The Calgary Airport Authority

Parallel Runway Project
Volume V – Item 9
Climate and Greenhouse Gases Baseline Report

Report

Environment

The Calgary Airport Authority

Parallel Runway Project
Volume V – Item 9
Climate and Greenhouse Gases Baseline Report

Prepared by:

AECOM
2540 Kensington Road NW   403 270 9200   tel
Calgary, AB, Canada T2N 3S3   403 270 0399   fax
www.aecom.com

Project Number:

60114017

Date:

June 2010

AECOM
2540 Kensington Road NW 403 270 9200 tel
Calgary, AB, Canada T2N 3S3 403 270 0399 fax
www.aecom.com

March 16, 2010 Project Number: 60114017

Peter Rudolf
Director Airfield Development
Calgary Airport Authority
2000 Airport Road N.E.
Calgary, AB
T2E 6WS

Dear Peter:

Re: Baseline Study – Climate and Greenhouse Gases
Comprehensive Study Environmental Assessment
Parallel Runway Project 16L-34R - Runway Development Program

This report presents the results of the baseline study for Climate and Greenhouse Gases conducted by AECOM Canada Ltd. for the Parallel Runway Project 16L-34R and connecting taxiways to be constructed at the Calgary International Airport in Alberta.

The report is part of the Comprehensive Study – Environmental Assessment and forms part of Volume V of that study.

If you have any questions concerning this report, please contact the undersigned at (403) 717-3498.

Sincerely,
AECOM Canada Ltd.

Barry Hawkins Project Manager
barry.hawkins@rwy-yyc.com

TJ:
Encl.
cc: File

Acronyms

Abbreviation	Full text
the Authority	Calgary Airport Authority
CEAA	Canadian Environmental Assessment Act
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CRAZ	Calgary Region Air Zone
CS	Comprehensive Study
EA	Environmental Assessment
GHG	Greenhouse Gas
GWP	Global Warming Potential
ICAO	International Civil Aviation Organization
IPCC	Intergovernmental Panel on Climate Change
LST	Local Standard Time
N_2O	Nitrous oxide
NO_2	Nitrogen Dioxide
O_3	Ozone
PRP	Parallel Runway Project
RSA	Regional Study Area
SO_2	Sulphur Dioxide
VOCs	Volatile Organic Compounds
YYC	Calgary International Airport

Symbol	Unit of measure
°C	Degrees Celsius
cm	Centimetres
km	Kilometre
km^2	Kilometre squared
kPa	Kilopascal
m	Metres
m asl	Metres above sea level
mm	Millimetres
m/s	Metres per second
Mt	Megatonne
t	Tonne
kt	Kilotonne

Executive Summary

Climate is the statistical average and variability of meteorological phenomena in a region over an extended period of time. Climate is an important variable in the atmospheric environment for many reasons, including its impact on the atmospheric fate and transport of constituents such as air contaminants. The Parallel Runway Project (PRP) will result in the emission of greenhouse gases (GHGs), thereby contributing to national and provincial GHG emission totals.

Climate change is defined by the Intergovernmental Panel on Climate Change (IPCC) as “the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persist for an extended period, typically decades or longer”.

The existing baseline technical data relating to climate are presented in this report to serve as a current reference of existing environmental conditions within the regional study area for the PRP.

Calgary has a continental climate with long, cold winters, and short, mild summers. Its dry, sunny, highly variable conditions are a result of the city's high elevation (approximately 1,048 m above sea level), prevailing atmospheric circulation and regional topography. Climate change is an intrinsic property of the climates in Canada. Climate change is a change in the statistical distribution of meteorology over periods of time. The emission of GHGs is one factor that may impact future climate change trends. The PRP will result in emissions of GHGs. As climate change trends may be affected by GHG emissions, it is important to assess the baseline conditions for GHGs. As such, the baseline conditions for GHGs within the RSA were assessed.

The regional existing GHG emissions were determined for the Province of Alberta and Canada by compiling data from Environment Canada’s 2007 GHG Inventory (Environment Canada 2009). In addition, existing GHG emissions from current operations at Calgary International Airport (YYC) were determined by reviewing YYC’s 2007 GHG inventory. The following sources were considered in YYC’s 2007 GHG emissions inventory calculations

- Landing and takeoff operations (LTOs)
- Road vehicles including both visitors’ and employees’ trips
- Airside movements, which include aircraft use of auxiliary generators, mobile generators, aircraft manoeuvring, air start compressors, ground vehicles and equipment
- Stationary power generation plants
- Heating and air conditioning for buildings
- Aircraft maintenance, engine testing, stationary emergency power generation units, airfield vehicles, aircraft de-icing and anti-icing fluid use, and fire training exercises

For baseline conditions, YYC has a GHG emissions account for 0.07% and 0.02% of the provincial and national emissions, respectively. The contribution of the YYC operations to the provincial and national GHG emission inventory is considered to be very small.

Table of Contents

Figures

List of Tables

1. Introduction

Climate is the statistical average and variability of meteorological phenomena in a region over an extended period of time. Climate is an important variable in the atmospheric environment for many reasons, including its impact on the atmospheric fate and transport of constituents such as air contaminants.

The Parallel Runway Project (PRP) will result in the emission of greenhouse gases (GHGs), thereby contributing to national and provincial GHG emission totals. GHGs are considered in the environmental assessment (EA) due to their intrinsic importance to climate change as a regional and international issue. Climate change is defined by the Intergovernmental Panel on Climate Change (IPCC) as "the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persist for an extended period, typically decades or longer".

The existing baseline technical data relating to climate are presented in this report to serve as a current reference of existing environmental conditions within the regional study area for the PRP.

This Baseline Report forms part of the CS for the proposed PRP at the Calgary International Airport (YYC). The CS is being prepared as part of an EA and approval process mounted by the Calgary Airport Authority (the Authority). The process shadows the EA process under the *Canadian Environmental Assessment Act* (CEAA).

The PRP consists of the following components:

- A 4267 m x 60 m runway (14000 ft x 200 ft)
- Associated taxiways
- A perimeter road with security fencing
- Grading of workspace to the east of the proposed runway
- Visual navigation aids
- Electronic navigation aids
- A maintenance building
- A field electric centre
- Changes to airside/groundside roads necessitated by construction of the runway
- Closure of part of Barlow Trail between 48 Avenue and Airport Road
- A taxiway underpass (designated Taxiway J Underpass) servicing the airport's cargo area for airport service vehicles to pass under one of the taxiways
- Utility services to the runway including some changes to the airfield storm drainage system
- A taxiway underpass (designated Taxiway F Underpass)

Further details regarding the process and project can be found Volume II, Chapter 5 of the CS.

This report provides a description of the climate and GHG baseline conditions in the existing environment associated with the Authority's PRP. A series of baseline studies have been undertaken to describe the biophysical, socio-economic and historical resource baseline conditions. In total, 13 baseline studies have been undertaken:

- Soils and Terrain
- Vegetation
- Surface Water and Aquatic Resources

- Wildlife and Wildlife Habitat
- Groundwater
- Transportation
- Land Use
- Noise
- Climate and Greenhouse Gases
- Air Quality
- Cultural Resources
- Socio-economics
- Human Health

During the CS the results of each of the baseline studies were documented in stand-alone technical reports such as this one. In each case, a draft was prepared and made available for public, stakeholder and government agency comment. The final baseline conditions will be summarized in each individual assessment chapter (Volume III), with each of the stand-alone technical reports becoming an appendix to the CS.

2. Regional Study Area

Meteorological phenomena occur on micro, meso, and synoptic scales, which combine to create weather in a given location. The climate of a region is typically understood by exploring averages, variations, and trends in local weather. For climate, the international nature of the GHGs and climate change issue dictates that the Regional Study Area (RSA) extends to include the Province of Alberta and Canada. The baseline data for meteorology will focus on information sources for the City of Calgary, and a discussion of regional factors influencing local weather.

2.1 Regulatory Framework

2.1.1 International and Federal

The Government of Canada has set targets for the reduction of GHGs. The Kyoto Protocol is an international accord designed to help reduce the effects of climate change through the reduction of GHG emissions. Canada signed the Kyoto Protocol in 1998, which became legally binding in 2005. Under the terms of the Protocol, Canada is required to reduce emissions to a level of 6% below 1990 levels in the period 2008-2012 (Environment Canada 2008). In March 2008, Environment Canada issued the publication “Turning the Corner, Regulatory Framework for Industrial Greenhouse Gas Emissions”. This publication further outlines Canada’s initiatives in reducing GHGs. The document outlines the regulations that will be implemented in 2010 to govern GHG emissions by major industrial sectors. The regulations will be reviewed every five years to ensure that Canada meets their GHG reduction targets. As outlined in the March 2008 publication, Canada’s future GHG reduction targets are: 20% reduction from 2006 levels in 2020; and a 60% - 70% reduction by 2050.

The PRP is to be built on lands leased from Transport Canada by the Calgary Airport Authority (the Authority). Normally this would mean that the PRP would be subject to environmental assessment under CEAA. However, currently CEAA does not apply to airport authorities, although it may do so in the near future. The Authority has elected to subject the PRP to a CS level environmental assessment by means of a process that shadows that which would normally be followed under CEAA. Further detail is provided in Volume II Chapter 5 of the CS.

2.1.2 Provincial

As stated above, the PRP is situated on federal land so Canadian legislation rather than Alberta legislation applies. It is important to note that where Canadian regulations do not deal specifically with a topic normal Federal regulatory practice is to require that operators comply with the equivalent provincial regulation. As such, provincial regulations and guidelines for GHGs are also considered.

Many provinces have set their own standards for the reduction of GHGs. Alberta is the first jurisdiction in North America to develop and implement a regulatory-based demand for carbon reductions. Alberta Regulation 139/2007, Specified Gas Emitters Regulation (SGER), requires those facilities in Alberta that emit over 100,000 metric tonnes of carbon dioxide equivalents per year to submit annual greenhouse gas (GHG) compliance reports. Companies that emit more than 100,000 tonnes of GHGs a year must reduce their emissions intensity by 12 percent starting July 1, 2007. The options for companies to reduce emissions intensity include the following: operational improvements; purchase of Alberta based offset credits; or contribution to a government-administered fund to invest in GHG-reducing technologies.

As of January 1, 2010, the Specified Gas Reporting Program requires all facilities emitting over 50, 000 tonnes of GHGs to report annual GHG emissions to Alberta Environment. The GHG annual report includes annual GHG emissions and production data and the facility's emissions intensity. However, at this time there is no compliance requirement to reduce emission intensities for facilities emitting over 50,000 tonnes of GHGs.

The following summarizes the regulations, guidelines and policies for all levels of government to assist in the assessment of potential future Project effects on GHG emissions in Alberta.

Table 1 International Regulations and Guidelines

International Regulations and Guidelines		
Permit/Authorization	**Agency**	**Rationale**
Kyoto Protocol	United Nations	Established targets for reducing emissions of GHGs. Countries commit to reducing GHG emissions through their own means, but can also be met by emissions trading, and by implementing GHG reduction in developing countries.

Table 2 Federal Regulations and Guidelines

Federal Regulations and Guidelines		
Permit/Authorization	**Agency**	**Rationale**
Clean Air Act	Environment Canada	Covers both Climate Change objectives and Greenhouse Gas initiatives.
Environment Protection Act	Environment Canada	Outlines mandatory reporting requirements for facilities that emit 50 000 tonnes or more of GHGs. The requirements in this Act will help guide the GHG effects assessment.
Regulatory Framework for Air Emissions (2007)	Environment Canada	Presents the regulatory framework for both industrial GHGs and air pollutants emission reductions.
Regulatory Framework for Industrial GHG Emissions	Environment Canada	The document outlines the regulations that will be implemented in 2010 to govern GHG emissions by major industrial sectors. The regulations will be reviewed every five years to ensure that Canada meets their GHG reduction targets of a 20% reduction from 2006 levels in 2020, and a 60% - 70% reduction by 2050.
Incorporating Climate Change Considerations in Environmental Assessments: General Guidance for Practitioners" (2003)	Canadian Environmental Assessment Agency	Primary document for guidance for addressing climate change for CEAA. The process includes establishing GHG emissions for each phase of the Project, estimating the contribution of Project to provincial and national emissions, and determining if the Project will be a low, medium, or high emitter.

Table 3 Provincial Regulations and Guidelines

Provincial Regulations and Guidelines		
Permit/Authorization/Guideline	**Agency**	**Rationale**
Climate Change and Emissions Management Act (2007)	Alberta Environment	AENV outlines a 50% target reduction in specified gas emissions by 2020, relative to 1990 levels. These gases include: CO_2, CH_4, NO_3, SF_6, and VOCs. The act also outlines emission offsets and mandatory reporting. The requirement of the Act will be used as a resource to help guide the GHG effects assessment for the operational phase.
Emissions Trading Regulation (2006)	Alberta Environment	This regulation summarizes the Alberta emissions trading program. Outlines the regulations on such processes as applying for baseline emission rates, emission credits, and use of credits for compliance.
Specified Gas Emitters Regulation (2007)	Alberta Environment	The regulation outlines that any facility emitting more than 100 000 tonnes of emissions are required to reduce emission intensities by 12% from baseline conditions. To meet this target, facilities can utilize emission offsets, fund credits and performance credits. This will be used to guide the GHG effects assessment process.
Specified Gas Reporting Regulation (2004)	Alberta Environment	These regulations outlining who is required to report emissions, and what information is required. The information that is required to meet the requirements of this regulation will be used as a guide for the effects assessment.

2.2 Methods

Historical regional climate data were obtained from records from Environment Canada's meteorological station at the airport. The historical data for Canadian climate normals from 1971 to 2000 were used to evaluate the regional climate baseline conditions for YYC. Climate normals are arithmetic calculations based on observed climate values for a given location over a specified time period. Thirty years is a time period that is considered representative to assess climate data for the RSA. It should be noted that the World Meteorological Organization considers thirty years a sufficient time period to eliminate year to year variations in climate data.

Winds were assessed by compiling and assessing the most recent five-year period of continuous hourly monitoring data (2004 – 2008) as available from Environment Canada for the YYC meteorological station. A five year period for winds is generally used since, in the opinion of the scientific community, the variability of air quality and GHG modelling results, due to the variability of the meteorological data input is adequately reduced if a 5-year period of record of meteorological data is used (US EPA, 2005).

In addition, existing GHG emissions were determined for the Province of Alberta and Canada by compiling data from Environment Canada's 2007 GHG Inventory (Environment Canada, 2009). Existing GHG emissions from current operations at YYC were determined by reviewing YYC's 2007 GHG inventory.

2.3 Regional Study Area Baseline Conditions

Calgary has a semi-arid, highland continental climate with long, cold winters and short, cool summers. Its dry, sunny, highly variable conditions are a result of the city's high elevation (approximately 1,048 m asl), prevailing atmospheric circulation and regional topography. The Pacific Coast Mountains and Rocky Mountains provide an effective barrier to moisture transfer from the Pacific Ocean, resulting in low relative humidity in the prevailing winds. The winds are predominantly westerly and south-westerly in the winter, and westerly and north-westerly in the summer.

Few natural barriers to the wind and a lack of topographical separation between the cold, dry Arctic to the north and warm, dry air from the American southwest result in windy, variable conditions, with low annual precipitation. The dry conditions translate into high totals for bright sunshine hours, including 60% of available hours in the summer and a national high of 40% in the winter.

Westerly winter winds break up the cold winters when warm, dry Chinooks routinely blow into the city from the Pacific Ocean. The ocean air from the west cools and loses moisture as it rises over the Pacific Coast Mountains, and warms by compression as it descends over the Rockies. The resulting Chinooks can raise temperatures by up to 15 °C in a few hours, and last several days. The frequency of the Chinooks is such that every winter month in the past 100 years has seen a thaw with the exception of January 1950. Most winter days in Calgary have a daily maximum temperature above 0 °C.

Droughts are common and can occur throughout the year, lasting for months or even years. Precipitation in the city decreases somewhat from west to east; consequently, groves of trees on the western outskirts give way to treeless grassland around the eastern city limit.

The following characteristics of regional climate are further characterized through this section:

- Ambient air temperature
- Precipitation
- Relative humidity
- Visibility
- Wind
- Severe weather
- Thermal inversions
- Fog and Sunshine
- GHGs

The description of the climate for the region surrounding the PRP is based upon climate normals from YYC meteorological station for 1971-2000 (Environment Canada, 2007). For each decade, Environment Canada updates the climate normals for as many climatic characteristics as possible. The climate data from this meteorological station are considered to be an accurate representation of average climate conditions for the assessment area. The YYC meteorological station is located at an elevation of 1084.1 m with a latitude of 51° 6.83’ N and a longitude of 114° 1.22’ W.

Table 4 below summarizes the climate normals for temperature, precipitation, relative humidity and visibility as outlined by Environment Canada’s climate normals from the YYC meteorological station.

Table 4 Monthly Climate Normals for YYC (1971 - 2000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature:												
Daily Average (°C)	-8.9	-6.1	-1.9	4.6	9.8	13.8	16.2	15.6	10.8	5.4	-3.1	-7.4
Standard Deviation	5	4.7	2.8	1.9	1.5	1.2	1.3	1.8	2	1.6	3.6	4.6
Daily Maximum (°C)	-2.8	-0.1	4	11.3	16.4	20.2	22.9	22.5	17.6	12.1	2.8	-1.3
Daily Minimum (°C)	-15.1	-12	-7.8	-2.1	3.1	7.3	9.4	8.6	4	-1.4	-8.9	-13.4
Extreme Maximum (°C)	16.5	22.6	22.8	29.4	32.4	35	36.1	35.6	33.3	29.4	22.8	19.5
Date (yyyy/dd)	1987/10	1992/27	1906/30	1926/29	1986/30	1926/26	1919/15+	1914/03	1967/01	1889/05+	1975/04	1999/27
Extreme Minimum (°C)	-44.4	-45	-37.2	-30	-16.7	-3.3	-0.6	-3.2	-13.3	-25.7	-35	-42.8
Date (yyyy/dd)	1893/31	1893/04	1951/08+	1954/02	1954/01	1891/08+	1884/05	1992/25	1926/24	1984/31	1893/30	1924/17
Degree Days:												
Above 24 °C	0	0	0	0	0	0	0.2	0	0	0	0	0
Above 18 °C	0	0	0	0	1	4.8	16.8	15.6	1.7	0.3	0	0
Above 15 °C	0	0	0	0.4	6.7	24	58.2	54.5	11.6	1.9	0	0
Above 10 °C	0	0.3	0.1	9.7	49.5	119.5	191.1	177.1	69.5	16.6	0.6	0
Above 5 °C	1.7	4	7.9	53	159	264	345.6	329	182.4	74	7.8	2.3
Above 0 °C	16.7	27.9	52.3	156.4	307.4	414	500.6	483.8	324.5	185.7	39.8	19.2
Below 0 °C	293.3	198.7	112.3	17.6	0	0	0	0	1	19.3	131.2	248.3
Below 5 °C	433.3	316.2	223	64.2	6.6	0	0	0.2	8.8	62.5	249.2	386.4
Below 10 °C	586.7	453.8	370.1	170.9	52.1	5.6	0.5	3.3	45.9	160.1	392	539.1
Below 15 °C	741.6	594.8	525	311.6	164.3	60.1	22.7	35.7	138	300.4	541.4	694.1
Below 18 °C	834.6	679.6	618	401.2	251.7	130.9	74.2	89.8	218.2	391.8	631.4	787.1
Precipitation:												
Rainfall (mm)	0.2	0.1	1.7	11.5	51.4	79.8	67.9	58.7	41.7	6.2	1.2	0.3
Snowfall (cm)	17.7	13.4	21.9	15.4	9.7	0	0	0	4.8	9.9	16.4	17.6
Precipitation (mm)	11.6	8.8	17.4	23.9	60.3	79.8	67.9	58.8	45.7	13.9	12.3	12.2
Extreme Daily Rainfall (mm)	7.6	6.4	23.4	37.1	65	79.2	95.3	80.8	92.6	45.7	9.2	6.4
Date (yyyy/dd)	1902/07	1885/26	1910/23	1912/30	1902/18	1932/01	1927/15	1945/25	1985/12	1915/01	1992/27	1885/03
Extreme Daily Snowfall (cm)	25.4	27.7	24.1	45.7	48.4	24.9	0.3	6.1	22.9	29.7	35.6	21.8
Date (yyyy/dd)	1913/03	1951/10	1889/13	1932/21	1981/06	1951/06	1918/23	1900/25	1895/19	1914/04	1914/13	1889/11

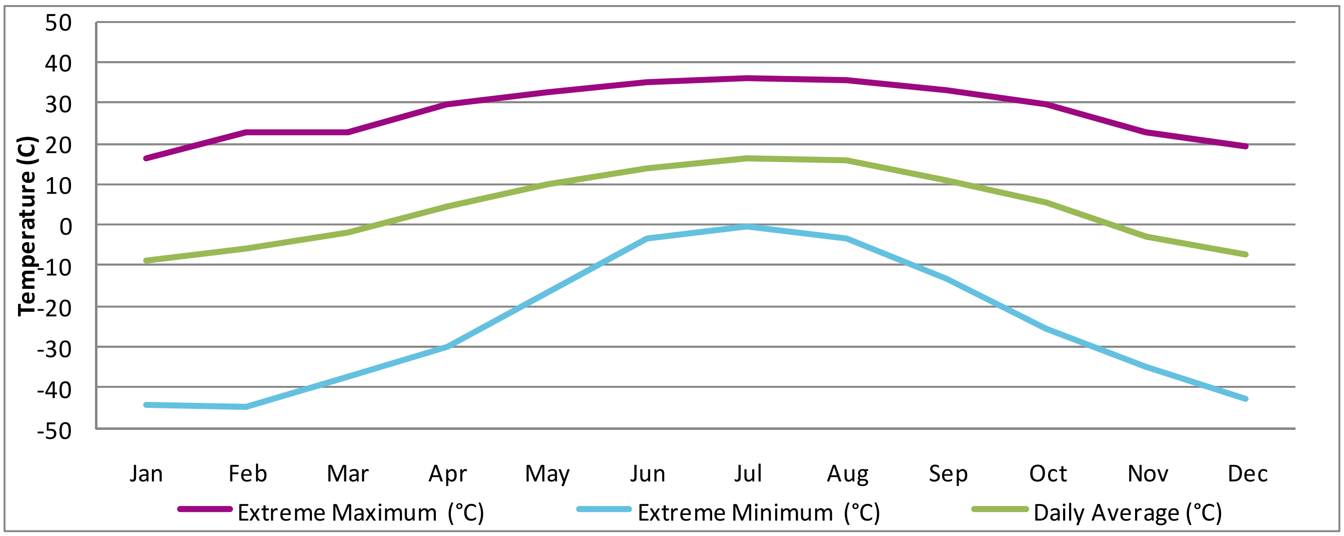
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extreme Daily Precipitation (mm)	25.4	27.7	25	45.7	65	79.2	95.3	80.8	92.6	45.7	35.6	21.8
Date (yyyy/dd)	1913/03	1951/10	1998/16	1932/21	1902/18	1932/01	1927/15	1945/25	1985/12	1915/01	1914/13	1889/11
Extreme Snow Depth (cm)	36	37	38	33	20	0	0	0	10	23	25	30
Date (yyyy/dd)	1997/10+	1978/13+	1998/18	1966/27	1966/01+	1955/01+	1955/01+	1955/01+	1965/26+	1957/22	1965/15+	1996/30+
Days with Rainfall:												
>= 0.2 mm	0.23	0.2	1.1	4.4	10.5	13.4	13	11	8.7	3.6	0.97	0.4
>= 5 mm	0	0	0.14	0.63	3.4	4.8	4.5	3.5	2.8	0.37	0.07	0
>= 10 mm	0	0	0.03	0.2	1.6	2.4	2.4	1.8	1	0.07	0	0
>= 25 mm	0	0	0	0.07	0.17	0.5	0.13	0.3	0.2	0	0	0
Days With Snowfall:												
>= 0.2 cm	9.7	7.6	9.4	6.3	2.2	0.03	0	0.1	1.6	3.8	7.8	8.2
>= 5 cm	0.47	0.53	1.3	0.77	0.55	0	0	0	0.4	0.57	0.93	0.9
>= 10 cm	0.17	0.1	0.28	0.23	0.17	0	0	0	0.07	0.23	0.27	0.2
>= 25 cm	0	0	0	0	0.07	0	0	0	0	0	0	0
Days with Precipitation:												
>= 0.2 mm	9	6.9	9.3	9	11.3	13.4	13	11	9.3	6.3	7.6	7.4
>= 5 mm	0.23	0.17	0.9	1.3	3.9	4.8	4.5	3.5	3.1	0.83	0.53	0.53
>= 10 mm	0.1	0.03	0.21	0.4	1.9	2.4	2.4	1.8	1.2	0.23	0.03	0.17
>= 25 mm	0	0	0.03	0.07	0.24	0.5	0.13	0.3	0.2	0	0	0
Humidity												
Average Vapour Pressure (kPa)	0.2	0.3	0.4	0.5	0.7	0.9	1.1	1.1	0.8	0.5	0.3	0.3
Average Relative Humidity 0600LST (%)	65.2	66.4	71.5	70.3	71.4	73.1	77.4	79.7	76	68.2	69.7	65
Average Relative Humidity 1500LST (%)	56.6	54.3	51.9	40.9	42.8	45.8	45.7	44.8	45.1	42.9	54.6	56.1
Visibility (hours with):												
< 1 km	12.1	9.3	13.6	6.1	3.1	1.3	0.5	2.1	3.9	7.3	14.4	8.6
1 to 9 km	107.2	99.7	105.3	57.1	35	16.3	8.1	21.1	30	38.5	85.3	86.4
> 9 km	624.7	569.5	625.1	656.8	705.9	702.4	735.5	720.8	686.2	698.2	620.3	649

Source: Environment Canada, 2009

2.3.1 Ambient Air Temperature

Daily average temperatures in Calgary range from −9 °C in January to 16 °C in July. During short-lived cold spells, temperatures fall below −30 °C on about five days per year. The extreme maximum and minimum temperatures are 36°C and -45°C, recorded during July of 1919 and February of 1893, respectively (Environment Canada, 2007). Figure 1 below illustrates monthly extreme maximum and minimum temperatures recorded in the 29 year period. Daily averages for each month are also illustrated in Figure 1 below.

Figure 1 Historical Extreme Ambient Air Temperature by Month



Source: Environment Canada, 2009

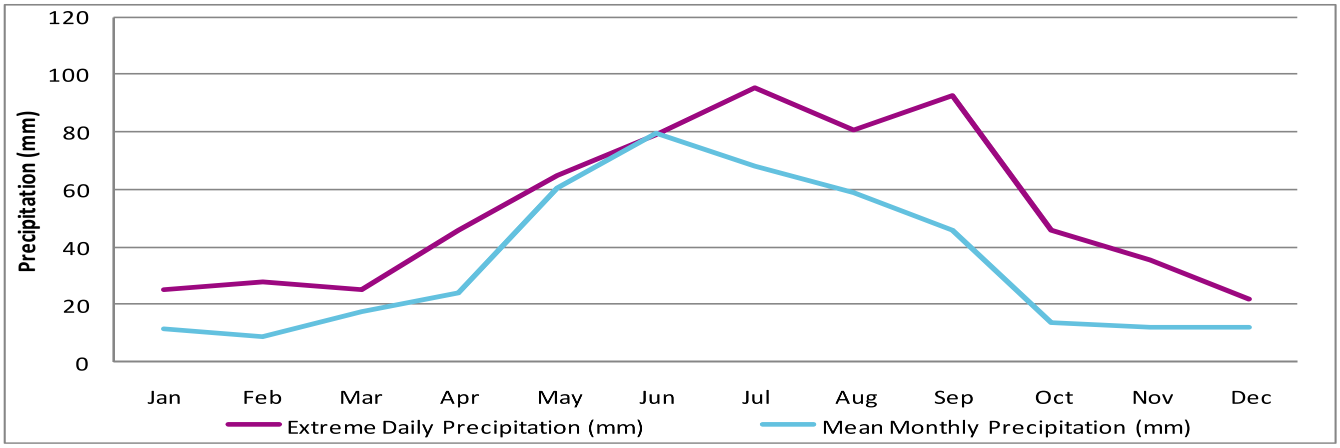
2.3.2 Precipitation

Calgary receives an average of 412.6 mm of precipitation annually, of which 320.6 mm originates as rain, and 126.7 cm as snow. Precipitation is heaviest between May and August, with average peak levels occurring in June. Approximately 30% of Calgary's precipitation falls as snow. The snow cover season, during which snow depths are greater than 1 cm, has an average duration of 88 days per year. The snow cover season is occasionally interrupted by Chinook-induced periods of thaw. There are on average 20 Chinooks per year.

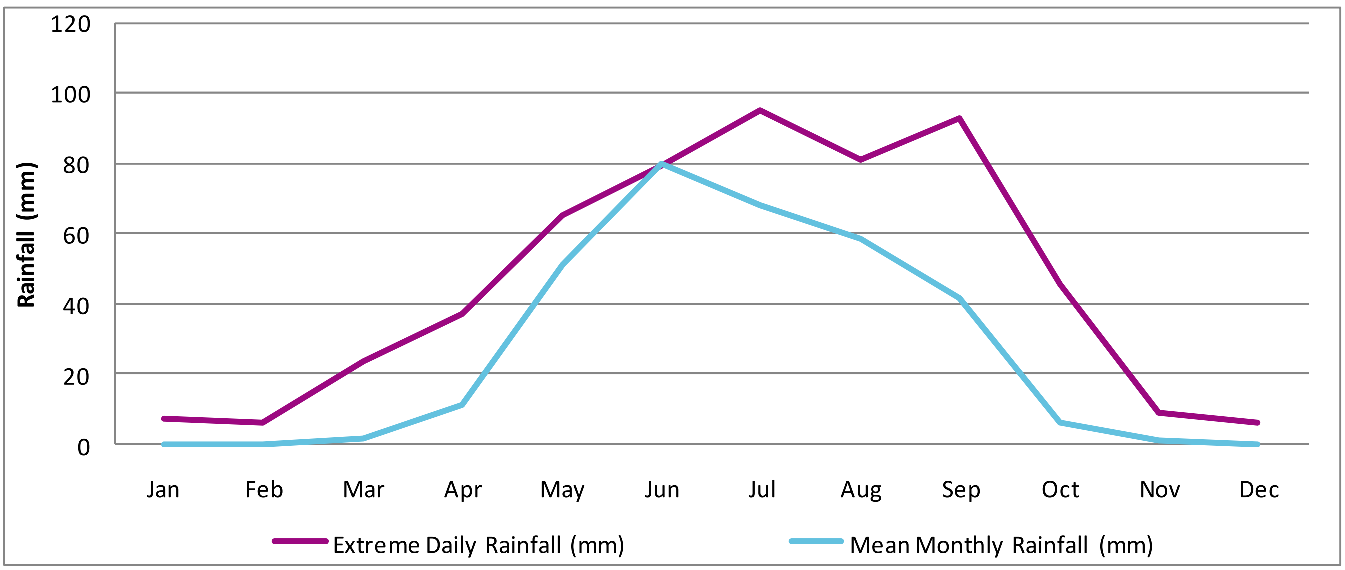
Figure 2 below, illustrates the historical monthly mean and extreme daily total precipitation, rainfall and snowfall, respectively.

Figure 2 Monthly Mean and Extreme Daily Total Precipitation, Rainfall and Snowfall

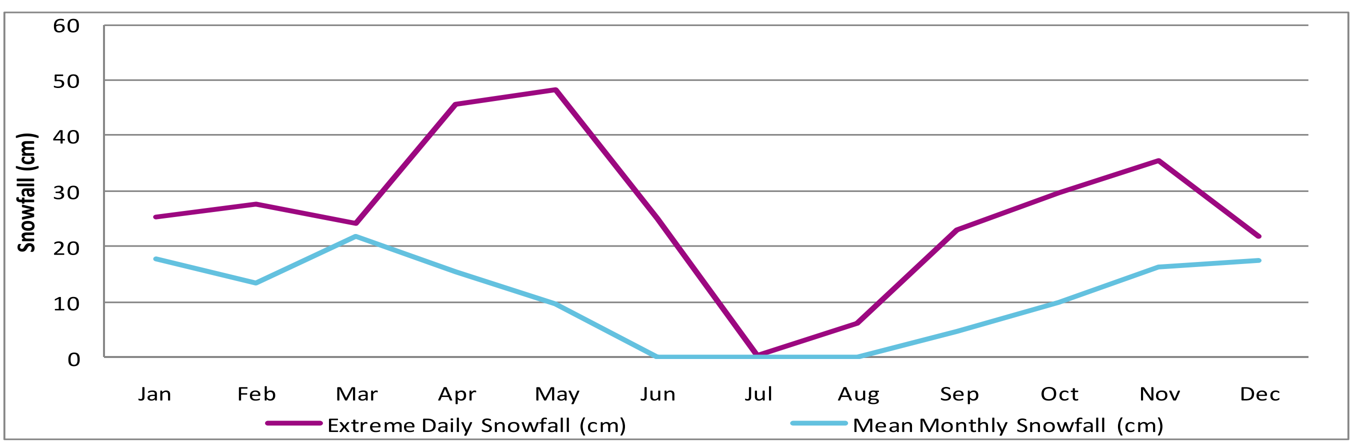
Monthly Mean and Extreme Daily Total Precipitation



Monthly Mean and Extreme Daily Total Rainfall



Monthly Mean and Extreme Daily Total Snowfall



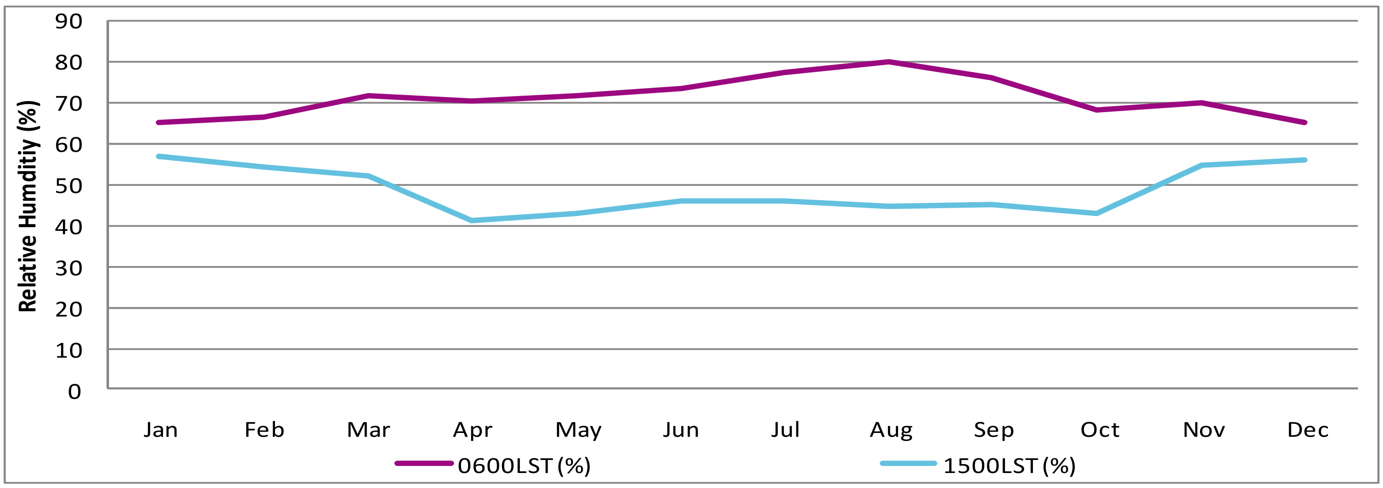
Source Environment Canada, 2009

2.3.3 Relative Humidity

Relative humidity is the ratio of atmospheric water vapour to the maximum amount of water vapour required for saturation at a particular temperature. With an average mid-day relative humidity of 55% in the winter and 45% in the summer, Calgary has a semi-arid climate typical of other cities in the Western Great Plains and Canadian Prairies.

The highest relative humidity occurs in Calgary during the summer at 6:00 Local Standard Time (LST) and the lowest relative humidity occurs during the summer at 15:00 LST. During the winter there is less variation between the morning and afternoon relative humidity measurements. Figure 3 provides the mean relative humidity for each month at 6:00 (morning) and 15:00 (afternoon) LST.

Figure 3 Monthly Mean Relative Humidity (Morning and Afternoon)



Source: Environment Canada, 2009

2.3.4 Visibility

Calgary typically has clear skies and good visibility (> 9 km), especially in the summer months, as provided in Table 5. In winter months, visibility is often limited to less than 9 km due to condensation of moisture in the atmosphere causing snow, fog or low clouds.

Table 5 Monthly Visibility (hours)

Month	< 1 km	1 to 9 km	> 9 km
January	12.1	107.2	624.7
February	9.3	99.7	569.5
March	13.6	105.3	625.1
April	6.1	57.1	656.8
May	3.1	35	705.9
June	1.3	16.3	702.4
July	0.5	8.1	735.5
August	2.1	21.1	720.8
September	3.9	30	686.2
October	7.3	38.5	698.2
November	14.4	85.3	620.3
December	8.6	86.4	649.0

2.3.5 Wind

The Environment Canada meteorological station data at YYC was used as representative data for local wind patterns. To assess the meteorological data, the most recent five year period from the meteorological station was assessed. The five year period included data from 2004 - 2008.

Wind roses are a convenient and efficient method to present wind data. As such, wind roses are used to present the measured total wind speed, wind direction and wind class frequency data for local wind patterns. Figure 4 depicts the wind roses for this data set for the 5 year period, 2004 - 2008. In the wind roses below, the length of radial barbs depict the total percent frequency of winds from the indicated direction, while portions of the barbs of different colours and widths illustrate the frequency of associated wind speed categories.

The frequency distribution for wind speeds are illustrated in Figure 5. As illustrated in the wind frequency distribution graph for the complete data set, 81.3% of the winds at YYC are slower than 5.7 m/s. The average wind speed for the total data set is 3.86 m/s with the greatest percentage of winds flowing from the northwest quadrant and southwest to southeast quadrants. The maximum wind speed is 19.5 m/s. Furthermore, the wind rose for the total data set shows that calm winds occur 5.68% of the time.

The seasonal analysis of the meteorological data incorporated the use of the following conventional monthly seasonal definitions:

- Winter (December, January, and February)
- Spring (March, April, and May)
- Summer (June, July, and August)
- Fall (September, October, and November)

Seasonal wind speed, wind class frequency data, and wind direction at the YYC from the years 2004-2008 are presented in Figure 4 as seasonal wind roses.

During winter and fall, predominant winds are from the north-west and south-west directions. Also, during the winter months, there is an increased percentage of higher wind speeds from the west. The average winter wind speed is 3.81 m/s with 6.99% calms. In the fall, the average wind speed is 3.66 m/s with 6.19% calms. During the spring and summer, there is less influence of winds from the south-west direction; the predominant winds are from the north-west quadrant and south-east quadrants. In the spring, the most frequent winds are northerly and north-westerly. The frequency distribution of windspeeds shows that spring has the highest average wind speeds, with an average wind speed of 4.33 m/s and only 4.24% calms. Wind directions are most variable in the summer, and the average wind speed is 3.67 m/s with 5.31% calms.

Analysis of YYC passenger statistics shows that peak operations occur in the month of August. To assess local wind patterns during peak operations, a wind rose was developed for the month of August. Calm winds occur 5.6% of the time. During the month of August, there is a significant decrease of winds flowing from the west.

Figure 4 Wind Roses for the LSA Based on Site-Specific Climate Monitoring

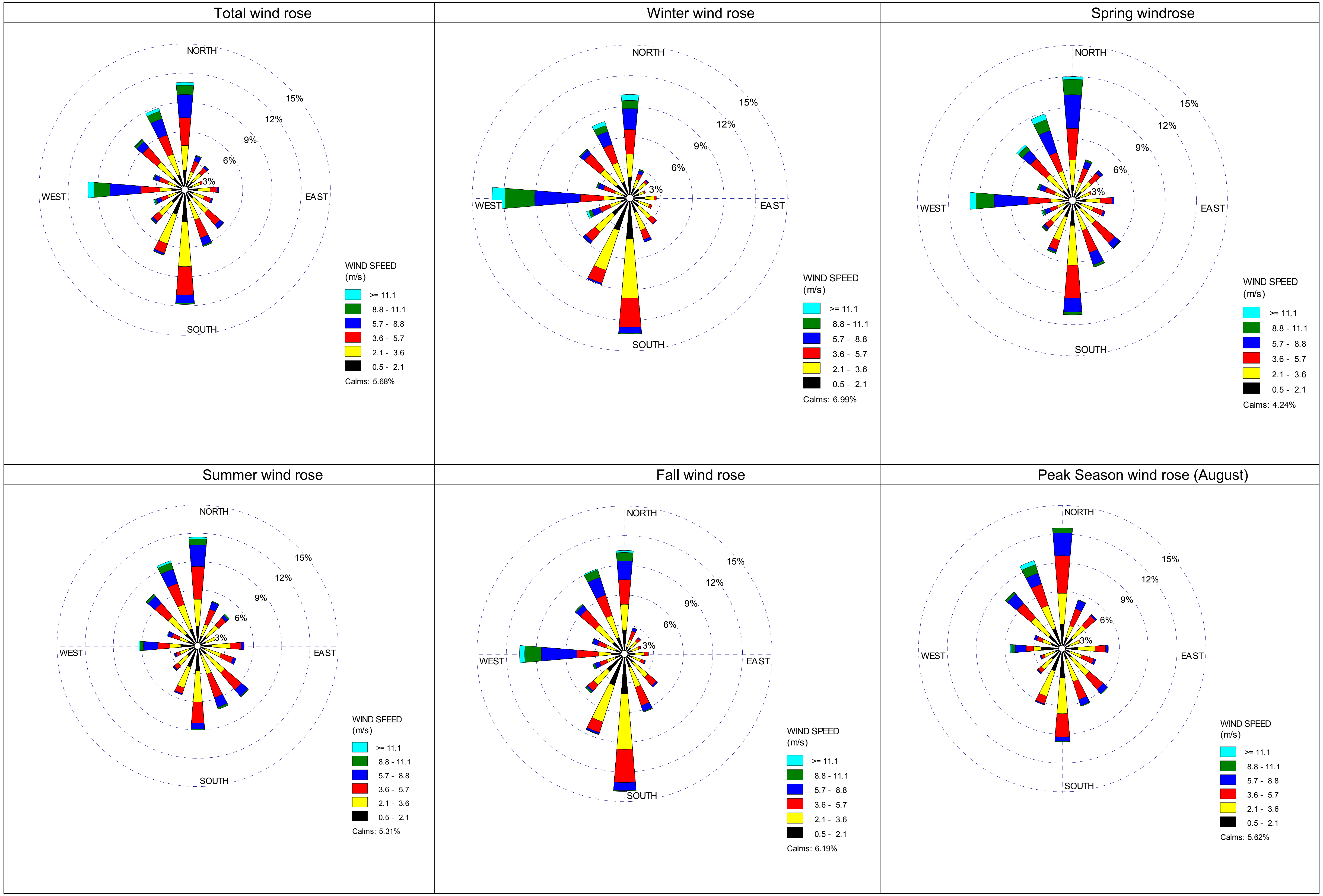
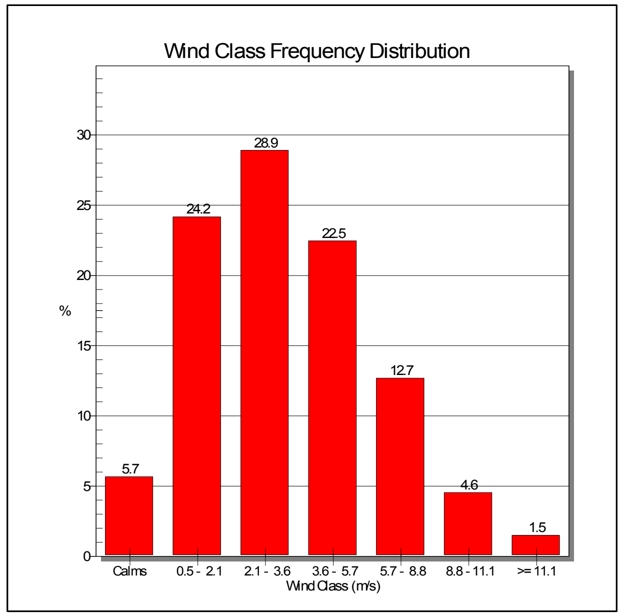
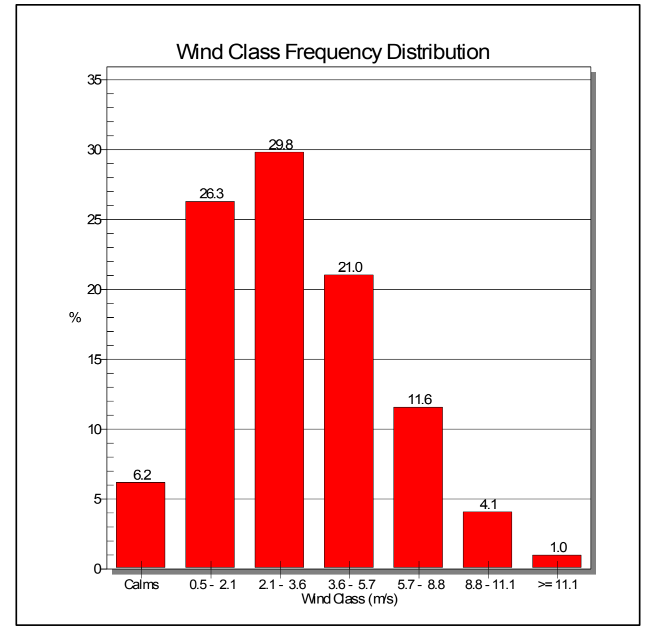


Figure 5 Summary of Wind Speed Class Frequency Distribution for the LSA Based on Site-Specific Climate Monitoring

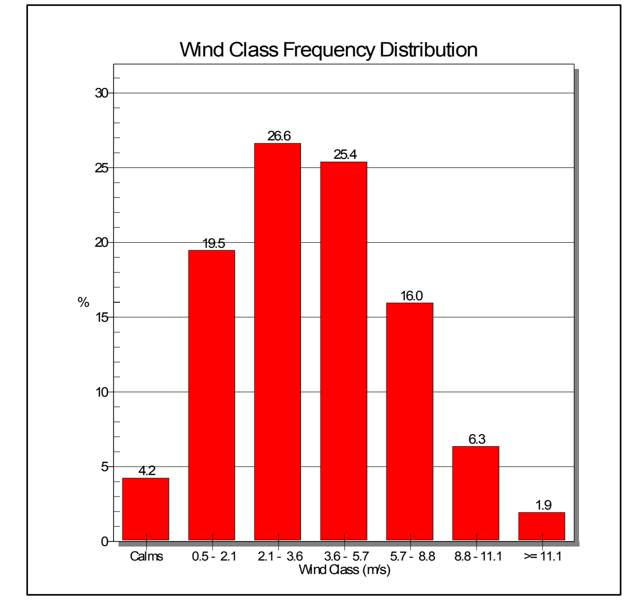
Total Frequency Distribution Graph



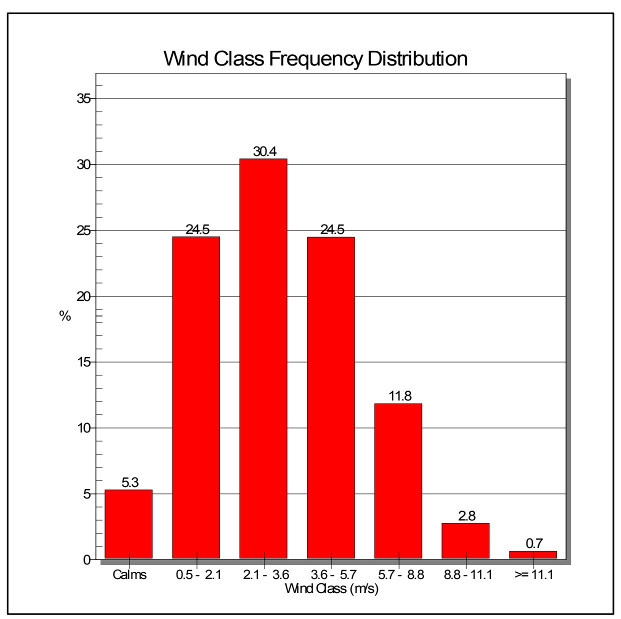
Winter Frequency Distribution Graph



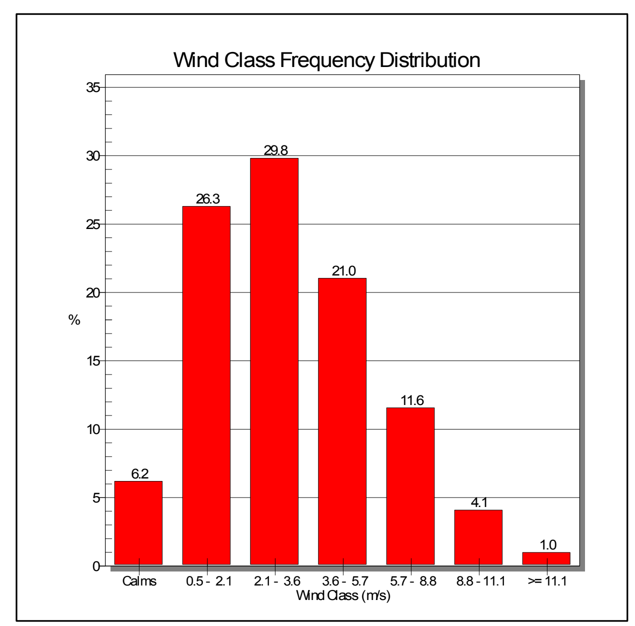
Spring Frequency Distribution Graph



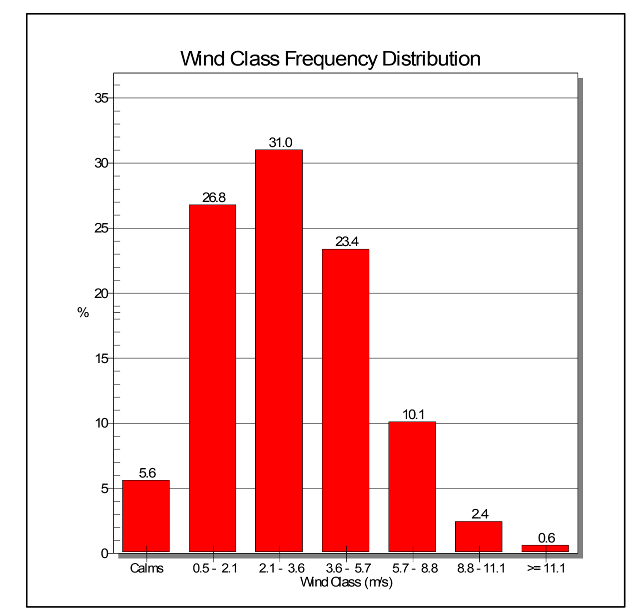
Summer Frequency Distribution Graph



Fall Frequency Distribution Graph



Peak Season Frequency Distribution Graph (August)

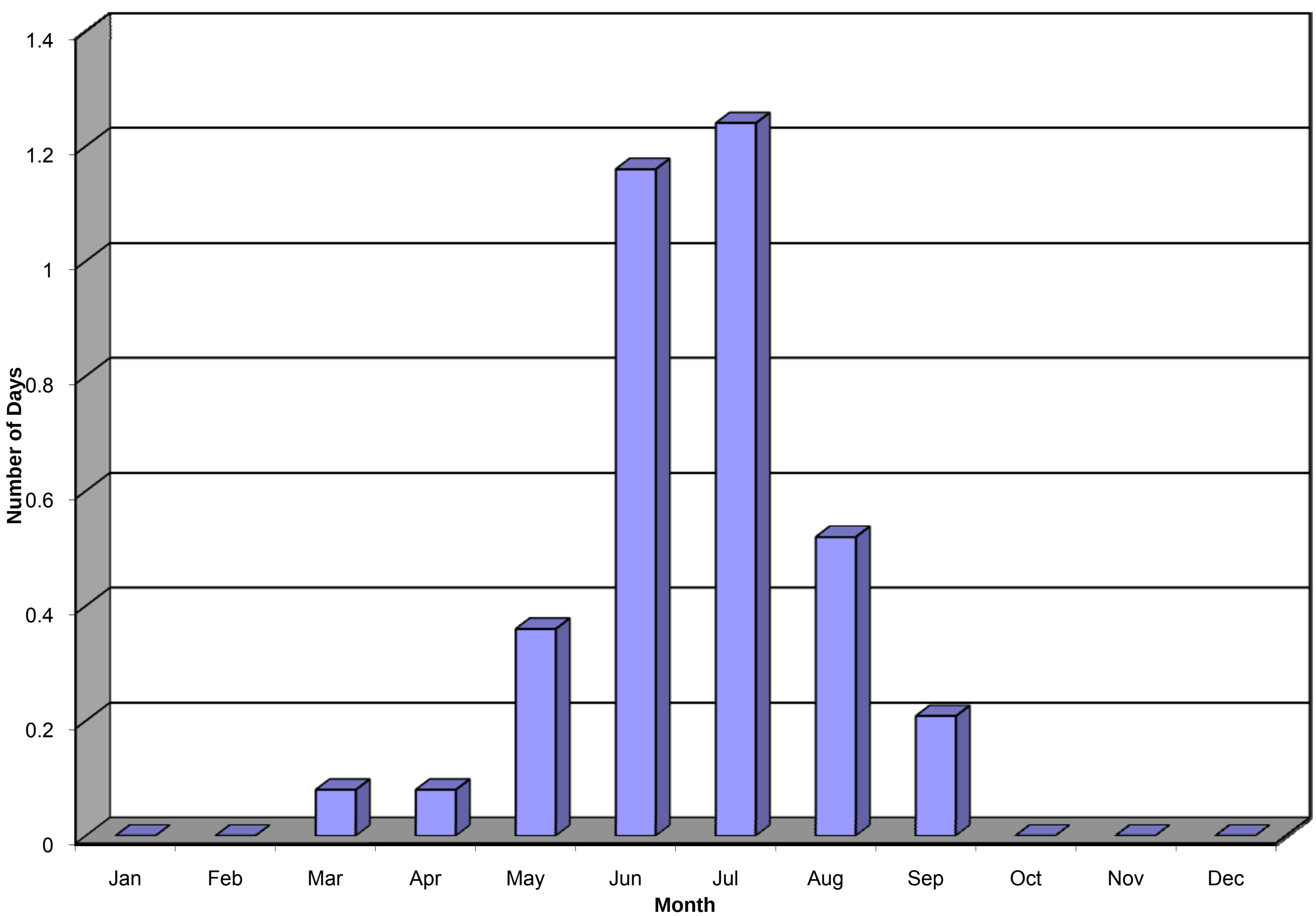


2.3.6 Severe Weather

Calgary averages over 22 days per year with thunderstorms, primarily occurring in the summer months. On average there are 79 lightning flashes per year per 100 km^2.

Calgary lies within the Central Alberta corridor known as hailstorm alley, which experiences relatively severe and frequent hailstorms. Environment Canada defines hail as precipitation consisting of ice particles with a diameter of 5 mm or more. Hail is generally observed during thunderstorms and can cause extensive damage to human life, plant life, animal life and property. The hailstorm that struck Calgary on September 7, 1991 was one of the most destructive natural disasters in Canadian history, resulting in $400 million dollars in damage. Hailstorms have occurred as many as ten times in one year. Figure 6 below illustrates the number of days per month that hailstorms have been identified over a 25 year period (1982 – 2006). The frequency of hail days is the highest during the months of June and July.

Figure 6 Average Number of Hail Days per Month for Calgary, Alberta



Being west of the dry line on most occasions, tornados are rare in the RSA. Between 1976 and 2007 there were 28 recorded tornado occurrences in Calgary (Environment Canada, 2009).

Blizzards are perhaps the most destructive winter storms that occur in the RSA. Blizzards are characterized by intense cold, strong winds, snow and low visibility. Visibility during blizzards is typically reduced to less than 1 km due to blowing snow. Although the snowfall during a blizzard may be light, the fierce winds can endanger life and cripple transportation. February is the month when the storms are most likely to occur. There are also spring storms. However, these spring storms often do not meet one or two of the criteria to be termed blizzards. As an example, a storm in May 14, 1986 resulted in knee-deep snow and 80 km/h winds. This storm was not characterised as a blizzard as it lacked the intense cold, but it still significantly affected southern Albertans by stranding motorists and leaving communities without utility services. For the period from 1960 – 1990, Environment Canada identified 13 blizzards from meteorological data from the YYC meteorological station (Environment Canada, 2009).

2.3.7 Temperature Inversions

A temperature inversion is a deviation from the typical temperature profile in which atmospheric temperatures increase with altitude. When the base of the temperature inversion is above the level of the air contaminant plume, vertical mixing of the air contaminants is restricted and dilution of the air contaminant concentrations are reduced. As such, under thermal inversions, accumulation of local pollutant concentrations may be enhanced.

Temperature inversions are formed when warm air creates a layer over cooler air. In Calgary, these are most likely caused by subsidence inversions or radiation inversions. Subsidence inversions form when out-flowing warm air from a front subsides onto the convecting surface. Radiation inversions form due to the differential diurnal heating of the surface and atmosphere, creating a night-time inversion which can persist for several days when daytime solar heating is weak.

In Calgary, temperature inversions are common prior to the occurrence of Chinooks. Temperature Inversions may occur several times per year in Calgary, lasting for up to a few days at a time.

2.3.8 Fog and Sunshine

The city is among the sunniest in Canada, with 2,400 hours of annual sunshine, on average. This is equivalent to approximately 333 of 365 days per year of measureable sunshine. Most days with bright sunshine occur during the summer months, but year-round the percent of available hours remains over 52%. The dry, sunny, and windy weather render fog formation a relatively rare occurrence. The average annual number of days with fog is only 20.

2.3.9 GHG Emissions

2.3.9.1 Regional GHG Emissions

The emission of GHGs is one factor that has the potential to affect climate change. The GHG effect is caused by absorbing gases that trap solar radiation within the atmosphere. These absorbing gases (known as GHGs) include but are not limited to, water vapour, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). GHGs are emitted from both anthropogenic and biogenic sources. Major anthropogenic emissions including fossil fuel combustion and industrial sources are adding to the biogenic concentration of GHGs in the atmosphere. This leads to an unbalanced absorption and release of energy within the atmosphere potentially causing climate change. For this reason, anthropogenic source of GHG emissions are evaluated here.

Environment Canada's "Turning the Corner, Regulatory Framework for Industrial Greenhouse Gas Emissions", issued in March 2008 outlines Canada's initiatives in reducing GHGs. The document outlines the regulations that will be implemented in 2010 to govern GHG emissions by major industrial sectors. The regulations will be reviewed every five years to ensure that Canada meets their GHG reduction targets: 20% reduction from 2006 levels in 2020; and a 60% - 70% reduction by 2050. Airports have not been identified as a major industrial sector contributing to GHGs.

In January 2008, the Alberta government issued the new Climate Change Strategy. This strategy builds upon Alberta's 2002 climate change action plan. The strategy focuses on implementing carbon capture and storage; greening energy production; and conserving and using energy efficiently. The initiatives outlined in the Climate Change Strategy are expected to deliver a 14% reduction below 2005 levels. As part of the greening energy production initiative, Alberta is the first jurisdiction in North America to develop and implement a regulatory-based demand for carbon reductions. Alberta Regulation 139 requires regulated facilities in Alberta that emit over 100,000 metric tonnes (t) of carbon dioxide equivalents (CO_2e) per year to submit annual GHG compliance reports. The compliance reports document how the regulated companies meet the annual GHG emissions intensity limits. As required by *Alberta's Climate Change and Emissions Management Amendment Act*, March 31, 2008 was the deadline for regulated companies to reduce the intensity of their GHG emissions by 12%. YYC does not trigger requirements under this regulation.

Total GHG emissions are determined based on the major GHGs listed above. Each GHG has a different potential to contribute to warming. A "global warming potential" (GWP) based on the gas' ability to contribute to climate change has been assigned to each gas in relation with CO_2. GHGs are then reported as CO_{2e}. The GWP for the above gases are listed below:

- CO_2 = 1.0
- CH_4 = 21.0
- N_2O = 310.0

Using these values, total GHG emissions are calculated using the equation below:

Total CO_{2e} (t) = (CO_2 t x 1.0) + (CH_4 t x 21.0) + (N_2O t x 310.0)
Total GHGs emissions by sectors for Alberta in 1990 and 2007 are presented in Table 6.

Table 6 Alberta GHG Emissions

	1990 Emissions (kt CO_{2e})	% of 1990 National Emissions	2007 Emissions (kt CO_{2e})	% of 2007 National Emissions
Energy	14,800	32%	212,000	35%
Industrial Processes	8,200	15%	12,900	25%
Solvent and Other Product Use	16	9%	34	11%
Agriculture	14,000	29%	19,000	32%
Land Use, Land-Use Change and Forestry	N/A	N/A	N/A	N/A
Waste	1,300	7%	1,600	8%
Total	171,000	29%	246,000	33%

Source: Environment Canada 2009.

In Alberta, energy is the leading source for GHG emissions. There is an overall increasing trend in energy GHG emissions in Alberta. In the table above, emissions from energy represent emissions from a combination of both stationary combustion sources and transportation sources. For Alberta GHG emissions, stationary combustion sources, dominated by the power generation and fossil fuel industries, contributed 65% and 64% of 1990 and 2007 energy emissions, respectively. In Alberta, transportation emissions contributed 15% and 18% of GHG energy emissions in 1990 and 2007, respectively.

In 2007, the province of Alberta was the second largest GHG emitter in Canada, generating 33.2% (245.7 Mt) of GHGs. Alberta's total GHG emissions and its relative contributions to national emissions are both trending upwards. As shown in Table 3, total GHG emissions increased by 74 Mt CO2e between 1990 and 2007. Alberta's contribution to the national total GHG emissions increased from 28.9% to 32.9%. Per capita emissions are also on the rise. Since 1990, Alberta's population has grown by 36.4%, while its GHG emissions have grown by 43.7%. The increased per capita emissions were predominantly driven by increases from the mining and fossil fuel industries (35.2 Mt), electricity and heat generation (15.1 Mt) and road transportation (7.7 Mt) sectors. Alberta's per capita GHG emission rate was 70.7 t GHG per person in 2007, making Alberta the highest per capita GHG emitter in Canada (Environment Canada, 2009).

Emissions from civil aviation accounted for 1.04% of the national GHG emissions for 2007. Civil aviation accounts for all GHG emissions from domestic air transport (commercial, private, military, agriculture, etc.) However, the civil aviation emissions reported by Environment Canada does not include emissions from associated ground transport and stationary combustion applications. These emissions are reported under separate categories in Environment Canada's national pollution reporting inventory (NPRI). In addition, emissions arising from fuel sold to foreign airlines and fuel sold to domestic carriers but consumed during international flights are considered to be international bunkers and are not reported as civil aviation emissions by Environment Canada.

2.3.9.2 YYC GHG Emissions

YYC contributions to GHGs were previously assessed for 2007. The GHG emissions from YYC 2007 operational activities are considered current and representative data for baseline conditions. In addition, YYC GHG data from 2007 allows for the assessment of the YYC GHG contribution to the provincial and national GHG emissions. The YYC 2007 GHG emissions inventory was developed by EBA Engineering Consultants. The following sources were considered in the GHG emissions inventory calculations

- Landing and takeoff operations (LTOs)
- Road vehicles including both visitors' and employees' trips
- Airside movements, which include aircraft use of auxiliary generators, mobile generators, aircraft manoeuvring, air start compressors, ground vehicles and equipment
- Stationary power generation plants
- Heating and air conditioning for buildings
- Aircraft maintenance, engine testing, stationary emergency power generation units, airfield vehicles, aircraft de-icing and anti-icing fluid use, and fire training exercises

LTO operations are the major GHG emitting activities at airports. As such, the 2007 GHG assessment used LTO cycles that were specific to YYC. For this emissions inventory, the calculations for overall aircraft GHG emissions were determined by correlating the maximum takeoff weight to engine fuel emissions and also considered a variety of aircraft within a range of LTO operations. The LTO operations that were considered included takeoff, climb, approach, and taxi/idle time. The time in mode for each of these operations that were used for the 2007 GHG aircraft emissions is outlined in Table 7 below. The time in mode for takeoff, climb and approach are consistent with those outlined by the International Civil Aviation Organization (ICAO). However, the taxi/idle time in mode has been modified to more accurately represent the YYC operations. In addition, to determine the time in mode for different aircraft, the US Environmental Protection Agency (EPA) default time in mode was used where specific data was lacking.

Table 7 Time in Mode for Each Aircraft Operation

Mode	Time in Mode (min) - Calgary
Takeoff	0.7
Climb	2.2
Approach	4.0
Taxi/Idle	8.6

CO_2 and N_2O were calculated for each emission source identified previously. Emission factors were used to calculate the amount of CO_2 and N_2O emitted from each source. The emissions of CO_2 and N_2O were then used to determine total CO_{2e} from the airport. The 2007 GHG emission inventory focused only on CO_2 and N_2O as the remaining GHGs were considered to not normally be attributed to airport-related emission sources (EBA, 2006).

Table 8 below summarizes YYC's 2007 GHG emission inventory by the source.

Table 8 YYC GHG Emissions

Airport-Related Emission Sources	Total GHG Emissions (t CO_{2e})
Aircraft	136, 881
Buildings	22, 889
Airfield Vehicles	1, 294
Ground Vehicles	9, 085
Other Sources	1, 458
Total	171, 607

Aircraft activities account for approximately 80% of YYC GHG emissions, while building emissions (GHG emissions from the combustion of natural gas) accounts for 13% of YYC emissions. Emissions of N_2O only accounted for 2.6% of the CO_{2e}. As such, CO_2 from aircraft activities is the major source for YYC GHG emission inventory.

It is important to understand the contribution of YYC's GHG emissions to the RSA. The 2007 National Emissions Inventory Report summarized the GHG emissions for Canada and for Alberta. In 2007 Canada was responsible for 747,000 Kt of GHG emissions, while Alberta was reported as emitting 246,000 Kt of GHGs. In relation to the provincial and national GHG emission, the 2007 YYC operations contributed to approximately 0.07% of Alberta's annual GHG emissions and 0.02% of the national annual GHG emissions.

3. Summary and Conclusions

Calgary has a continental climate with long, cold winters, and short, mild summers. Its dry, sunny, highly variable conditions are a result of the city's high elevation (approximately 1,048 m above sea level), prevailing atmospheric circulation and regional topography. Climate change is a change in the statistical distribution of meteorology over periods of time. Climate change is therefore an intrinsic property of the climates in Canada. The emission of GHGs is one factor that may impact future climate change trends. The PRP will result in emissions of GHGs. As climate change trends may be affected by GHG emissions, it is important to assess the baseline conditions for GHGs. As such, the baseline conditions for GHGs within the RSA were assessed. For baseline conditions, the YYC GHG emissions account for 0.07% and 0.02% of the provincial and national emissions, respectively. The contribution of the YYC operations to the provincial and national GHG emission inventory is considered to be very small.

4. References

Alberta Government. January 2008. Alberta's 2008 Climate Change Strategy. Available online at: http://environment.gov.ab.ca/info/library/7894.pdf

Alberta Government. 2007. Alberta Regulation 139/2007, Climate Change and Emissions Management Act, Specified Gas Emitters Regulation. Available online at: http://environment.alberta.ca/3.html

Alberta Government. 2007. Climate Change and Emissions Management Act. Available online at: http://environment.alberta.ca/3.html

Environment Canada. 2009a. Canadian Climate Normals or Averages 1971-2000 – YYC. (Accessed November 12, 2009) Available online at: climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html

Environment Canada. April 2009b. National Inventory Report – Greenhouse Gas Sources and Sinks in Canada 1990 - 2007. (Accessed November 12, 2009) Available online at: www.ec.gc.ca/pdb/ghg/inventory_report/2007/full_inv_2007_eng.cfm

Environment Canada. 2009c. Atmospheric Hazards – Prairie and Northern Region. Available online at: http://pnr.hazards.ca/blizzard.html

Environment Canada. 1990. The Climates of Canada. Catalogue No. EN56-1/1990E ISSN0-660-13459-4.

Government of Canada. March 2008. Turning the Corner: Regulatory Framework for Industrial Greenhouse Gas Emissions. (Accessed November 12, 2009) Available online at: www.ecoaction.gc.ca/news-nouvelles/20070426-2-eng.cfm?turning

2007 YYC Greenhouse Gas Inventory, prepared by EBA Engineering Consultants.

U.S. Environmental Protection Agency, 2005. Guidelines on Air Quality Models. CFR 40, Part 51, Appendix W. Federal Register, Vol. 70, No. 216, Nov. 2005.

Statement of Qualifications and Limitations

The attached Report (the “Report”) has been prepared by AECOM Canada Ltd. (“Consultant”) for the benefit of the client (“Client”) in accordance with the agreement between Consultant and Client, including the scope of work detailed therein (the “Agreement”).

The information, data, recommendations and conclusions contained in the Report:

- are subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the “Limitations”)
- represent Consultant’s professional judgement in light of the Limitations and industry standards for the preparation of similar reports
- may be based on information provided to Consultant which has not been independently verified
- have not been updated since the date of issuance of the Report and their accuracy is limited to the time period and circumstances in which they were collected, processed, made or issued
- must be read as a whole and sections thereof should not be read out of such context
- were prepared for the specific purposes described in the Report and the Agreement
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time

Unless expressly stated to the contrary in the Report or the Agreement, Consultant:

- shall not be responsible for any events or circumstances that may have occurred since the date on which the Report was prepared or for any inaccuracies contained in information that was provided to Consultant
- agrees that the Report represents its professional judgement as described above for the specific purpose described in the Report and the Agreement, but Consultant makes no other representations with respect to the Report or any part thereof
- in the case of subsurface, environmental or geotechnical conditions, is not responsible for variability in such conditions geographically or over time

The Report is to be treated as confidential and may not be used or relied upon by third parties, except:

- as agreed by Consultant and Client
- as required by law
- for use by governmental reviewing agencies

Any use of this Report is subject to this Statement of Qualifications and Limitations. Any damages arising from improper use of the Report or parts thereof shall be borne by the party making such use.

This Statement of Qualifications and Limitations is attached to and forms part of the Report.