1.0 WHAT ARE WE TRYING TO DO AND WHY ARE WE TRYING TO DO IT?

1.1 INTRODUCTION

The City of Toronto needs good information about present local weather and climate, the factors that influence them, and future local weather and climate so that the City can be prepared to address and adapt to any changes that will occur. Of key interest are extreme weather events and their spatial and temporal resolution, such as micro-bursts, intense local rainfall events leading to sewer discharges, roadway and river flooding and strong local pressure gradients and wind events that might occur within Toronto's urban area.

A series of questions form the focus for this project as follows:

1. What is Toronto's current weather and climate? And why?
2. How are Toronto's current weather and climate drivers expected to change? And why?
3. What will be Toronto's future weather and climate? And why?
4. What tools, data and information can be used to adequately determine future climate and weather in Toronto? And why?
5. What magnitudes, frequency and probability of occurrence do present extreme weather events and significant weather events have in Toronto? And why?
6. What magnitudes, frequency and probability of occurrence do future extreme weather events and significant weather events have in Toronto? And why? and
7. Which technology, or technologies, among (1) the one used for the study, (2) using a General Circulation Model (GCM), (3) using a Regional Climate Model (RCM) together with (4) downscaling and (5) other related techniques, holds the best promise of best understanding the future weather and climate of Toronto and the surrounding areas? And why?

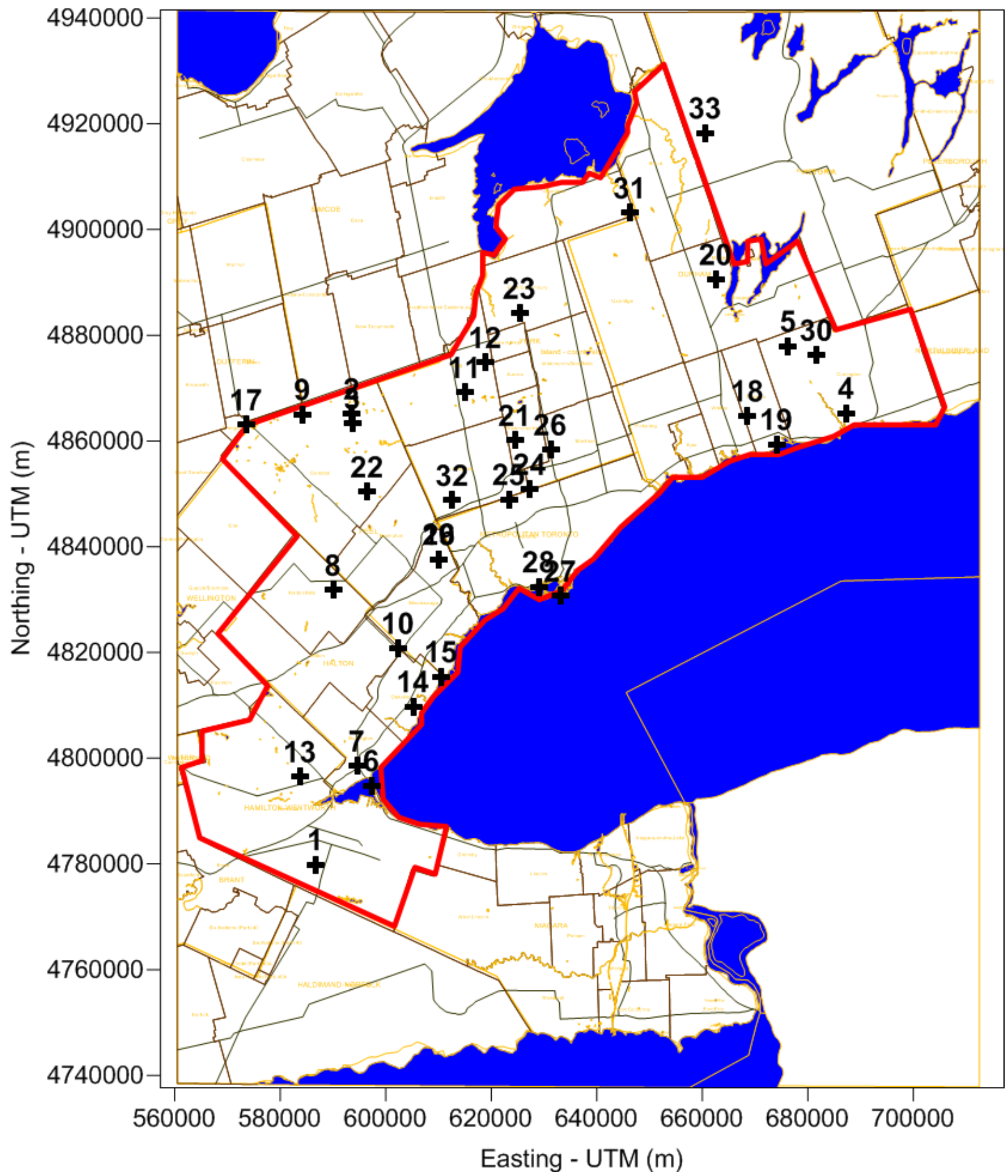
The main deliverable from this project is an understanding of what the City of Toronto currently experiences and, more importantly, why the City experiences what it does now, and why and what the City of Toronto will experience in the future. This study is to develop the data, information and simple and applicable tools to assess weather and climate that the City of Toronto must address and adapt to in the near future.

1.2 WHICH CLIMATE STATIONS ARE USED?

The study area is shown in Figure 1 (outlined in red). It also shows the Climate Stations (numbers) that were available from Environment Canada for use in the analysis. Table 1 gives the names and locations of the Climate Stations that were available for use for the current climate analyses.

Each station in Table 1 measures different parameters and has a different length of record. Analyzing the trends from these stations showed quite different changes over the various periods of record.

Figure 1 Study Area Climate Stations Used



As a result, SENES decided to use Pearson Airport as a reference station for this analysis because it had a long period of record and a high level of data quality. While the trend data for each of the listed stations is available as part of the project record, it will not be presented in this report. SENES decided for consistency and quality purposes to compare model outputs at locations across Toronto and the GTA that were of interest to the client.

Table 1 Environment Canada Stations Used for Current Climate Summaries

Stn. No	Environment Canada Station Name	Longitude (^{0})	Latitude (^{0})
1	HAMILTON A	79.93333	43.16667
2	ALBION	79.83333	43.93333
3	ALBION FIELD CENTRE	79.83333	43.91667
4	BOWMANVILLE MOSTERT	78.66667	43.91667
5	BURKETON MCLAUGHLIN	78.80000	44.03333
6	BURLINGTON PIERS (AUT)	79.80000	43.30000
7	BURLINGTON TS	79.83333	43.33333
8	GEORGETOWN WWTP	79.88333	43.63333
9	GLEN HAFFY MONO MILLS	79.95000	43.93333
10	HORNBY TRAFALGAR TS	79.73333	43.53333
11	KING RADAR	79.56667	43.96667
12	KING SMOKE TREE	79.51667	44.01667
13	MILLGROVE	79.96667	43.31667
14	OAKVILLE GERARD	79.70000	43.43333
15	OAKVILLE SOUTHEAST WPCP	79.63333	43.48333
16	ONTARIO WEATHER CENTRE	79.63333	43.68333
17	ORANGEVILLE MOE	80.08333	43.91667
18	OSHAWA A	78.90000	43.91667
19	OSHAWA WPCP	78.83333	43.86667
20	PORT PERRY NONQUON	78.96667	44.15000
21	RICHMOND HILL	79.45000	43.88333
22	SANDHILL	79.80000	43.80000
23	SHARON	79.43333	44.10000
24	THORNHILL GRANDVIEW	79.41667	43.80000
25	TORONTO MSC HEADQUARTERS	79.46667	43.78333
26	TORONTO BUTTONVILLE A	79.36667	43.86667
27	TORONTO HEADLAND (AUT)	79.35000	43.61667
28	TORONTO ISLAND A	79.40000	43.63333
29	TORONTO LESTER B. PEARSON INT'	79.63333	43.68333
30	TYRONE	78.73333	44.01667
31	UDORA	79.16667	44.26667
32	WOODBRIDGE	79.60000	43.78333
33	WOODVILLE	78.98333	44.40000

AUT = Automatic Station

1.3 DETAILED OUTPUT POINTS

In this document (Volume 1) only the Toronto Pearson International Airport (Pearson Airport) is used to illustrate the results, while all other points selected for presentation are tabularized in Volume 2 of the report. Figure 2 presents a map of the locations selected by the City of Toronto for the presentation of detailed results. Figure 3 represents points selected by the City throughout the GTA.

Figure 2 Locations Selected for Results Presentation within the City of Toronto

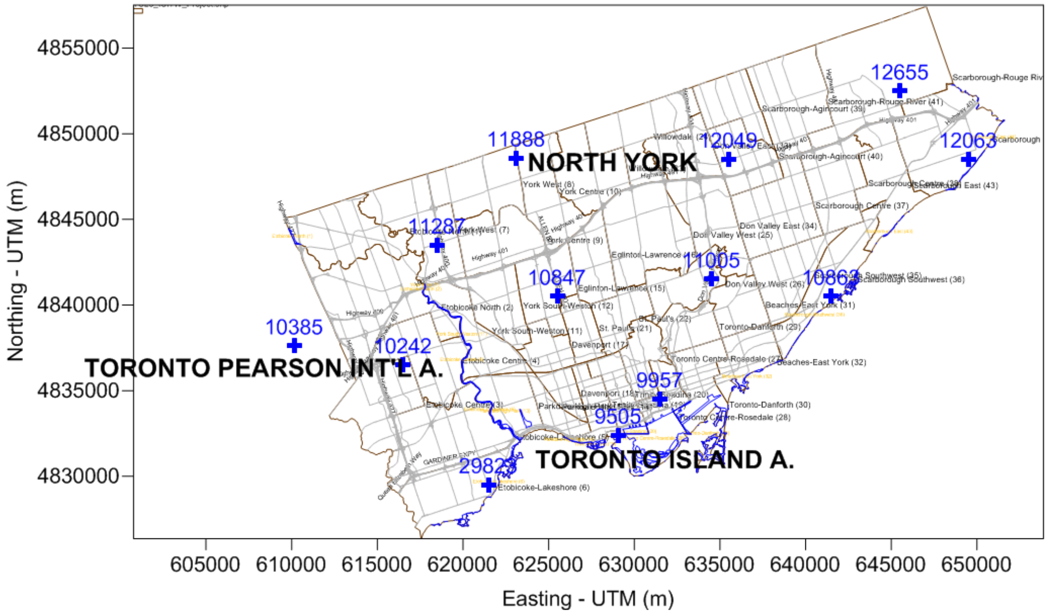


Table 2 lists all of the 36 locations selected along with the Volume 2 table location numbers where detailed results can be found. The table also gives the model output grid location used.

Figure 3 Locations Selected for Results Presentation across the GTA

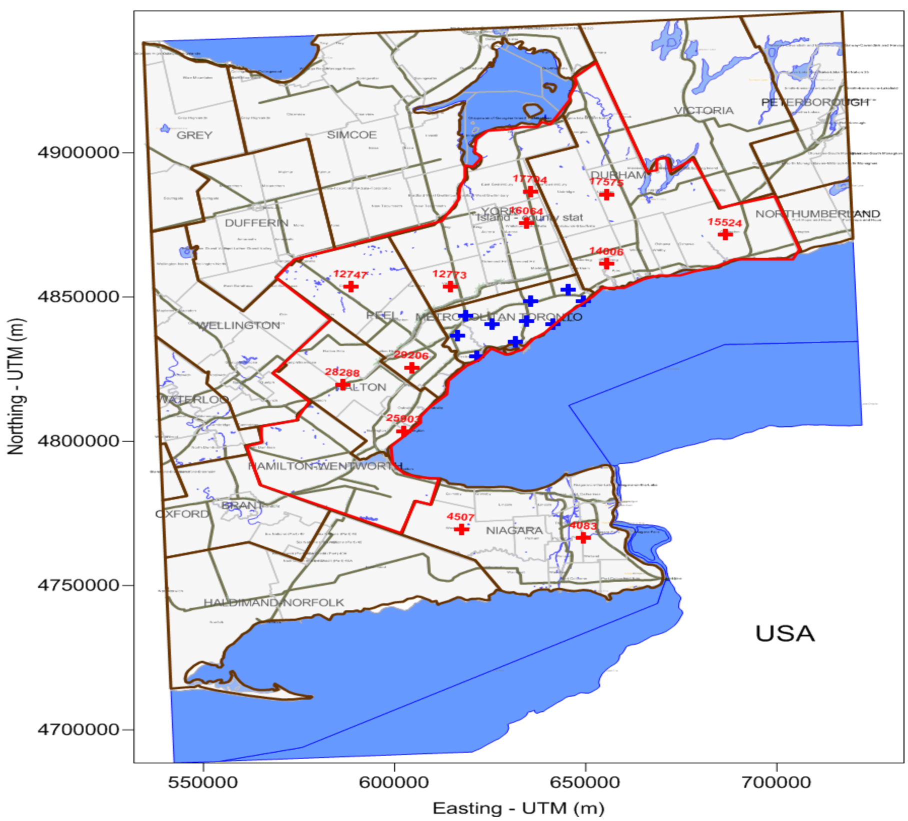


Table 2 List of Grid Points and Tables of Results for Volume 2

Table	Name	Grid Point
1	***Toronto Pearson***	10385
2	***Hamilton***	5989
3	***Toronto North York***	11888
4	***Toronto Island***	9505
5	***Hwy 427-401***	10242
6	***Beaches-East York***	10863
7	***York South-Weston***	10847
8	***DVP-Don Mills Road***	11005
9	***Etobicoke North***	11287
10	***Scarborough***	12063
11	***Don Valley East***	12049
12	***Scarborough - Rouge River***	12655
13	***Mississauga***	29823
14	***Trinity Spadina***	9957
15	***Pelham -Thorold***	4083
16	***West Lincoln***	4507
17	***Caledon***	12747
18	***Vaughan***	12773
19	***Pickering***	14006
20	***Clarington***	15524
21	***Whitchurch Stouffville***	16064
22	***Uxbridge***	17575
23	***East Gwillimbury***	17704
24	***Burlington***	25903
25	***Milton***	28288
26	***Mississauga-Milton***	29206
27	***Richmond Hill***	13677
28	***Oshawa***	14317
29	***Udora***	20096
30	***Niagara Falls***	5608
31	***King Smoke Tree***	15752
32	***Orangeville MOE***	14073
33	***Georgetown WWTP***	29942
34	***Oakville Southeast WPCP***	27562
35	***Burlington Piers***	8114
36	***Millgrove***	8402

1.4 WHY ARE WE DOING IT?

The City of Toronto's climate is characterized by four seasons, albeit of perceptually variable length. Summers are warm to hot, and winters are usually cool to cold. As a result of the rapid passage of weather systems (i.e., high and low air pressure cells), day-to-day weather is variable in each season but the parameters such as precipitation and temperature are relatively uniform within longer periods, such as month-to-month. Since it is located in close proximity to Lake Ontario, the city of Toronto experiences moderated and less extreme temperatures in both winter and summer. Relative to areas further inland and to what Toronto's temperatures would be like in the absence of Lake Ontario and other nearby Great Lakes, temperatures are cooler during the spring and summer and warmer during the fall and winter. Other factors such as the height and shape of the land (i.e., topography) as well as the use of the land (open farm land versus houses and buildings) also affect the City's climate.

This purpose of this document is to discuss the factors which influence the weather and climate of the City of Toronto. First, a background on what drives the weather is provided. Subsequently the document describes, in general, factors which influence climate and explains how these factors help to shape the climate of Toronto. On the subject of climate change, this document also examines how some of the anticipated changes to the planet (specifically the planet's integrated system components of the atmosphere, the hydrosphere, the lithosphere and the biosphere) may affect the weather and climate of Toronto in the future.

SENES Consultants Limited has predicted, to the degree possible, the likely changes in future weather system patterns that will be experienced in and around Toronto and has prepared new "normals" and new patterns of extreme events by magnitude and frequency and their probability of occurrence. The main focus of the study was to identify intense events that occur within a limited geographical area and over short time frames (that is, spatially and temporally intense events). This information is to be used by the City as it prepares for potential changes in the severity and frequency of extreme storm events and the associated damages and costs of resultant flooding and washouts. This will help problem avoidance planning undertaken by groups such as Toronto Water and Toronto Transportation. A secondary focus was to look at regional events like heat waves and cold snaps that are ameliorated by the Great Lakes. This information is to be used to corroborate with analyses previously derived by Toronto Public Health.

1.5 HOW DID WE ANSWER THE QUESTIONS?

First a set of detailed state-of-the-science weather model statistics, based on the period 2000-2009, formed the baseline 1x1 km gridded, hourly summary of current climate summary for the Greater Toronto Area and addresses and provides insight into Question 1 (What is Toronto's current weather and climate and why?). This period was also used for model validation against the current observational data. This data combined with long term observed weather will be used to answer Question 5 (What magnitudes, frequency and probability of occurrence do present extreme weather events and significant weather events have in Toronto and why?).

The second step was to use the output from a Regional Climate Model (RCM) for a 10-year period in the future (2040-2049) driven by a maximum impact scenario that represents a balance of consumption and pollution release across all energy sources. The output was used as input to the same state-of-the-science weather model to develop an hour-by-hour simulation of the future on the same 1x1 km grid for the GTA. This 10-year data set was examined for major storms, extreme weather and the other climate parameters. The resulting averages and statistics form the future climate summary for Toronto which was used to answer Question 3 (What will be Toronto's future weather and climate and why?) and Question 6 (What magnitudes, frequency and probability of occurrence do future extreme events and significant weather events have in Toronto and why?) posed in the study.

The third step was to compare the outputs from the present and the future climate simulation in order to provide insight into Question 2 (How are Toronto's current weather and climate drivers expected to change and why?) posed in this study.

The SENES Team, based on their knowledge and current literature, determined the answers to Question 4 (What tools, data and information can be used to adequately determine future climate and weather in Toronto and why?) and Question 7 (Which technology, or technologies, among (1) the one used in this study, (2) using a Global Climate Model (GCM), (3) using an Regional Climate Model (RCM) together with (4) downscaling and (5) other related techniques, holds the best promise of understanding the future weather and climate of Toronto and surrounding areas and why?) of the study.

1.6 WHY DID WE TAKE THIS APPROACH?

Computer models are often regarded as a little suspect by the general public, and computer based climate models are no exception to this. Someone puts lots of data in to one side of a black box, presses a button and answers seem to magically appear out the other side. To the general public, what goes on in the black box is mostly unknown, and what little is explained - is unclear. Doubt and suspicion can follow.

Scientists who create and manipulate the equations and feed the data into the black box "know" that the equations "mimic", to the extent possible, the complexity of all the atmospheric processes that collectively create the climate. They know that the integrated equations contain all the science; they know that the equations contain all that is known about why we get the climate that we get.

A commonality between the general public and climate scientists is that both recognize that mistakes can be made and that common sense and more rigorous safety checks are a necessary requirement for any acceptance of the output from any such climate black box.

The obvious safety checks to be undertaken are: do the answers make sense, or can they be explained. Rather than simply accepting the answers scientists and the public must ask – "do they make sense"?

In the context of the present study, a major portion of the work is to identify the role of "climate drivers" in producing the weather and climate we get now, and to further identify how these same "climate drivers" are expected to change or be modified with the advent of a changing climate, and then subsequently to also identify how the modified climate drivers produce the weather we will get.

In essence, rather than saying "these are the answers so trust them", it is essential that the changes, or pattern variations, can be explained both individually and collectively in a logical and coherent manner. A logical argument that goes along with the computer model output (or the numbers from the black box) and that specifically explains the numbers derived is essential: a) to gain greater public acceptance, and, b) to provide a safety check that the derived numbers do fit the science, and that no human errors have crept into the preparation of the model or the provision of the input data. This is like a cook with a new recipe who is using strange ingredients and that leads to something unexpected – was it the recipe, the ingredients or the cook?

In the context of present and future weather and climate, the logical argument, or story, tries to embrace the following questions:

- what do we get now?
- why do we get what we get now?
- how will the "why" change in future?
- what will we get in future?
- how big will the future change be?

This last question is really addressed by running the computer model(s). It is very hard for human minds to grapple with complex changes among hundreds of variables all at the same time, but a computer is designed to do just this. Even so, the scale, direction and nature of any and all change still have to make sense and be clearly seen as good, acceptable science – or to encourage new scientific research be undertaken to evaluate and determine if the theory and the output is valid. If the theory is wrong, the theory has to be changed and the results have to be rejected.

In this study we have shown that the theory (as applied through the combination of a climate and a weather model) is able to predict the weather that we have already seen and that gives us confidence that our projection of the future is equally valid.