TOWN OF AJAX

Community Climate Study

Natural Capita (FINAL)

October 2018 – 18-7286

The preparation of this study was carried out with assistance from the Government of Canada and the Federation of Canadian Municipalities. Notwithstanding this support, the views expressed are the personal views of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.

Table of Contents

Figures

Tables

Appendices

References

1.0 Introduction

1.1 Background

The Town of Ajax (the Town) has been impacted by significant climatic events which, among other things, have caused property damage, disruptions to transportation and energy systems and resulted in economic and social impacts to the community.

The Town identified a need to better understand the threats and risks faced by the community as a result of changing trends associated to the following three climate variables: severe weather, temperature and precipitation. Three main community outlooks were identified of particular concern to the Town and included overland and stormwater flooding, threats to the natural capita, and impacts to emergency preparedness and response services. The purpose of the Town Community Climate Study is to provide a GIS-based tool for the Town to assist in identifying, analyzing, evaluating and ultimately managing climate change based risks as part of an overall Climate Change Adaptation Plan being developed by the Town.

1.2 Study Area

The Town is located east of the Greater Toronto Area within Durham Region. The Town is primarily situated between Duffins Creek and Carruthers Creek, with its southern border along the shorelines of Lake Ontario. Minor tributaries of Lynde Creek also fall within the eastern area of the Town.

The Town covers an area of 67km^2 and is a predominantly suburban area, with greenbelt lands located to the east and north. According to the 2011 Census, The Town is home to approximately 120,000 residents, the majority of which live within the west and south areas of the town. Due to the presence of the two major creeks noted above that outlet to Lake Ontario, the Toronto Region and Conservation Authority (TRCA), and the Central Lake Ontario Conservation Authority (CLOCA) regulate, and have jurisdiction over development within the lands adjacent to the creeks.

1.3 Purpose of the Study

Urban forests and other natural capita provide many beneficial ecosystem and social services to municipalities that can be broadly categorized as provisioning services (e.g., food, wood, shading, etc.), regulating services (climate regulation, water filtration, pollution removal, crop pollination, etc.) and cultural services (e.g., community spaces, aesthetic/economic value, educational, heritage, psychological, etc.). Natural capita in the urban environment are already stressed systems and therefore may be more susceptible to climate change. For example, an increase or decrease in annual temperature could result in the decline of certain tree species.

This study examines the vulnerability of natural capita within the Town to projected climate change. Natural capita within the Town primarily consists of municipal trees, woodland and wetland communities, with the occasional open country area. Trees are often the dominant vegetation within both an urban and natural community, and should they be detrimentally impacted by future change, this could have profound implications on the functioning of these ecosystems in the absence of significant intervention.

Trees have been well studied and good data exists on their bioclimatic envelops (i.e., their temperature and precipitation requirements to grow successfully). Using these bioclimatic indicators, a quantitative examination was undertaken to estimate the response of trees and their applicable urban forest and natural features in the Town to the predicted climate in 2049 in Ajax. Where bioclimatic data did not exist to evaluate other natural capita variables potentially influenced by the conditions predicted under the 2049 climate model, a qualitative examination was made based on the prevailing research and general ecological trends observed in the southern Ontario.

The aim of this study is to determine the potential risk for the following:

- Threats to urban forests (municipal tree and natural features) based on species and plant hardiness
- Identification of areas susceptible to heat island effect
- Tree conflicts with electrical and communication transmission infrastructure
- Response of major diseases, pests and invasive species to climate change
- Potential climate change impacts to species at risk (SAR) and other wildlife habitat
- Wetland and other natural area susceptibility to drought

2.0 Approach

2.1 Climate Predictions

The climate predictions for the Town were derived from the *Durham Region's Future Climate (2040-2049) Summary* and *Volume 2 – Data Tables (2000-2009 and 2040-2049)* (SENES 2013, 2014). The Durham Region Climate Report used computer models and climate scenarios developed by the International Panel on Climate Change (IPCC) to project climate conditions in 2049 such as major storms, extreme weather and climatological parameters. Select temperature and precipitation climatological parameters were the basis for the urban forest climate vulnerability assessment as bioclimatic envelopes for most tree species in Canada have been developed by Natural Resources Canada (2018).

2.2 Threats to the Urban Forests

The following section outlines the methodology used to estimate the vulnerability of municipal trees and natural features in the Town to the predicted climate in 2049 in Ajax.

2.2.1 Municipal Tree Data

A list of tree species within the Town was obtained from the Town's municipal tree data. Trees within this data set are owned by the Town and are located on boulevards and parks; privately owned trees or woodlots were not included in this study. This tree data contained records 46,920 individual trees, but data (e.g., species name) was missing from 1,445 trees and therefore these trees were removed from the study. In addition, several inconsistencies were observed within the data specific to species nomenclature (e.g., Littleleaf Linden and Greenspire Littleleaf Linden; *Tilia cordata*); thus, common names were adjusted to a consistent naming convention. Tree species that represented the 85% of the total municipal tree abundance were selected for analysis (i.e., assessment of the bioclimatic data); each tree species had an individual abundance of greater than 0.9%. Additional tree species were selected based on their presence in the natural communities as identified through review of the Ecological Land Classification (ELC) data set. In total, 57 trees were selected for analysis, representing 93.3% of the total municipal trees within the Town's tree database. Trees that were identified as being removed by the Town were not included in the final analysis. For example, many *Fraxinus* (Ash) trees have been removed due to infestation with the Emerald Ash Borer (EAB).

This municipal tree data included the location of the tree and its size measure as the standard diameter-at-breast height (dbh). However, no additional data was available such as tree condition, vigor, the number of stems, tree height, leaf area, percentage canopy missing, or percentage ground cover. Therefore, trees within the municipal data set were assumed to be in good health at the time of assessment in 2017.

Crown projection area (CPA) is an estimated crown volume or leaf area. The CPA for each tree was estimated from the dbh following the methodology by Shimano (1997). A United States Department of Agriculture (USDA) Forest Service study of growth models for forest trees demonstrated that average annual individual-tree diameter was approximately 0.30 cm/year (0.11 inches/year) (Teck & Hilt 1991). It has been assumed that individual landscape trees regardless of species would increase in diameter by 1 cm per year, which would represent favourable to optimal tree growing conditions without competition. Trees that were identified to the species level, but had no dbh data were assumed to have a dbh less than 1 cm. The data was assumed to be accurate as of 2017; therefore, there would be 32 years of growth to 2049, resulting in an increase in dbh by 32 cm for each tree by 2049. The projected dbh at 2049 was then entered into a power-sigmoid CPA model to estimate the CPA for coniferous and deciduous trees.

2.2.2 Natural Areas Data

Ecological Land Classification (ELC) data was obtained from the Toronto and Region Conservation Authority (TRCA) and Central Lake Ontario Conservation Authority (CLOCA). The TRCA data was conducted to a higher level of detail with respect to the ELC community (e.g., vegetation type vs. ecosite). As such, where the two data sets overlapped, the TRCA data was used in the climate vulnerability model.

2.2.3 Bioclimatic Data

The change in the optimal distribution ranges for the tree species was analysed by comparing the climate envelope for each species to the projected climate in 2049 within The Town and was based on the methodology in Yang (2009). Climate envelopes were obtained from Natural Resources Canada (2018). Six bioclimatic indicators were used to represent the climate envelope of each species:

- Annual mean temperature;
- Minimum temperature of the coldest month;
- Maximum temperature of the warmest month;
- Annual precipitation;
- Precipitation in the warmest quarter; and
- Precipitation in the coldest quarter.

This set of variables defines important climatic constraints on tree survival and growth in North America (McKenney et al. 2007). These six variables are highly correlated with other environmental variables such as growing degree days. While they are correlated, they do not add exaggerated constraints, but rather give a more accurate picture of species habitat ranges (Kahn 2017). The species core range is defined by climate values between the 5th and 95th percentiles (i.e., 90% of the climate values where the species exist; McKenney et al. 2007). Bioclimatic data was obtained from the literature for Gingko (*Ginkgo biloba*; Matsumoto et al. 2003; Sun et al. 2003), Littleleaf Linden (De Jaegere et al. 2016), and London Plane Tree (Patrick et al. 2012). When data could not be obtained from either database or the literature species from the same genus were used as a close approximation (i.e., Common Lilac was used as a proxy for Japanese Lilac).

2.2.4 Climate Vulnerability Assessment Scoring

The methodology for constructing the climate vulnerability score model to estimate municipal tree and natural feature climate vulnerability is outlined in this section.

2.2.4.1 Climate Vulnerability for Municipal Trees

To determine if the future climate of The Town will meet the climatic requirements of individual tree species or increase the tree's vulnerability, a climate vulnerability score was created for each tree. Climate vulnerability was assessed by comparing the bioclimatic variables for each tree species (e.g., temperature and precipitation) to the future climate projection in The Town in 2049. A binary score was then assigned to each variable, if the climate in 2049 was within the species bioclimatic envelope a score of 0 was applied; if the climate of 2049 was outside the bioclimatic envelope, a score of 1 was applied.

The climate vulnerability score for each tree is represented as a proportion, by dividing the cumulative score for each tree by the total number of variables. Therefore, a score of 0 implies there will likely be little impact on the tree as a result of the predicted climate in 2049, while a score of 1 implies the tree could be highly vulnerable.

Table 1: Bioclimatic Variables Used to Calculate the Climate Vulnerability Score

Bioclimatic Variable	Description of Bioclimatic Variable
Annual Temperature	The mean of all the weekly temperatures.
Annual Precipitation	Total precipitation in mm
Maximum Temperature	The highest temperature predicted in the warmest season
Minimum Temperature	The lowest temperature in the coldest season
Precipitation in the warmest quarter	Total precipitation in the warmest quarter (July - September)
Precipitation in the coldest quarter	Total precipitation in the coldest quarter (January - March)

2.2.4.2 Climate Vulnerability Score for Natural Areas

Tree species were assigned to an ELC community based on the community type. Each community was assigned a climate vulnerability score based on the average climate vulnerability scores for the dominant tree species that were associated with the ELC community. For example, the climate vulnerability scores for Sugar Maple (*Acer saccharum*) and American Beech (*Fagus grandifolia*) were averaged when estimating the vegetation community climate vulnerability score for Dry-Fresh Sugar Maple - Beech Deciduous Forest vegetation type.

2.2.4.3 Grid Score

To identify areas of climate vulnerability within Ajax, the town was divided into 50 m^2 grids. A climate vulnerability score for each grid was assigned based on the following equation:

$$= \frac{\sum[(CV_i \times Area_i) + (CV_{ii} \times Area_{ii}) + (CV_n \times Area_n)]}{2{,}500}$$

CV – Climate vulnerability of tree or ELC community
i – ELC/individual tree species
n – Total number of ELC/individual tree species
Area – The predicated Crown Projection Area for each tree or the area of the ELC community
2,500 – the area of the 50 m^2 grid.

The minimum score each grid can receive is 0 (i.e., no climate vulnerability) and the maximum score is 1 (i.e., the ELC community/tree has a high vulnerability under the predicted future climate. Note, theoretically the grids representing the municipal tree score could obtain a score of greater than 1, because the predicted CPAs could overlap.

2.2.5 Tree Physiological Characteristics Data

Tree physiological data were collected to identify potential additional vulnerabilities species could have to environmental conditions or events, based on the methodology of Kahn (2017). Morphological features, physiological characteristics and phenology vary between tree species that could result in a competitive advantage or disadvantage in terms of the potential for maximizing growth. Importantly, some of these features could make a tree more prone or resilient to failure in extreme weather conditions.

Physiological data on drought tolerance of trees and the requirement for cold stratification were gathered from the USDA plant characteristic database (USDA, 2018). Drought tolerance information was also obtained from municipal planning reports and guidance documents from the City of Toronto (2012) and City of Guelph (2017). Trees categorized as medium or highly drought tolerant were identified as being drought tolerant in the GIS dataset When there was a disagreement between the two data sources (municipal vs USDA), the Ontario-based municipal data was preferred as this data is based on local experience applicable to Ajax.

Ice storms have the potential to damage trees beyond repair leading to their eventual failure. Ice storms occur when a warm, moist air front meets a cooler layer of surface-air to create super cooled water droplets that immediately freeze upon impact onto surfaces, which creates a layer of ice (Hauer et al. 2006). Southern regions of Canada are expected to have temperatures closer to 0 °C, which could result in more ice storms. In general, ice storms are infrequent and will continue to be so according to the 2049 climate prediction for Ajax; however, when they occur, they have the potential to cause a lot of damage to trees which could become hazardous to surrounding properties and infrastructure. Ice storm damage susceptibility data for trees was retrieved from Hauer et al. (2006). Trees characterized as susceptible or intermediately susceptible were both identified as susceptible to ice storms in the database.

To identify trees that are tolerant to salt spray and saline soils, the Grand River Conservation Authority's (GRCA's) *Salt Resistance of Trees and Shrubs – Grand River Forestry Fact Sheet* and The Town of Richmond Hill's *Urban Forest Planting Guidelines* (Schollen & Company Inc. 2016) were used as resources. Between the two resource documents there were discrepancies for the following trees: Norway Maple (*Acer platanoides*), Common Hackberry (*Celtis occidentalis*), Kentucky Coffeetree (*Gymnocladus dioicus*), Black Walnut (*Juglans nigra*), Black Cherry (*Prunus serotina*), Bur Oak (*Quercus macrocarpa*), Red Oak (*Quercus rubra*), White Spruce (*Picea glauca*) and Red Pine (*Pinus resinosa*). Where there was discrepancies, the species was identified as having overall salt tolerance provided at least one reference document identified it as highly tolerant and the other identified it as at least moderately tolerant (i.e., not low tolerance).

The tree physiological characteristics were provided as supplemental information to the bioclimatic indicators used in the climate vulnerability assessment.

Table 2: Tree Physiological Variables Used to Supplement Climate Change Vulnerability Assessment

Tree Physiological Variable	Description of Tree Physiological Variable	Comment
Cold Stratification	Period of time with temperatures around 1 – 4 °C that is required for seed germination.	Not applicable to Municipal trees as they do not reproduce/disperse through natural seed germination. This information is provided as supplemental to the climate vulnerability scoring for natural areas within the Town
Drought Tolerance	Plants that can tolerate long periods of drought.	The climate in 2049 is expected to get wetter, with increased rainfall in the summer months. Therefore, it does not appear that drought will be an issue for trees within the Town. This information is provided as supplemental to the climate vulnerability scoring for municipal trees and natural areas within the Town.
Ice Storm Damage Susceptibility	Trees susceptible to breaking limbs and cracking during an ice storm.	Although ice storms are predicted to become rarer in 2049, one ice storm can have a large impact, resulting in severe injury to multiple trees. This could be an important factor for trees located adjacent to overhead utility lines. This information is provided as supplemental to the climate vulnerability scoring for municipal trees and natural areas within the Town.
Salt Tolerance	Plants that can tolerate salt spray and saline soils.	Not direct applicable to climate change; however, salt usage within the municipality will be dependent on weather conditions that will be affected by the projected climate.

2.3 Identification of Areas Susceptible to Heat Island Effect

Surface temperature data was obtained from the Town for potential inclusion in this study to assess the effect of heat island on natural capita. This data represents the heat given off by the land, buildings and other surfaces, such as vegetation. While it is possible to estimate air temperatures from surface temperature data, these estimates are less reliable than direct measurements (EPA, 2018). To calculate the urban heat island, meteorologists process the surface temperature through various models to estimate air temperatures and calculate a heat index (City of Cambridge, Massachusetts, 2015).

Using surface temperature alone to estimate heat island is limited as there is not a direct correlation with air temperature (Stewart 2010; provides a critique of the methodology in urban island literature). For example, the surface temperature of a leaf may be recorded at 20°C, but a leaf has the ability to cool itself through evapotranspiration. Therefore, the actual air temperature may be much higher.

Surface temperature data can identify, however, that one surface is a different temperature from another (e.g., a vegetated area is cooler than a paved surface). This data can be used to infer where heat islands may exist, but their impact on trees cannot be quantified as the predicted air temperature is not known. Surface temperature data is represented in 1°C increments and can be used in combination with the municipal tree data to show where individual trees or treed areas may suffer from additional heat stress.

2.4 Tree Conflicts with Electrical and Communication Transmission Infrastructure

As an application of the model that generated municipal tree climate vulnerability scores based on a tree species' bioclimatic envelop, the interactive GIS mapping of the estimated tree CPA can be used to identified tree species that may be predisposed to elevated risk in the future predicted climate conditions. The CPA values rely on assumptions with respect to tree growth which are detailed in Section 2.7. When combining the climate vulnerability data set for trees with the locations of above-ground utilities infrastructure a risk assessment is possible. This application is a potential operational tool for Town staff that want to identify and manage municipal trees in proximity to infrastructure that could be vulnerable in the long term to changing climate and other factors.

2.5 Response of Major Diseases, Pests and Invasive Species to Climate Change

Trees already stressed due to changes in the climate variables are more likely to suffer reduction in condition, mortality and failure from pests and bacteria, viruses, or other microorganisms that can cause disease (Allen et al. 2008; Woods et al. 2006). In addition, the shifting climate has and will continue to allow for the introduction of pests as well as potentially create an environment with more favourable conditions for pests and disease that are already established (Kahn 2017). The potential effect of climate change on pests and diseases affecting trees species was obtained from Boland et al. (2004) and Yang (2009). Both studies assessed the potential effects of future climate by assessing the impact on overwintering, population growth rates, length of development, and increase likelihood of favourable conditions. Tree pest and pathogen data are provided as supplemental information to the bioclimatic indicators used in the climate vulnerability assessment.

2.5.1 Invasive Flora Species Data

Shifting climate has and is expected to continue to allow for the introduction, establishment and potential proliferation of existing and new invasive plant species by creating more favourable bioclimatic conditions. With few exceptions, bioclimatic indicators for most invasive plant species do not exist. Further, the location and extent of invasive species within the Town's municipal boundary has not been mapped. As such, a qualitative assessment of the influence the predicted climate could have on invasive plant species was included in the study.

Potential Climate Change Impacts to Species at Risk and Other Wildlife Habitat Species at Risk are identified as species listed as either *Endangered* or *Threatened* under the Ontario *Endangered Species Act*, 2007. The following wildlife atlases and other data sources were searched to identify the potential for a SAR to occur within the Town based on species geographic range distribution and/or past occurrences:

- ANSI - Areas of Natural and Scientific Interest, obtained from Land Information Ontario (LIO), 2015.
- Provincially Tracked Species - Obtained from LIO and last revised December 28th 2016.
- DFO SAR Segments - Stream segments identifying the SAR distributions and status, obtained from the Department of Fisheries and Oceans, 2015.
- DFO SAR Critical Habitat (line) - Line features identifying critical habitat for SAR, obtained from the Department of Fisheries and Oceans, 2015.
- DFO SAR Critical Habitat (polygon) - Polygon features identifying critical habitat for SAR<, obtained from the Department of Fisheries and Oceans, 2015.
- Ontario Christmas Bird Count - Data obtained and compiled for 2015 from Birds Canada.
- Important Bird Areas - Data obtained from Bird Studies Canada, 2015.
- SAR by Municipality - Data obtained in 2017 from https://www.ontario.ca/environment-and-energy/species-risk-area and joined to LIO 2015 Municipal Boundaries.
- Ontario Mammals Data - Data obtained from NatureServe, Mammals for the Western Hemisphere v3.0, released in 2007 and compiled in 2010.
- Regulated Habitat Lower - Data obtained in 2017 from Ontario Regulation 242/08 and joined to LIO 2015 Lower and Single Tier Municipal Boundaries.
- Regulated Habitat Upper - Data obtained in 2017 from Ontario Regulation 242/08 and joined to LIO 2015 Upper Tier and District Municipal Boundaries.
- Herptiles by Municipality - Data obtained in 2017 (for Species-at-Risk only) from http://www.ontarioinsects.org/herpatlas/herp_online_expert.html and joined to LIO 2015 Municipal Boundaries.

- Lepidoptera by Municipality - Data obtained in 2017 (for Species-at-Risk only) from http://www.ontarioinsects.org/atlas_online.htm and joined to LIO 2015 Municipal Boundaries.
- Odonata by Municipality - Data obtained from Atlas of Ontario Odonata in 2017 (for Species-at-Risk only), and MNRF NHIC, and joined to LIO 2015 Municipal Boundaries.
- OBBA - Ontario Breeding Bird Atlas information, currently displaying only SAR for Ontario, with additional information in some areas, data obtained 2017.

A SAR's potential to occur within the Town was further refined based on their known habitat preferences cross-referenced with the ELC vegetation community data. SAR with identifiable potential habitat within the Town's limits were included in the analysis. Although this background screening may identify the potential for SAR habitat within Ajax, it does not confirm the SAR is present; rather, only detailed field surveys can confirm presence.

The potential for SAR to be impacted by the future climate was based on the climate vulnerability score of the ELC vegetation communities which could function as their respective habitat. For instance, an ELC community with a low climate vulnerability score is likely to persist in 2049, and therefore, may still provide habitat for the SAR. In contrast, an ELC community with a high climate vulnerability score may be impacted and may not provide suitable habitat for SAR. Accordingly, the SAR assessment identified whether future climate conditions will remain favourable for the SAR terrestrial habitat types currently existing within the Town's predominantly treed natural features.

2.6 Wetland and Other Natural Area Susceptibility to Drought

Bioclimatic data for non-woody, wetland vegetation (e.g., herbaceous and graminiod species) is not readily available. More importantly, vegetation communities at lower strata levels (e.g., marshes) are more resilient to shifts in the temperature and precipitation bioclimatic indicators assessed in this study. Therefore, in this report, we provide a qualitative description of the predicted vulnerability of wetland communities to the drought potential projected in the regional climate 2049 model.

2.7 Natural Capita Study Assumptions

Table 3 outlines the assumptions used to in the natural capita study.

Table 3: Assumptions of the Natural Capita Climate Vulnerability Assessment Study

No.	Assumption	Comment
1	All trees within the municipal data set are assumed to be in good health at the time of assessment in 2017	No tree health data was provided. Trees currently in poor health will be more susceptible to future climate than trees in good health.
2	Tree dbh would increase by 1 cm per year	Different species have correspondingly varying rates of growth, or radial/basal area increment. Tree growth rates are influenced by genetic differences among species (Black et al. 2008; Loehle, 1998; Bryukhanova et al. 2011), and numerous variables such as age and the factors of plant's physical environment (Heightshoe 1988). These other factors often have a more profound effect on tree growth rates as compared to genetic predisposition, especially in the urban environment. The other factors affecting tree growth rates include resources availability (e.g., nutrients, light and water; Black et al. 2008), competition with other species (Orwig and Abrams, 1997), extreme weather conditions, stress from pollutants, pests and disease (Orwig and Abrams, 1997; Bryukhanova et al. 2011; Ashmore 2005; Reich 1987), and differences in growing season across geographic ranges. The urban stress factors that could inhibit tree growth typical of large, densely populated urban settings such as restricted growing space are generally assumed to be of minimal influence in Ajax. As such, a rate of 1 cm diameter per year is considered a reasonable, albeit likely an upper limit assumption for the growth of individual trees in a landscaped environment with generally minimal competition for growing space.
3	Relationship between dbh and crown projection area (CPA) using power-sigmoid model in Shimano (1997).	This model allows for the calculation of CPA from dhb for coniferous and deciduous trees. The data to create the model was gathered from the temperate zone in Japan and was based on natural trees. Therefore, the modelled CPA may not be precisely how the CPA of municipal street trees will develop, but is a reasonable estimation.

No.	Assumption	Comment
4	Urban surface temperature could be generally indicative of the potential for Urban Heat Island effects	Surface temperature is not indicative of air temperature without further calculation and meteorological modelling. For example, surface temperature only demonstrates that asphalt is retains heat to a greater extent than the surface of a leaf, which has the ability to cool itself through evapotranspiration. However, the data can be used to indicate where areas of the Town may be susceptible to the urban heat island effect. Therefore, we have used this data as a guide, as in its current form it cannot be used to quantify the effect of the urban heat island.
5	Climate Vulnerability Score	One variable within the climate vulnerability score is generally unlikely to independently cause a tree species to decline or fail. Rather, it is the cumulative effect of multiple stressors that is more likely to result in tree decline or failure. For example, a tree may be stressed in a warmer environment, but will likely survive. However, it may not have sufficient resources to overcome exposure to a pathogen or pest that in a cooler climate it could resist or recover from. The climate vulnerability score assumes that no maintenance or preventative action will take place such as vaccinating the tree against a disease or pest as well as other forms of tree maintenance such as pruning or cabling.
6	Ice Storm Damage Susceptibility	Although ice storms are predicted to reduce in frequency, ice storm damage susceptibility was included in the climate vulnerability score because when ice storms do occur they can have negative impacts on trees that may lead to immediate or future decline or failure.
7	Precipitation and Infiltration	This study assumes that increases in precipitation will result in relatively commensurate increases in infiltration. If this is not the case, then the precipitation variables could be removed from the climate vulnerability scoring model as they moderate temperature increases and often lower the overall climate vulnerability score. Under the future climate conditions, the increase in precipitation could be the result of intense storms. If

No.	Assumption	Comment
		these occur on dry compacted ground, water may not infiltrate as readily, but rather result in an increase in surface runoff. Importantly, this analysis also assumes street trees are planted in permeable ground. If they are surrounded by impermeable surfaces (such as concrete), infiltration may not occur and the tree may experience drought conditions more readily. Moreover, in heavily urbanize settings drought conditions could increase the probability of tree stress, decline and failure.

3.0 Threats to the Urban Forest

3.1 Climate Vulnerability Assessment

The results of the climate vulnerability assessment for the urban forest (municipal trees and treed natural features) are provided below. Figures 1-6 are the tree bioclimatic envelopes for variables used in this assessment.

Supplemental tree pest and disease, drought tolerance, salt tolerance, cold stratification and ice storm damage susceptibility data has been imported into the GIS database enabling queries of these variables for municipal trees and treed natural areas. This database can supplement information on climate vulnerability by identifying additional tree vulnerability or resilience to other environmental factors. Tree species within the Town of Ajax are categorized by drought tolerance, requiring cold stratification, susceptible to ice storm damage and/or salt tolerance in Table A1 of Appendix A. Figure 7 maps the locations of drought tolerant tree species and Figure 8 depicts the locations of salt tolerant tree species within the Town of Ajax.

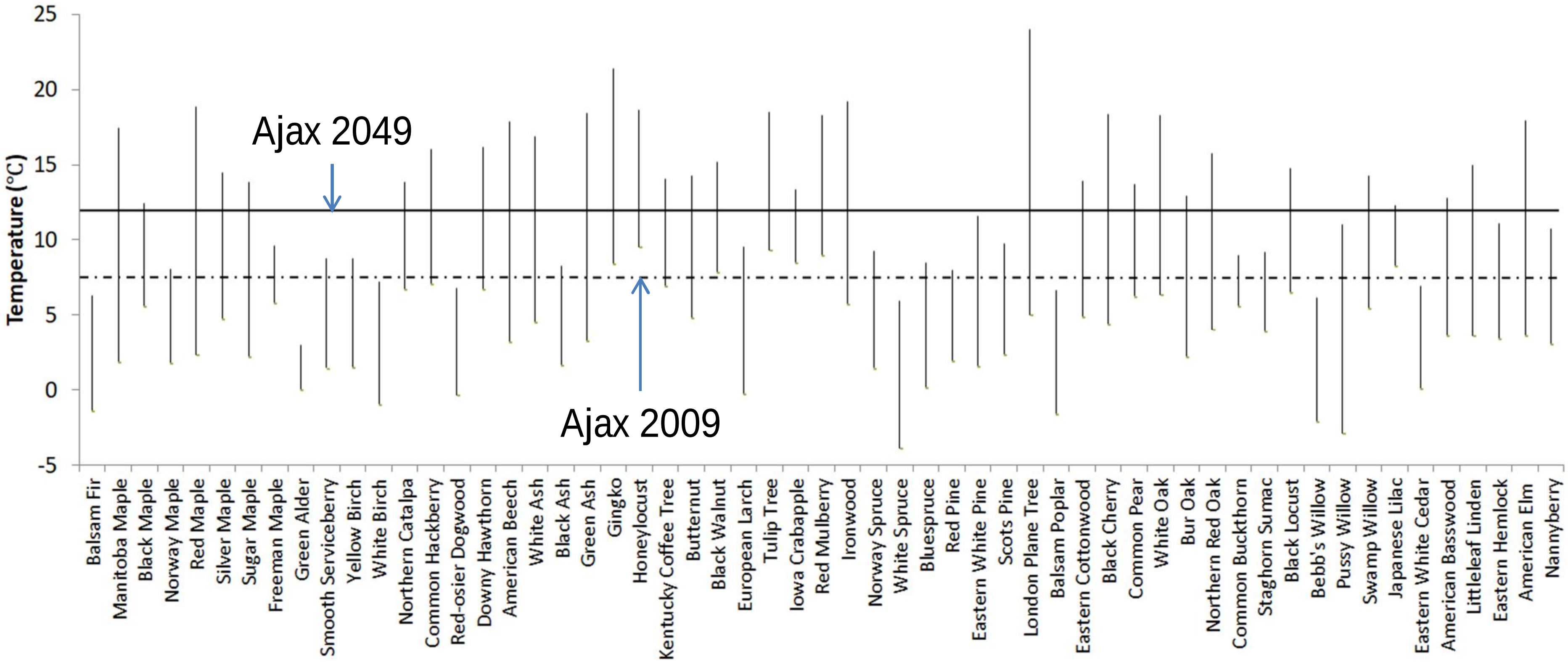


Figure 1: Average annual temperature bioclimatic envelope for the most abundant trees in Ajax with current and predicted annual temperature levels

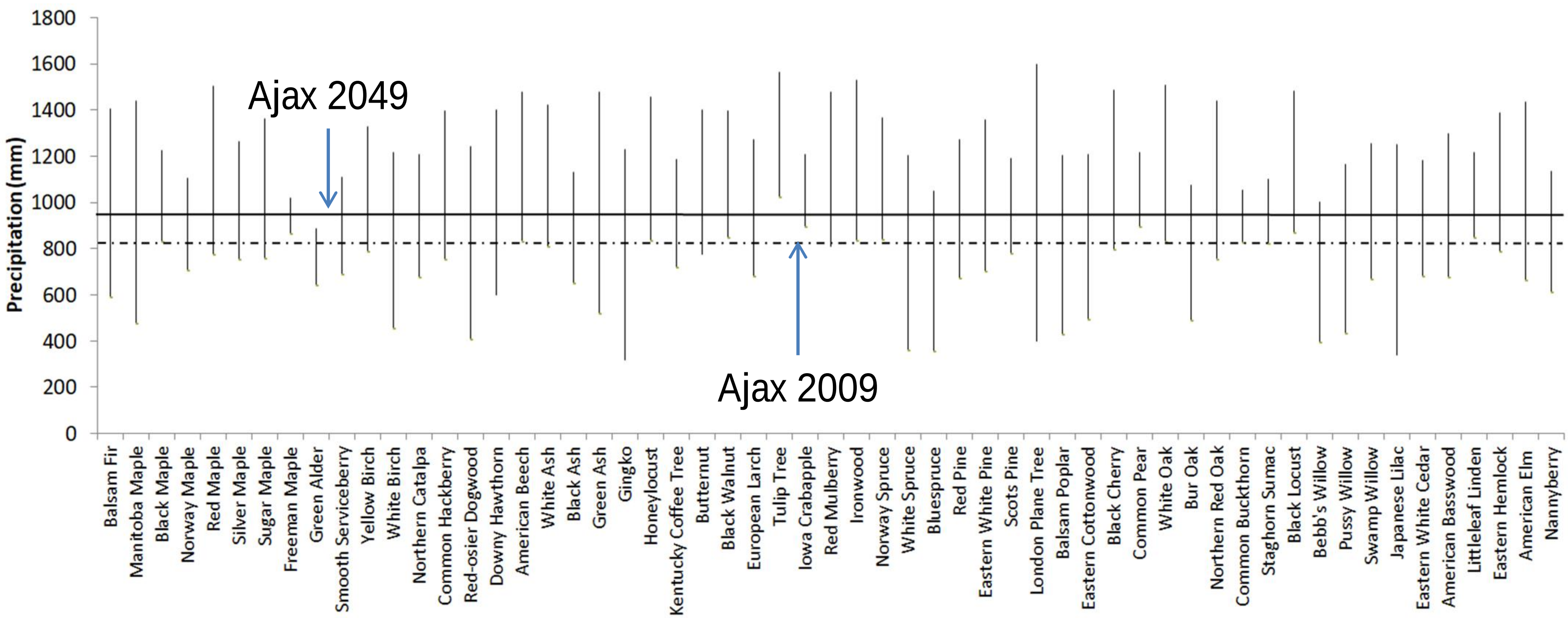


Figure 2: Annual total precipitation bioclimatic envelope for the most abundant trees in Ajax with current and predicted annual temperature levels

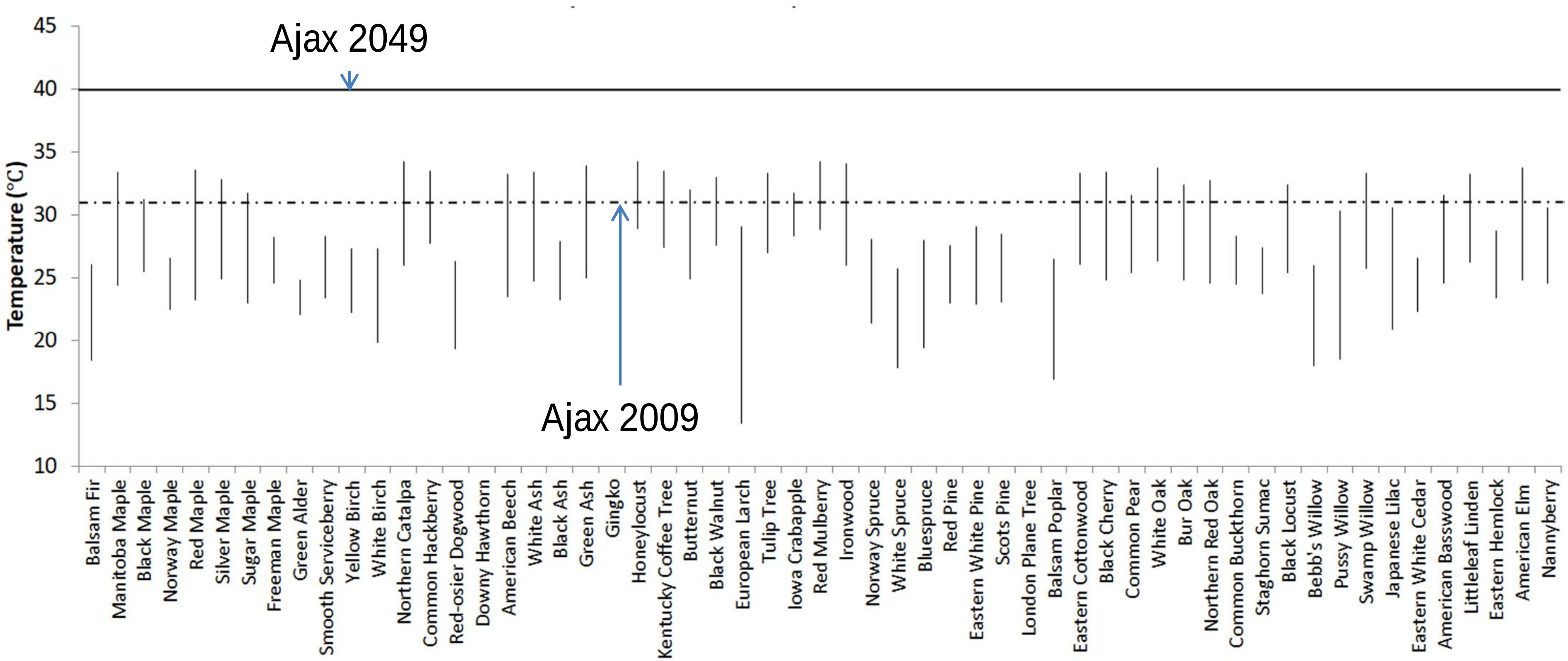


Figure 3: Maximum temperature bioclimatic envelope for the most abundant trees in Ajax with current and predicted annual temperature levels

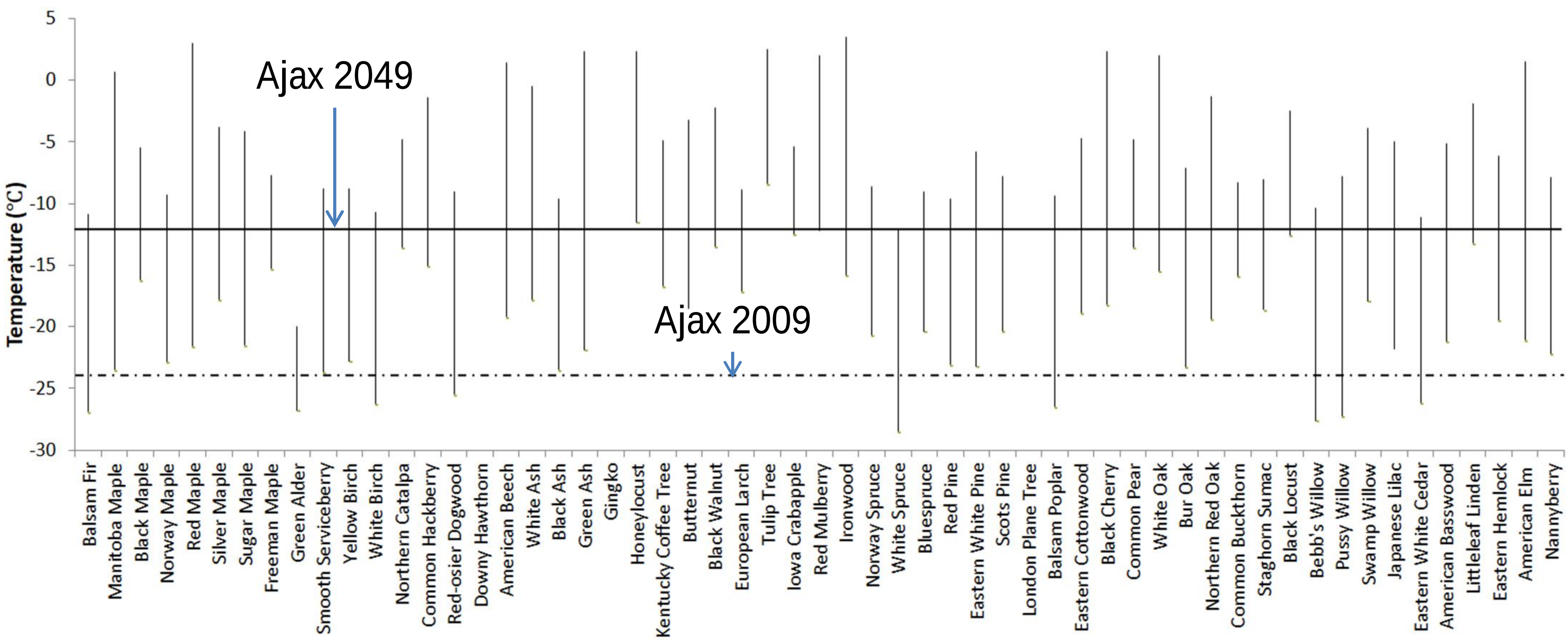


Figure 4: Minimum temperature bioclimatic envelope for the most abundant trees in Ajax with current and predicted annual temperature levels

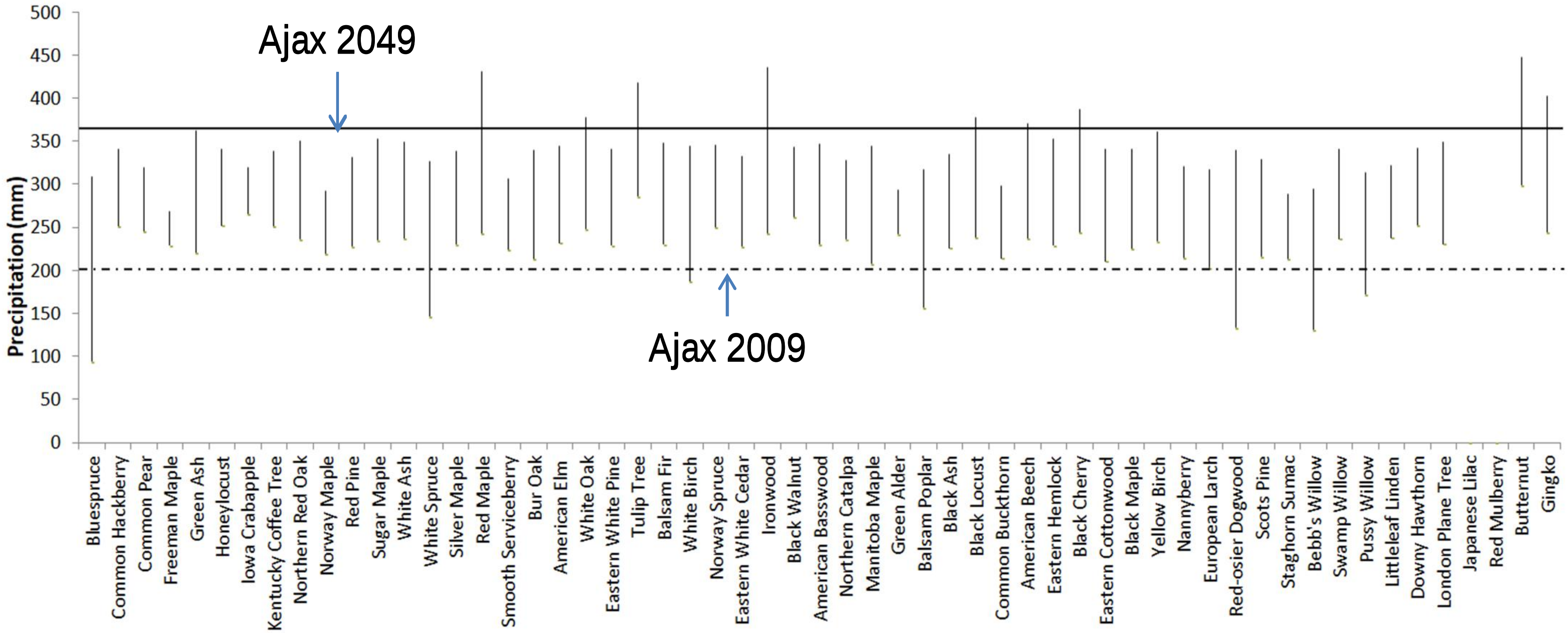


Figure 5: Total precipitation in the warmest quarter bioclimatic envelope for the most abundant trees in Ajax with current and predicted precipitation levels

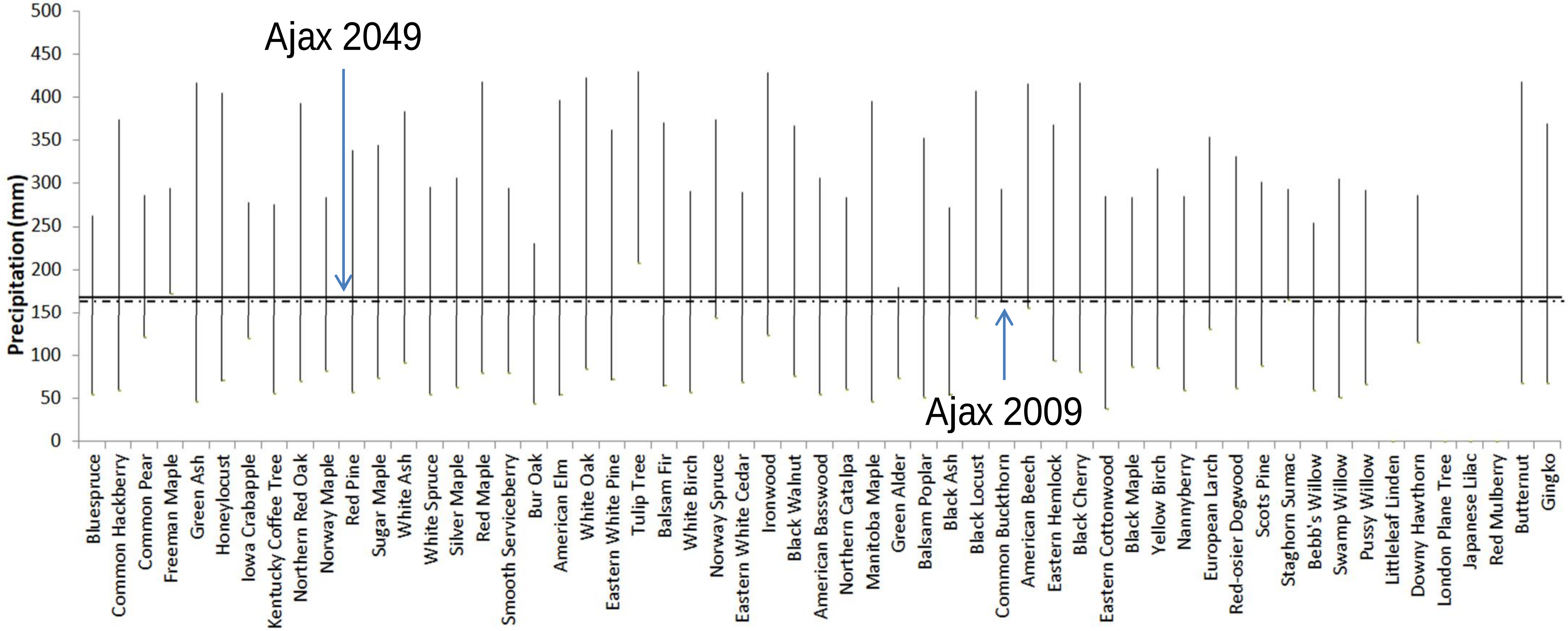
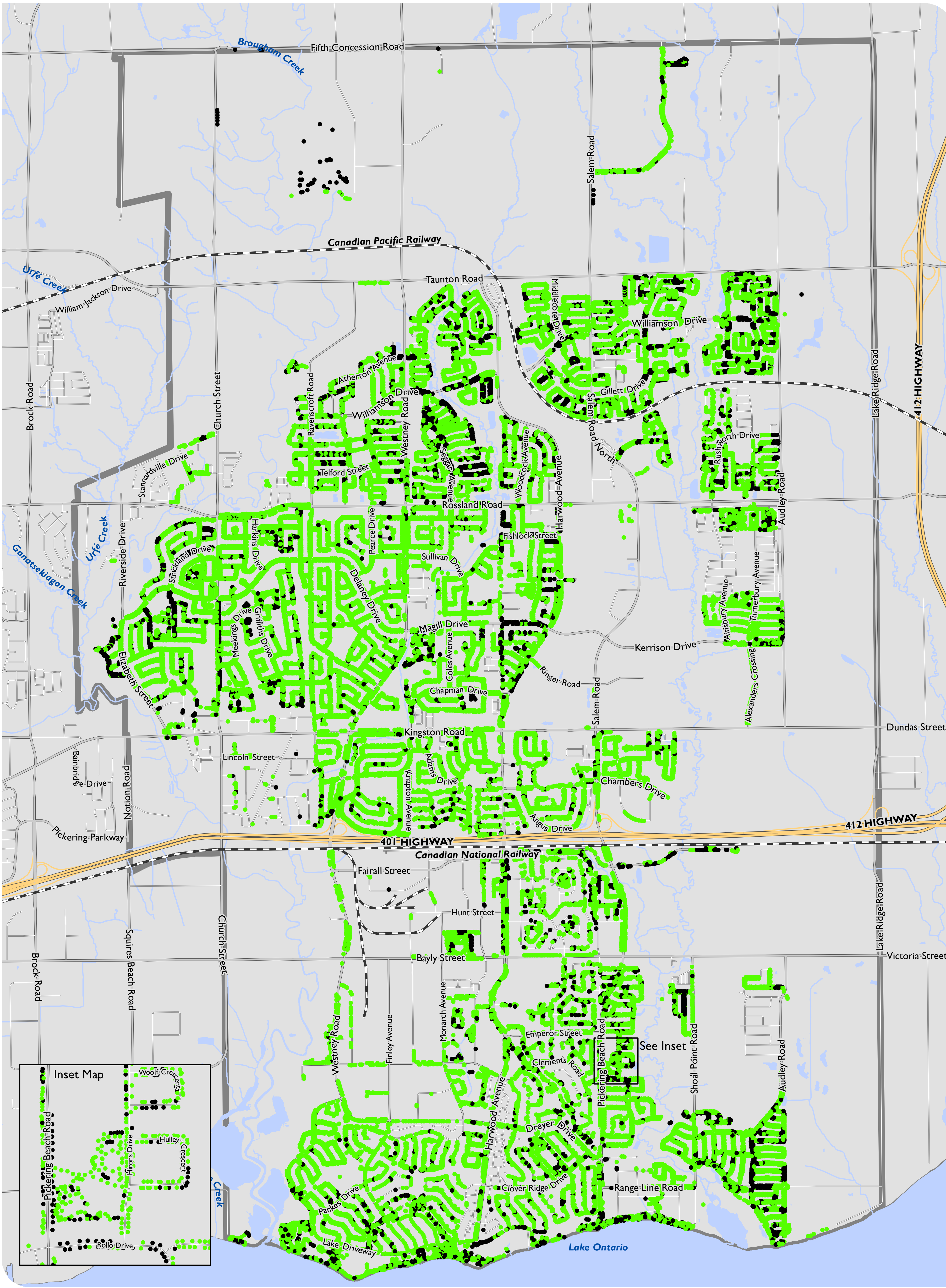


Figure 6: Total precipitation in the coldest quarter bioclimatic envelope for the most abundant trees in Ajax with current and predicted precipitation levels



Drought Tolerant Municipal Tree
Other Municipal Tree
Railway

TOWN OF AJAX
COMMUNITY CLIMATE STUDY

FIGURE 7
MUNICIPAL TREES IDENTIFIED AS DROUGHT TOLERANT

DILLON CONSULTING

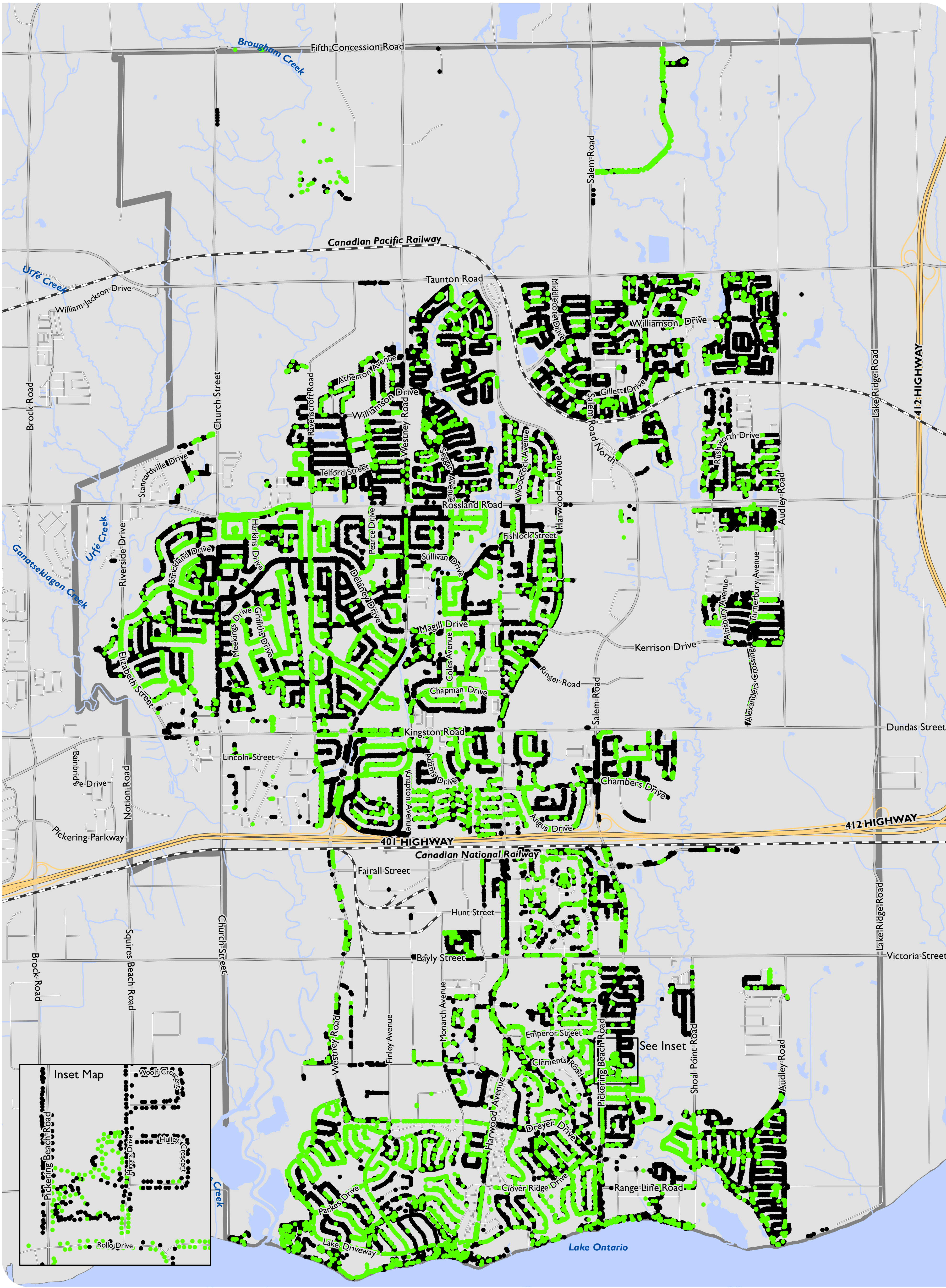
MAP DRAWING INFORMATION:
DATA PROVIDED BY AJAX

MAP CREATED BY: GM
MAP CHECKED BY:
MAP PROJECTION: NAD 1983 UTM Zone 17N

1:32,000
0 250 500 1,000 m

PROJECT: 187286 STATUS: DRAFT DATE: 2018-10-12

FILE LOCATION: I:\GIS\187286 - Town of Ajax Community Climate Study\mxd\Natural Capital\Figure 7 Municipal Trees - Drought Tolerance.mxd



- Salt Tolerant Municipal Tree
- Other Municipal Tree
- Railway

TOWN OF AJAX

COMMUNITY CLIMATE STUDY

FIGURE 8

MUNICIPAL TREES IDENTIFIED AS SALT TOLERANT

1:32,000

0 250 500 1,000 m

MAP DRAWING INFORMATION:
DATA PROVIDED BY AJAX

MAP CREATED BY: GM
MAP CHECKED BY:
MAP PROJECTION: NAD 1983 UTM Zone 17N

DILLON CONSULTING

PROJECT: 187286 STATUS: DRAFT DATE: 2018-10-12

FILE LOCATION: I:\GIS\187286 - Town of Ajax Community Climate Study\mxd\Natural Capita\Figure 8 Municipal Trees - Salt Tolerance.mxd

3.1.1 Municipal Tree Data

Climate vulnerability results for municipals trees are provided in Table 4 and Figures 9 and 10. The most common stresses on these trees are the change in temperature outside their bioclimatic envelops (see Figures 1, 3 and 4; Table A1 of Appendix A). However, the vulnerability associated with increasing temperatures may be offset by the predicted increase in precipitation whereby the tree is allowed to cool through evapotranspiration as well as tree physiological processes. This assumes that precipitation will infiltrate into the ground and street trees will have access to the water, which may not be the case in the urban environment. Under a low infiltration rate scenario, street trees would not benefit from the increase in precipitation and may be more prone to heat and other stresses, decline and/or failure.

There are several tree species with bioclimatic envelopes that are outside of the predicted mean annual temperature level according the Durham Region climate model, including Balsam Fir (*Abies balsamea*), Norway Maple, Freeman Maple (*Acer x freemanii*), Green Alder (*Alnus viridis*), European Larch (*Larix decidua*), Eastern White Cedar (*Thuja occidentalis*), and several of the spruce and pine species (Figure 1). Conversely, only Tulip Tree (*Liriodendron tulipifera*) and Green Alder, the latter being a species not typically planted as individual landscape trees, have bioclimatic envelopes that are outside of the climate model's predicted annual precipitation level (Figure 2). All trees assessed in this study contained bioclimatic envelopes below the maximum predicted temperature according to the regional climate model (Figure 3); however, the highest extreme maximum temperature differences between 2000-2009 (recent) and 2040-2049 (predicted) modelled periods are expected in the winter months (Senes 2013). White Spruce is the only municipal tree with a bioclimatic envelope below the predicted minimum temperature, while Honeylocust (*Gleditsia triacanthos*) and Tulip Tree will continue to have bioclimatic envelope above the predicted level (Figure 4). Most municipal tree species have bioclimatic envelopes that fall between the 2009 and 2049 levels modelled for precipitation in the warmest months (Figure 5); although some species such as Tulip Tree, Red Maple (*Acer rubrum*), Ironwood (*Ostrya virginiana*), Black Locust (*Robinia pseudoacacia*), American Beech, Black Cherry, Butternut (*Juglans cinerea*) and Gingko could benefit from higher precipitation levels during these months based on their bioclimatic envelopes. Further, all municipal trees species assessed that are currently within the bioclimatic envelop for precipitation in the coldest quarter will remain so as precipitation levels during this period are only predicted to marginally increase (Figure 6).

Based on the 50 m^2 grid analysis, the majority municipal trees have a low (0 - 0.2) to low-moderate (0.2 - 0.4) climate vulnerability score (Figure 9). This indicates that the majority of the individual trees that comprise the urban forest canopy should continue to survive under the projected climate of 2049.

Tulip Tree has the highest climate vulnerability score of 0.67, indicating it has at medium-high level of risk. The annual precipitation and precipitation in the coldest period are below Tulip Tree's bioclimatic envelop for these precipitation variables in 2049, and the predicted minimum and maximum temperature are outside its bioclimatic envelope (see Table A1 in Appendix A). However, Tulip Tree has a relatively low abundance within the Town (i.e., 146 trees) and the majority of these trees are small in size, and as such, this species is not expected to pose a large risk. Furthermore, the current climate (2009) has lower precipitation and lower minimum temperatures that those predicted in 2049. Although the climate of 2049 will continue to be unfavourable, Tulip Tree could actually benefit from predicted changes in these bioclimatic variables.

With the exception of Freeman Maple, the most abundant tree species represented by Norway Maple, Littleleaf Linden (*Tilia cordata*), Sugar Maple, Japanese Lilac (*Syringa vulgaris*), Honeylocust, Common Pear (*Pyrus communis*), Northern Red Oak (*Quercus rubra*), Common Hackberry and Green Ash (*Fraxinus pennsylvanica*) had low-moderate climate vulnerability scores (i.e., 0.33 or less; see Table 4 below). Freeman Maple had a moderate climate vulnerability score of 0.50. Coniferous tree species (i.e., spruces, pines and firs) had low-moderate climate vulnerability scores of 0.33. Downy Hawthorn (*Crataegus mollis*) had a climate vulnerability score of 0.

Table 4: Tree Climate Vulnerability Score and Abundance within the Town of Ajax

Scientific Name	Common Name	Number of Municipal Trees	Climate Vulnerability Score
Abies balsamea	Balsam Fir	137	0.33
Acer negundo	Manitoba Maple	68	0.17
Acer nigrum	Black Maple	27	0.17
Acer platanoides	Norway Maple	7244	0.33
Acer rubrum	Red Maple	303	0.17
Acer saccharinum	Silver Maple	353	0.17
Acer saccharum	Sugar Maple	3740	0.17
Acer x freemanii	Freeman Maple	3205	0.50
Alnus viridis	Green Alder	---	---
Amelanchier laevis	Smooth Serviceberry	303	0.33
Betula alleghaniensis	Yellow Birch	---	---
Betula minor	White Birch	119	0.33
Catalpa speciosa	Northern Catalpa	53	0.17
Celtis occidentalis	Common Hackberry	1238	0.17
Cornus sericea ssp sericea	Red-osier Dogwood	6	0.33
Crayaegus mollis	Downy Hawthorn	6	0.00
Fagus grandifolia	American Beech	---	---
Fraxinus americana	White Ash	264	0.17
Fraxinus nigra	Black Ash	1	0.33

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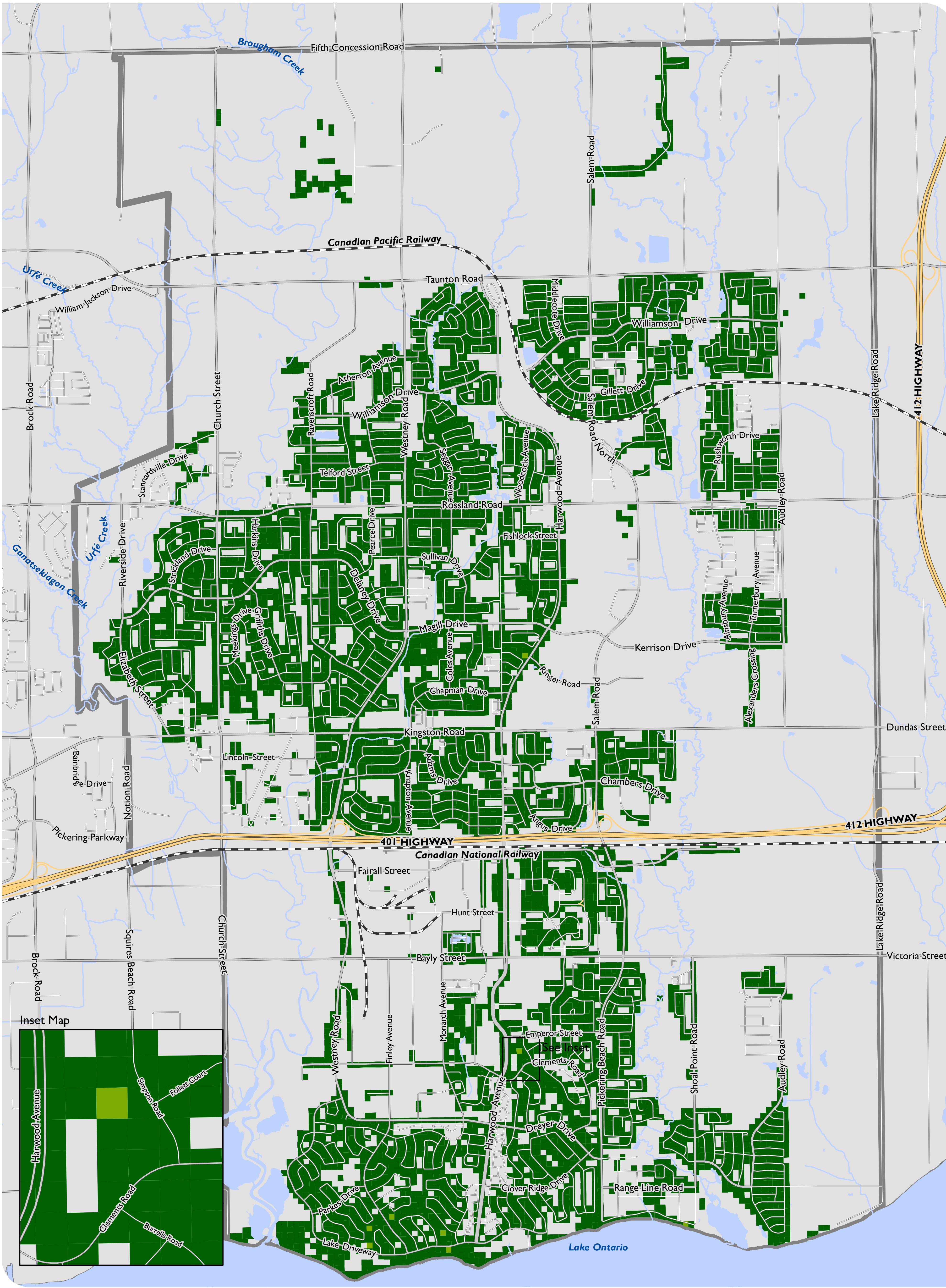
Scientific Name	Common Name	Number of Municipal Trees	Climate Vulnerability Score
Fraxinus pennsylvanica	Green Ash	1184	0.17
Ginkgo biloba	Gingko (Matsumoto et al. 2003; Sun et al. 2003)	696	0.33
Gleditsia triacanthos	Honeylocust	2325	0.33
Gymnocladus dioicus	Kentucky Coffee Tree	428	0.17
Juglans cinerea	Butternut	38	0.33
Juglans nigra	Black Walnut	66	0.17
Larix decidua	European Larch	14	0.33
Liriodendron tulipifera	Tulip Tree	146	0.67
Malus pumila	Iowa Crabapple	614	0.17
Morus rubra	Red Mulberry	---	---
Ostrya virginiana	Ironwood	71	0.17
Picea abies	Norway Spruce	113	0.33
Picea glauca	White Spruce	738	0.33
Picea pungens	Bluespruce	515	0.33
Pinus resinosa	Red Pine	406	0.33
Pinus strobus	Eastern White Pine	206	0.33
Pinus sylvestris	Scots Pine	10	0.33
Platanus × acerifolia	London Plane Tree (Patrick et al. 2012)	921	0.33
Populus balsamifera	Balsam Poplar	8	0.33
Populus deltoides ssp. deltoides	Eastern Cottonwood	---	---
Prunus serotina	Black Cherry	140	0.17
Pyrus communis	Common Pear	1841	0.17
Quercus alba	White Oak	232	0.17
Quercus macrocarpa	Bur Oak	317	0.17
Quercus rubra	Northern Red Oak	1673	0.33
Rhamnus cathartica	Common Buckthorn	1	0.33
Rhus hirta	Staghorn Sumac	3	0.17
Robinia pseudoacacia	Black Locust	17	0.33
Salix bebbiana	Bebb's Willow	40	0.33

Scientific Name	Common Name	Number of Municipal Trees	Climate Vulnerability Score
Salix discolor	Pussy Willow	---	---
Salix nigra	Swamp Willow	---	---
Syringa vulgaris	Japanese Lilac (Common Lilac uses as surrogate)	2668	0.17
Thuja occidentalis	Eastern White Cedar	105	0.33
Tilia americana	American Basswood	95	0.17
Tilia cordata	Littleleaf Linden (De Jaegere et al. 2016)	6367	0.17
Tsuga canadensis	Eastern Hemlock	9	0.33
Ulmus americana	American Elm	144	0.17
Viburnum lentago	Nannyberry	---	---



TOWN OF AJAX

COMMUNITY CLIMATE STUDY

FIGURE 9

CLIMATE VULNERABILITY GRID SCORES FOR MUNICIPAL TREES

Railway

Town of Ajax Municipal Boundary

Climate Vulnerability Grid Score 2049

- 0 - 0.2 Low
- >0.2 - 0.4 Low-Moderate
- >0.4 - 0.6 Moderate
- >0.6 - 0.8 Moderate-High
- >0.8 - 1 High

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MAP DRAWING INFORMATION:
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MAP CREATED BY: GM
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MAP PROJECTION: NAD 1983 UTM Zone 17N

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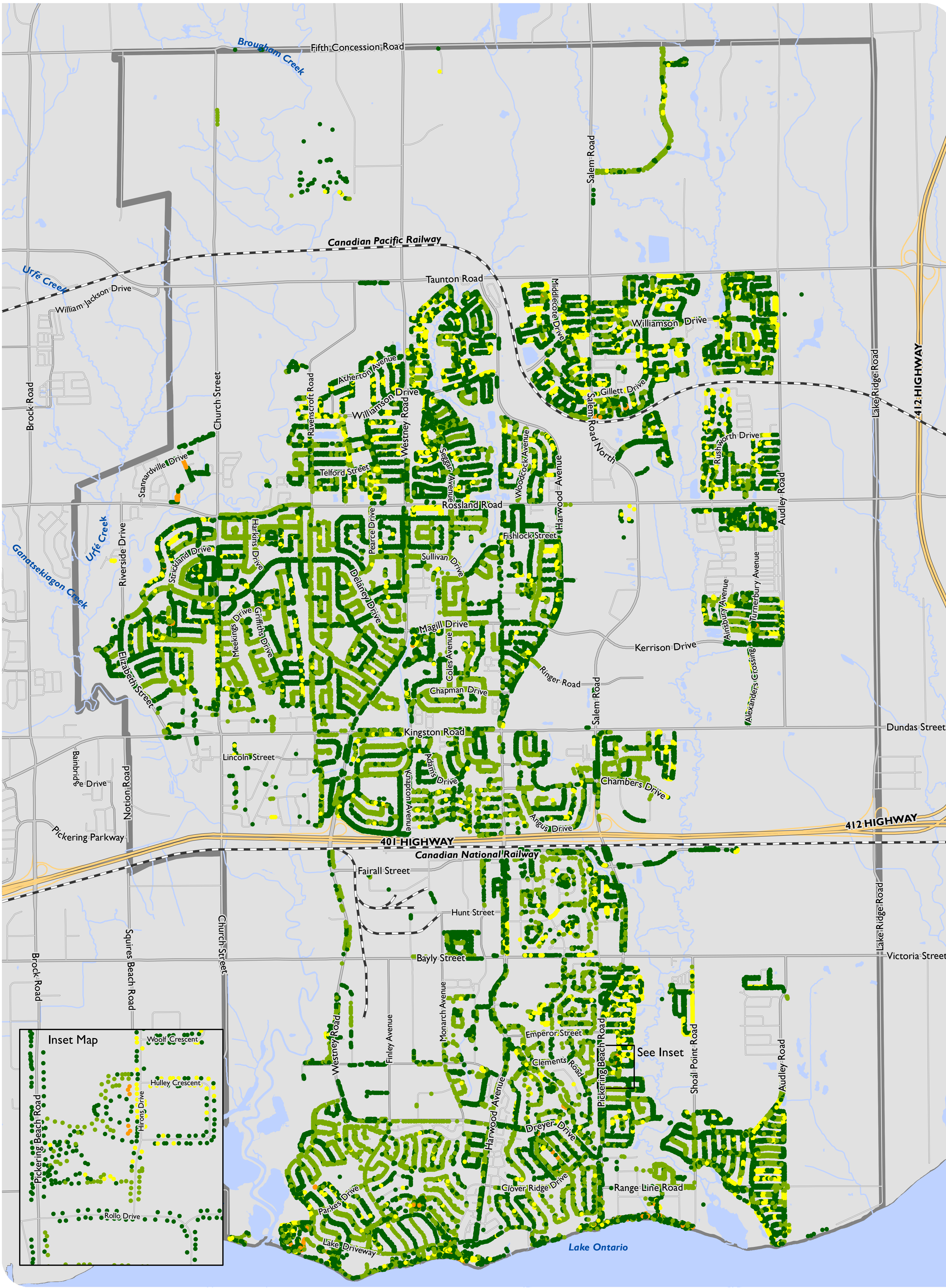
FILE LOCATION: I:\GIS\187286 - Town of Ajax Community Climate Study\mxd\Natural Capita\Figure 9 Climate Vulnerability Grid Scores for Municipal Trees.mxd



TOWN OF AJAX
COMMUNITY CLIMATE STUDY

FIGURE 10
CLIMATE VULNERABILITY SCORES FOR MUNICIPAL TREES

Climate Vulnerability Score 2049
- 0 - 0.2 Low
- >0.2 - 0.4 Low-Moderate
- >0.4 - 0.6 Moderate
- >0.6 - 0.8 Moderate-High
- >0.8 - 1 High

Railway
Town of Ajax Municipal Boundary

DILLON CONSULTING

MAP DRAWING INFORMATION:
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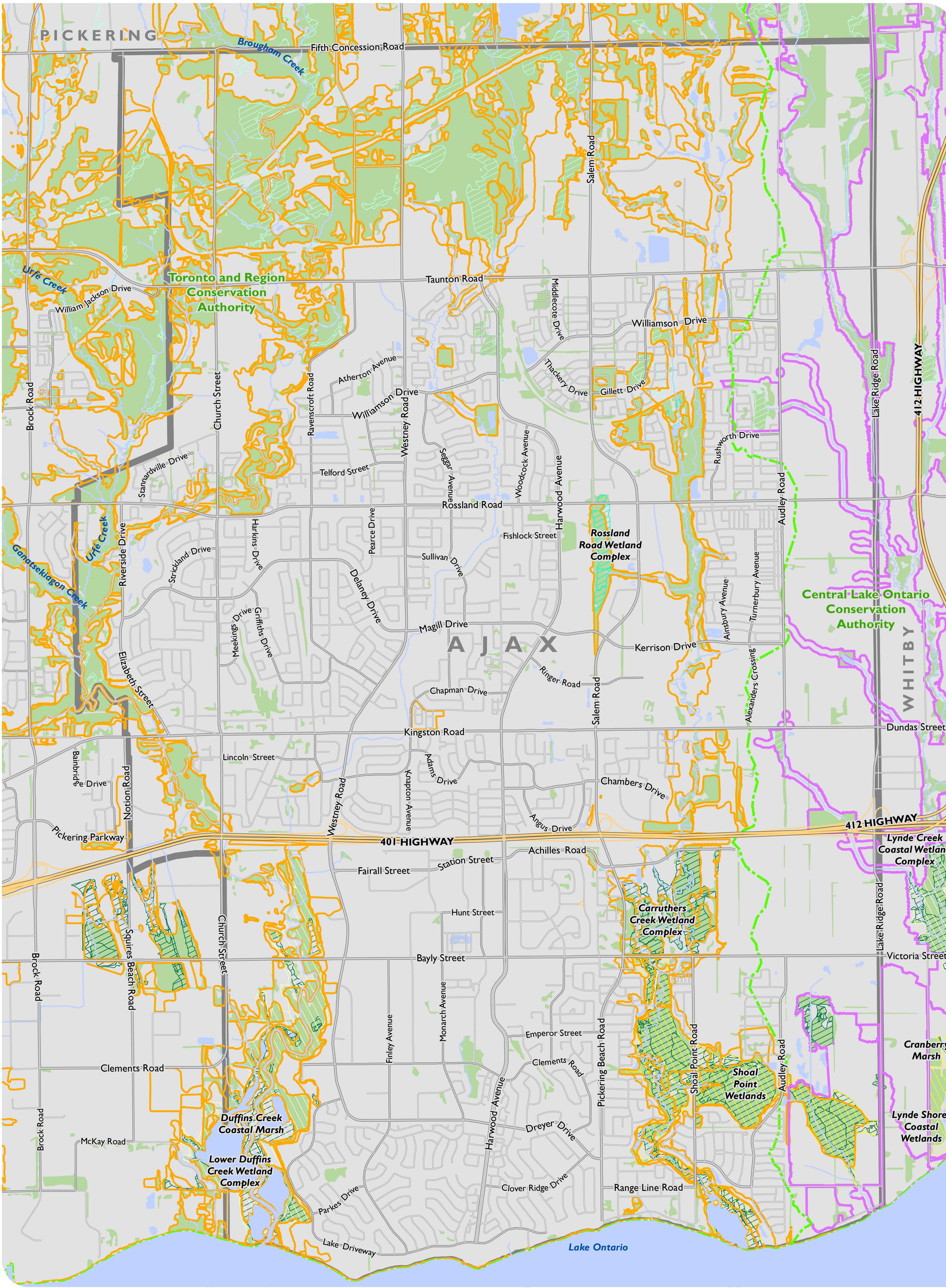
FILE LOCATION: I:\GIS\187286 - Town of Ajax Community Climate Study\mxd\Natural Capital\Figure 10 Climate Vulnerability Scores for Municipal Trees.mxd

3.1.2 Natural Areas

Natural areas with the within the Town's jurisdiction include wetlands, woodlands and other natural features within the natural heritage system (see Figure 11). The major natural features in the Town are associated with Duffins Creek, Carruthers Creek and Lynde Creek. These creek systems originate headwater tributaries and associated terrestrial natural features in the northern part of the Town and extend to Lake Ontario, providing the primary ecological corridors in the Town's natural heritage system.

The vulnerability assessment of treed natural areas was based on the average climate vulnerability scores for the dominant tree species that were associated with the known vegetation communities classified by the TRCA and CLOCA (Figure 12). The climate vulnerability scores for natural areas ranged from low-moderate to low (i.e., 0 - 0.04) indicating a low level of risk as a result of the predicted climate in 2049 (see Figure 13).

There were no natural areas with moderate to high climate vulnerability scores as the individual scores for dominant trees within these vegetation communities are ranged from low-moderate to low. Similar to the vulnerability assessment for individual trees, the natural area assessment considered six bioclimatic indicators comprised of three variables each for temperature and precipitation. When examining the annual and extreme maximum temperature climate variables in isolation of the precipitation variables, certain ecological communities with species typical of latitudes north of Ajax such as coniferous forests and swamps may be vulnerable to predicted temperature levels in 2049 (Figure 14). Further discussion on this topic is provided in Section 4.0.



TOWN OF AJAX
COMMUNITY CLIMATE STUDY

FIGURE 11
NATURAL FEATURES

- Conservation Authority Boundary
- Natural Heritage System (CLOCA)
- Natural Heritage System (TRCA)
- ANSI, Life Science (MNRF)
- Candidate ANSI, Life Science (MNRF)
- Provincially Significant Wetland (MNRF)
- Evaluated Wetland (MNRF)
- Unevaluated Wetland (MNRF)
- Woodland (MNRF)
- Town of Ajax Municipal Boundary

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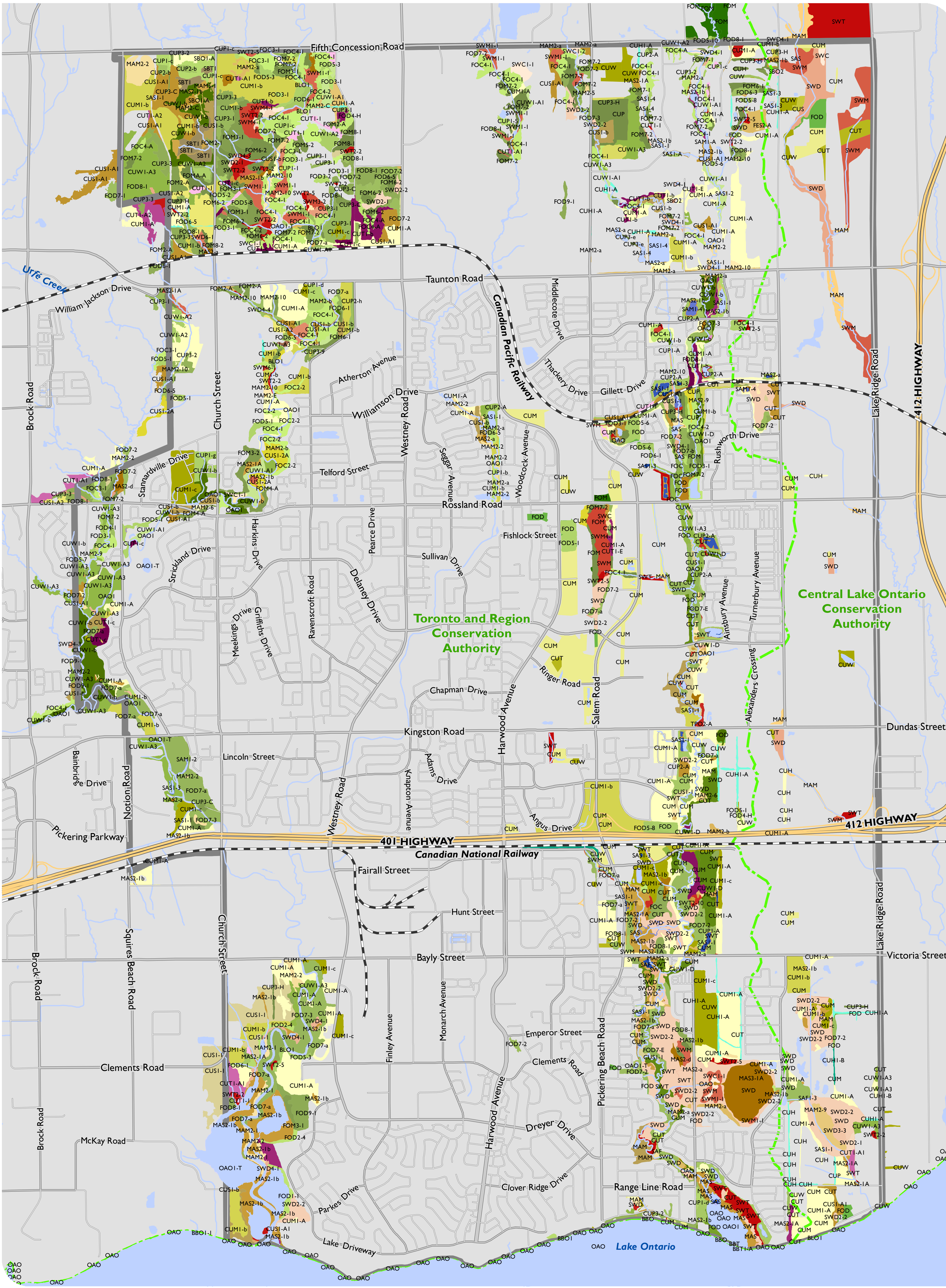
FILE LOCATION: I:\GIS\187286 - Town of Ajax Community Climate Study\mxd\Natural Capita\Figure 11 Natural Features.mxd



Conservation Authority Boundary

Town of Ajax Municipal Boundary

TOWN OF AJAX

COMMUNITY CLIMATE STUDY

FIGURE 12

ECOLOGICAL LAND CLASSIFICATION

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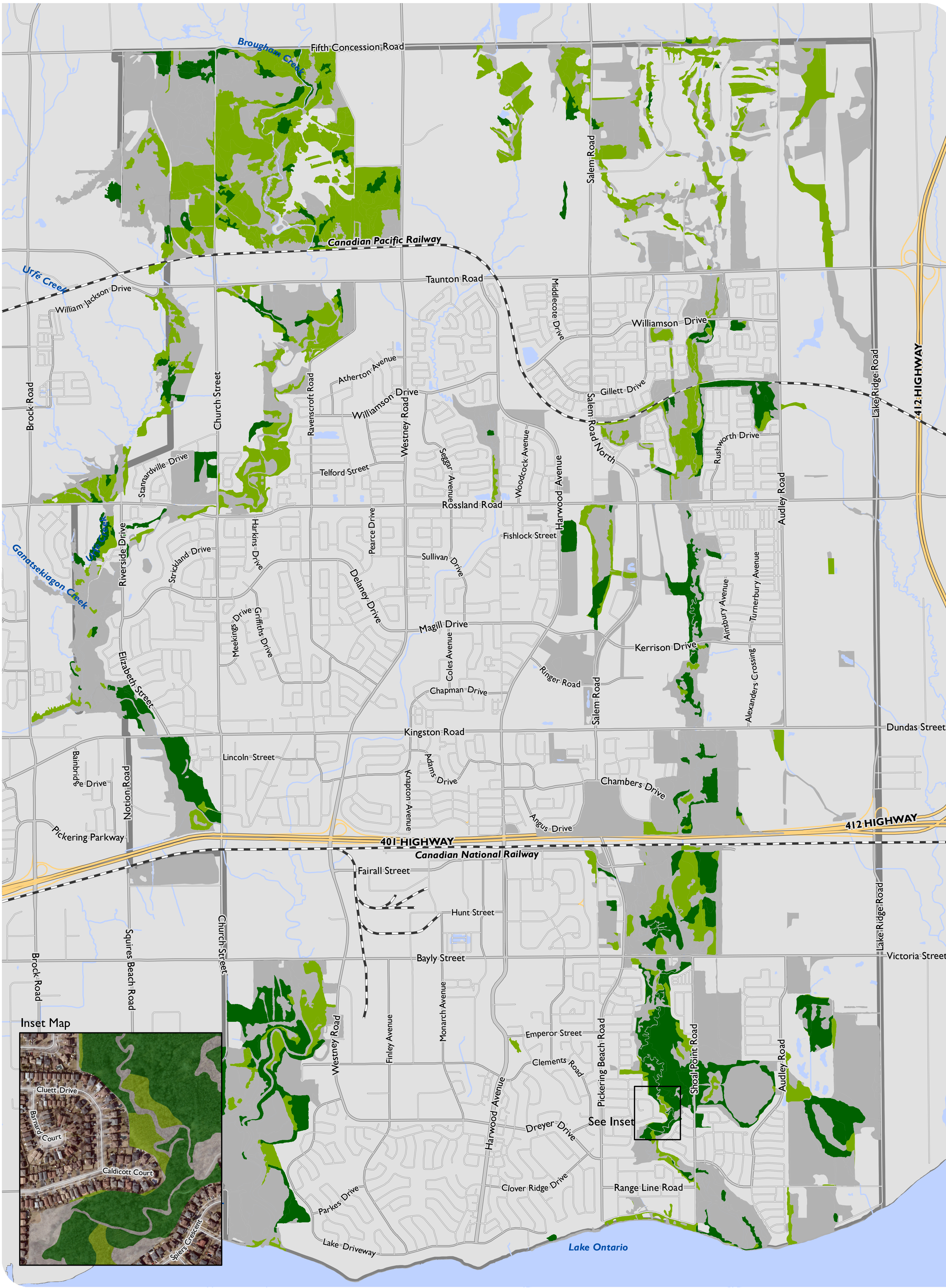
TRCA Ecological Land Classification

- BBO1-1: Sea Rocket Open Sand Beach
- BBO1-A: Open Riparian Sand / Gravel Bar
- BBO1: Mineral Open Beach
- BBS1-2A: Willow Shrub Beach
- BBS1-2B: Willow Shrub Riparian Bar
- BBT1-A: Mineral Treed Beach
- BLO1: Mineral Open Bluff
- BLT1-A: White Cedar Treed Bluff
- BLT1-B: Deciduous Treed Bluff
- CBS1: Shrub Clay Barren
- CUH1-A: Treed Hedgerow
- CUH1-B: Native Shrub - Sapling Hedgerow
- CUM1-A: Native Forb Meadow
- CUM1-b: Exotic Cool-season Grass Graminoid Meadow
- CUM1-c: Exotic Forb Meadow
- CUP1-1: Sugar Maple Deciduous Plantation
- CUP1-5: Silver Maple Deciduous Plantation
- CUP1-A: Restoration Deciduous Plantation
- CUP1-b: Willow Deciduous Plantation
- CUP1-c: Black Locust Deciduous Plantation
- CUP1-d: Horticultural Deciduous Plantation
- CUP1-g: Apple Deciduous Plantation
- CUP2-A: Restoration Mixed Plantation
- CUP2-b: Black Locust - Conifer Mixed Plantation
- CUP2-h: Horticultural Mixed Plantation
- CUP3-1: Red Pine Coniferous Plantation
- CUP3-2: White Pine Coniferous Plantation
- CUP3-3: Scots Pine Coniferous Plantation
- CUP3-9: Norway Spruce - European Larch Coniferous Plantation
- CUP3-A: Restoration Coniferous Plantation
- CUP3-C: White Spruce Coniferous Plantation
- CUP3-G: White Cedar Coniferous Plantation
- CUP3-H: Mixed Conifer Coniferous Plantation
- CUP3-e: Norway Spruce Coniferous Plantation
- CUS1-1: Hawthorn Successional Savannah
- CUS1-2A: White Cedar Successional Savannah
- CUS1-A1: Native Deciduous Successional Savannah
- CUS1-A2: White Pine Successional Savannah
- CUS1-b: Exotic Successional Savannah
- CUT1-1: Sumac Deciduous Thicket
- CUT1-5: Raspberry Deciduous Thicket
- CUT1-A1: Native Deciduous Sapling Regeneration Thicket
- CUT1-A2: Native Mixed Sapling Regeneration Thicket
- CUT1-E: Red Osier Dogwood Deciduous Thicket
- CUT1-b: Buckthorn Deciduous Thicket
- CUT1-c: Exotic Deciduous Thicket
- CUW1-2: Red Oak Non-tallgrass Woodland
- CUW1-A1: White Cedar Successional Woodland
- CUW1-A2: White Pine Successional Woodland
- CUW1-A3: Native Deciduous Successional Woodland
- CUW1-A4: Fresh-Moist Cottonwood Tall Treed Woodland
- CUW1-D: Hawthorn Successional Woodland
- CUW1-b: Exotic Successional Woodland
- FES2-A: Willow Shrub Mineral Fen
- FET2-A: White Cedar Low Treed Mineral Fen
- FOC1-2: Dry-Fresh White Pine (- Red Pine) Coniferous Forest
- FOC2-2: Dry-Fresh White Cedar Coniferous Forest
- FOC3-1: Fresh-Moist Hemlock Coniferous Forest
- FOC3-A: Fresh-Moist Hemlock - White Pine Coniferous Forest
- FOC4-1: Fresh-Moist White Cedar Coniferous Forest
- FOC4-2: Fresh-Moist White Cedar - Hemlock Coniferous Forest
- FOC4-A: Fresh-Moist White Cedar - White Pine Coniferous Forest
- FOD1-1: Dry-Fresh Red Oak Deciduous Forest
- FOD2-4: Dry-Fresh Oak - Hardwood Deciduous Forest
- FOD3-1: Dry-Fresh Poplar Deciduous Forest
- FOD3-2: Dry-Fresh Paper Birch Deciduous Forest
- FOD4-1: Dry-Fresh Beech Deciduous Forest
- FOD4-H: Dry-Fresh Hawthorn - Apple Deciduous Forest
- FOD5-10: Dry-Fresh Sugar Maple - Paper Birch - Poplar Deciduous Forest
- FOD5-1: Dry-Fresh Sugar Maple Deciduous Forest
- FOD5-2: Dry-Fresh Sugar Maple - Beech Deciduous Forest
- FOD5-3: Dry-Fresh Sugar Maple - Oak Deciduous Forest
- FOD5-6: Dry-Fresh Sugar Maple - Basswood Deciduous Forest
- FOD5-7: Dry-Fresh Sugar Maple - Black Cherry Deciduous Forest
- FOD5-8: Dry-Fresh Sugar Maple - White Ash Deciduous Forest
- FOD6-1: Fresh-Moist Sugar Maple - Ash Deciduous Forest
- FOD6-2: Fresh-Moist Sugar Maple - Black Maple Deciduous Forest
- FOD6-3: Fresh-Moist Sugar Maple - Yellow Birch Deciduous Forest
- FOD6-5: Fresh-Moist Sugar Maple - Hardwood Deciduous Forest
- FOD7-1: Fresh-Moist White Elm Lowland Deciduous Forest
- FOD7-2: Fresh-Moist Ash Deciduous Forest
- FOD7-3: Fresh-Moist Willow Lowland Deciduous Forest
- FOD7-E: Fresh-Moist Hawthorn - Apple Deciduous Forest
- FOD7-a: Fresh-Moist Manitoba Maple Lowland Deciduous Forest
- FOD7-b: Fresh-Moist Norway Maple Deciduous Forest
- FOD7-c: Fresh-Moist Exotic Deciduous Forest
- FOD8-1: Fresh-Moist Poplar Deciduous Forest
- FOD8-B: Fresh-Moist Paper Birch Deciduous Forest
- FOD9-1: Fresh-Moist Oak - Sugar Maple Deciduous Forest
- FOD9-3: Fresh-Moist Bur Oak Deciduous Forest
- FOM2-1: Dry-Fresh White Pine - Oak Mixed Forest
- FOM2-2: Dry-Fresh White Pine - Sugar Maple Mixed Forest
- FOM2-A: Dry-Fresh White Pine - Hardwood Mixed Forest
- FOM3-1: Dry-Fresh Hardwood - Hemlock Mixed Forest
- FOM3-2: Dry-Fresh Hemlock - Sugar Maple Mixed Forest
- FOM4-A: Dry-Fresh White Cedar - Hardwood Mixed Forest
- FOM5-2: Dry-Fresh Poplar Mixed Forest
- FOM6-1: Fresh-Moist Sugar Maple - Hemlock Mixed Forest
- FOM6-2: Fresh-Moist Hemlock - Hardwood Mixed Forest
- FOM7-1: Fresh-Moist White Cedar - Sugar Maple Mixed Forest
- FOM7-2: Fresh-Moist White Cedar - Hardwood Mixed Forest
- FOM8-1: Fresh-Moist Poplar Mixed Forest
- FOM8-2: Fresh-Moist Paper Birch Mixed Forest
- FOMA-A: Fresh-Moist White Pine - Sugar Maple Mixed Forest
- MAM2-10: Forb Mineral Meadow Marsh
- MAM2-1: Bluejoint Mineral Meadow Marsh
- MAM2-2: Reed Canary Grass Mineral Meadow Marsh
- MAM2-5: Narrow-leaved Sedge Mineral Meadow Marsh
- MAM2-6: Broad-leaved Sedge Mineral Meadow Marsh
- MAM2-7: Horsetail Mineral Meadow Marsh
- MAM2-9: Jewelweed Mineral Meadow Marsh
- MAM2-C: Rush Mineral Meadow Marsh
- MAM2-E: Bulrush Mineral Meadow Marsh
- MAM2-a: Common Reed Mineral Meadow Marsh
- MAM2-b: Purple Loosestrife Mineral Meadow Marsh
- MAM3-5: Narrow-leaved Sedge Organic Meadow Marsh
- MAM3-9: Forb Organic Meadow Marsh
- MAM5-1: Mineral Fen Meadow Marsh
- MAS2-1A: Broad-leaved Cattail Mineral Shallow Marsh
- MAS2-1b: Narrow-leaved Cattail Mineral Shallow Marsh
- MAS2-2: Bulrush Mineral Shallow Marsh
- MAS2-4: Broad-leaved Sedge Mineral Shallow Marsh
- MAS2-7: Bur-reed Mineral Shallow Marsh
- MAS2-8: Rice Cut-grass Mineral Shallow Marsh
- MAS2-9: Forb Mineral Shallow Marsh
- MAS2-C: Horsetail Mineral Shallow Marsh
- MAS2-a: Common Reed Mineral Shallow Marsh
- MAS2-b: Purple Loosestrife Mineral Shallow Marsh
- MAS2-d: Reed Canary Grass Mineral Shallow Marsh
- MAS3-1A: Broad-leaved Cattail Organic Shallow Marsh
- OAO1-T: Turbid Open Aquatic (unvegetated)
- OAO1: Open Aquatic (unvegetated)
- SAF1-1: Water Lily - Bullhead Lily Floating-leaved Shallow Aquatic
- SAF1-3: Duckweed Floating-leaved Shallow Aquatic
- SAM1-2: Duckweed Mixed Shallow Aquatic
- SAM1-4: Pondweed Mixed Shallow Aquatic
- SAM1-6: Bladderwort Mixed Shallow Aquatic
- SAM1-A: Water Lily - Bullhead Lily Mixed Shallow Aquatic
- SAS1-1: Pondweed Submerged Shallow Aquatic
- SAS1-2: Waterweed Submerged Shallow Aquatic
- SAS1-3: Stonewort Submerged Shallow Aquatic
- SAS1-4: Water Milfoil Submerged Shallow Aquatic
- SAS1-A: Coon-tail Submerged Shallow Aquatic
- SBO1-A: Dropseed Open Sand Barren
- SBO1-B: Flat-stemmed Bluegrass - Forb Open Sand Barren
- SBO2: Anthropogenic Sand / Gravel Barren
- SBT1: Treed Sand Barren
- SDS1-A: Willow Shrub Sand Dune
- SDT1-2: Balsam Poplar Treed Sand Dune
- SWC1-1: White Cedar Mineral Coniferous Swamp
- SWC1-2: White Cedar - Conifer Mineral Coniferous Swamp
- SWD2-1: Black Ash Mineral Deciduous Swamp
- SWD2-2: Red (Green) Ash Mineral Deciduous Swamp
- SWD3-3: Swamp Maple Mineral Deciduous Swamp
- SWD3-4: Manitoba Maple Mineral Deciduous Swamp
- SWD4-1: Willow Mineral Deciduous Swamp
- SWD4-2: White Elm Mineral Deciduous Swamp
- SWD4-3: Paper Birch - Poplar Mineral Deciduous Swamp
- SWD4-4: Yellow Birch Mineral Deciduous Swamp
- SWD5-1: Black Ash Organic Deciduous Swamp
- SWD6-1: Red Maple Organic Deciduous Swamp
- SWD7-2: Yellow Birch Organic Deciduous Swamp
- SWM1-1: White Cedar - Hardwood Mineral Mixed Swamp
- SWM3-1: Birch - Conifer Mineral Mixed Swamp
- SWM3-2: Poplar - Conifer Mineral Mixed Swamp
- SWM4-1: White Cedar - Hardwood Organic Mixed Swamp
- SWM6-1: Birch - Conifer Organic Mixed Swamp
- SWT2-10: Nannyberry Mineral Thicket Swamp
- SWT2-1: Alder Mineral Thicket Swamp
- SWT2-2: Willow Mineral Thicket Swamp
- SWT2-5: Red Osier Dogwood Mineral Thicket Swamp
- TPO2-A: Fresh-Moist Tallgrass Prairie Planting

CLOCA Ecological Land Classification

- BBO: Open Beach / Bar
- BBT: Treed Beach / Bar
- CUH: Cultural Hedgerow
- CUM: Cultural Meadow
- CUP: Plantation
- CUS: Cultural Savannah
- CUT: Cultural Thicket
- CUW: Cultural Woodland
- FOC: Coniferous Forest
- FOD: Deciduous Forest
- FOM: Mixed Forest
- MAM: Meadow Marsh
- MAS: Shallow Marsh
- OAO: Open Aquatic
- SAF: Floating Leave Shallow Aquatic
- SAS: Submerged Shallow Aquatic
- SWC: Coniferous Swamp
- SWD: Deciduous Swamp
- SWM: Mixed Swamp
- SWT: Thicket Swamp



TOWN OF AJAX
COMMUNITY CLIMATE STUDY

FIGURE 13

CLIMATE VULNERABILITY SCORES FOR NATURAL AREAS

Climate Vulnerability Score 2049

- 0 - 0.2 Low
- > 0.2 - 0.4 Low-Moderate
- > 0.4 - 0.6 Moderate
- > 0.6 - 0.8 Moderate-High
- > 0.8 - 1 High
- Natural Area with no Climate Vulnerability Score

- Railway
- Town of Ajax Municipal Boundary

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0 250 500 1,000 m

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MAP DRAWING INFORMATION:
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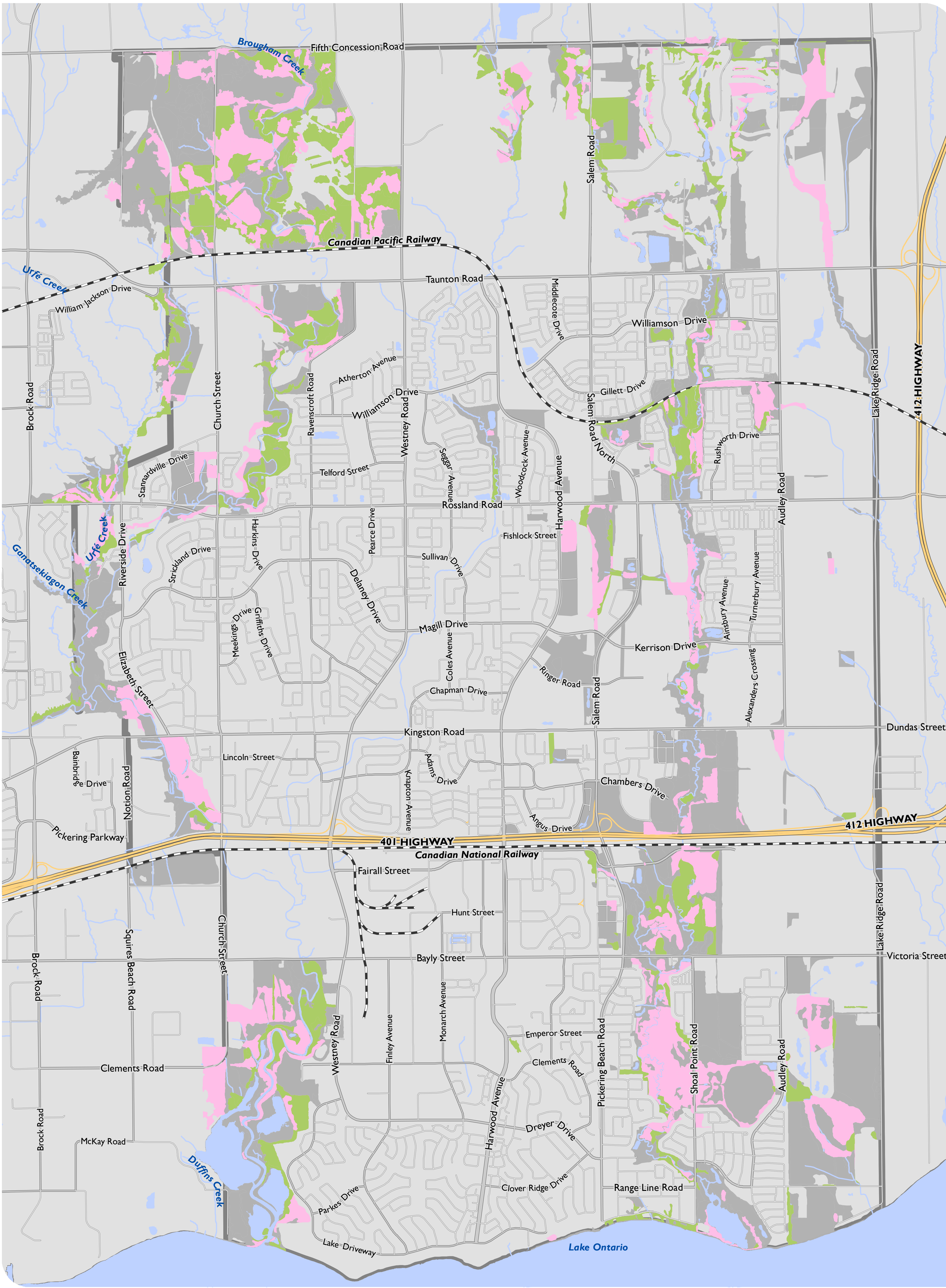
MAP CREATED BY: GM
MAP CHECKED BY:
MAP PROJECTION: NAD 1983 UTM Zone 17N

PROJECT: 187286 STATUS: DRAFT DATE: 2018-10-12

FILE LOCATION: I:\GIS\187286 - Town of Ajax Community Climate Study\mxd\Natural Capita\Figure 13 Climate Vulnerability Scores for Natural Areas.mxd



Natural Area Vulnerable to Predicted Mean Annual and Maximum Temperature Climatic Conditions

Natural Area Not Vulnerable to Predicted Mean Annual and Maximum Temp Climatic Conditions

Natural Area with no Climate Vulnerability Score

Town of Ajax Municipal Boundary

TOWN OF AJAX

COMMUNITY CLIMATE STUDY

FIGURE 14

NATURAL AREAS VULNERABLE TO PREDICTED AVERAGE ANNUAL AND MAXIMUM TEMPERATURE CLIMATIC CONDITIONS

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FILE LOCATION: I:\GIS\187286 - Town of Ajax Community Climate Study\mxd\Natural Capita\Figure 14 Natural Areas Vulnerable to Predicted Average Annual and Maximum Temperature Climatic Conditions.mxd

4.0 Identification of Areas Susceptible to Heat Island Effect

As identified in Section 3.6, surface temperature alone does not indicate the presence of an urban heat island. Nevertheless, the *Heat Island Map* (Figure 15) shows that the majority of municipal trees are located in areas surrounded by paved surfaces that could be susceptible to the impacts of the heat island. This may result in localized temperature increases beyond the predicted annual and maximum temperatures. As a result of the potential urban heat island effect, tree species in these areas could be susceptible to decline due to prolonged higher temperatures or increased frequency of extreme high temperatures at or above the levels that have been identified in the regional climate model.

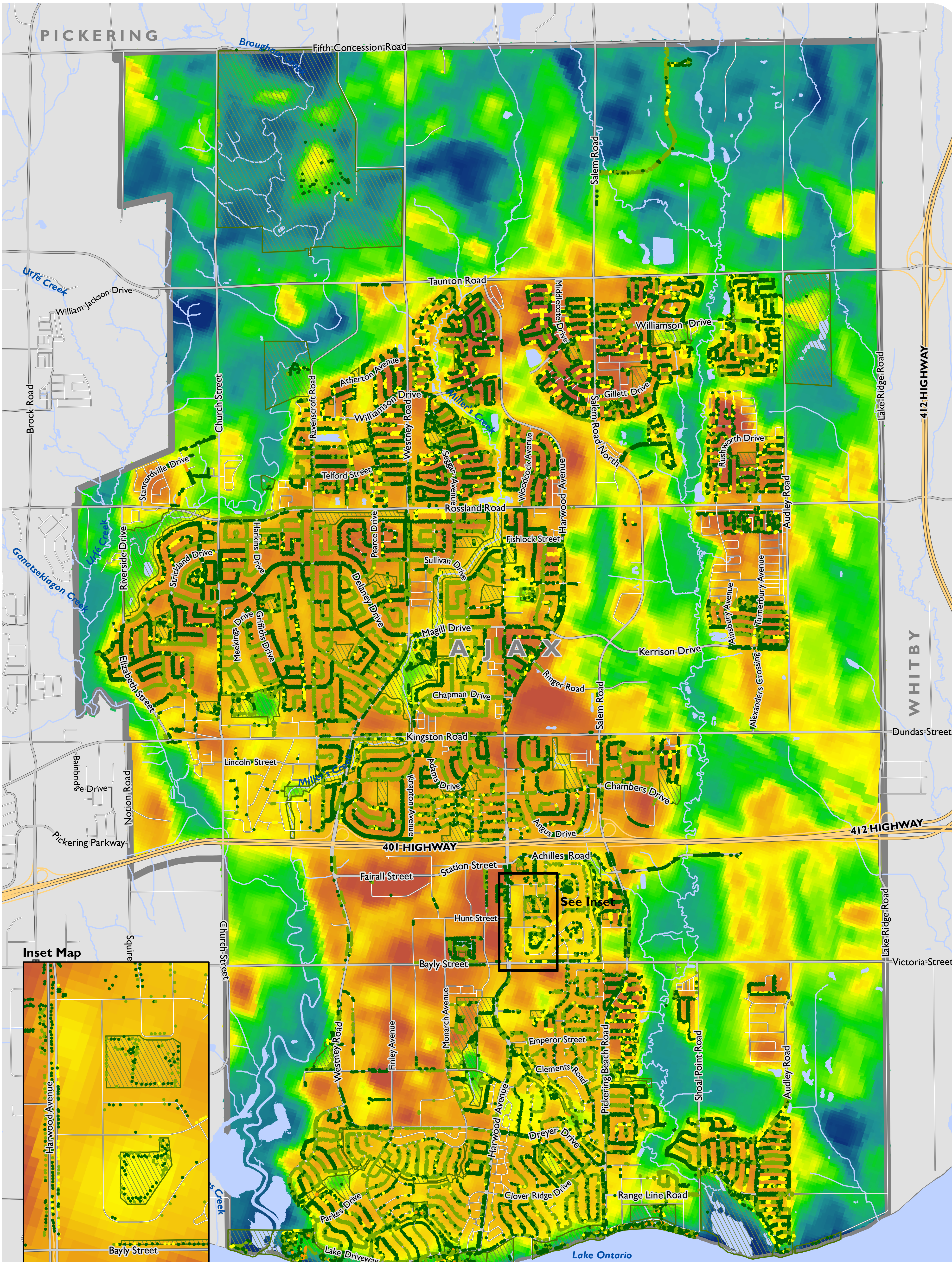
4.1 Heat Island Effects on Trees

The thermal death threshold for trees is approximately 46°C (Coder 1999). The climate model expects there to be six days with greater than 30°C temperatures, with temperatures in the summer months approaching 40°C. Typically, urban areas with greater than one million people can have temperatures of 1-3 ℃ higher than the surrounding rural areas (Akbari 2005). The heat island could result in an increase in temperature close to the thermal death threshold. This threshold is not solely determined by the air temperature and is dependent on the trees age, health, water availability and other factors. Also, trees can thermoregulate through evapotranspiration if there is sufficient moisture in the soil; however, when evapotranspiration is limited by hot temperatures and the tree is surrounded by non-evaporative surfaces (hard surfaces), leaf temperatures may rise above the thermal death threshold (Coder 1999).

We have identified municipal parks on Figure 14 as more intensive management of public trees in these landscapes such as irrigation could be required in areas where the heat island effect is pronounced. The heat island effect is not anticipated to be a concern in natural areas where built infrastructure is minimal which is supported by the low land surface temperatures observed in 2016 in these areas (Figure 14).

4.2 Air Pollutants and Air Temperature

Nitrogen dioxide (NO_2) is a greenhouse gas, primarily emitted from vehicle exhaust. Ground level ozone (O_3) may be created by chemical reactions between oxides of nitrogen NO_x such as NO_2 and volatile organic compounds (VOCs). Nitrogen dioxide and ozone are associated with increased air temperatures (Bloomer et al 2009). For example, in the Great Lakes Region, ozone concentrations increase by a factor of 2.1 parts per billion by volume per degree Celsius (ppbv/°C; Bloomer et al 2009).



TOWN OF AJAX

COMMUNITY CLIMATE STUDY

FIGURE 15

LAND SURFACE TEMPERATURE DATA (HEAT ISLAND)

Municipal Tree Climate Vulnerability Score 2049

- 0 - 0.2 Low
- >0.2 - 0.4 Low-Moderate
- >0.4 - 0.6 Moderate
- >0.6 - 0.8 Moderate-High
- >0.8 - 1 High
- Municipal Park
- Town of Ajax Municipal Boundary

Land Surface Temperature 2016 (NASA Develops) °C

High : 33.0391

Low : 14.8522

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MAP DRAWING INFORMATION:
DATA PROVIDED BY AJAX

MAP CREATED BY: GM
MAP CHECKED BY:
MAP PROJECTION: NAD 1983 UTM Zone 17N

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PROJECT: 187286 STATUS: DRAFT DATE: 2018-10-12

FILE LOCATION: \\dillon.ca\DILLON_DFS\Toronto\Toronto GIS\187286 - Town of Ajax Community Climate Study\mxd\Natural Capita\Figure 15 Land Surface Temperature Data (Heat Island).mxd

4.2.1 Effects of Air Pollutants on Vascular Plants

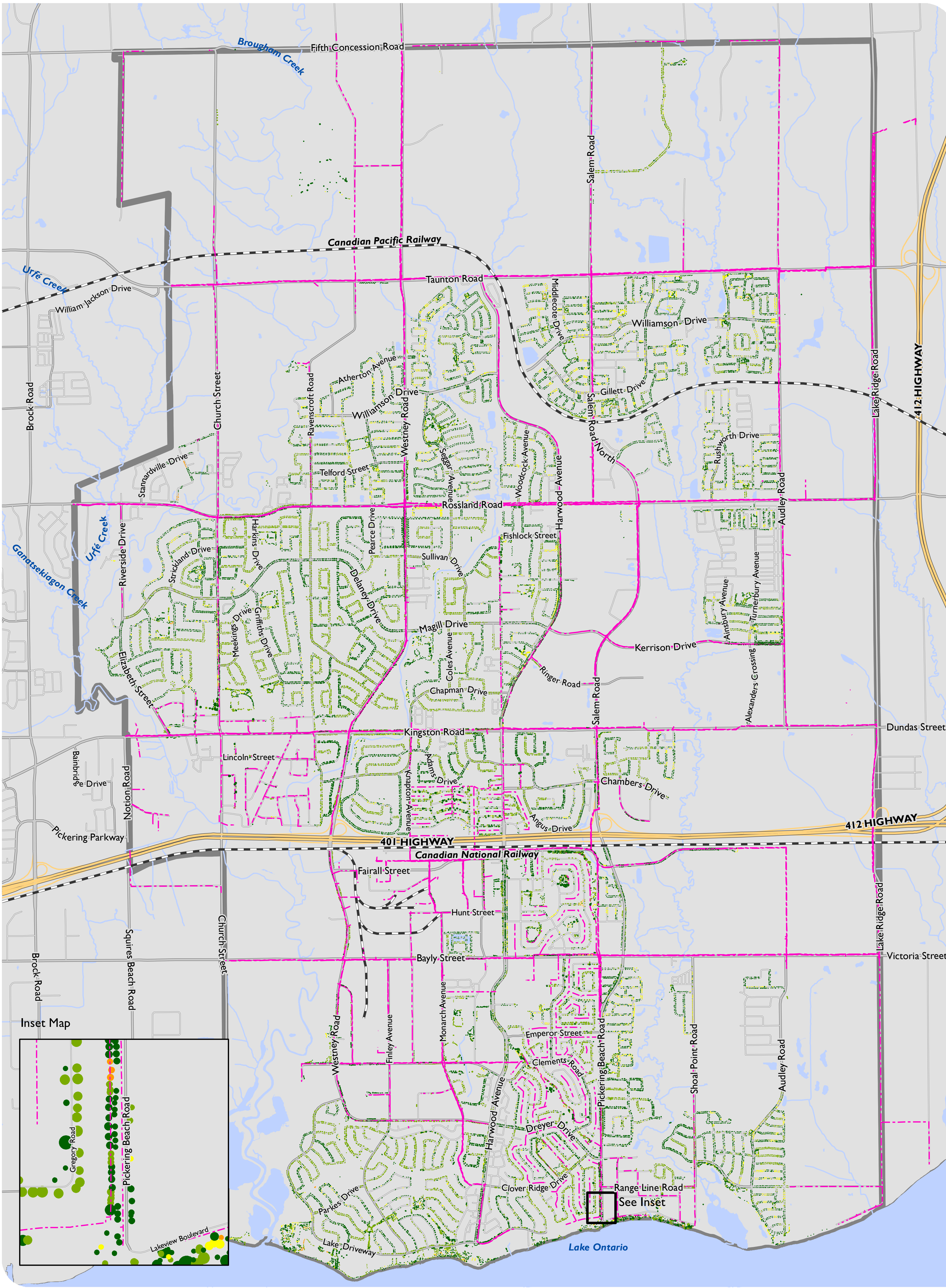
The negative effects of ozone on human health and vascular plants are well documented (Bloomer et al 2009). There is evidence that increased ozone can reduce plant and tree growth through sequestering chlorophyll concentrations and photosynthesis (Reich 1987). Increases in ozone may also cause competition for nutrients among vegetation communities (Andersen et al 2001) and visible foliar symptoms in trees and vascular plants (Ashmore 2005), such as leaf damage or insect predation (Bignal et al 2007). When paired with poor nutrient availability, the effects of ozone on vascular plants appear to be worsened (Whitfield et al 1998). Conversely, other nutrient-deprived plant species under ozone stress show resistance to the leaf loss via anti-oxidative defenses (Maurer et al 1997).

Roadside pollution emitted from automobiles can result in a localized increase in NO_2 concentrations and high levels of ground level ozone. Localized impacts of roadside NO_2 emissions and ozone are reduced to background levels anywhere from 50 to 100 m from roadways, depending on the level of traffic present (Bignal et al 2008; Bignal et al 2007). Within the area of influence, field studies noted that the health and diversity of vegetation communities was found to be significantly impacted; however, it is unclear if this effect is solely due to roadside pollution versus additional environmental and anthropogenic factors (Bignal et al 2008; Bignal et al 2007; Truscott).

5.0 Tree Conflicts with Overhead Electrical Transmission and Distribution Line Infrastructure

Municipal trees are located adjacent to the overhead electrical lines. The model that generated climate vulnerability scores based on tree species bioclimatic envelops can be geospatially represented in GIS mapping using the vulnerability score and estimated tree CPA (Figure 16). This could be used as an operational tool to identify and prioritize monitoring and maintenance of trees or treed areas that may be predisposed to elevated risk as a result of the predicted climate in 2049.

As previously discussed, the majority of the individual trees that comprise the urban forest canopy did not demonstrate a moderate-high or high climate vulnerability score. As such, municipal street trees should continue to survive under the projected climate conditions according to the 2049 regional climate model.



TOWN OF AJAX

COMMUNITY CLIMATE STUDY

FIGURE 16

CLIMATE VULNERABILITY SCORES FOR MUNICIPAL TREES ADJACENT TO ELECTRICAL TRANSMISSION LINES

Municipal Tree Estimated Canopy Area CV Score

- 0 - 0.2 Low
- > 0.2 - 0.4 Low-Moderate
- > 0.4 - 0.6 Moderate
- > 0.6 - 0.8 Moderate-High
- > 0.8 - 1 High

Overhead Electrical Transmission Line

Town of Ajax Municipal Boundary

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MAP CREATED BY: GM
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PROJECT: 187286 STATUS: DRAFT DATE: 2018-10-12

FILE LOCATION: I:\GIS\187286 - Town of Ajax Community Climate Study\mxd\Natural Capita\Figure 16 Climate Vulnerability Scores for Municipal Trees Adjacent to Electrical Transmission Lines.mxd

6.0 Response of Major Diseases, Pests and Invasive Species to Climate Change

Tree pest and disease data is provided as supplemental information to the bioclimatic indicators used in the climate vulnerability assessment (see Table A2 in Appendix A). The supplemental data set identifies if trees examined in this study could be susceptible to both pests and pathogens regardless of the predicted change in climate conditions. Moreover, the supplemental data is not a predictive tool for determining the severity of the impacts as a result of tree vulnerability to a pest or pathogen causing disease and the potential exacerbation of this vulnerability by a change in climate; although, it is conceivable that trees under a condition of multiple stressors could be more vulnerable to decline and failure. For example, Emerald Ash Borer has devastated the Ash tree population in parts of Ontario and has impacted trees in good condition, while powdery mildew does not normally cause the tree to fail. However, if a tree is stressed due to changes in temperature and precipitation a formally mild disease or pest could be sufficient to cause the tree to become stressed, decline and/or fail.

6.1.1 Invasive Flora Species

The predicted climate could continue to allow for the introduction, establishment and potential proliferation of existing and new invasive plant species. This could be accomplished by creating more favourable bioclimatic conditions and/or causing a decline in natural areas that would present the opportunity for invasion and colonization of non-native invasive plants that are typically adapted to establish and proliferate in recently disturbed environments.

Where bioclimatic data was available, the climate vulnerably scores were modelled for select non-native and/or invasive tree species, including Common Buckthorn (0.33 – low-moderate), Common Lilac (0.17 - low) and Manitoba Maple (0.17 - low). As evident by their low climate vulnerability scores, these non-native and/or invasive tree species are not expected to be affected by the predicted 2049 regional climate conditions.

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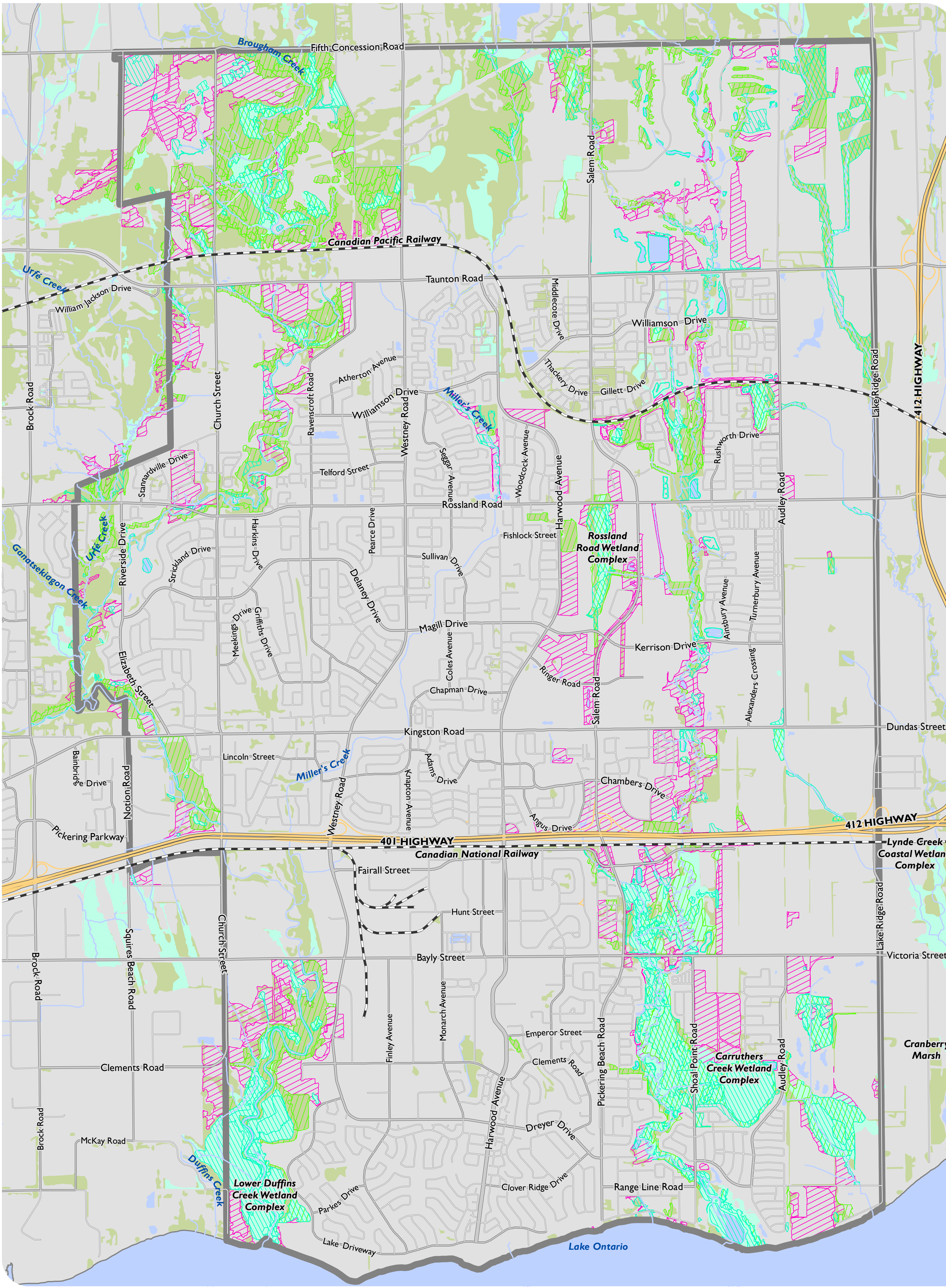
7.0 Potential Climate Change Impacts to Species at Risk and Other Wildlife Habitat

Habitat for SAR listed as either *Endangered* or *Threatened* under the Ontario *Endangered Species Act*, 2007 and species of conservation concern was assessed for the potential to be impacted by the future climate based on the climate vulnerability score of the ELC communities which represents their respective habitat type (Figure 17). As identified in Section 3.2.1, the climate vulnerability scores for natural areas within the Town's jurisdiction ranged from low-moderate to low (i.e., 0 - 0.04) indicating a low level of risk to potential SAR and other wildlife habitat associated with these areas factoring in the predicted climate in 2049. Based on the predicted climate variables used in this assessment, future climate conditions will remain favourable for the SAR and other terrestrial habitat types currently existing within the Town's treed natural areas.

A summary of the SAR screening is provided in Table A3 in Appendix A. While, no significant new bioclimatic threats to SAR habitat are expected as a result of the change in climate by 2049, a by-product of this change could be an increase in invasive species that compete with native species and disturb or alter habitat potentially used by SAR or other wildlife to fulfill a life process.

While correlations exist in field observations between changes to seasonal climate and the overall fitness of a species, direct or indirect links to the effects of climate change are not certain. Several other factors, including seasonal differences in resource availability (i.e. habitat and food) as well as stress experienced by individuals of a species (e.g. high predator concentrations, anthropogenic influences, etc.), can produce significant variability in the success of species at the population level.

Species-specific climate change effects data does not exist for many species, as it is difficult to reproduce natural conditions in laboratory settings. As such, summaries below describe current research on the effects of warmer temperatures, increased precipitation, and drought on individual wildlife species, ecological guilds (species that exploit the same resources or that exploit different resources in related ways) or groups of species occupy similar habitat types to support their life processes.



TOWN OF AJAX

COMMUNITY CLIMATE STUDY

FIGURE 17

POTENTIAL HABITAT FOR SPECIES AT RISK AND SPECIES OF CONSERVATION CONCERN

- Town of Ajax Municipal Boundary
- Potential Herptofauna Wetland Habitat
- Potential Forest Habitat
- Potential Grassland Habitat
- Wetland
- Woodland
- Waterbody - Potential Aquatic Habitat

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY AJAX

MAP CREATED BY: GM
MAP CHECKED BY:
MAP PROJECTION: NAD 1983 UTM Zone 17N

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FILE LOCATION: \\dillon.ca\DILLON_DFS\Toronto\Toronto GIS\187286 - Town of Ajax Community Climate Study\mxd\Natural Capita\Figure 17 Potential SAR Habitat.mxd

7.1 Herpetofauna Habitat

Herpetorfauna encompasses reptiles (turtles, snakes, skinks, etc.) and amphibians (frogs, toads and salamanders) which typically occupy a particular region or habitat. Below we summarize the potential general effects of changing climate on amphibians and turtles, some of which are considered SAR or species of conservation concern in the Town.

Turtles

Maximum temperature tolerances of North American turtle species has not been examined in a lab setting; however, previous studies have compared historical and present weather data to the timing of turtle life history events such as the initiation of nesting behavior (Rollinson et al 2012; Hedrick et al 2017; Iverson and Smith 1993; Riley et al 2014). While indirect effects of nutrient availability may be associated with environmental temperature, significant evidence exists to support that temperature may have an effect on breeding and nesting behavior of female turtles as well as on the hatchling success for midland painted turtles (*Chrysemys picta*) and snapping turtles (*Chelydra serpentina*) (Rollinson et al 2012; Hedrick et al 2017), which are commonly found in marsh wetland and aquatic habitat in Ajax. Warmer temperatures in spring influence earlier nesting activity by females (Iverson and Smith 1993). Warmer spring and fall temperatures (13 -14ºC) of the year prior to nesting can positively influence clutch size and clutch mass produced by gravid females (Rollinson et al 2012; Hedrick et al 2017; Riley et al 2014). Warmer nests (> 27ºC) were found to produce more female hatchlings (Riley et al 2014) and gravid females from southern geographic ranges appeared to choose warmer nest sites on average than individuals from northern areas (Riley et al 2014).

Amphibians

Key life history events of frogs are particularly sensitive to changes in environmental temperature (Gao et al 2015a; Gau et al. 2015b). The maximum critical temperature (38.4 ºC) for western chorus frogs and tadpoles (*Pseudacris triseriata*) is not expected to be reached in current climate change projections, however, lab and field studies provide evidence that warmer temperatures may negatively influence frog phenology (smaller size), as well as influence earlier emergence from hibernation, and earlier reproduction and egg laying (Gao et al 2015a; Gau et al. 2015b; Sheridan et al 2018). Warmer winters and earlier spring seasons could also positively influence survival over hibernation due to decreased loss of energy stores (Petranka 1998).

Precipitation may also have an effect on the reproductive success of North American frogs (Rodenhouse 2009; Hayhoe et al 2007; Petranka 1998). Field studies postulate that low precipitation, and low soil moisture levels may provide poor conditions for terrestrial stages of frogs (Hayhoe et al 2007), limiting the dispersal distances of post-metamorphic individuals (Petranka 1998). Prolonged periods of drought are expected to adversely affect larval and adult survival (Palis et al 2006; Faccio 2003). While speculated, researchers predict that smaller breeding ponds available for shorter periods in spring and summer may reduce recruitment of adults from the larval stage (Faccio 2003).

The critical thermal maximum (CTM) of salamanders observed in water baths under laboratory conditions ranges from 30.5 to 36.96°C (Hutchison 1961; Lutterschmidt and Hutchison 1997). There is evidence that environmental conditions can impact salamander fitness in the field (Blaustein et al 2001; Lowe 2012; Caruso et al 2014); however, there is no data to support an increase in temperature of this magnitude in aquatic environments under future climate change projections. Furthermore, decreased precipitation may limit the size of vernal pool habitat for larvae (Lowe 2012; DeMaynadier and Hunter 1995). While not formally studied in the field or lab, studies speculate that drier climates may reduce moist organic cover of forested habitats and may restrict movement of adults (Lowe 2012; DeMaynadier and Hunter 1995).

7.2 Avian Habitat

Annual patterns of North American bird species have been extensively studied in the field and lab. Warmer temperatures and changes in climate may affect species distributions, and breeding success.

Historical data sets for North American songbirds have been used in models to predict how climate change will impact species distributions (Butler 2003; Mathews et al. 2011; Rodenhouse et al. 2009). Many models predict reductions in current available habitat, particularly for grassland and boreal forest ecosystems (Dunn and Winkler 2010; Mathews et al. 2011). Results of models mirror data sets collected for grassland birds in the mid-west; warmer spring climates and periods of drought have reduced the area of suitable breeding habitat for area-sensitive species (Herkert 1994). Periods of drought are expected to increase in Southern Ontario if current emission rates continue (Natural Resources Canada 2017a).

Changes to phenology induced by increases in temperature may impact breeding success. As of now, the critical maximum temperature of songbirds has not been studied. While not examined in the field, experimentally increased incubation temperatures of zebra finch (*Taeniopygia guttata)* eggs indicated that warmer temperatures (36.2 – 38.4°C) may produce skewed sex ratios, producing clutches with a higher proportion of females; males able to survive higher incubation temperatures had lower lean and fat mass (Wada et al. 2018). Evidence also suggests that warmer temperatures may positively influence earlier breeding activity (Dunn and Winkler 2010), however; it should be noted that nutritional availability may also indirect affect these processes.

For some species, the success of breeding activities may be dependent on timing nesting to environmental cues to match resources in the environment (Dunn and Winkler 2010). Seasonal adjustments in climate may create asynchrony by adjusting the timing of peak food availability (i.e. the emergence of insects or seeds; Dunn and Winkler 2010). This strategy may not be relevant for all bird species: earlier breeding activity permitted by warmer weather may benefit multi-brood species that attempt to rear multiple clutches per growing season.

7.3 Pollinators

As with other animal groups, temperature is the primary environmental cue driving the circannual rhythms of insects, including several insect pollinator species (Batalden et al 2007; Roy et al 2001; Rodenhouse et al 2009). The potential effect on pollinator species from the Order Lepidoptera (butterflies and moths) and Family Apidae (bees) due to changing climate conditions is summarized below.

Butterflies

Strong evidence suggests that the onset of early spring and summer temperatures positively increase the rate of development of butterfly larvae. Lab tests indicated that the time to pupation of monarch butterfly larvae was significantly higher when host plants were artificially warmed (Lemoine et al 2015). Historical data also suggests that flight times of some species of adult Lepidoptera may be advancing earlier in response to early spring and summer temperatures (Batalden et al 2007; Roy et al 2001; Rodenhouse et al 2009).

Bees

The critical maximum temperature (CMT) for bumble bees, *Bombus impatiens* (52 – 55ºC; Oyen and Dillon 2018) is not expected to be reached in future climate change projections; however trends of increasing annual winter and spring temperatures may affect the survival of individual hymenoptera (bees, ants, wasps, and sawflies) and colonies of bees (Rodenhouse et al 2009). Shorter, warmer winters may reduce the risk of desiccation during winter hibernation (Rodenhouse et al 2009). However, evidence suggests that warmer winters may also permit the survival of mites and other parasites leading to earlier infestations and failures of hives (Rodenhouse et al 2009; Kraus and Velthuis 1997).

7.4 Freshwater Fish

Effects of temperature on North American fresh water fishes have been studied extensively. Lethal aquatic temperatures for adult rainbow trout (*Salmo gairdneri*) and Atlantic salmon (*Salmo salar*) were determined in laboratory manipulations to be 25.6ºC and 27.5ºC, respectively (Garside 1973; Hokanson et al 1977). Furthermore, embryo development of Chinook salmon (*Oncorhynchus tshawytscha*) was significantly impaired in eggs placed in water bath treatment groups greater than 10ºC (Heming 1982), where warmer temperatures caused embryos to absorb stored egg yolk at a faster rate, reducing available resources for continued development (Heming 1982). Gradients in water temperatures also produce differences in growth rates in the field (Bjornn 1971; Hedger et al. 2013; Kaushal et al 2010). Atlantic salmon born to warmer streams in southern geographic areas on average developed faster and grew to smaller sizes than northern counterparts (Hedger et al. 2013). While temperature is a primary factor influencing development, thresholds for turbidity in streams and individual foraging ability may also influence the distribution of freshwater fish species (Hedger et al. 2013; Gregory and Northcote 1993; Bisson and Bilby 1982).

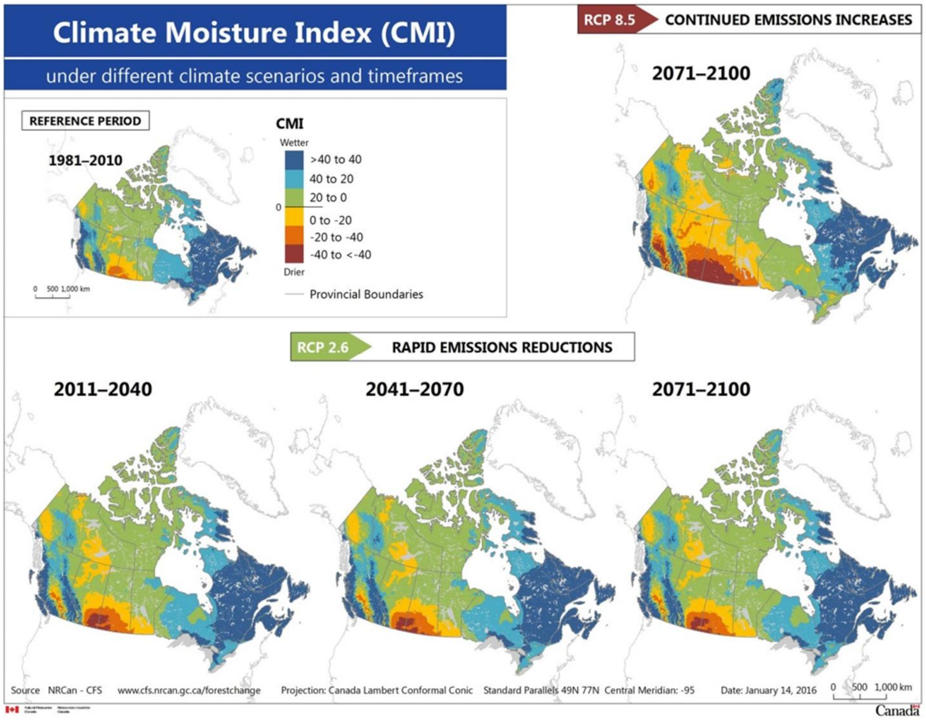
8.0 Wetland and Other Natural Area Susceptibility to Drought

Climate related disturbances, such as drought, can lead to the premature death of healthy trees (Gabriel and Kreutzwiser 1993; Natural Resources Canada 2017b). Tree mortality can occur at regional scales when climate conditions exceed species-specific biological limits, or if changes in climate trigger outbreaks of insect or pest species (Natural Resources Canada 2017b). Despite estimated climate projections, the effect of climate change on trees and forest communities is difficult to predict as ecological functions are complex, with many interacting factors (Natural Resources Canada 2017a,b).

Wetlands are distinct ecosystems characterized by periods of permanent or temporary inundation and include marsh meadows, marshes, swamp thickets, swamps, fens, bogs and open aquatic areas. In municipal landscapes, wetlands are typically influenced by both natural processes/cycles and factors relating to land development pressure such as ecological disturbance, fragmentation and changes in hydrology and hydrogeology which were not a focus of this study. Based on the predicted climate model, an increase in annual and seasonal precipitation in the warmer months is expected, a time of year when drought is of most concern. Further, wetlands are low-lying areas that are repositories for surface water runoff and are adapted for short or prolonged periods of inundation. As such, wetland communities are not expected to be affected by drought conditions should they manifest as a result of changing climate.

The Climate Moisture Index (CMI) is a scale that indicates the potential loss of water vapor from a landscape covered by vegetation, by determining the difference between annual precipitation and potential evapotranspiration (Natural Resources Canada 2017a). Positive CMI values are indicative of wet or moist conditions (Natural Resources Canada 2017a). Positive values indicate that precipitation levels are sufficient to sustain a closed-canopy forest. On the other hand, negative CMI values represent dry conditions, able to support only parkland green spaces (Natural Resources Canada 2017a). If current emission rates continue, current CMI values for the Greater Toronto Area (GTA) and surrounding areas (including Ajax) are projected to decrease by the year 2071 (Natural Resources Canada 2017a - Figure 18). While predicted decreases in CMI for the GTA still consist of positive values, a decrease in moisture content may have adverse effects to vegetation, particularly swamp and upland forest communities.

Figure 18: Climate Moisture Index for Canada



8.1 Increased Susceptibility of Grasslands to Wildfires

Fires are a natural process in ecological systems and act to regenerate plant communities and add additional nutrients to soil to promote new growth (Pyne, 2010). Many plant species have adapted over generations to respond to stresses imposed by fires as well as seasonal drought conditions. Adaptations may include the exaggerated development of biomass beneath the ground surface as protection, permitting rapid re-growth once the conditions improve (Pyne, 2010).

While periodic burnings are a natural part of grassland and forest ecology, the frequency at which wildfires occur is expected to increase in response to the potential impacts of climate change (International Panel on Climate Change 2007; U.S. Climate Change Science Program 2008). Wildfire conditions are optimal when periods of drought (1 – 2 years) are combined with high seasonal temperatures, low humidity, and high winds (International Panel on Climate Change 2007; U.S. Climate Change Science Program 2008; McKenzie et al 2004). The prevalence of wildfires across North America is expected to increase with increasing annual average temperatures and reductions in precipitation rate (International Panel on Climate Change 2007; U.S. Climate Change Science Program 2008; McKenzie et al 2004). Furthermore, rising early temperatures in spring and increased ambient temperatures in summer seasons will likely extend the wildfire season (International Panel on Climate Change 2007; U.S. Climate Change Science Program 2008; Westerling et al 2006).

Increased mean annual temperatures, increased temperatures in the warmest months and projected reductions in CMI within the Town of Ajax may lead to an increase in frequency of wildfires in local natural areas. Beyond the obvious human health and safety and property damage concerns, consequences of increased wildfire prevalence within the Town of Ajax may include a change in the distribution and abundance of the dominant plant species. While current research is not conclusive, invasive species may possess additional adaptations to outcompete native species during periods of environmental stress (Grace et al 2000). If wildfires promote the growth of invasive plants in previously burned areas, additional effort may be required by the Town of Ajax to manage these areas.

9.0 Summary

The Town of Ajax has a number of natural capita resources that provide valuable ecosystem provisional, regulating and cultural services resulting in social benefits realized by residence and visitors alike. These natural resources are an asset to the Town and include an extensive urban forest consisting of, but not limited to municipal trees and treed natural areas, other natural features such as wetlands, and their associated wildlife habitat. There are a number of risk factors, some of which are related to climate change projections, that could devalue the Town's natural capita putting these valued ecosystem services at risk.

This study assessed the potential vulnerabilities of these natural capita assets to the bioclimatic conditions predicted in the 2049 Durhan Region climate model. A summary of the potential risks imposed by conditions predicted in the regional model and resulting assessment findings are provided in Table 5 below.

Table 5: Summary Table

Assessment Topic	Potential Risk/Impacts	Assessment Findings

Threats to Urban Forests	· Decline in the condition of trees
	· Increase in the mortality and failure of trees
	· Reduction in tree species richness and abundance
		· Climate Vulnerability (CV) scores for the urban forest resource in Ajax (municipal trees and treed natural areas) derived through the assessment of bioclimatic envelopes generally range from low to low-moderate.
		· The most abundant tree species in Ajax's urban forest will not likely be impacted by conditions projected in the regional climate model.
		· Tree vulnerability could be exacerbated by their physiological characteristics and phenology, including:
		  · a cold stratification requirement,
		  · ice storm damage susceptibility,
		  · salt tolerance, and
		  · drought tolerance.

Identification of Areas Susceptible to Heat Island Effect	· Potential for an increase in drought conditions · Increases in surface temperature, a correlate of air temperature, which could result in localized heat island effect in higher density urban areas · Increases in concentrations	· Project surface temperature data provided by the Town was an estimate of projected air temperature and cannot be considered a conclusive determination of areas susceptible to heat island effect. As such, the estimated effect on municipal trees can only be inferred in a general manner. · Urban areas in Ajax were found to have surface temperatures that are warmer than adjacent

Assessment Topic	Potential Risk/Impacts	Assessment Findings
	of localized air pollution near roads and highways · Potential for tree decline and vegetation loss in urban parklands resulting in more intense management requirements	lands with vegetative cover. · Further air temperature modelling studies may be required within Ajax to determine potential areas where Heat Island Effect is projected to occur.
Tree Conflicts with Overhead Electrical Transmission and Distribution Line Infrastructure	· Hazards to public safety · Damage to public infrastructure	· Overlaying municipal tree CV scores combined with CPA, potentially vulnerable trees in proximity to overhead electrical lines can be discerned. · Municipal trees generally have low to low-moderate CV scores, and as a result, tree decline is generally not anticipated due to the projected climate conditions.
Responses of Major Diseases, Pests and Invasive Species to Climate Change	· Increase in the prevalence of pests and diseases · Decline in the condition of trees · Increase in the mortality and failure of trees · Reduction in tree species richness and abundance	· Effects of tree pests and disease and invasive species on urban trees and treed natural areas cannot be directly correlated with regional climate model information available. · Data regarding the bioclimatic envelopes and locations of most invasive species in the Town is unavailable. · Further documentation and mapping of infested or diseased areas or areas occupied by invasive species would further inform urban forest adaptive management requirements.
Potential Climate Change Impacts to Species at Risk and Other Wildlife Habitat	· Loss of suitable habitat due to long-term shifts in climate · Decreased fitness and survival due to changes in temperature and precipitation causing habitat alteration/degradation	· Potential treed habitats of SAR and other wildlife are not anticipated to be substantially impacted by variables examined in the regional climate model. · There is insufficient information currently available to determine direct or indirect effects of climate change on specific wildlife habitats. · Further lab and field-based scientific studies on relevant study species and/or habitats are required to refine this assessment.
Wetland and other Natural Susceptibility to Drought	· Increased annual temperature · Decrease in moisture content in natural areas · Adverse effects to	· Wetlands and natural areas are not expected to be susceptible to drought. · Decreases in Climate Moisture Index (CMI) are predicted for Ajax if current emission rates remain; however, modelled CMI values are

Assessment Topic	Potential Risk/Impacts	Assessment Findings
	vegetation in natural areas	predicted to remain positive, indicating persistent moist conditions up to the Year 2100

9.1 Summary of Recommendations

The recommendations resulting from the natural capita climate vulnerability assessment are summarized below. The primary limitation of the natural capita assessment was a lack of available data. As such, opportunities may exist for the Town of Ajax to complete additional studies on the potential effects of climate change at the local scale.

Potential Future Studies

- Stream temperature monitoring for Conservation Authorities (TRCA and CLOCA), which may include the installation and use of data loggers in stream systems to monitor surface water temperature and flow rates over time and correlate this data with seasonal weather trends and extreme weather events.
- Research bioclimatic factors (envelopes) affecting plant species other than trees to determine the climate vulnerability of vegetation communities outside of woodlands (swamps, forests, open woodlands and plantations).
- Determine more detailed information for the vegetation composition of treed natural areas to more reliably predict the climate vulnerability for these areas in the model.
- Complete surveys in natural areas where ELC information is lacking within the Town of Ajax to acquire a more comprehensive and updated data set for the natural heritage system. This would address ELC gaps in the existing data set within the Town.
- Conduct a heat island modelling study for the Town of Ajax.
- Track and document the growth (e.g., bole diameter, crown size, location, age, etc.) of municipal street trees within the Town of Ajax over time to model tree growth rates (radial/basal area, CPA/leaf area, etc.) stratified by different land uses within the urban environment. Growth data could be used to examine relationships between growth and influencing factors such as site conditions and stewardship/management practices.
- Conduct a study to model infiltration rates of in natural areas following rain events of different magnitudes.
- Study climate vulnerability of wildlife habitat for species identified as species at risk or species of conservation concern.

Additional recommendations presented below could be used by planning, forestry, parks and public works staff in the planning, monitoring, management and sustainability of the urban forest and other natural capita resources.

Resources/Tools

- Information provided in the Natural Capita Report could be integrated into the Town's GIS system for the ongoing maintenance and monitoring of urban trees and treed natural areas. Mapping could be provided in an interactive GIS mapping format to allow for use by Town staff.

Training

- There may be opportunity to provide training to Town staff on the use of GIS mapping technology to assist in the use of GIS data as an urban forest asset management tool.

Protocols/Plans

- Opportunities may exist to review current urban forestry planning policy, by-laws and guidance documents, operational protocols, programming and procedures, and asset management practices to assess if they are compatible with information presented in this report with respect to tree and other vegetation climate vulnerability. The overall goal would be to ensure the longevity and health of the urban forest and natural areas, and determine if there is a need for increased urban forestry and/or natural heritage system management and intervention. The review could include:
    - Examining the operational programming and scheduling of hazard risk monitoring activities for municipal trees in the urban setting and along forested recreational trails to determine if the monitoring resources are adequate to manage risk associated with tree failure for species potentially vulnerable to the following:
        i. Temperature and precipitation conditions predicted in the regional climate model
        ii. Urban heat island
        iii. Diseases and pests.
    - Review current typical tree plantings detail and specifications to allow for appropriate tree species selection, proper installation and maintenance, and favourable growing conditions for urban trees under the predicted climatic conditions.
    - In conjunction with the local Conservation Authority, review natural feature monitoring and adaptive management programs within the Town's natural heritage system to track the risk factors identified in the report (e.g., drought, forest pests and disease, invasive species, etc.).

Appendix A
Additional Report Tables

Table A-1: Climate Vulnerability Variables and their Anticipated Influence on the Most Abundant Tree Species within the Town of Ajax

Scientific Name	Common Name	Annual Temperature	Annual Precipitation	Maximum Temperature	Minimum Temperature	Precipitation in the warmest quarter	Precipitation in the coldest quarter	Cold Stratification	Drought Tolerant	Ice Storm Damage Susceptibility	Salt Tolerant	Pathogens included in the score (True/False)	Disease	Pests
Abies balsamea	Balsam Fir	1	0	1	0	0	0	1	0	0	1	TRUE	2,	---
Acer negundo	Manitoba Maple	0	0	1	0	0	0	1	0	1	---	TRUE	1,4,6,19, 24	2,6,8, 21
Acer nigrum	Black Maple	0	0	1	0	0	0	1	1	---	0	TRUE	1,4,6,19, 24	2,6,8, 21
Acer platanoides	Norway Maple	1	0	1	0	0	0	1	1	0	1	TRUE	1,4,6,19, 24	2,6,8, 21
Acer rubrum	Red Maple	0	0	1	0	0	0	0	1	1	0	TRUE	1,4,6,19, 24	2,6,8, 21
Acer saccharinum	Silver Maple	0	0	1	0	0	0	0	1	2	0	TRUE	1,4,6,19, 24	2,6,8, 21
Acer saccharum	Sugar Maple	0	0	1	0	0	0	1	0	1	0	TRUE	1,4,6,19, 24	2,6,8, 21
Acer x freemanii	Freeman Maple	1	0	1	0	0	1	---	1	---	0	TRUE	1,4,6,19, 24	2,6,8, 21
Alnus viridis	Green Alder	1	0	1	0	0	0	---	---	---	0	FALSE	---	---
Amelanchier laevis	Smooth Serviceberry	1	0	1	0	0	0	1	1	---	0	FALSE	---	---
Betula alleghaniensis	Yellow Birch	1	0	1	0	0	0	1	0	1	---	TRUE	2,	2,7,8,12, 21, 24, 25
Betula minor	White Birch	1	0	1	0	0	0	0	0	---	1	TRUE	2,	2,7,8,12, 21, 24, 25
Catalpa speciosa	Northern Catalpa	0	0	1	0	0	0	0	1	---	---	FALSE	---	---
Celtis occidentalis	Common Hackberry	0	0	1	0	0	0	1	1	1	1	FALSE	---	---
Cornus sericea ssp sericea	Red-osier Dogwood	1	0	1	0	0	0	1	1	---	---	TRUE	1,6	3
Crayaegus mollis	Downy Hawthorn	0	0	1	0	0	0	1	1	0	---	FALSE	---	---
Fagus grandifolia	American Beech	0	0	1	0	0	0	1	0	1	---	TRUE	2, 22	2,12
Fraxinus americana	White Ash	0	0	1	0	0	0	1	0	1	1	TRUE	1,6,20	7
Fraxinus nigra	Black Ash	1	0	1	0	0	0	1	0	1	---	TRUE	1,6,20	7
Fraxinus pennsylvanica	Green Ash	0	0	1	0	0	0	1	1	1	0	TRUE	1,6,20	7
Ginkgo biloba	Gingko (Matsumoto et al. 2003; Sun et al. 2003)	0	0	1	1	0	0	---	1	---	0	FALSE	---	---
Gleditsia triacanthos	Honeylocust	0	0	1	1	0	0	0	1	1	0	TRUE	---	10
Gymnocladus dioicus	Kentucky Coffee Tree	0	0	1	0	0	0	0	1	0	1	TRUE	20	
Juglans cinerea	Butternut	0	0	1	1	0	0	1	0	---	1	TRUE	3, 23, twig blight	
Juglans nigra	Black Walnut	0	0	1	0	0	0	0	1	0	1	TRUE	23	6,19

Scientific Name	Common Name	Annual Temperature	Annual Precipitation	Maximum Temperature	Minimum Temperature	Precipitation in the warmest quarter	Precipitation in the coldest quarter	Cold Stratification	Drought Tolerant	Ice Storm Damage Susceptibility	Salt Tolerant	Pathogens included in the score (True/False)	Disease	Pests
Larix decidua	European Larch	1	0	1	0	0	0	0	0	0	1	TRUE	Larch Canker (Lachnellula wilkimmii)	25
Liriodendron tulipifera	Tulip Tree	0	1	1	1	0	1	1	1	1	0	TRUE	3,4	19
Malus pumila	Iowa Crabapple	0	0	1	0	0	0	1	1	---	---	TRUE	---	Powdery Mildew (Podosphaera leucotricha), Tent catapillar, apple scab
Morus rubra	Red Mulberry	1	0	1	0	0	0	1	1	---	---	TRUE	---	6,19
Ostrya virginiana	Ironwood	0	0	1	0	0	0	1	1	0	0	FALSE	---	---
Picea abies	Norway Spruce	1	0	1	0	0	0	0	1	0	0	TRUE	6,10	1,16,17
Picea glauca	White Spruce	1	0	1	0	0	0	1	1	0	0	TRUE	6,10	1,16,17
Picea pungens	Bluespruce	1	0	1	0	0	0	0	1	0	1	TRUE	6,10	1,16,17
Pinus resinosa	Red Pine	1	0	1	0	0	0	0	0	1	0	TRUE	9,10,18, 26	1,15,20
Pinus strobus	Eastern White Pine	1	0	1	0	0	0	0	1	1	0	TRUE	9,10,18, 25, 26	1,15,20
Pinus sylvestris	Scots Pine	1	0	1	0	0	0	1	1	1	---	TRUE	6,9,18, 26	1,15
Platanus × acerifolia	London Plane Tree (Patrick et al. 2012)	0	0	1	1	0	0	---	1	---	0	TRUE	1,7,17	18
Populus balsamifera	Balsam Poplar	1	0	1	0	0	0	0	0	---	---	TRUE	6, 21, 23	8
Populus deltoides ssp. deltoides	Eastern Cottonwood	0	0	1	0	0	0	0	1	2	---	TRUE	6, 21, 23	8
Prunus serotina	Black Cherry	0	0	1	0	0	0	1	1	2	1	TRUE	5	3,4,8
Pyrus communis	Common Pear	0	0	1	0	0	0	1	0	---	---		---	---
Quercus alba	White Oak	0	0	1	0	0	0	0	1	0	1	TRUE	1,4,6,14,15,17, 21	7,8,12,14
Quercus macrocarpa	Bur Oak	0	0	1	0	0	0	1	1	0	0	TRUE	1,4,6,14,15,17, 21	7,8,12,14
Quercus rubra	Northern Red Oak	0	0	1	0	0	0	1	1	1	1	TRUE	1,4,6,14,15,17, 21	7,8,12,14
Rhamnus cathartica	Common Buckthorn	1	0	1	0	0	0	1	1	---	---	FALSE	---	---
Rhus hirta	Staghorn Sumac	1	0	1	0	0	0	0	1	---	1	FALSE	---	---
Robinia	Black Locust	0	0	1	0	0	0	0	1	2	1	TRUE	---	13

Scientific Name	Common Name	Annual Temperature	Annual Precipitation	Maximum Temperature	Minimum Temperature	Precipitation in the warmest quarter	Precipitation in the coldest quarter	Cold Stratification	Drought Tolerant	Ice Storm Damage Susceptibility	Salt Tolerant	Pathogens included in the score (True/False)	Disease	Pests
pseudoacacia														
Salix bebbiana	Bebb's Willow	1	0	1	0	0	0	0	0	2	---	FALSE	---	---
Salix discolor	Pussy Willow	1	0	1	0	0	0	0	0	---	---	FALSE	---	---
Salix nigra	Swamp Willow	0	0	1	0	0	0	---	0	2	---	FALSE	---	---
Syringa vulgaris	Japanese Lilac (Common Lilac uses as surrogate)	0	0	1	0	0	0	1	1	---	0	FALSE	---	---
Thuja occidentalis	Eastern White Cedar	1	0	1	0	0	0	0	1	---	0	TRUE	---	1,17, 22
Tilia americana	American Basswood	0	0	1	0	0	0	1	1	2	0	TRUE	---	7,8,11,12,19
Tilia cordata	Littleleaf Linden (De Jaegere et al. 2016)	0	0	0	0	0	0	1	1	0	0	TRUE	---	7,8,11,12,19
Tsuga canadensis	Eastern Hemlock	1	0	1	0	0	0	1	0	0	0	TRUE	6	9,17
Ulmus americana	American Elm	0	0	1	0	0	0	1	1	2	0	TRUE	4,11	6,8,11
Viburnum lentago	Nannyberry	1	0	1	0	0	0	1	1	---	---	FALSE	---	---

Table A-2: List of Diseases/Pathogens and Pests that could Affect Tree Species within The Town (data obtained from Boland et al. (2004) and Yang (2009))

Number	Disease	Pathogen			Number	Pest	Scientific Name
D1	Anthracnose	*Apiognomonia spp.*			P1	Bagworm	*Thyridopteryx ephemeraeformis*
D2	Armillaria root rot	*Armillaria ostoyae*			P2	Birch lace bug	*Corythucha pallipes*
D3	Bacterial leaf scorch	*Xylella fastidiosa*			P3	Dogwood borers	*Synanthedon scitula*
D4	Bacterial wetwood	*Clostridium spp.*			P4	Eastern tent caterpillars	*Malacosoma americanum*
		Bacillus spp.			P5	European pine sawfly	*Nodiprion sertifer*
		Enterobacter spp.			P6	Fall webworm	*Hyphantria cunea*
		Klebsiella spp.			P7	Forest tent caterpillar	*Malacosoma disstria*
		Pseudomomas spp.			P8	Gypsy moth	*Lymantria dispar*
D5	Black knot	*Apiosporina morbosa*			P9	Hemlock woolly adelgid	*Adelge tsugae*
D6	Bleeding canker	*Phytophthora spp.*			P10	Honey locust plant bug	*Diaphnocoris chlorionis*
D7	Canker stain	*Geratocystis fimbriata f. Platan*			P11	Japanese beetle	*Popillia japonica*
D8	Cedar apple rust	*Gymnosporangium juniper-virinianae*			P12	Linden Looper	*Erranis tiliaria*
D9	Cyclaneusma needlecast	*Cyclaneusma minus*			P13	Locust borers	*Megacyllene robiniae*
D10	Cytospora canker	*Cytosphora kunzei var. piceae*			P14	Oak skeletonizer	*Bucculatrix ainsliella*
D11	Dutch elm disease	*Ophiostoma novo-ulmi*			P15	Pine bark adelgid	*Pineus strobe*
D12	Fire blight	*Erwinia amylovora*			P16	Pine needle scale	*Chionaspis pinifoliae*
D13	Kabatina twig blight	*Katabina juniper*			P17	Spruce spider mites	*Oligonychus ununguis*
D14	Oak leaf blister	*Taphrina caerulescens*			P18	Sycamore lace bug	*Corythuca ciliata*
D15	Oak wilt	*Ceratocystis fagacearum*			P19	Tuliptree scale	*Toumeyella liriodendra*
D16	Phomopsis twig blight	*Phomopsis juniperovora*			P20	White pine sheath mite	*Setoptus strobacus*
D17	Powdery mildew	*Uncinula spp.*			P21	Asian long-horned beetle	*Anoplophora glabripennis*
		Microsphaea spp.			P22	Cedar leafminer complex	*Various species*
D18	Sphaeropsis tip blight	*Sphaeropsis sapinea*			P23	Aspen twoleaf tier	*Enargia decolour*
D19	Tar spot	*Rhytisma spp.*			P24	Birch casebearer	*Coleophora serratella*
D20	Verticillium wilt	*Verticillium dahlia*			P25	Birch skeletonizer	*Bucculatrix canadensisella*
D21	Sudden Oak Death	*Phytophthora ramorum*					
D22	Beech bark disease	*Nectina coccinea var. faginata*					
D23	Thousand cankers disease	*Geosmithia morbida*					
D24	Sapstreak disease	*Ceratocystis coerulescens*					
D25	White pine blister rust	*Cronartium ribicola*					
D26	Brown spot needle blight	*Mycosphaerella dearnessii*					

Table A-3: Potential Impacts to Species at Risk Habitat with the Potential to Occur within the Town of Ajax

Family	Group	Scientific Name	Common Name	SARA Status[1]	ESA Status[2]	SRank[3]	Information Source[4]	Habitat Requirements[2,5]	Potential Habitat in the Study Area	Potential impact to habitat under 2049 climate
Apodidae	Swifts	*Chaetura pelagica*	Chimney Swift	THR	THR	S4B,S4N	OBBA	Commonly found in urban areas near buildings and man-made structures with vertical faces which are used as surfaces for nest-building. Nests and roosts are most commonly in chimneys, and typically in larger chimneys with open tops. Also nests and roosts in other parts of man-made structures, in hollow trees, or crevices of rock cliffs. Nesting and roosting sites are typically near areas of water where abundant insects provide food sources.	No ELC associated with habitat. Anthropogenic structures most common, CVR types	No probable impact to the species.
Ardeidae	Bitterns, Herons, and Allies	*Ixobrychus exilis*	Least Bittern	THR	THR	S4B	NHIC, OBBA, MNRF SAR in Area	Deep marshes, swamps, bogs; marshy borders of lakes, ponds, streams, ditches; dense emergent vegetation of cattail, bulrush, sedge; nests in cattails; intolerant of loss of habitat and human disturbance.	MAM, MAM2-10, MAM2-2, MAM2-5, MAM2-6, MAM2-a, MAM2-C, MAM2-E, MAM3-5, MAM3-9, MAS, MAS2-1A, MAS2-1b, MAS2-2, MAS2-4, MAS2-9, MAS2-a, MAS2-d, MAS3-1A, SWC, SWC1-1, SWC1-2, SWD, SWD2-1, SWD2-2, SWD3-4, SWD3-3, SWD4-1, SWD4-2, SWD4-3, SWD4-4, SWD5-1, SWD6-1, SWD7-2, SWM, SWM1-1, SWM3-1, SWM3-2, SWM4-1, SWM6-1, SWT, SWT2-1, SWT2-10, SWT2-2, SWT2-5	No probable impact. Annual precipitation and summer precipitation is projected to increase under the predicted future climate. Therefore, wetland habitat is expected to maintain its existing boundaries or possibly increase in size.
Hirundinidae	Swallows	*Hirundo rustica*	Barn Swallow	THR	THR	S4B	OBBA, MNRF SAR in Area	Farmlands or rural areas; cliffs, caves, rock niches; buildings or other man-made structures for nesting; open country near body of water.	No ELC associated with habitat. Anthropogenic structures most common, CVR types	No probable impact to the species.
Hirundinidae	Swallows	*Riparia riparia*	Bank Swallow	THR	THR	S4B	OBBA	Sand, clay or gravel river banks or steep riverbank cliffs; lakeshore bluffs of easily crumbled sand or gravel; gravel pits, road-cuts, grassland or cultivated fields that are close to water; nesting sites are limiting factor for species presence..	BLO1, BLT1-A, BLT1-B, SDS1-A,SDT1-2	No probable impact to the species.
Icteridae	Blackbirds	*Dolichonyx oryzivorus*	Bobolink	THR	THR	S4B	OBBA, MNRF SAR in Area	Can be found in a variety of grassland habitat such as tallgrass prairie, hayfields, meadows or fallow fields; generally requires tracts of grassland >50 ha though can be found in habitat areas as small as 4 ha.	TPO2-A, CUM, CUM1-A, CUM1-b, CUM1-c	No probable impact to the species. Future climate is not expected to impact grassland habitat due to the predicted increase in rain.

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Family	Group	Scientific Name	Common Name	SARA Status[1]	ESA Status[2]	SRank[3]	Information Source[4]	Habitat Requirements[2,5]	Potential Habitat in the Study Area	Potential impact to habitat under 2049 climate
Icteridae	Blackbirds	*Sturnella magna*	Eastern Meadowlark	THR	THR	S4B	NHIC, OBBA, MNRF SAR in Area	Open, grassy meadows, farmland, pastures, hayfields or grasslands with elevated singing perches; cultivated land and weedy areas with trees; old orchards with adjacent, open grassy areas >10 ha in size.	TPO2-A, CUM, CUM1-A, CUM1-b, CUM1-c, CUS, CUS1-1, CUS1-2A, CUS1-A1, CUS1-A2, CUS1-b	No probable impact to the species. Future climate is not expected to impact grassland habitat due to the predicted increase in rain.
Rallidae	Rails, Gallinules, and Coots	*Rallus elegans*	King Rail	END	END	S2B	NHIC, MNRF SAR in Area	Large, shallow, fresh water marshes, shrubby swamps, marshy borders of lakes and ponds with abundant vegetation; an 'edge' species; territories are 0.3 to 0.5 ha; loss of large marshes in the south is limiting to this species.	MAM, MAM2-10, MAM2-2, MAM2-5, MAM2-6, MAM2-a, MAM2-C, MAM2-E, MAM3-5, MAM3-9, MAS, MAS2-1A, MAS2-1b, MAS2-2, MAS2-4, MAS2-9, MAS2-a, MAS2-d, MAS3-1A, SWC, SWC1-1, SWC1-2, SWD, SWD2-1, SWD2-2, SWD3-4, SWD3-3, SWD4-1, SWD4-2, SWD4-3, SWD4-4, SWD5-1, SWD6-1, SWD7-2, SWM, SWM1-1, SWM3-1, SWM3-2, SWM4-1, SWM6-1, SWT, SWT2-1, SWT2-10, SWT2-2, SWT2-5	No probable impact. Annual precipitation and summer precipitation is projected to increase under the predicted future climate. Therefore, wetland habitat is expected to maintain its existing boundaries or possibly increase in size.
Cyprinidae	Fish and Eels	*Clinostomus elongatus*	Redside Dace	END	END	S2	NHIC, MNRF SAR in Area, MNRF Reg. Habitat	Pools and slow-moving areas of small streams and headwaters with pool and riffle habitats and a moderate to high gradient, typically in segments with overhanging grasses and shrubs, undercut banks, or instream cover (boulders and large woody debris) in open meadows, pasture or shrub over-story, rather than closed forest canopy. Substrates are typically gravel but may vary from silt to boulders. Waters are typically clear but may have moderate turbidity. Preference is for cool waters, generally avoiding cold or warm waters. Summer water temperatures are typically near or below 20°C but may be higher (e.g. 23 °C). Stream widths typically range from 1 to 10 m, though individuals may occur in larger main stems of rivers. Suitable pool depths are typically 11 to 100 cm. Spawns in shallow gravel riffles. Assumed to overwinter in deep pool areas with little current. In Canada, the species is found in a few tributaries of Lake Huron, in streams flowing into western Lake Ontario, the Holland River (a tributary of Lake Simcoe), and Irvine Creek (a tributary of the Grand River and Lake Erie).	CUM, CUM1-A, CUM1-b, CUM1-c, CUP, CUP1-1, CUP1-5, CUP1-A, CUP1-b, CUP1-c, CUP1-d, CUP1-g, CUP2-A, CUP2-b, CUP2-h, CUP3-1, , CUP3-2, CUP3-3, CUP3-9, CUP3-A, CUP3-C, CUP3-e, CUP3-G, CUP3-H, CUS, CUS1-1, CUS1-2A, CUS1-A1, CUS1-A2, CUS1-b, CUT, CUT1-5, CUT1-A1, CUT1-A2, CUT1-b, CUT1-c, CUT1-1, CUT1-E, CUW, CUW1-2, CUW1-A1, CUW1-A2, CUW1-A3, CUW1-A4, CUW1-b, CUW1-D, FES2-A, FET2-A, FOC, FOC1-2, FOC2-2, FOC3-1FOC3-A, FOC4-1, FOC4-2, FOC4-A, FOD, FOD1-1, FOD2-4, FOD3-1, FOD3-2, FOD4-1, FOD4-H, FOD5-1, FOD5-10, FOD5-2, FOD5-3, FOD5-6, FOD5-7, FOD5-8, FOD6-1, FOD6-2, FOD6-3, FOD6-5, FOD7-1, FOD7-2, FOD7-a, FOD7-3, FOD7-b, FOD7-c, FOD7-E, FOD8-1, FOD8-B, FOD9-1, FOD9-3, FOM, FOM2-1, FOM2-2, FOM2-A, FOM3-1, FOM3-2, FOM4-A, FOM5-2, FOM6-1, FOM7-1, FOM7-2, FOM8-1, FOM8-2, FOMA-A, TPO2-A	No probable impact. Annual precipitation and summer precipitation is projected to increase under the predicted future climate. Therefore, grassland and wetland habitat is expected to maintain its existing boundaries or possibly increase in size. Some individual trees within the woodland communities may be more stressed under the future climate and some trees may die. However, widespread canopy dieback of riparian vegetation is not anticipated, therefore ecosystem functioning should be maintained.

Family	Group	Scientific Name	Common Name	SARA Status[1]	ESA Status[2]	SRank[3]	Information Source[4]	Habitat Requirements[2,5]	Potential Habitat in the Study Area	Potential impact to habitat under 2049 climate
Emydidae	Turtle	*Emydoidea blandingii*	Blanding's Turtle	THR	THR	S3	MNRF SAR in Area, OHA	Shallow water marshes, bogs, ponds or swamps, or coves in larger lakes with soft muddy bottoms and aquatic vegetation; basks on logs, stumps, or banks; surrounding natural habitat is important in summer as they frequently move from aquatic habitat to terrestrial habitats; hibernates in bogs; not readily observed.	MAS, MAS2-1A, MAS2-1b, MAS2-2, MAS2-4, MAS2-9, MAS2-a, MAS2-d, MAS3-1A, SWC, SWC1-1, SWC1-2, SWD, SWD2-1, SWD2-2, SWD3-4, SWD3-3, SWD4-1, SWD4-2, SWD4-3, SWD4-4, SWD5-1, SWD6-1, SWD7-2, SWM, SWM1-1, SWM3-1, SWM3-2, SWM4-1, SWM6-1, SWT, SWT2-1, SWT2-10, SWT2-2, SWT2-5	No probable impact. Some individual trees within the woodland communities may be more stressed under the future climate and some trees may die. Entire stands of coniferous trees are most susceptible. However, widespread canopy dieback of riparian vegetation is not anticipated, therefore ecosystem functioning should be maintained.
Vespertilionidae	Plain-nosed Bats	*Myotis leibii*	Eastern Small-footed Myotis	---	END	S2S3	MWH	Roosts in caves, mine shafts, crevices or buildings that are in or near woodland; hibernates in cold dry caves or mines; maternity colonies in caves or buildings; hunts in forests.	CUP, CUP1-1, CUP1-5, CUP1-A, CUP1-b, CUP1-c, CUP1-d, CUP1-g, CUP2-A, CUP2-b, CUP2-h, CUP3-1, , CUP3-2, CUP3-3, CUP3-9, CUP3-A, CUP3-C, CUP3-e, CUP3-G, CUP3-H, CUS, CUS1-1, CUS1-2A, CUS1-A1, CUS1-A2, CUS1-b, CUW, CUW1-2, CUW1-A1, CUW1-A2, CUW1-A3, CUW1-A4, CUW1-b, CUW1-D, FOC, FOC1-2, FOC2-2, FOC3-1FOC3-A, FOC4-1, FOC4-2, FOC4-A, FOD, FOD1-1, FOD2-4, FOD3-1, FOD3-2, FOD4-1, FOD4-H, FOD5-1, FOD5-10, FOD5-2, FOD5-3, FOD5-6, FOD5-7, FOD5-8, FOD6-1, FOD6-2, FOD6-3, FOD6-5, FOD7-1, FOD7-2, FOD7-a, FOD7-3, FOD7-b, FOD7-c, FOD7-E, FOD8-1, FOD8-B, FOD9-1, FOD9-3, FOM, FOM2-1, FOM2-2, FOM2-A, FOM3-1, FOM3-2, FOM4-A, FOM5-2, FOM6-1, FOM7-1, FOM7-2, FOM8-1, FOM8-2, FOMA-A,	No probable impact. Some individual trees within the woodland communities may be more stressed under the future climate and some trees may die. Entire stands of coniferous trees are most susceptible. However, widespread canopy dieback of riparian vegetation is not anticipated, therefore ecosystem functioning should be maintained.
Vespertilionidae	Plain-nosed Bats	*Myotis lucifugus*	Little Brown Myotis	END	END	S4	MWH	Uses caves, quarries, tunnels, hollow trees or buildings for roosting; winters in humid caves; maternity sites in dark warm areas such as attics and barns; feeds primarily in wetlands, forest edges.	CUP, CUP1-1, CUP1-5, CUP1-A, CUP1-b, CUP1-c, CUP1-d, CUP1-g, CUP2-A, CUP2-b, CUP2-h, CUP3-1, , CUP3-2, CUP3-3, CUP3-9, CUP3-A, CUP3-C, CUP3-e, CUP3-G, CUP3-H, CUS, CUS1-1, CUS1-2A, CUS1-A1, CUS1-A2, CUS1-b, CUW, CUW1-2, CUW1-A1, CUW1-A2, CUW1-A3, CUW1-A4, CUW1-b, CUW1-D, FOC, FOC1-2, FOC2-2, FOC3-1FOC3-A, FOC4-1, FOC4-2, FOC4-A, FOD, FOD1-1, FOD2-4, FOD3-1, FOD3-2, FOD4-1, FOD4-H, FOD5-1, FOD5-10, FOD5-2, FOD5-3, FOD5-6, FOD5-7, FOD5-8, FOD6-1, FOD6-2, FOD6-3, FOD6-5, FOD7-1, FOD7-2, FOD7-a, FOD7-3, FOD7-b, FOD7-c, FOD7-E, FOD8-1, FOD8-B, FOD9-1, FOD9-3, FOM, FOM2-1, FOM2-2, FOM2-A, FOM3-1, FOM3-2, FOM4-A, FOM5-2, FOM6-1, FOM7-1, FOM7-2, FOM8-1, FOM8-2, FOMA-A,	No probable impact. Some individual trees within the woodland communities may be more stressed under the future climate and some trees may die. Entire stands of coniferous trees are most susceptible. However, widespread canopy dieback of riparian vegetation is not anticipated, therefore ecosystem functioning should be maintained.

Family	Group	Scientific Name	Common Name	SARA Status[1]	ESA Status[2]	SRank[3]	Information Source[4]	Habitat Requirements[2,5]	Potential Habitat in the Study Area	Potential impact to habitat under 2049 climate
Vespertilionidae	Plain-nosed Bats	*Myotis septentrionalis*	Northern Myotis	END	END	S3	MWH	Hibernates during winter in mines or caves; during summer males roost alone and females form maternity colonies of up to 60 adults; roosts in houses, manmade structures but prefers hollow trees or under loose bark; hunts within forests, below canopy.	CUP, CUP1-1, CUP1-5, CUP1-A, CUP1-b, CUP1-c, CUP1-d, CUP1-g, CUP2-A, CUP2-b, CUP2-h, CUP3-1, , CUP3-2, CUP3-3, CUP3-9, CUP3-A, CUP3-C, CUP3-e, CUP3-G, CUP3-H, CUS, CUS1-1, CUS1-2A, CUS1-A1, CUS1-A2, CUS1-b, CUW, CUW1-2, CUW1-A1, CUW1-A2, CUW1-A3, CUW1-A4, CUW1-b, CUW1-D, FOC, FOC1-2, FOC2-2, FOC3-1FOC3-A, FOC4-1, FOC4-2, FOC4-A, FOD, FOD1-1, FOD2-4, FOD3-1, FOD3-2, FOD4-1, FOD4-H, FOD5-1, FOD5-10, FOD5-2, FOD5-3, FOD5-6, FOD5-7, FOD5-8, FOD6-1, FOD6-2, FOD6-3, FOD6-5, FOD7-1, FOD7-2, FOD7-a, FOD7-3, FOD7-b, FOD7-c, FOD7-E, FOD8-1, FOD8-B, FOD9-1, FOD9-3, FOM, FOM2-1, FOM2-2, FOM2-A, FOM3-1, FOM3-2, FOM4-A, FOM5-2, FOM6-1, FOM7-1, FOM7-2, FOM8-1, FOM8-2, FOMA-A,	No probable impact. Some individual trees within the woodland communities may be more stressed under the future climate and some trees may die. Entire stands of coniferous trees are most susceptible. However, widespread canopy dieback of riparian vegetation is not anticipated, therefore ecosystem functioning should be maintained.
Vespertilionidae	Plain-nosed Bats	*Pipistrellus subflavus*	Tri-colored Bat	END	END	S3?	MWH	Can be found in a variety of forested habitats. They form day roosts and maternity colonies in older forest and occasionally in barns or other structures, and overwinter in caves. They forage over water and along streams in the forest.	CUP, CUP1-1, CUP1-5, CUP1-A, CUP1-b, CUP1-c, CUP1-d, CUP1-g, CUP2-A, CUP2-b, CUP2-h, CUP3-1, , CUP3-2, CUP3-3, CUP3-9, CUP3-A, CUP3-C, CUP3-e, CUP3-G, CUP3-H, CUS, CUS1-1, CUS1-2A, CUS1-A1, CUS1-A2, CUS1-b, CUW, CUW1-2, CUW1-A1, CUW1-A2, CUW1-A3, CUW1-A4, CUW1-b, CUW1-D, FOC, FOC1-2, FOC2-2, FOC3-1FOC3-A, FOC4-1, FOC4-2, FOC4-A, FOD, FOD1-1, FOD2-4, FOD3-1, FOD3-2, FOD4-1, FOD4-H, FOD5-1, FOD5-10, FOD5-2, FOD5-3, FOD5-6, FOD5-7, FOD5-8, FOD6-1, FOD6-2, FOD6-3, FOD6-5, FOD7-1, FOD7-2, FOD7-a, FOD7-3, FOD7-b, FOD7-c, FOD7-E, FOD8-1, FOD8-B, FOD9-1, FOD9-3, FOM, FOM2-1, FOM2-2, FOM2-A, FOM3-1, FOM3-2, FOM4-A, FOM5-2, FOM6-1, FOM7-1, FOM7-2, FOM8-1, FOM8-2, FOMA-A,	No probable impact. Some individual trees within the woodland communities may be more stressed under the future climate and some trees may die. Entire stands of coniferous trees are most susceptible. However, widespread canopy dieback of riparian vegetation is not anticipated, therefore ecosystem functioning should be maintained.
Juglandaceae	Hickories	*Juglans cinerea*	Butternut	END	END	S3?	NHIC	Usually grows alone or in small groups in deciduous forests. It prefers moist, well-drained soil and is often found along streams. It is also found on well-drained gravel sites and rarely on dry rocky soil. This species does not do well in the shade, and often grows in sunny openings and near forest edges.	CUP, CUP1-1, CUP1-5, CUP1-A, CUP1-b, CUP1-c, CUP1-d, CUP1-g, CUP2-A, CUP2-b, CUP2-h, CUP3-1, , CUP3-2, CUP3-3, CUP3-9, CUP3-A, CUP3-C, CUP3-e, CUP3-G, CUP3-H, CUS, CUS1-1, CUS1-2A, CUS1-A1, CUS1-A2, CUS1-b, CUW, CUW1-2, CUW1-A1, CUW1-A2, CUW1-A3, CUW1-A4, CUW1-b, CUW1-D, FOC, FOC1-2, FOC2-2, FOC3-1FOC3-A, FOC4-1, FOC4-2, FOC4-A, FOD, FOD1-1, FOD2-4, FOD3-1, FOD3-2, FOD4-1, FOD4-H, FOD5-1, FOD5-10, FOD5-2, FOD5-3, FOD5-6, FOD5-7, FOD5-8, FOD6-1, FOD6-2, FOD6-3, FOD6-5, FOD7-1, FOD7-2, FOD7-a, FOD7-3, FOD7-b, FOD7-c, FOD7-E, FOD8-1, FOD8-B, FOD9-1, FOD9-3, FOM, FOM2-1, FOM2-2, FOM2-A, FOM3-1, FOM3-2, FOM4-A, FOM5-2, FOM6-1, FOM7-1, FOM7-2, FOM8-1, FOM8-2, FOMA-A,CUH, CUH1-A	Butternut had a climate vulnerability score of 0.38.Indicating it is at low-medium level of risk that is a result of increases in maximum temperature, low minimum temperatures and the presence of pathogens (e.g., Butternut Canker). Individuals that are exposed and experience temperature fluctuations may fail. Butternut is a relatively rare species and its loss will not impact the ecosystem functioning of the community as a whole.

Family	Group	Scientific Name	Common Name	SARA Status[1]	ESA Status[2]	SRank[3]	Information Source[4]	Habitat Requirements[2,5]	Potential Habitat in the Study Area	Potential impact to habitat under 2049 climate
Moraceae	Mullberries	*Morus rubra*	Red Mulberry	END	END	S2	NHIC	In Ontario, Red Mulberry occurs in both sandy soils of forested sites near Lake Erie in Hackberry-Red Cedar-Sugar Maple woodlands and calcareous soils in Sugar Maple-Basswood-White Ash-Red Oak-Hackberry-Ironwood woodlands of the Niagara Escarpment and Erie Islands. Red Mulberry tends to occur in moist forest habitats, such as slopes and benches in the Niagara Escarpment where moisture levels remain high, in floodplain and river valleys, and on swales of the sandspits of Point Pelee, Fish Point on Pelee Island and Pointe aux Pins at Rondeau Provincial Park.	FOC, FOC1-2, FOC2-2, FOC3-1FOC3-A, FOC4-1, FOC4-2, FOC4-A, FOD, FOD1-1, FOD2-4, FOD3-1, FOD3-2, FOD4-1, FOD4-H, FOD5-1, FOD5-10, FOD5-2, FOD5-3, FOD5-6, FOD5-7, FOD5-8, FOD6-1, FOD6-2, FOD6-3, FOD6-5, FOD7-1, FOD7-2, FOD7-a, FOD7-3, FOD7-b, FOD7-c, FOD7-E, FOD8-1, FOD8-B, FOD9-1, FOD9-3, FOM, FOM2-1, FOM2-2, FOM2-A, FOM3-1, FOM3-2, FOM4-A, FOM5-2, FOM6-1, FOM7-1, FOM7-2, FOM8-1, FOM8-2, FOMA-A	Red Mulberry had a climate vulnerability score of 0.38.Indicating it is at low-medium level of risk that is a result of increases in annual air temperature, maximum temperature, and the presence of pathogens (e.g., Fall webworm). Individuals that are exposed and experience high temperatures may fail. Red Mulberry is a relatively rare species and its loss will not impact the ecosystem functioning of the community as a whole.

1 – Status identified by the Committee on the Status of Endangered Wildlife in Canada under the federal SARA, 2002; 2 – SAR in Ontario List under the provincial ESA, 2007; 3 – Ontario SRank; S5 = secure; S4= apparently secure; S3 = vulnerable; S2 = imperilled; SX = Extirpated; SH = Possibly Extirpated; SNA = non-native or exotic species to Ontario; 4 – NHIC = MNRF Natural Heritage Information Centre, MNRF SAR in Area = MNRF Species at Risk in Ontario List by area of the province; MNRF Reg. Habitat = MNRF Regulated Habitat (O. Reg. 242/08); MNRF Consult. = MNR Consultation, OBBA = Ontario Breeding Bird Atlas, MWH = Digital Distribution Maps of the Mammals of the Western Hemisphere, version 3.0, OHA = Ontario Herpetofaunal Atlas, OOA = Ontario Odonata Atlas; OBA = Ontario Butterfly Atlas; CBC = Christmas Bird Count; 5 – MNRF Significant Wildlife Technical Guide - Appendix G (2000).

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