oral Health Navigation

13) To support awareness of, access to, and utilization of the HSO Program, the board of health shall:
   a) Support children and youth 17 years old and under, and their families to improve their oral health knowledge and awareness of oral health services through **health promotion** and targeted outreach to priority populations and/or communities;
   b) Assist children and youth 17 years old and under, and their families to enroll in the HSO Program, including assisting to complete and/or submit all of the required documentation and/or consents.
   c) Assist HSO-PSO and HSO-EESS clients to enroll in the Core Services Stream of the HSO Program where eligible;
   d) Assist eligible children and youth 17 years old and under, and their families with finding a dental provider, accessing and initiating treatment as needed, and assisting with the establishment of a **dental home** when the child/youth has never visited a dental professional and/or does not have a dental home.[4]
   e) Support organizations that serve social assistance recipients to improve awareness and access to the HSO program;
   f) Increase awareness of available oral health services among community partners and providers, and encourage participation in the HSO program; and
   g) Utilize referral networks in order to assist children, youth, and their families to access oral health services.

Data Collection and Analysis

14) The board of health shall:
   a) Collect and record oral screening and surveillance information as specified by the ministry, either during screening or at the first opportunity post-screening.
   b) Collect and record treatment data as specified by the ministry for HSO-enrolled children and youth treated in publicly funded dental clinics.
   c) Analyze and interpret oral screening, surveillance, and treatment data as specified by the ministry.

Glossary

The following definitions have been developed for the purpose of the Oral Health Protocol. They may differ from definitions used in other contexts.

Assessment: The systematic collection and analysis of information in respect of an individual in order to provide a basis for making decisions about that individual's health care. This includes the assessment of clinical and financial eligibility for the HSO Program.

Caries: Open carious lesions into the dentine. The lesions should be obvious enough that the parent or guardian can easily see them. Lesions would be equivalent to the International Caries Detection and Assessment System (ICDAS) codes 5 or 6.[5]

d + D: Decayed primary teeth (d) + decayed permanent teeth (D).[6]

Dental Home: Is inclusive of all aspects of oral health that result from the interaction of the patient, parents, dentists, dental professionals, and non-dental professionals.[4]

DMFT: Decayed, missing (due to caries) and filled permanent teeth.[6]

dmft: Decayed, missing (due to caries) and filled primary teeth.[6]

f + F: Filled primary teeth (f) + filled permanent teeth (F).[6]

Haemorrhage: A sudden or serious loss of blood associated with trauma to the orofacial tissues.

Health Promotion: is defined by the World Health Organization as "the process of enabling people to increase control over, and to improve, their health. It moves beyond a focus on individual behaviour towards a wide range of social and environmental interventions".[7] Health promotion strategies include: 1 - build healthy public policy; 2- create supportive environments; 3- strengthen community action; 4- develop personal skills; and 5- re-orient health services. It involves the population as a whole in the context of their everyday lives rather than focusing on people at risk for specific diseases and is directed toward action on the determinants or causes of health.[8]

Infection: Abscesses and/or acute gingival conditions requiring immediate clinical treatment (e.g., necrotizing ulcerative gingivitis).

m + M: Missing primary teeth (m) + missing permanent teeth (M).[6]

Oral Screening: A relatively short assessment by a regulated dental professional that can indicate the need for dental care. Oral screening is not a replacement for a complete dental examination conducted by a regulated dental professional.

Pain: A condition(s) which is/are presently causing pain or have/has caused pain in the week immediately preceding (excluding pain related to exfoliation and/or eruption of teeth).

Pathology: Any specific pathological condition of the orofacial tissues where investigation is required for diagnosis and clinical treatment.[9]

Periodontal Conditions: A condition of the periodontium which is not reversible by adequate oral hygiene, and requires clinical treatment.

Surveillance: The systematic and ongoing collection, collation and analysis of information in respect of a population of individuals in order for a board of health to plan, monitor, report on and evaluate programs.

Trauma: Injury to the orofacial tissues that requires clinical treatment.

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