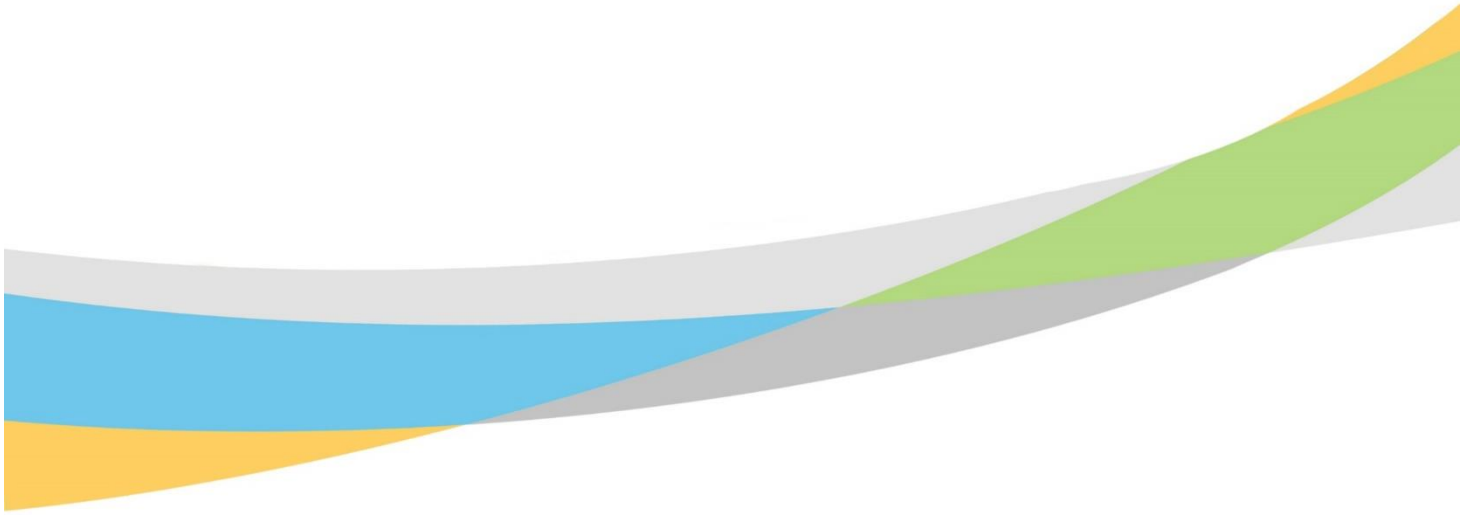

Toronto and Region Conservation Authority

Carruthers Creek Watershed Plan
Urban Forest Assessment

Prepared for the Region of Durham

May 2019

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FOREWORD

The Region of Durham recognizes watershed plans as an effective tool to inform the management of Durham's water resources, natural heritage, and natural hazards, such as flooding. In 2015, the Region retained the Toronto and Region Conservation Authority (TRCA) to update the watershed plan for Carruthers Creek.

This four-year study will build upon the goals, objectives, and management recommendations established in the 2003 *Watershed Plan for Duffins Creek and Carruthers Creek.*

The following report is one of a series of scenario analysis technical reports that follow the watershed characterization studies (completed in 2017). Information contained in these technical reports will examine potential impacts of future growth and land use changes in combination with other influences such as climate change. Additionally, these technical reports provide the knowledge base necessary to develop the plan's management recommendations. Any recommendations contained in the scenario analysis technical reports are consolidated in the Carruthers Creek Watershed Plan's management framework. The Watershed Plan is the final source for goals, objectives, indicators and management recommendations related to Carruthers Creek. Readers are encouraged to refer to the technical reports for more detailed implementation suggestionss.

There are several references within this document to the Carruthers Creek Watershed Plan (CCWP) - Terrestrial Impact Assessment (TIA) Report (*in progress*), which examined natural cover in the watershed and assessed impacts on terrestrial ecosystem-based objectives and targets. While the TIA Report and Urban Forest Assessment analyses used some overlapping data, especially in the natural cover portions of the watershed, they are unique in their goals, objectives, and scope, and as such, remain separate technical documents. The term tree and shrub canopy cover used throughout the following report refers to areas denoted as forest cover in the TIA in addition to all tree and shrub cover in all other land categories (e.g. street trees, trees in residential yards). Data used to create this report are limited and unique compared to the other technical reports and this report is part characterization and part extrapolation to future land use scenarios.

SUMMARY

- The urban forest encompasses trees and shrubs in both natural and built portions of the urban portion of the Carruthers Creek watershed. This assessment was undertaken because of the strong interconnection that exists between urban forests and watershed management objectives.
- Tree and shrub canopy were assessed using orthophoto imagery from 2008 and 2017 to estimate change in tree and shrub canopy cover in the urban portion of the watershed over a 10-year period to infer the overall trends, to identify priority areas for urban forest enhancement, and to highlight key recommendations for future watershed management decisions.
- Overall tree and shrub canopy cover has remained at about the same proportion across the urban portion of the watershed from 2008 (17.0 +/- 1.4) to 2017 (18.8 +/- 1.4). This is a positive finding that demonstrates the effort the Town of Ajax has put into its urban forest, given the amount of development that has also occurred in the watershed over this same period.

- Priority neighbourhoods were identified for urban forest enhancements (tree planting and maintenance) based on low existing tree cover and a high amount of space available for new trees. Memorial Village/Downtown, Midtown and Southwood/Lake Vista in Ajax were identified as priority neighbourhoods for enhancement. Some of these neighbourhoods were also identified as Durham Health Neighbourhood priorities and scored higher on Ajax's social vulnerability index than other neighbourhoods in the watershed.
- A priority neighbourhood identified for urban tree preservation based on the findings of the Terrestrial Impact Assessment Report is the Carruthers Creek Business Area and the low plantable space for new tree establishment.
- Based on the species composition of the urban forest in Carruthers Creek Watershed, several threats and pressures have been identified including changing growing conditions due to the impacts of climate change, introduced pests, land use changes and changes in land ownership and tenure.
- With the urban development that has occurred over the 2008 -2017 period, there was an observed increase in impervious surfaces, which reduces the space available for new trees in many neighbourhoods. In areas that have already seen development, opportunities for retrofits and enhancements that could fit trees into these challenging urban sites are discussed.
- Opportunities for urban forest enhancements were identified and include: strengthening collaboration among stakeholders dealing with urban forest pests, undertaking a regional comprehensive urban forest study, tree planting and management on regional lands, and continued and expanded support for residential tree planting programs.

INTRODUCTION

Trees play an important role in protecting water resources. The connection between forests and watershed health was incorporated in the terrestrial component of the 2003 Carruthers Creek Watershed plan entitled *Watershed Plan for Duffins Creek and Carruthers Creek.* At that time, the watershed plan focused exclusively on forests and woodlands and did not account for trees outside natural settings, in the built portions of the watershed. The term urban forest refers to all trees, shrubs and soils within and adjacent to human settlements, including trees and shrubs growing in natural and manicured settings in urban, suburban and peri-urban areas. All the trees and shrubs within the watershed impact and are impacted by the human population and are considered part of the urban forest. Understanding of the significance of urban forests has evolved over the past decades, and the importance of trees both inside and outside natural settings to urban watersheds has evolved since the *Watershed Plan for Duffins Creek and Carruthers Creek* was published (e.g. Bell et al., 2016). Governments and land managers are increasingly acknowledging the benefits of green infrastructure, defined as the natural vegetative systems, including urban forests, that collectively provide society with a multitude of economic, environmental and social benefits (Green Infrastructure Ontario Coalition, n.d.). In some cases, individual trees outside natural settings may have a larger per capita impact on stormwater runoff, particularly those that overhang impervious surfaces, such as sidewalks (Kuehler et al., 2017). This increased understanding of urban forests overall, and the extent to which urban

expansion that has occurred within the watershed, has led to the decision to incorporate urban forest considerations in the current initiative to update the watershed plan for Carruthers Creek, entitled the Carruthers Creek Watershed Plan (CCWP).

Toronto and Region Conservation Authority worked with local municipalities in the Toronto region to undertake some of the first urban forest assessments done in Ontario, starting in 2008 (see Figure 1 for map of study locations) (TRCA, 2009 & TRCA, 2012). TRCA continues to play a role in urban forest studies and policy guidance, typically supporting regional and local area municipalities on research and policy, as urban forest assessments and management are typically undertaken at the local area municipal level. In 2009, TRCA and the Town of Ajax completed an urban forest study with the urban portion of the Town (TRCA, 2009). More recently, the Town of Ajax (Ajax) has undertaken a land cover assessment as part of their climate change vulnerability work that includes mapping of forest cover throughout the town, including trees outside natural settings (Town of Ajax, 2019, unpublished). TRCA also completed an urban forest study with the City of Pickering (Pickering) in 2012, though only the urban portions of Pickering were included in that assessment, which are not located in the watershed.

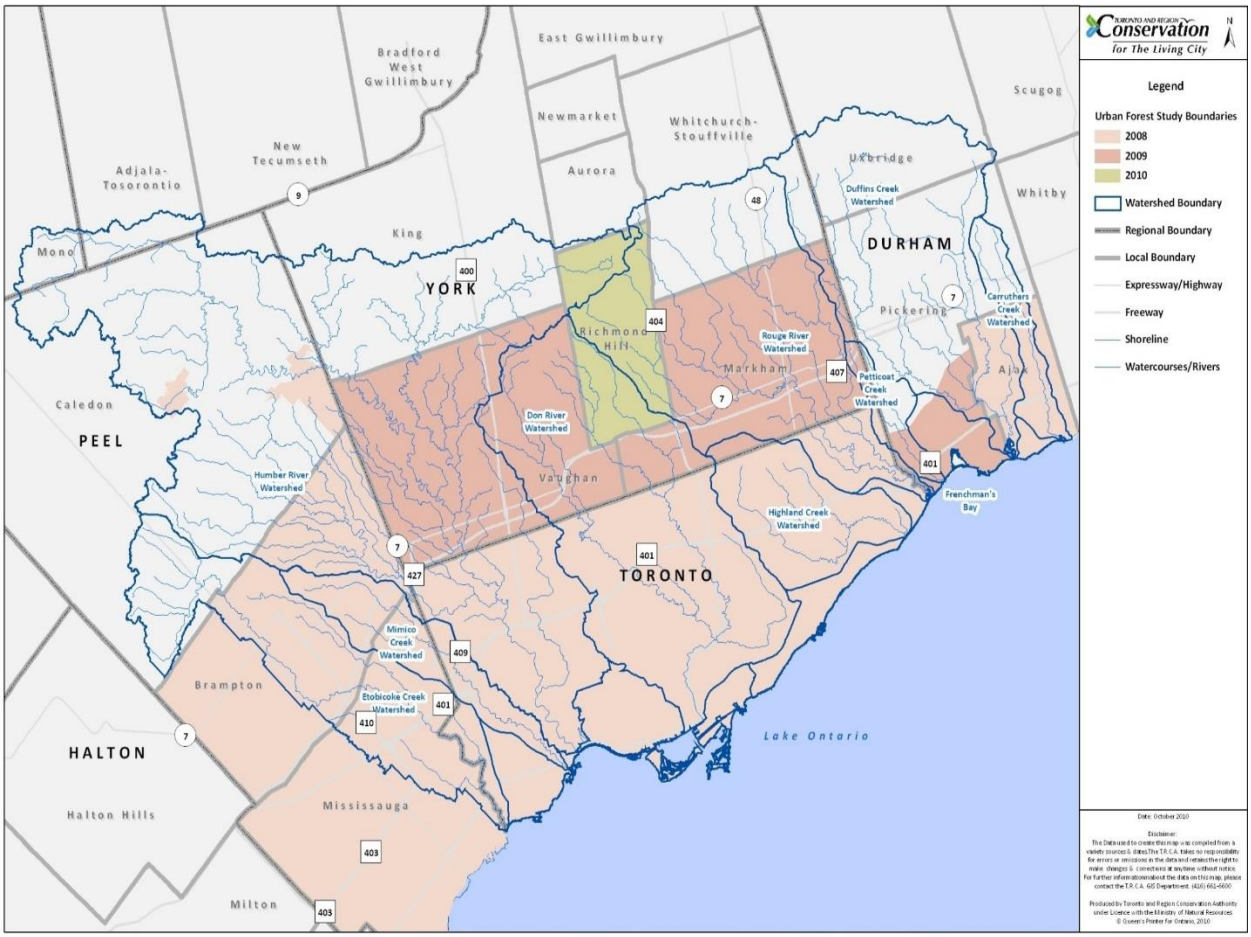


FIGURE 1 URBAN FOREST STUDY LOCATIONS ACROSS TRCA'S JURISDICTION

As with many other components of land use planning, urban forest planning benefits from assessment and intervention at multiple scales depending on specific objectives. Watershed planning provides an opportunity to evaluate the overall status of the urban forest as it relates to water management. This is important because the urban forest both influences and is influenced by local hydrology. With anticipated impacts of the changing climate and increased urbanization in the watershed, the urban forest will play critical roles in achieving a sustainable and resilient future for the watershed and its residents.

This assessment was undertaken to inform the CCWP and provides a high-level desktop assessment to provide increased understanding of the urban portion of the watershed in terms of:

- tree and shrub canopy cover and plantable space,
- priority areas for urban tree canopy enhancement,
- urban forest composition and structure,
- pressures and threats to the tree and shrub canopy, and
- opportunities for urban forest enhancements.

Results of this analysis provide insights into the state of the tree and shrub community within the watershed, including the extent of tree and shrub canopy coverage and general composition of the urban forest in both natural and manicured settings. Priority areas of the watershed for urban forest enhancement, including planting, maintaining and conserving, are recommended based on areas with low existing tree canopy and high opportunity for planting. Despite having relatively high existing tree and shrub canopy cover for the Greater Toronto Area (GTA), the rural portion of the watershed provides great opportunity for forest restoration, some of which is outlined in the CCWP Terrestrial Impact Analysis Report (*in process*). Spatial priorities outlined in this report focus on the urban portion of the watershed, which falls south of the Greenbelt and within Ajax.

Urban and rural areas of the watershed

For the purposes of this report, all lands below the Greenbelt, south of Taunton road are considered “urban” and are the focus of this report (see Figure 2). The lands north of Taunton road represent important areas of existing and potential tree cover both inside and outside the natural system. Trees in hedgerows, along roads, on golf courses and in yards north of Taunton play an important role in water management and other ecosystem services. Information on tree cover across the watershed in both urban and rural areas is provided in Appendix 1.

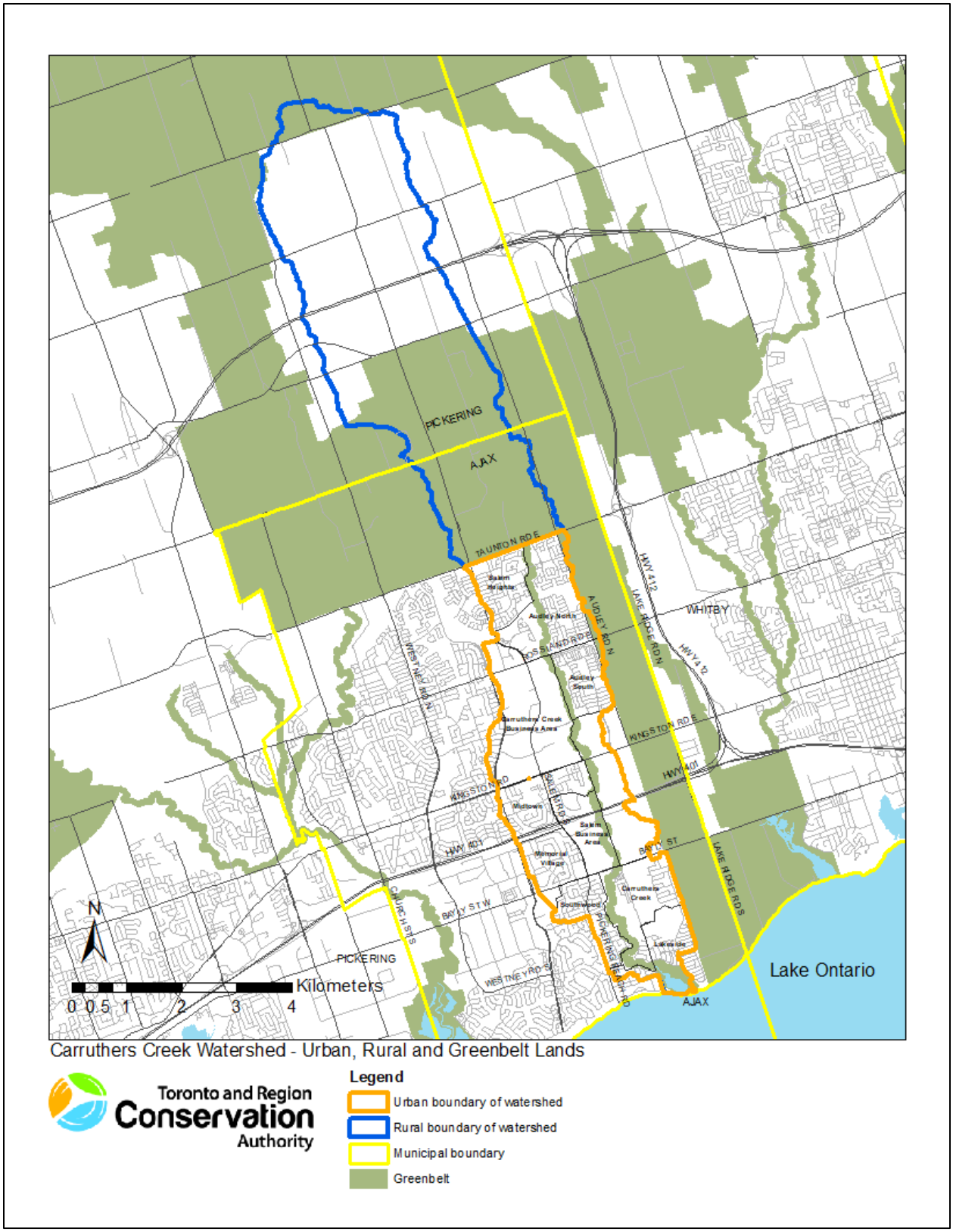


FIGURE 2 URBAN, RURAL AND GREENBELT LANDS IN THE CARRUTHERS CREEK WATERSHED

METHODS

Canopy Cover, Impervious Surface and Plantable Space

A tree and shrub canopy cover assessment was undertaken to estimate the extent of tree and shrub canopy cover in the urban portion of the Carruthers Creek Watershed using the i-tree canopy method developed by the United States Department of Agriculture's Forest Service (Nowak et al., 2018). This method is consistent with other urban forest studies in the GTA including those conducted for Ajax and Pickering (TRCA, 2009 and TRCA, 2012). A technician classified random points laid over orthophotographs into predetermined land cover categories. Orthophotographs from 2008 and 2017 were used to estimate the change in tree and shrub canopy cover in the watershed over a 10-year period. Images were obtained from First Base Solutions and have a resolution of 0.15 m (2017) and 0.20 m (2008). The watershed was segmented before analysis into rural and urban portions of the watershed. A total of 735 points were distributed across the urban (Ajax) portion of the watershed. Sample points were classified into 6 pre-determined land cover classes (Table 1 and Figure 3).

Table 1 Land cover classifications

Category	Examples of land cover types included	Final category
Road/building	Road or building	Impervious surface
Impervious other	Parking lot, driveway, sidewalk, patios etc.	Impervious surface
Plantable space	Non-tree pervious surfaces that are generally suitable for tree planting e.g. yards, parklands, un-paved medians	Plantable space
Unsuitable vegetation	Active sports fields and agricultural fields	Vegetation other
Tree/shrub outside forest	Trees in urban settings including parks, yards, streetside	Tree canopy
Tree/shrub inside forest	Points that fall within TRCA's natural cover layer in either successional or forest lands are automatically put in this category	Tree canopy
Water	Rivers, lakes	Water

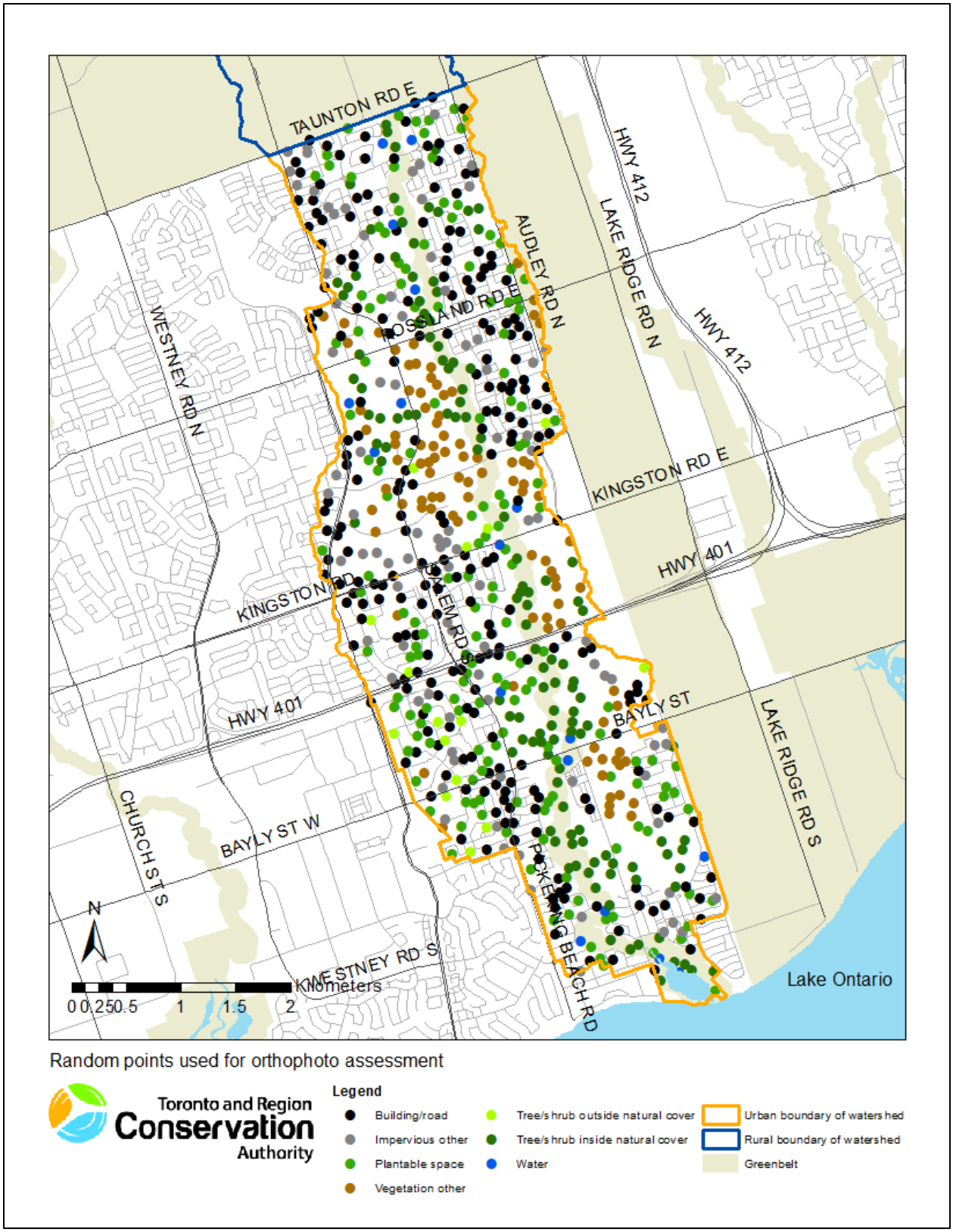


FIGURE 3 RANDOM POINTS USED FOR ORTHOPHOTO ASSESSMENT

Post-classification of the watershed into neighbourhoods, as determined by the neighbourhood boundary data downloaded from Ajax's open data site in June 2018, was undertaken to determine the variability of tree and shrub canopy cover across the watershed (note: when only a small portion of a neighbourhood fell in the watershed, it was combined with the next neighbourhood for larger sample size).

As a secondary source of land cover information to compare and validate the results of this land cover assessment, TRCA obtained land cover information developed in 2018 by Ajax in partnership with The United States National Aeronautics and Space Administration (NASA). Ajax and NASA developed an automated land classification model of land cover in 2017 based on high resolution imagery. As this classified land cover map was available only for one year, this information was used only for comparison with current tree cover in the Ajax portion of the watershed.

Urban Forest Composition and Structure

Understanding the composition and structure of the urban forest is necessary for effective management. Considerations that can provide valuable information on the resiliency of an urban forest as well as the ecosystem services it provides include: biodiversity, size class distribution, spatial arrangement and health condition. The structural nature of urban forests is also important to understand from a risk mitigation perspective, with a greater diversity leading to reduced risk of loss from pests. Additionally, knowing the types of trees is important to better estimate the services they provide. For example, coniferous trees capture more particulate matter than deciduous trees, which typically absorb more gaseous pollutants (Beckett & Freer, 2000; Bolund & Hunhammar, 1999).

Tree species and size information were compiled from existing sources to get some understanding of the composition of the urban forest in the watershed. This coarse examination used three sources of urban forest information: TRCA's flora inventory (2002-2017), Ajax's Urban Forest Study plots (n=64 plots, 557 trees, 2011) and Ajax's town-owned tree inventory (n=12,253 trees, 2018).

Data are summarized to provide a comprehensive list of known species occurrence within the watershed, which allows some insight into potential threats, but does not allow for analysis into the proportional representation of species across the watershed. Furthermore, TRCA does not have appropriate information to make any reference to the genetic diversity of trees within the watershed or their health condition.

Ajax has recently undertaken a climate change vulnerability assessment of the Town's natural capita, including exploring the climate conditions within which local tree species are known to establish (climatic envelope) and determining the proportion of the urban forest that is at risk to local climatic changes. This assessment was undertaken at a Town-wide scale in 2018 and the results will be published in 2019 (Town of Ajax, 2019, unpublished). The information on the vulnerability of the Town's street and park trees was assessed at the watershed scale. Results of this assessment are included in the *Pressures and Threats* section of this report.

Priority Areas for Urban Tree Canopy Enhancement

To provide some spatially explicit recommendations for tree canopy enhancements, including tree planting and conservation, TRCA used existing decision support tools for the watershed. Priority areas were deemed to be those areas that have lower tree canopy and higher available space for planting (plantable space) than the average for the urban portion of the watershed. Additionally, urban forest priority maps created by the Region of Durham's Health Neighbourhood initiative (Durham Region, 2018) and Ajax's Social Vulnerability Index for their climate change vulnerability work (*in progress*, provided by Ajax September 2018) were used as secondary screening tools for priority areas. Areas that were highlighted as existing habitat for forest wildlife species and zoned for future development, as outlined in the Terrestrial Impact Assessment Technical Report (*in progress*), were also highlighted as priority areas for tree and soil preservation to reduce impacts of development on wildlife, and to retain more of the existing ecosystem function and associated services in those areas.

RESULTS AND DISCUSSION

Canopy Cover and Impervious Surface

Based on the random point classification of the orthophotos, tree and shrub canopy cover in the urban portion of the watershed has stayed about the same (Table 2). Although the overall proportion of tree and shrub canopy cover remained about the same, there were gains and losses observed. Gains observed in tree and shrub canopy cover may be from natural succession of non-forested lands to forest, restoration and other tree planting efforts, and natural canopy growth and regeneration. However, in some cases what appears to be neighbourhood level increases in tree and shrub canopy cover may be more reflective of landscapes in transition during our benchmark year of 2008. A good example of this are lands that were cleared for development in 2008 followed by tree planting within the newly established neighbourhoods (Appendix 4). Examples of tree canopy loss in the watershed include tree removals for land conversion from open space/agricultural lands to industrial lands (Appendix 4). It should be noted that using sample points to assess urban tree and shrub canopy cover can have different results when compared to other remote sensing techniques (Parmehr et al., 2016) and the method used should be considered when comparing results to other jurisdictions or analyzing changes over time.

Impervious surface in the urban area of the watershed exhibited a much stronger trend than tree and shrub canopy cover. Between 2007-2018 there was an increase in the percent of impervious surface that is in the range of 12-19% of the urban portion of the watershed. This is a large increase in 10 years, particularly given that the urban portion of the watershed was already about 30% impervious cover (Table 2).

TABLE 2 ESTIMATED PERCENT CANOPY COVER AND IMPERVIOUS SURFACE COVER IN THE URBAN PORTION OF CARRUTHERS CREEK WATERSHED BASED ON RANDOMLY SAMPLED POINT ORTHOPHOTO INTERPRETATION (N=735)

Urban Area	2008	2017	Change
Tree and shrub canopy cover (%)	17.0 +/- 1.4	18.8 +/- 1.4	n/a
Impervious surface (%)	30.5 +/-1.7	46.0 +/- 1.8	12-19

Tree and shrub canopy cover varied across the urban portion of the watershed, and its distribution seems to be driven by the natural forest cover on the landscape (Figure 4). Through both this analysis and the analysis completed by NASA and Ajax based on 2016 imagery, the neighbourhoods in the southwestern portion of the watershed, particularly Midtown/Memorial and Lake Vista/Southwood, have the lowest tree and shrub canopy cover in the watershed, at less than 5%. As the watershed has become more urbanized in recent years, tree and shrub canopy cover exists mainly in the natural system. As planted and intensively managed trees in parks, yards and along streets mature it can be expected that the tree and shrub canopy cover will become more distributed across the urban areas. This assumption is based on the assumption that the trees planted, largely by Ajax and its residents, can survive and grow.

The Salem Heights neighbourhood, south of the Greenbelt underwent residential development and has the highest increase in impervious cover from 2008-2017 from approximately 18% to 71% impervious cover. An increase in impervious surface associated with residential development was also observed to a lesser extent in the Carruthers Creek neighbourhood. Increases in impervious surface reduce the space available for planting new trees and can cause alterations to hydrology and soil structure that can cause stress on nearby trees. While trees can be established in dense residential neighbourhoods, it will require investment to ensure adequate rooting room and water are available for the new trees. It does not appear that trees or soil was conserved in situ throughout the development of these neighbourhoods, which may make the establishment of new urban tree cover more difficult. Conserving trees and soil throughout the construction process can ensure there is adequate habitat for new trees.

Compared to the Town of Ajax's 2016 modeled forest cover assessment, the random point orthophoto interpretation method came up with a higher percentage of urban tree canopy (18.8 +/- 1.4% versus 13%). As the Town of Ajax modeled forest cover using different imagery at a larger resolution (3m versus TRCA's .15m imagery), it was anticipated that the random point sampling method would identify trees that the modeled forest cover did not. The difference between the two methods is most striking in neighbourhoods with high tree and shrub canopy cover. For example, in the Lakeside neighbourhood in the southeast of the watershed the Town of Ajax's modeled forest cover is much lower than the random point classification estimate, largely because the orthophotos used were captured before the leaves were out in the summer and there is a large area of standing dead trees in the Ajax Warbler Swamp in this neighbourhood. While both methods of assessment are valid and useful approaches, the TRCA

method is relied on throughout this report as it allowed for comparison from 2008-2017. Examples of trees captured by each method can be found in Appendix 2.

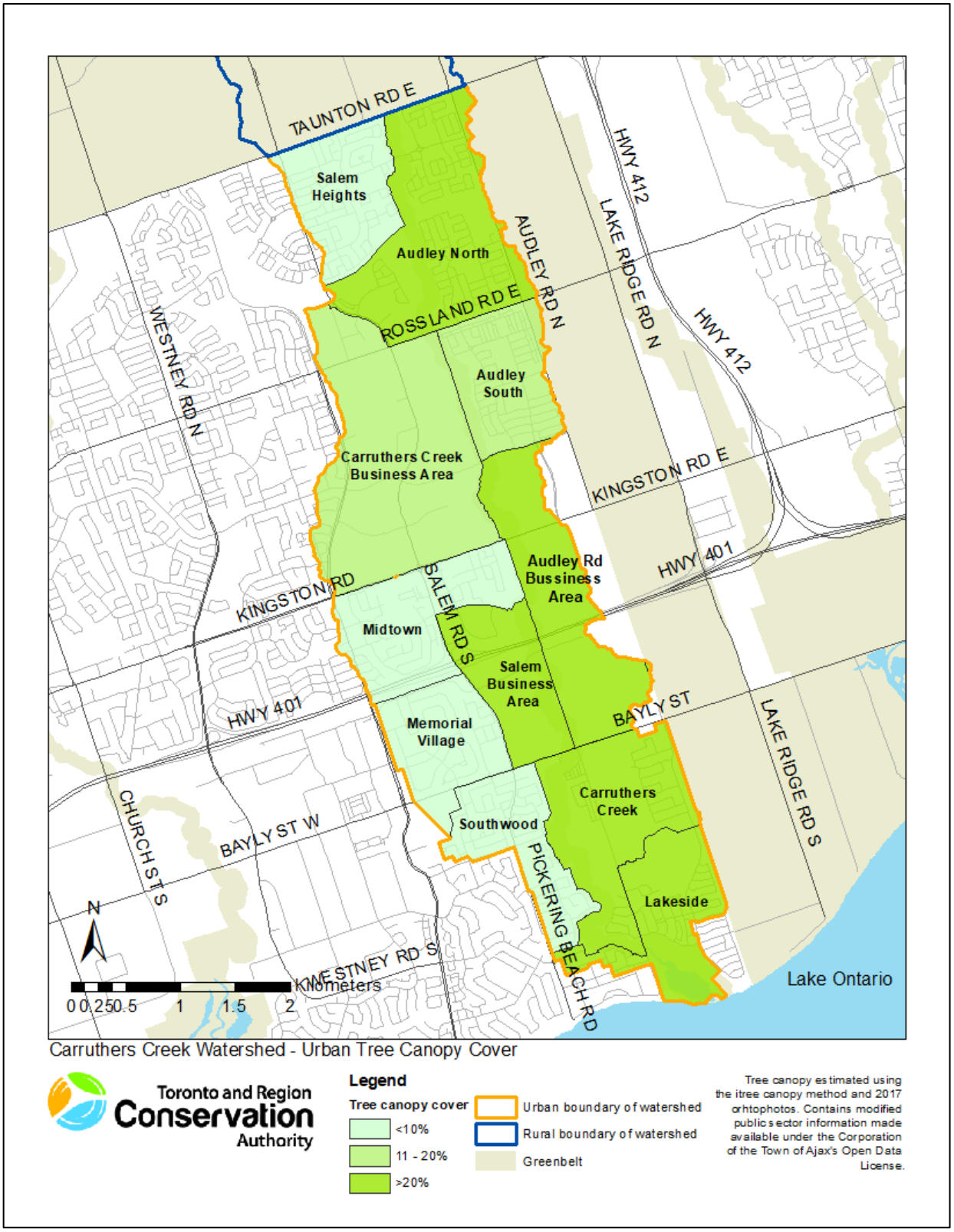


FIGURE 4 2017 TREE CANOPY ESTIMATED ACROSS THE URBAN PORTION OF CARRUTHERS CREEK WATERSHED, BY NEIGHBOURHOOD

Urban Forest Composition and Structure

Tree species in the watershed are typical to the Great Lakes St. Lawrence and Deciduous forest regions, with some additional introduced species common in urban areas. Ninety-four (94) genera of woody plant species are known to occur in the watershed, with over 270 species or varieties (Appendix 5).

Ajax has inventoried 12,253 Town-owned trees in the watershed, including street and park trees. Freeman maple (*Acer x Freemanni*), is the most common street and park tree in the Ajax portion of the watershed and makes up over 10% of the Town-owned trees and over 34% of the Town-owned trees are in the genus *Acer* (maple). This high proportion of trees of one species presents risk to the urban forest, as it is likely that most if not all of these trees will be susceptible to the same pests and impacts of climate change. For example, the Asian longhorned Beetle (*Anoplophora glabripennis*), a pest known to kill several tree species, including maples, poses a significant threat to the urban forest in the watershed. Maple trees are native to this region and many grow well in urban conditions (silver and Freeman maples, in particular). With their large mature height and crowns, they produce many ecosystem services, including heat reduction, and stormwater management. However, given the nature of the watershed, which is facing pressures associated with urbanization, climate change and introduced pests and diseases, a diversity of tree species could provide more resilience. While there is no available information on the genetic diversity of the Town-owned trees, many urban trees, including Freeman maples tend to be sold as cultivars, which are selected because of desired traits (e.g. nice fall colour) and propagated through cloning techniques, like grafting. Higher proportions of these trees can create even greater risk, as these trees are genetically identical, meaning they would have the same natural resistance to any pest or other stressor, reducing the overall resistance of the population as the proportion of these cultivars increase (Jung et al, 2014 & Fernandez-Conradi et al., 2017).

Parks contain trees larger in size and more native species compared with streets in the watershed based on the Town-owned tree inventory. This highlights the important role manicured parks can play in conserving large-growing native tree species. Available soil in parks is typically much greater in both quantity and quality and trees in parks typically face less pressure from pollutants, like road salt and vehicle emissions. With the ability to support larger trees, parks may prove critical in increasing water-related ecosystem services in the watershed, like stormwater reduction and water quality improvements. Additionally, park trees are known to provide a cooling effect, termed “urban park cooling island” which provides water quality benefits in addition to human health benefits (Vidrih & Medved, 2013).

82 species (or subspecies/varieties) were identified within the urban portion of the watershed through the urban forest study completed by TRCA in 2009. The most common was eastern white cedar (*Thuja occidentalis*). TRCA uses the Ontario Ministry of Natural Resources and Forestry’s Ecological Land Classification (ELC) system to categorize terrestrial ecosystems based on the flora and fauna observed in the area. According to ELC data collected in the watershed, Sugar maple (*Acer saccharum*) forests are the most common forest vegetation type.

Urban forest composition in the watershed is represented largely by species that are native to the region; however, as mentioned above, the genetic diversity even within these trees is an important factor in resiliency, as is the overall health of the trees and their location relative to each other. More information on the genetic make-up of the tree population and their health status would be beneficial for risk management.

Plantable Space

Based on the random point classification of the orthophotos in 2008-2017, about 20+/-1% of the urban area was still available in 2017 for planting new trees (plantable space). The true amount of space available for tree planting is likely smaller than this, as conflicts, including above and below ground utilities and other competing land uses beyond recreational fields were not accounted for in this estimate.

In areas of the watershed that were already developed by 2008, there appears to be opportunity for planting, particularly in the southwest (Figure 5).

The maintenance of the tree and shrub canopy cover from 2008-2017 in the watershed is a very positive sign and may be demonstrating the payoff of the urban forest enhancement efforts within Ajax through the last ten years of development. The loss of suitable planting space may be the limiting factor in growing the tree canopy in the urbanized portion of the watershed. As observed in the Audley South neighbourhood, residential development has led to a significant increase in the amount of impervious surface and a reduction in pervious soil to plant trees in (Figure 5). Furthermore, because of the development in these neighbourhoods, the soil that remains has likely been compacted by the development process and associated topsoil stripping, which will limit the number of tree species that could survive in the new neighbourhood (Kozlowski, 1999).

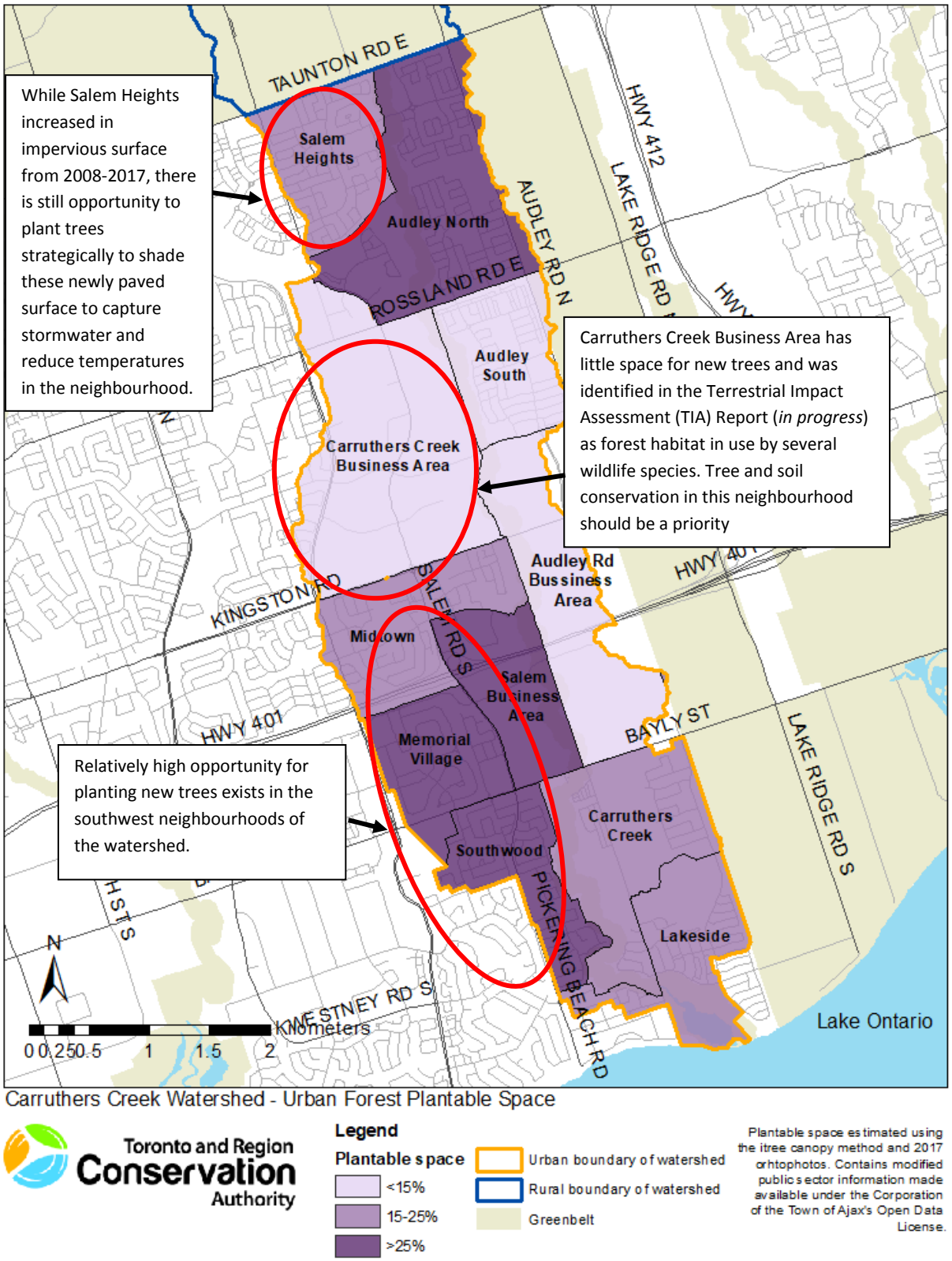


FIGURE 5 2017 PLANTABLE SPACE ESTIMATED ACROSS THE URBAN PORTION OF CARRUTHERS CREEK WATERSHED, BY NEIGHBOURHOOD

Tree and shrub canopy cover is just one measure of the urban forest quality and it is possible that urban forest quality can decline even with higher tree canopy. A good example of this is when the invasive buckthorn shrubs contribute to the tree and shrub canopy cover. While these shrubs provide some ecosystem services, they outcompete many large-growing native species that would ultimately provide more ecological function and derivative services. Nearby communities have found an increase in the proportion of invasive shrubs, like buckthorn over the last 10 years (Town of Oakville, 2015) and regionally, there has been a similar increasing trend in woody shrub growth (TRCA, 2015).

Priority Areas for Urban Tree Canopy Enhancement

Despite the high tree and shrub canopy cover that already exists in the agricultural area to the north (beyond the scope of this report) it should be noted taht this area still represents opportunity to increase cover. Priority areas for natural system improvement and restoration can be found in the TIA Report (in progress).

Three areas were identified as having high potential for new tree planting and maintenance. These were selected because they had higher plantable space and lower existing tree canopy compared to the watershed average and include the following neighbourhoods: Memorial Village/Downtown, Midtown and Southwood/Lake Vista (Figure 6). One additional neighbourhood, Carruthers Creek Business Area, was identified in the TIA Report (*in progress*) as currently providing habitat to woodland species. This neighbourhood has already seen a loss of plantable space from 2008-2017 due to development on the west end and development of the east is identified in the Ajax's Official Plan. For these reasons, this area has been identified as a priority area for tree and soil preservation.

The three priority neighbourhoods for tree planting align with Durham Region's Priority Health Neighbourhood in Ajax as well as areas identified as moderately to highly vulnerable through Ajax's Social Vulnerability Index (Figure 6). Furthermore, this area has some of the highest land surface temperatures in the watershed based on a Landsat 8 Image taken on September 21, 2018 (Appendix 2).

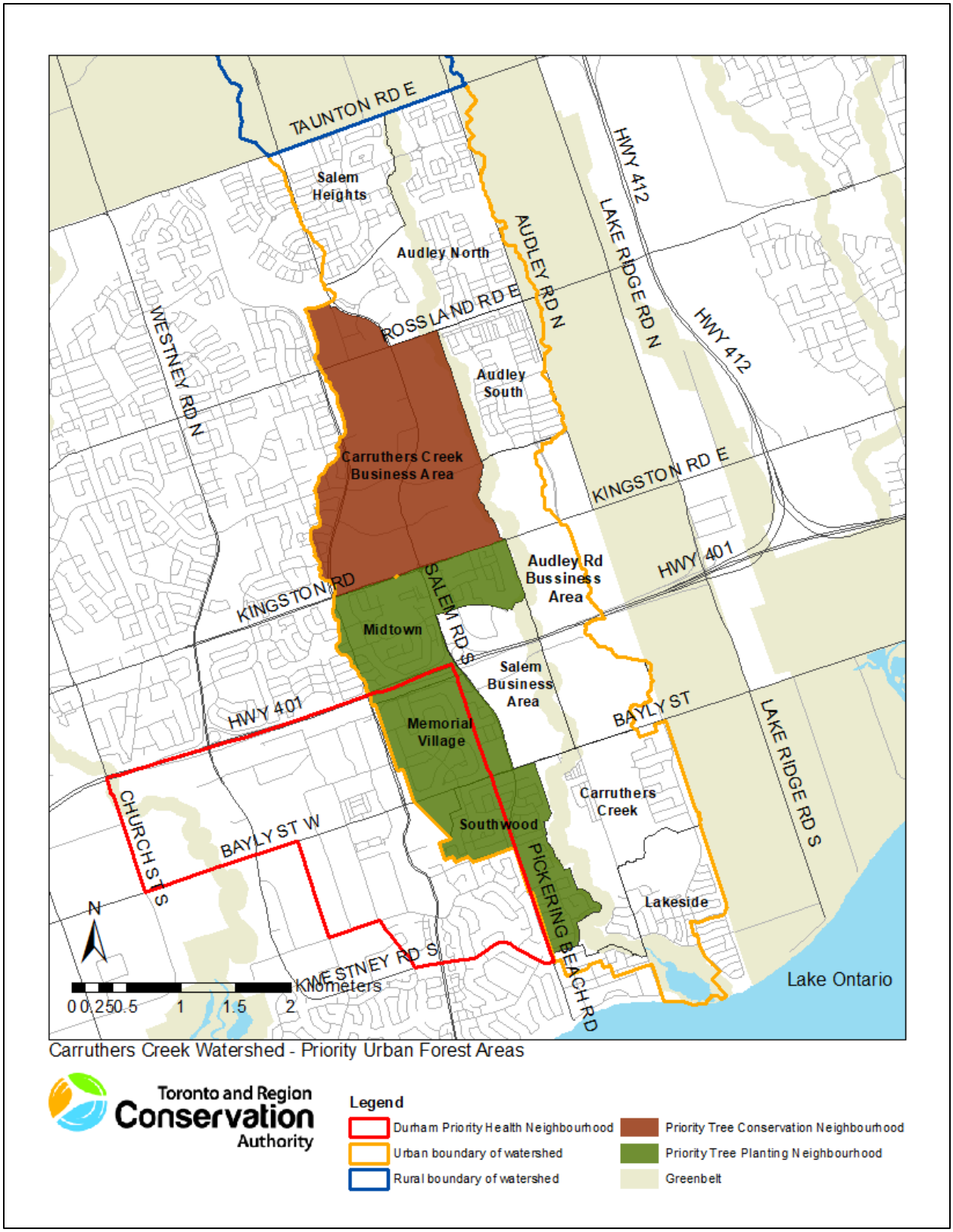


FIGURE 6 PRIORITY AREAS FOR URBAN FOREST ENHANCEMENT IDENTIFIED BASED ON LOW TREE CANOPY AND HIGH PLANTABLE SPACE

Pressures and Threats

Loss of tree canopy can have direct impacts on human health and wellbeing (Graham et al., 2016). There are multiple threats and pressures to the urban forest in the Carruthers Creek Watershed, some of which are outlined below. All of these pressures and threats will be further exacerbated by the changing climate. While the analysis of this report focused on the urban portions of the watershed, these pressures and threats could apply to trees throughout the watershed.

Climate change (general) – The changing climate is impacting the urban forest, and these impacts are projected to increase over the coming decades. Durham's Community Climate Adaptation Plan identifies the need for urban foresters to consider climate change impacts when selecting species and planting locations. As mentioned earlier in this report, the Town of Ajax has undertaken a climate change vulnerability assessment for Town-owned trees. The summary of this assessment at the watershed scale is reflective of the findings at the Town scale, namely that the most common trees on Town lands are at low to low-moderate risk to climate change impacts. However, the most common tree, Freeman maple, are moderately vulnerable. This result further stresses the need to diversify tree communities on Town lands and lower the proportion of Freeman maples. As this climate change vulnerability assessment was undertaken by the Town of Ajax, there are gaps in knowledge about the vulnerability of the tree communities in the Pickering portion of the watershed. A similar approach should be undertaken by Pickering and the Region of Durham for existing and new trees along regional roads and on other regional properties to identify adaptation measures. In addition to needing to take adaptation measures to ensure the urban forest is resilient to the impacts of climate change, Durham's Community Climate Adaptation Plan identifies that trees in urban areas can also be an adaptation measure to climate change impacts like extreme heat events. By providing cooling and improved thermal comfort to humans, expanded tree canopy is one of the best-known adaptation interventions for heat events. Investments in trees will result in communities more resilient to the impacts of climate change.

Changes to hydrology – While trees influence the movement of water through a watershed, they are also negatively impacted by changes in hydrology (Brandt, 2014). Changes to drainage patterns that can lead to an increase or decrease in the amount and duration of water around tree roots can be detrimental to tree health. These changes can occur on small-scales, like backyard trees being impacted by grading changes for landscaping, or larger scales like new development and associated drainage pattern changes that can lead to flooding of woodlands. As noted in the TIA Report (*in progress*), there was obvious tree canopy loss in the Carruthers Wetland Complex in the southeast of the watershed, possibly due to flooding, which may have been caused by the establishment of a new stormwater management pond during development that occurred nearby from 2011-2016. The presence of a beaver dam prior to this development was also noted and could have altered the local hydrology.

Pests and diseases – There are many existing and potential pests and diseases that affect the tree and shrub species in the watershed. The Town of Ajax has spent over $2 million dollars addressing the recent Emerald Ash Borer (EAB) infestation (Gilligan, 2016), and several new pests pose an imminent threat to the tree species that exist in the watershed. There is not enough data to assess the exact extent and impact of EAB in the watershed. An updated urban forest study could provide some indication to the amount of ash lost across the watershed. Pending and known pests are shown in Table 3.

Changes to soil structure – Changes in soils related to urban development permanently alter the soil structure and greatly reduce the number of species that can be established (Pavao-Zuckerman, 2008). Additionally, construction can cause soil compaction and associated damage to mature trees that surround development sites. Soil that is brought in following development is frequently of lower quality and can be limited in quantity compared to the soils present prior to intensive development.

Changes in land use – The conversion of much of the land in the urban areas into residential properties brings both challenges and opportunities for urban forest enhancement. Residents of the urban portion of the watershed may have varying opinions about trees on their property and are likely to have competing uses for their residential lots including patios, swimming pools and lawn. Given the potential that residential lots provide for tree planting and a high-level of monitoring and care, education, stewardship and tree planting programs that focus on residents will become increasingly important.

Land tenure and tree protection – While there are a several policies including Ontario's Greenbelt Act and local bylaws protecting trees in natural areas (and boulevard trees in Ajax), individual trees on private property outside the Greenbelt and natural areas are not protected and can be removed. As the watershed becomes more urban and land becomes increasingly parceled, the urban forest may be impacted. A private tree by-law protecting mature trees on private urban residential lands is a common tool that has been implemented in other jurisdictions to reduce unnecessary removals and require re-planting. The development of a private tree by-law for the urban areas in Pickering and Ajax may be a good tool in protecting and enhancing the urban forest. The existing tree conservation bylaws that provide direct and indirect protection of trees in certain areas across the region include the Region of Durham's Trees in Woodlands Bylaw 31-2012 (update in process), the City of Pickering's Tree Protection Bylaw 6108/03, the City of Pickering's Fill and Topsoil Disturbance Bylaw 6060/02, the Town of Ajax's Tree Bylaw 137-2006 and Boulevard Tree Protection Bylaw 138-2006. These bylaws play an important role maintaining tree cover in the watershed and should continue to be monitored for their efficacy and updated as necessary.

TABLE 3 EXAMPLES OF PESTS AND DISEASES THAT AFFECT SPECIES FOUND IN THE CARRUTHERS CREEK WATERSHED

Pest/disease	Known to be present in Carruthers Creek Watershed	Host and impact
Asian Long-horned Beetle (ALHB)	No	These beetles feed on multiple host species, many of which are common species in the watershed, which makes them a relatively high threat level to the watershed's urban forest. They were last detected in the City of Mississauga and the City of Toronto in 2013 (CFIA, 2019).
Spotted Lanternfly	No	This invasive insect feeds on many different hosts, and could be of particular threat to fruit trees/vines in the watershed. These insects were detected in Pennsylvania in 2014 (CFIA, 2019).
Hemlock Woolly Adelgid	No	Hemlocks are one of the most common tree species in the Town of Ajax according to the 2009 Urban Forest Study. This insect was detected in Etobicoke in 2013 (Invasive Species Center, 2018).
Oak Wilt	No	This fungal pathogen infects oak trees through open wounds caused by injury including pruning or through root transfer from neighbouring infected trees. Oak wilt has not been detected in Ontario, but is well established in the

		northern portion of Michigan bordering Ontario (Invasive Species Centre, 2019).
Verticillium	Yes	This common soil-living fungus is a threat to already stressed trees, and may become more of an issue with increased water stress and/or the presence of other pests like ALHB.
Emerald Ash Borer (EAB)	Yes	The impact of EAB was very high since its introduction in the early 2000s and the ash population in the watershed has now decreased significantly since the arrival of EAB. EAB will continue to be a threat to natural regenerated ash, but ash is no longer planted by the main tree planting agencies in the watershed (TRCA, Ajax, Pickering).
Beech bark disease	Yes	Beech would commonly be found in the climax forest type in much of the watershed. Resistance to beech bark disease is very low and this disease poses a very real threat to an important food resource for wildlife. Additionally, mature beech trees are large and provide many ecosystem services that are at risk because of this disease (Invasive Species Centre, 2019).
Beech leaf disease	No	As a relatively new and not well understood disease, this leaf disease is spreading quickly and was first detected in Elgin County, Ontario in 2017 (Invasive Species Centre, 2019). This disease combined with beech bark disease and other beech pathogens is likely to be very detrimental to the beech population in Ontario.
Dutch elm disease (DED)	Yes	This disease decimated the elm population in southern Ontario since its arrival in the 1940s and as such, few elm trees persist on the landscape. New hybrids and varieties of elm are now commonly planted urban trees and may be at risk to DED in the future, particularly with compounded stressors.
Gypsy moth	Yes	Gypsy moth have been present in southern Ontario for over a century. They feed on multiple hosts and can cause damage to many large-growing species. Control measures exist but are costly.

Implications of Future Land Use Scenarios

This report is part of the larger phase two of the watershed planning process which is meant to examine potential impacts of future growth and land use changes in combination with other influences such as climate change on the watershed. As part of the phase two reports, land use/cover scenarios were developed to examine potential impacts on the entire watershed. A full description of the land use scenarios and how they were developed can be found in Appendix 6. As this report focuses on the urban portion of the watershed only, there is little difference between some of the scenarios, as the urban portion of the watershed is already fairly built out. However, there are some minor changes between the current, the Official Plan (OP) and the enhanced natural heritage system scenarios. The implications of Scenario 5 (potential future urban) are discussed in Appendix 1.

As outlined above, land use conversions are associated with impacts to the urban forest. While the above analyses were not undertaken using the land use scenarios developed for the CCWP (Figure 7), extrapolation of the above results allows some insight into potential urban forest impacts of each scenario.

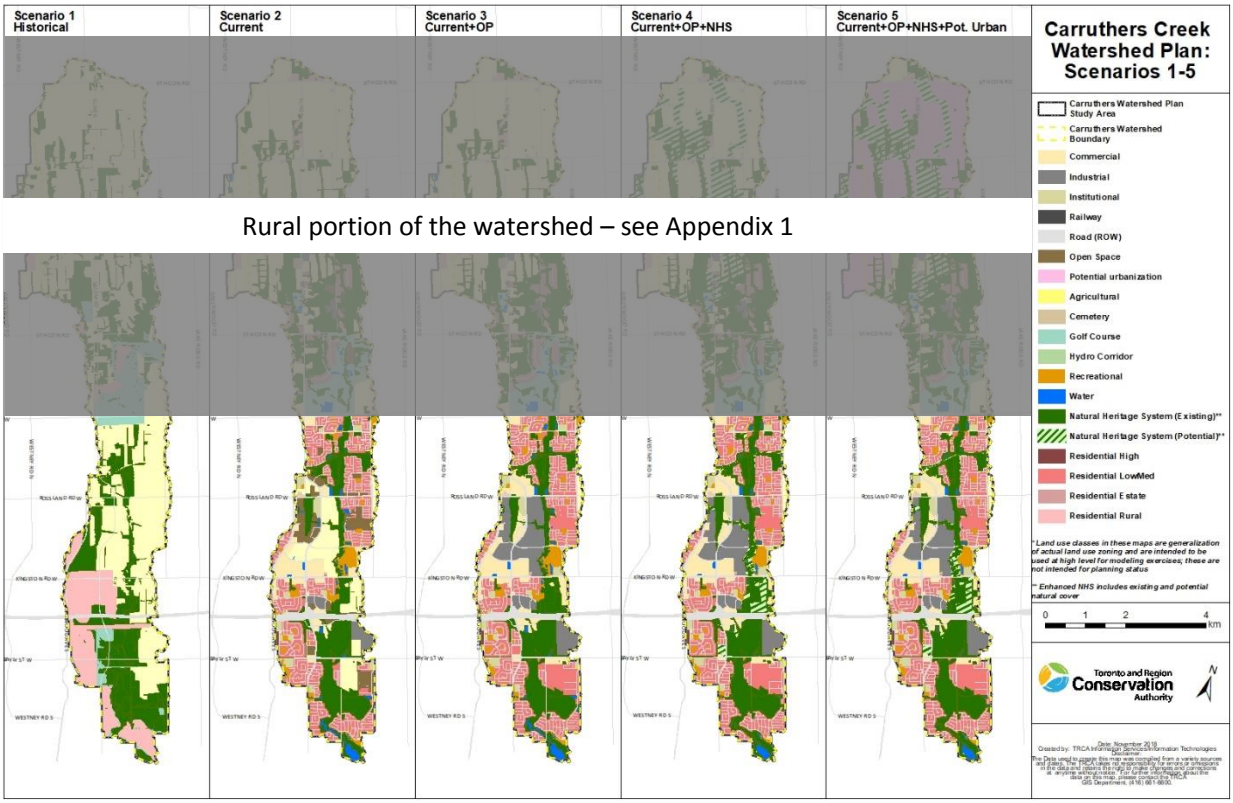
Historical:
The Historic scenario was not assessed as no data on tree and shrub canopy during the time of the historical scenario (from 1999) other than natural cover was available. The changes in tree and shrub canopy between 2008-2017 were described above.

Current:
The current scenario is existing land use conditions from 2015 and shows tree and shrub canopy cover at 18.8 +/- 1.4% of the urban portion of the watershed, with most of the tree canopy existing within the natural system. About 20+/-1% of the urban area is still available for planting new trees.

Scenario 1 (+OP):
Refines Current scenario by assuming all lands south of the Greenbelt are now developed as approved up to 2031 in the Ops. This may reduce the proportion of canopy in this neighbourhood as well as plantable space and associated ability to enhance the urban forest. The increased impervious surface that comes with industrialized lands could also alter the hydrology and impact the health of trees in surrounding neighbourhoods. This area was identified as a priority area for existing tree and soil conservation, which could reduce some of the negative impacts of development in the area.

Scenario 2 (+NHS):
Refines Scenario 1 (+OP) by adding an enhanced NHS as per approved OPs and using updated information on terrestrial habitat connectivity, habitat configurations, and climate change vulnerabilities. This scenario also highlights additional “plantable” space from a restoration perspective. Under this scenario, overall composition and structure (and associated functions) will also be enhanced for overall system resiliency. As with Scenario 1 (+OP), to have a more equitable distribution of ecosystem services and access to the urban forest, the urban portions of the watershed will still require conservation and retrofits outside the natural system to provide the benefits of urban tree canopy to all residents.

Scenario 3 (+Potential Urban):
Illustrates prospective development post-2031 in the headwaters area outside of the enhanced NHS identified in Scenario 2. There is no change in the existing urban area south of the Greenbelt so opportunities for enhancing the urban forest are similar to those in Scenario 2.



Rural portion of the watershed – see Appendix 1

FIGURE 7 LAND USE SCENARIOS DEVELOPED IN PHASE ONE OF THE CARRUTHERS CREEK WATERSHED PLAN

Recommendations for Tree Canopy Enhancement

Based on the results of the tree canopy assessment and what is known about the urban forest structure and composition in the Carruthers Creek Watershed, several opportunities exist for tree canopy enhancement in the watershed. These recommendations were developed based on the findings of assessing the urban portion of the watershed, but many of these recommendations are at a higher strategic level and would benefit from participation from all urban forest partners in the watershed, including the Region of Durham, the Town of Ajax, the City of Pickering, local not-for-profit organizations, watershed residents and TRCA. These opportunities are in addition to those already being undertaken in the watershed, including important activities undertaken by Ajax, Pickering and TRCA's urban forest management teams. Ajax's urban forest management plan and TRCA's Guideline for Ecosystem Compensation are two examples of documents that contain important recommendations that should be implemented to enhance tree cover in the watershed.

Recommendations to leverage these opportunities include:

1. Prioritizing urban forest enhancement where their ecosystem services are most needed
    a. Where possible, Town and TRCA planners should ensure development in the area identified in this report for tree conservation (Carruthers Creek Business Area) is undertaken in a manor that reduces impact on the native soil and woodlands

   b. Tree planting programs run by the Town and TRCA should, with regional support, focus enhancements on the priority neighbourhoods identified in this report which had proportionally higher plantable space and lower tree canopy, including the Memorial Village/Downtown, Midtown and Southwood/Lake Vista neighbourhoods in Ajax. Planting in this area will make the most impact on equitable distribution of ecosystem services where there are still opportunities to plant. Furthermore, part of these neighbourhoods fall in Durham's priority health neighbourhood and planting should therefore be supported by the Region.

2. Develop a regional comprehensive urban forest monitoring program
   a. Tree composition, age and condition should be monitored in the watershed, potentially through updating the urban forest studies previously led by TRCA.
   b. The Region of Durham should support the local municipalities in undertaking a comprehensive tree canopy assessment for the Town of Ajax and the City of Pickering to inform a more detailed tree preservation and planting plan. This study could identify explicitly mapped plantable space as well as map tree and shrub canopy cover that is vulnerable to loss due to land use changes and associated hydrological changes. Examples of Regions that have recently supported this kind of land cover mapping include Peel and York Region.
   c. Based on the results of the tree canopy assessment, the Town of Ajax, the City of Pickering and the Region of Durham should identify areas/streets and individual areas/trees of high conservation value, particularly large, mature trees that are providing a higher contribution of ecosystem services than smaller trees.
   d. Based on the results of the tree canopy assessment, identify areas at greatest risk to pests and impacts of climate change on Regional roads and throughout the watershed. The Town of Ajax has done this risk assessment for their jurisdiction. Use this information to inform targeted outreach to educate tree owners on the risk and how to prepare for threats to their trees.
   e. The Region, the Town and TRCA should complete/update an inventory of regional, municipal and conservation authority owned trees along roads, in parks and woodlands to identify risk level for tree pests and climate change. Additionally, remnant woodlands that have been surrounded by development should be monitored by the area municipalities in partnership with the TRCA. Existing inventory efforts by TRCA and the Town should be built on.
   f. All levels of government should support the development of a pest monitoring program to support Integrated Pest Management (IPM)
3. Enhance collaborative effort
   a. Provide regional support in establishing collaborative initiatives between the local municipalities, the Region and TRCA to share knowledge and work planning, particularly associated with pest management and invasive shrub management. This can be done through the forest working group recently developed in Durham by the TRCA.
4. Invest in green infrastructure
   a. The Region and the Town of Ajax should support partners already invested in urban forestry and provide funding to implement and maintain urban forests as a key tool for climate adaptation, as identified in Durham's Community Climate Adaptation Plan

   b. The Region and the Town of Ajax should continue and expand support for residential tree planting programs throughout the Region, as land use in the watershed becomes increasingly residential
5. Conserve trees and soil through new development process
   a. The Region and the Town of Ajax should require certified arborists and/or urban foresters' involvement early in site plan development
   b. The Region and the Town of Ajax should protect trees marked for preservation on site using appropriate tree protection tools (e.g. the City of Toronto's Tree Protection Policy and Specifications for Construction Near Trees)
   c. The Region and the Town of Ajax should limit the amount of impervious surface for parking lots, patios etc. and use low impact development techniques in all new developments
   d. Where necessary to move soil, the TRCA's *Preserving and Restoring Healthy Soil: Best Practices for Urban Construction* should be used. Where native soil has been removed for hard surfaces, replace with structured soil cells and other technologies that allow proper root structure development and additional space for new trees
   e. The Town of Ajax should have a landscape architect inspect/test topsoil prior to plantings in new developments and their buffers to ensure the specified quantity and quality of topsoil has been used.
   f. The Region and the area municipalities should continue to communicate the ecosystem services of trees through existing homeowner outreach materials like the Town of Ajax's Tree Care Kit and the Region's Made for Shade guide for creating shade at home. A residential stormwater credit system could be developed to educate residents on the harm caused by impervious surfaces and encourage tree planting. Additional coordinated communication materials could highlight the benefit of trees and shrubs to local wildlife including pollinator populations.
   g. The Town of Ajax should consider implementing an individual private tree protection bylaw to protect trees outside the natural system. In addition to the existing tree bylaws, a private tree bylaw (along with proper enforcement) could reduce the loss of tree canopy on private lands. Though not the focus of this report, the City of Pickering should consider a similar bylaw.
6. To enhance tree planting and protection on regional roads and operations facility land, the Region should:
   a. Increase the capacity of the Region to enhance the urban forest through an in-house arborist or forester position to work with the local municipalities and the TRCA to enhance tree canopy on regional lands. Similar models of in-house regional forestry expertise exist in near-by Regional governments including York and Halton
   b. Partake in knowledge-sharing and collaboration through the Regional Public Works Commissioners of Ontario's Urban Forestry Sub-Working Group and ISA Ontario's Municipal Arborist & Urban Foresters Association
   c. Implement a tree planting and maintenance program along currently low-cover regional roads in the watershed, for example along Taunton Road
   d. Develop a tree conservation policy for trees on regional lands
7. Partake in collective action with industry partners

a. The Region of Durham and the TRCA should facilitate and support partnerships between the tree nursery industry and local municipalities to plan long term to increase procurement of a diverse range of species sourced as much as possible from local stock with higher genetic diversity
b. The Region of Durham, the City of Pickering and the Town of Ajax, along with local utility providers, should explore and identify areas to plan new utility locations and maintenance to reduce the impact on existing trees or potential areas for trees. Additionally, this partnership could provide collective communications to homeowners about where and how to plan yard trees to reduce conflict with above and below ground utilities.

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Appendix 1: Tree canopy across the watershed

As discussed at length in the above report, trees outside of natural systems play an important role in achieving watershed objectives. While this report focused on the urban portion of the watershed, this is also true in the rural portion which has seen little development in the last ten years but may see more in the future. An assessment of tree canopy for the entire watershed was undertaken in the same method as the urban portion of the watershed to serve as a benchmark for any future changes that may occur in the watershed.

Conservation of existing trees and soils throughout the development process, both inside and outside of woodlands is the best way to achieve continued ecosystem services. In particular, trees in hedgerows and on golf courses are often removed through the development process in the Toronto region as they are not protected by woodland conservation bylaws. Having an individual private tree bylaw in place could reduce this kind of ecosystem service loss, though it would require increased capacity from the local municipalities for enforcement.

The assessment for the tree canopy across the entire watershed used 1616 points, with 735 in the urban portion, 169 in the Greenbelt portion of Ajax and 712 within Pickering. Tree and shrub canopy cover for the overall watershed did not change significantly from 2008-2017, though a positive trend observed (Table A.1).
Tree and shrub canopy cover in Carruthers Creek Watershed was 20.5 ± 1% in 2008 and 22.6 ± 1% in 2017.

Table A.1: Tree and shrub canopy cover for the entire Carruthers Creek Watershed

Location	Canopy Cover (%) 2008	Canopy Cover (%) 2017	Change in Canopy Cover (%)
Pickering	22.6 ± 2	24.0 ± 2	+ 1.4
Ajax	18.9 ± 1	21.6 ± 1	+ 2.7
Overall	20.5 ± 1	22.6 ± 1	+ 2.1

Land use scenario implications for the entire watershed:

The land use scenarios 4 and 5 pertain more to the entire watershed and the “potential future urban” portion of the watershed which is in the City of Pickering.

Current:
The current conditions show the urban tree canopy is higher in the northern, rural portion of the watershed (the Greenbelt and Pickering) at 24.0 ± 2% and a little lower in the more urban portion of the watershed (Ajax) at 21.6 ± 1%.

Scenario 1 (+OP):
The Official Plan scenario has some increases in intensive land use, from what is currently open space to industrial/commercial. There are also some small areas that are planned to become residential. These changes are likely to impact tree and shrub cover initially but can be recovered over time if properly planned and effort is made to retain soil integrity and make residential tree planting and maintenance

easy. Having more residential land use in the watershed will also create a higher demand for ecosystem services like the cooling benefits of trees.

Scenario 2 (+NHS):
The enhanced Natural Heritage System (NHS) scenario has much higher opportunity for increased tree canopy in rural areas thereby increasing overall tree canopy in the watershed. This scenario also highlights additional "plantable" space from a restoration perspective. Under this scenario, overall composition and structure (and associated functions) will also be enhanced for overall system resiliency. As with the Scenario 1, to have a more equitable distribution of ecosystem services and access to the urban forest, the urban portions of the watershed will still require conservation and retrofits to provide the benefits of urban tree canopy to vulnerable populations.

Scenario 3 (+Potential Urban):
Land use conversion from agricultural to "future urban" is likely to have an immediate negative impact on the tree canopy as construction occurs, but there is potential to restore this lost canopy. Agricultural lands north of the Greenbelt currently have similar tree and shrub canopy cover to some of the older residential neighbourhoods in Ajax; if these lands are to urbanize through the municipal planning process, then tree canopy could partly return over time through the enhanced natural heritage system, preservation of large stands of trees within development blocks; and appropriate site planning for healthy soil volume and composition.

The greatest impact of Scenario 3 to the tree canopy in the watershed is likely the loss of plantable space and quality soil that will occur with development, as was observed in several portions of the watershed between 2008-2017. Topsoil stripping is a common practice in master planned communities that reduces the structural integrity and the nutrients available to new trees. This leads to a reduction in the number of tree species that can survive these conditions. There are very few species, and almost no native tree species, that can be established in the years following development that involved soil stripping and compaction. This means even within the trees that do establish, the diversity is so low that the entire population may be at higher risk to incoming pests compared to the existing population (Jactel & Brockerhoff, 2007).

Existing urban areas in the watershed exhibit much higher land surface temperatures compared to more rural or natural areas (Appendix 2). With increased impervious surfaces that retain heat and decreased natural cover that provides cooling through shading and evapotranspiration, new urban areas are anticipated to become hotter. As discussed in Durham's Community Climate Adaptation Plan, trees play a key adaptation role in helping communities cope with increasing temperatures. This applies both to the impact of climate change and to the increased urban heat island that is associated with land cover changes. To create healthy and resilient neighbourhoods in any part of the watershed, the Region and the local municipalities should prioritize tree conservation. Tree and shrub canopy cover over 40% has shown to be a threshold above which cooling benefits of trees are even greater (Ziter et al, 2019).

Extrapolating the results that showed Town-owned trees in the watershed are larger in parks than along streets, it follows that losing parks/open space may lead to an urban forest made up of smaller trees, limiting tree canopy and its associated benefits to the watershed. Implementing soil conservation practices and ensuring trees in yards and along streets have adequate soil volume is one opportunity to resolve this. It is also critical that any future urban developments include open greenspaces with trees planted to a high standard and maintained for their lifespan to ensure urbanizing portions of the

watershed also have green infrastructure for the water management and other ecosystem services they provide.

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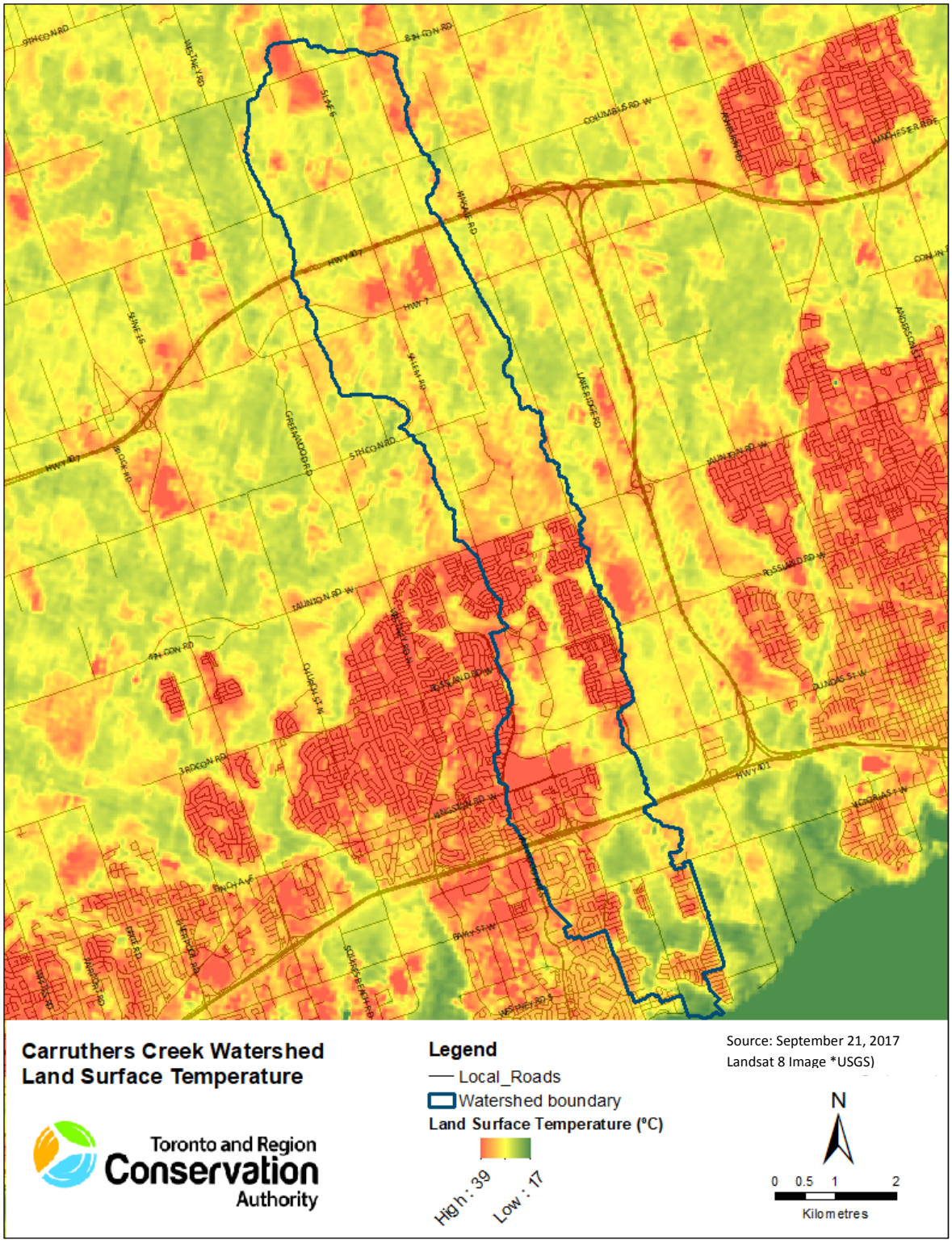
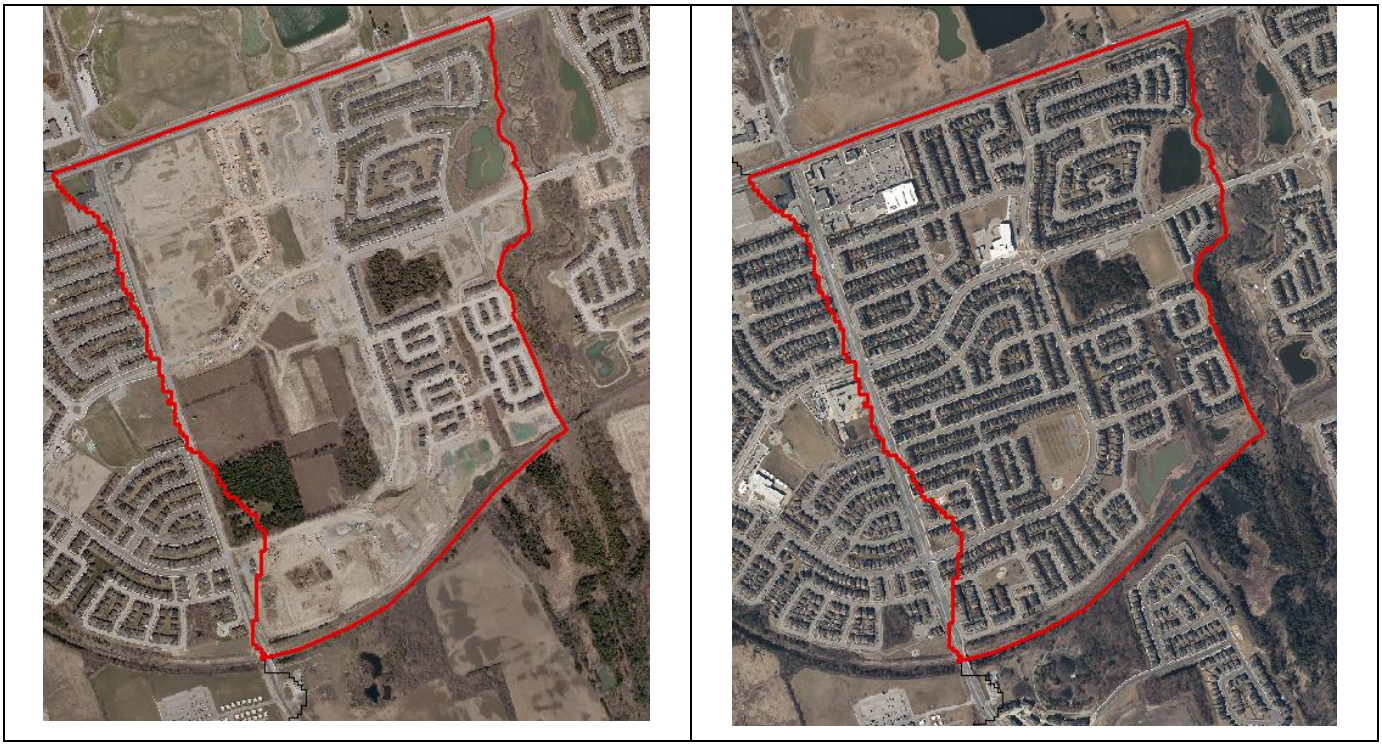
Appendix 2: Random Sample Classification Compared to the Town of Ajax's 2016 Forest Cover

Appendix 3: Land Surface Temperature of Carruthers Creek Watershed



Appendix 4: Examples of Observed Tree Canopy and Plantable Space Changes

EXAMPLE OF TREE LOSS FROM AGRICULTURAL TO INDUSTRIAL LAND USE CONVERSION IN AUDLEY NORTH NEIGHBBOURHOOD, AJAX. LEFT IMAGE SHOWS RANDOM POINT USED FOR PHOTO INTERPRETATION ON 2008 IMAGERY AND THE RIGHT IMAGE SHOWS THE SAME POINT IN 2017.



SALEM HEIGHTS NEIGHBOURHOOD HAS 75% LESS PLANTABLE SPACE IN 2017 COMPARED TO 2008

Appendix 5: List of Tree species/varieties known to be present in Carruthers Watershed

Tree species/Type
Abies balsamea
Abies concolor
Acer negundo
Acer platanoides
Acer rubrum
Acer saccharinum
Acer spicatum
Acer x freemanii
Aesculus glabra
Aesculus hippocastanum
Ailanthus altissima
Alnus glutinosa
Alnus incana ssp. rugosa
Amelanchier arborea
Amelanchier interior
Amelanchier laevis
Amelanchier sanguinea
Berberis thunbergii
Berberis vulgaris
Betula alleghaniensis
Betula papyrifera
Betula pendula
Buxus sempervirens
Caragana arborescens
Carya cordiformis
Catalpa speciosa
Celastrus orbiculatus
Celastrus scandens
Celtis occidentalis
Cornus alternifolia
Cornus obliqua
Cornus racemosa
Cornus rugosa
Corylus cornuta
Cotinus coggygria
Crataegus coccinioides
Crataegus crus-galli
Crataegus holmesiana
Crataegus mollis
Crataegus monogyna
Crataegus punctata
Crataegus submollis
Diervilla lonicera
Rubus flagellaris
Rubus hispidus
Euonymus alatus
Euonymus fortunei
Fagus grandifolia
Fagus sylvatica
Forsythia viridissima
Fraxinus americana
Fraxinus excelsior
Fraxinus nigra
Fraxinus pennsylvanica
Gleditsia triacanthos
Gymnocladus dioicus
Hamamelis virginiana
Hydrangea macrophylla
Ilex verticillata
Juglans ailantifolia
Juglans cinerea
Juglans nigra
Juglans regia
Juglans x bixbyi
Juniperus chinensis
Juniperus virginiana
Juniperus x pfitzeriana
Larix decidua
Larix laricina
Larix x pendula
Liriodendron tulipifera
Lonicera caerulea
Lonicera japonica
Lonicera maackii
Lonicera morrowii
Lonicera tatarica
Lonicera x bella
Lonicera xylosteum
Malus baccata
Malus prunifolia
Malus pumila
Metasequoia glyptostroboides
Morella pensylvanica
Morus alba
Ostrya virginiana
Paeonia suffruticosa
Parthenocissus quinquefolia
Phellodendron amurense
Physocarpus opulifolius
Viburnum opulus ssp. opulus
Viburnum recognitum
Pinus banksiana
Pinus nigra
Pinus resinosa
Pinus strobus
Pinus sylvestris
Platanus x hispanica
Populus alba
Populus balsamifera
Populus deltoides
Populus grandidentata
Populus nigra var. italica
Populus tremula
Populus tremuloides
Populus x canadensis
Populus x heimburgeri
Populus x jackii
Prunus avium
Prunus domestica
Prunus nigra
Prunus pensylvanica
Prunus serotina
Pyrus communis
Quercus alba
Quercus bicolor
Quercus macrocarpa
Quercus palustris
Quercus robur
Quercus rubra
Rhamnus cathartica
Rhodotypos scandens
Rhus aromatica
Ribes americanum
Ribes cynosbati
Ribes nigrum
Ribes rubrum
Ribes triste
Ribes uva-crispa
Robinia pseudoacacia
Rosa blanda
Rosa canina
Rosa multiflora
Rosa palustris
Rosa rubiginosa var. rubiginosa
Rosa rugosa
Acer nigrum
Acer palmatum

Rubus idaeus ssp. idaeus
Rubus occidentalis
Rubus odoratus
Rubus phoenicolasius
Salix alba
Salix amygdaloides
Salix bebbiana
Salix caprea
Salix cinerea
Salix cordata
Salix discolor
Salix eriocephala
Salix interior
Salix lucida
Salix nigra
Salix petiolaris
Salix purpurea
Salix viminalis
Salix x fragilis
Salix x pendulina
Salix x sepulcralis
Sorbaria sorbifolia
Sorbus aucuparia
Sorbus x thuringiaca
Spiraea alba
Spiraea x vanhouttei
Staphylea trifolia
Syringa reticulata
Syringa vulgaris
Taxus cuspidata
Thuja occidentalis
Tilia americana
Tilia cordata
Tilia x flavescens
Toxicodendron radicans var. radicans
Toxicodendron radicans var. rydbergii
Tsuga canadensis
Ulmus americana
Ulmus glabra
Ulmus pumila
Ulmus rubra
Viburnum acerifolium
Viburnum lantana
Viburnum lentago
Vitis riparia
Weigela florida
Rhamnus
Ribes
Rosa
Bursaria
Potentilla
Prunus virginiana
Quercus
Crataegus
Crataegus chrysocarpa
Weigela
Prunus
Taxus
Manilkara bahamensis
Picea
Spiraea japonica
Hibiscus syriacus
Juniperus
Malus domestica
Cornus
Salix
Quercus x macnabiana
Solanum
Ulmus
Ulmus parvifolia
Viburnum
Cornus sericea
Spiraea
Corymbia
Euonymus
Fraxinus
Populus trichocarpa
Physocarpus
Ligustrum
Crataegus x mordenensis
Betula
Sorbus
Rubus
Acer ginnala
Prunus x cistena
Acer
Acer campestre
Acer pseudoplatanus
Acer saccharum
Adonidia alba
Aesculus x carnea
Betula nigra
Carpinus caroliniana
Castanea dentata
Castanea pumila
Cercidiphyllum japonicum
Cercis canadensis
Cornus florida
Corylus
Corylus colurna
Crataegus viridis
Diospyros virginiana
Eucommia ulmoides
Frangula
Ginkgo biloba
Ilex
Liquidambar styraciflua
Magnolia
Magnolia acuminata
Malus
Malus tschonoskii
Morus rubra
Pinus
Pinus rigida
Platanus hybrida
Populus nigra 'Italica'
Prunus cerasifera
Pseudotsuga menziesii
Pyrus
Pyrus calleryana
Quercus coccinea
Quercus ellipsoidalis
Quercus muehlenbergii
Quercus prinus
Quercus/live virginiana
Rhus hirta
Salix x sepulcralis Simonkai
Sassafras albidum
Sorbus hybrida
Tilia cordata 'Greenspire'
Tsuga

Appendix 6: *Carruthers Creek Watershed Plan (CCWP) Land use Scenarios November 30, 2018*

Context:

Urbanization continues to drive land use change, converting areas dominated by natural cover to other land uses with impermeable surfaces. This has direct and indirect effects on ecological systems including its structure, processes, and functions that contribute to ecosystem and community well-being (Box 1). These benefits are important considerations when making decisions that will affect our ecological, social, and economic systems in urban and urbanizing areas.

Box 1: Ecosystem Structure, Function, and Service

The biophysical structures in the landscape (e.g. woodlands, wetlands) and the processes happening within them (e.g. net primary productivity and infiltration) enable proper functioning of the ecosystem (e.g. viable species populations and maintaining water flows). This produces important ecosystem services (e.g. wildlife viewing opportunities and flood protection) that benefit human well-being in various ways (e.g. improving mental health and safer communities).

In Durham Region various policies, plans, programs, strategies, and initiatives have been put it place to help achieve a sustainable and resilient future. This includes watershed plans, natural heritage systems, and climate adaptation plans, at both local and regional scales. The development of an updated Carruthers Creek Watershed Plan (CCWP), is one such initiative that will provide the Region with up-to-date information on the natural and built infrastructure within the watershed, their functions and interrelationships, and the services they provide for watershed and human health.

An effective way to assess how a watershed will respond to the potential future change is to develop, analyze, and compare several alternate scenarios, each reflecting a different composition of possible land use conditions. In this way, land use scenario modeling is used as a “gaming tool” to compare how possible future land uses might add to existing pressures on the natural system, and how these pressures might affect watershed health outcomes. Land use scenario modelling is a technical exercise that is typically undertaken when developing TRCA watershed plans to ensure management recommendations are based on the best available science. The results help guide the evaluation of proposed management actions and support municipalities in land use planning decisions. It is important to stress that scenario modeling does not result in decisions about the type and configuration of land uses, but instead it can inform these decisions, which are ultimately the responsibility of municipalities to make. The land use type and configuration, as determined by the municipality at the end of this process, may look very different from those that were applied through the scenario modelling exercise while developing the watershed plan.

While the Carruthers Creek watershed is relatively healthy today, it is not a static system. Despite good watershed management efforts to date by various stakeholders, the watershed exhibits signs of stress due to impacts from urbanization, other land uses, and likely climate change. Based on our knowledge of these pressures, future urban growth is expected to result in increased impacts on the watershed. The key components of watershed health, including hydrology, geomorphology, water quality, groundwater-surface water interactions, and terrestrial and aquatic ecosystems, and the potential impacts to these components are assessed under five land use scenarios. These scenarios reflect historical conditions (1999), existing

conditions (2015), and three potential future conditions that model the possible changes in both built and natural environments. The scenarios are a generalized version of the detailed land use maps depicted in municipal official plans, and some of the land use classes are combined for the modelling exercise. This process has minimal effects on the overall model results due to the scale and sensitivity of the models.

A comparison of impacts of each scenario will then be used to (i) update CCWP goals, objectives and targets, (ii) provide a better understanding of the implications of each land use scenario on each objective, and (iii) identify strategic actions that will assist Durham Region in its objective to achieve greater sustainability and resiliency.

The details of the impact assessments will be provided as separate technical documents as part of the CCWP Phase II. This brief provides an overview of the land use scenarios (summarized in Table 1 and Figure 1).

Land-Use Scenarios:

i. **Historical (1999)**

The "Historical" land use scenario reflects the land use that was in place prior to the 2003 Carruthers Creek watershed plan. The intent of this scenario is to show the historical context and illustrate changes in land use between 1999 and 2015, when the majority of the land use change occurred within the watershed. This scenario allows an understanding of the shifts in land use conditions and implications on the CCWP objectives.

ii. **Current (2015):**

The "Current" land use scenario assumes existing land use conditions and associated land cover characteristics (i.e., areas of imperviousness, vegetation, etc.) are maintained. Existing land uses and Natural Heritage Systems (NHS) were delineated based on aerial photo interpretation, land use data, NHS data from municipalities, and Ecological Land Classification data (TRCA 2015). Agricultural lands were updated using maps that were ground verified. This scenario provides a benchmark for describing current watershed conditions, identifies elements to be protected, and describes existing problems to be addressed.

iii. **Scenario 1 (+OP):**

The "Official Plan" scenario uses information from current local and Regional Official Plans (OPs) to provide insight into how the watershed conditions will likely change as approved OPs are implemented, and whether key priorities for CCWP objectives may emerge for management consideration.

The most up-to-date OP data were downloaded from Ajax, Pickering, and Durham, which was refined with on-the-ground information for both land use and land cover categories as well as NHS information as currently delineated in the OPs. In addition, all key natural heritage features and system, key hydrologic areas and other surface water features, including headwater drainage features, were delineated based on Growth Plan definitions (MMA 2017). Vegetation protection zones (30 m) were added to these features based on good state of practice (MMA 2017).

iv. Scenario 2 (+NHS)

The "Enhanced Natural Heritage System" scenario is based on the "Official Plan" (+OP) scenario supplemented with updated information from natural heritage planning science and practice locally and globally. This scenario provides insights into how the watershed conditions may change as OPs are implemented with explicit consideration for additional protection and management for goals and objectives associated with natural heritage features and system. This identifies additional potential key priorities and opportunities for proactive management to move towards a sustainable and resilient future.

This scenario includes OP land use designations including the NHS, and the 2007 TRCA Regional Terrestrial Natural Heritage System (TNHS) (TNHSS 2007). Minor refinements were made to the 2007 TNHS to ensure it is based on the most up to date information and reflects current developments as well as restoration opportunities. In addition to the refinements, additional areas for natural habitat protection and restoration were identified based on three major priorities and associated data as outlined below. Spatial data, landscape ecology principles, and expert opinion were used in conjunction with the data to identify locations within the watershed that would most effectively address these three priorities. Aerial photos and land use data were used to inform proposed additions that were practical/feasible.

a. *Priorities for local and regional connectivity for habitat and wildlife movement*

In recent years, habitat connectivity and wildlife movement priorities have been highlighted and addressed through various development planning and environmental planning processes in Durham and elsewhere with support from the partner Conservation Authorities including TRCA, LSRCA, and CLOCA. The new and updated data and information on habitat connectivity is available through TRCA (also used in TRCA Valley and Stream Corridor Crossings Guideline 2015). This was used to identify the priority areas for local connectivity important for daily and seasonal movements of wildlife as well as regional connectivity important for long-term adaptation movements. The updated information on north-south as well as east-west connections were used to identify potential additional areas for protection/restoration, where possible, within the watershed as a part of the enhanced NHS.

b. *Priorities for climate change adaptation for highly vulnerable areas*

Climate change adaptation is a principal consideration for priority planning, embraced by many governments both locally and globally. TRCA undertook a climate change vulnerability assessment for terrestrial systems to identify areas that are predicted to be highly vulnerable to changes in

climate. The climate condition that was assumed predicts the region to be hotter at all times of the year, changes to seasonal precipitation patterns, more rainstorms and more heat waves. Winter, spring, and fall are predicted to be wetter, while summer is predicted to be drier on average, but punctuated by heavy storms. Based on this the terrestrial systems including forests, wetlands, and meadows were assessed to identify the level of vulnerability. The areas assessed to be more vulnerable were used to identify additional protection / restoration / management measures, where possible, within the watershed as part of the enhanced NHS.

c. *Priorities for enhancing habitat size and configuration for ecosystem quality and diversity*
The size and configuration of natural features influences habitat quality and the ability to support a diversity of vegetation communities and species. Size and configuration (both existing and potential) in conjunction with TRCA's restoration opportunities database, species inventory data, and the available information on existing and planned land uses were used to identify additional areas for potential enhancement to the NHS.

The enhanced NHS scenario was developed based on the TRCA's TNHSS (TRCA 2007) principle that if there is a robust natural system that can sustain ecosystem functions in terms of habitat and species diversity in the face of climate and land use change, then it will likely ensure the long-term provision of a variety of ecosystem services for human well-being. Thus, it is important to note that this scenario explicitly included additional areas based on the needs and opportunities for enhancing the terrestrial natural system only. Specific needs such as driven by Species at Risk (SAR) legislation and other priorities will require additional consideration to supplement the proposed enhancements in this scenario.

v. Scenario 3
(+Potential Urban)

The "Potential Urbanization" scenario assumes an urban boundary expansion within the "whitebelt" area in northern parts of the watershed. The potential urbanization area was added to Scenario 2, which included the existing land use and OP and the enhanced NHS. This illustrates prospective development in the headwaters area outside of the enhanced NHS should such land area be intensified from a land needs perspective. These areas are assumed to be built with similar implications on watershed processes and thus any analysis using this scenario interprets the entire potential urbanization area as having a uniform value. There is no change expected in the existing urban area south of the Greenbelt. Evaluation of this scenario in relation to watershed objectives provides insight into how the watershed conditions will likely change if urbanization is planned in this portion of the watershed and whether there are key priorities that emerge for management consideration.

Next Steps:

As of October 29, 2018, the land use scenarios are being used to assess impacts on various watershed goals, objectives, and targets related to hydrology, geomorphology, water quality, groundwater-surface water interactions, and terrestrial and aquatic ecosystems outlined in the 2003 CCWP. The preliminary results of the comparative assessment of impacts under each of the scenarios are iteratively being used to (i) update these goals, objectives and targets, (ii) provide a better understanding of the implications of each land use scenario on each objective, and (iii) identify strategic actions on the ground that will assist Durham Region meet its sustainability and resiliency.

Table A.6.1 Descriptions of future land use scenarios for the Carruthers Creek watershed

Scenario	**Description**
Historical	Historical land use conditions from 1999 prior to 2003 Carruthers Creek Watershed Plan.
Current	Existing land use conditions from 2015 based on aerial photo interpretation.
Scenario 1 (+OP)	Refines Current conditions by assuming all lands south of the Greenbelt are now developed as approved up to 2031 in the applicable Official Plans. Only minor changes from 2015 have resulted as most of the urban area was already developed in 2015.
Scenario 2 (+NHS)	Refines Scenario 1 by adding an enhanced Natural Heritage System as per the approved Official Plans and using updated information on terrestrial habitat connectivity, habitat configurations, and climate vulnerabilities.
Scenario 3 (+Potential Urban)	Illustrates prospective development in the headwaters area outside of the enhanced Natural Heritage System identified in Scenario 3. There is no change in the existing urban area south of the Greenbelt.

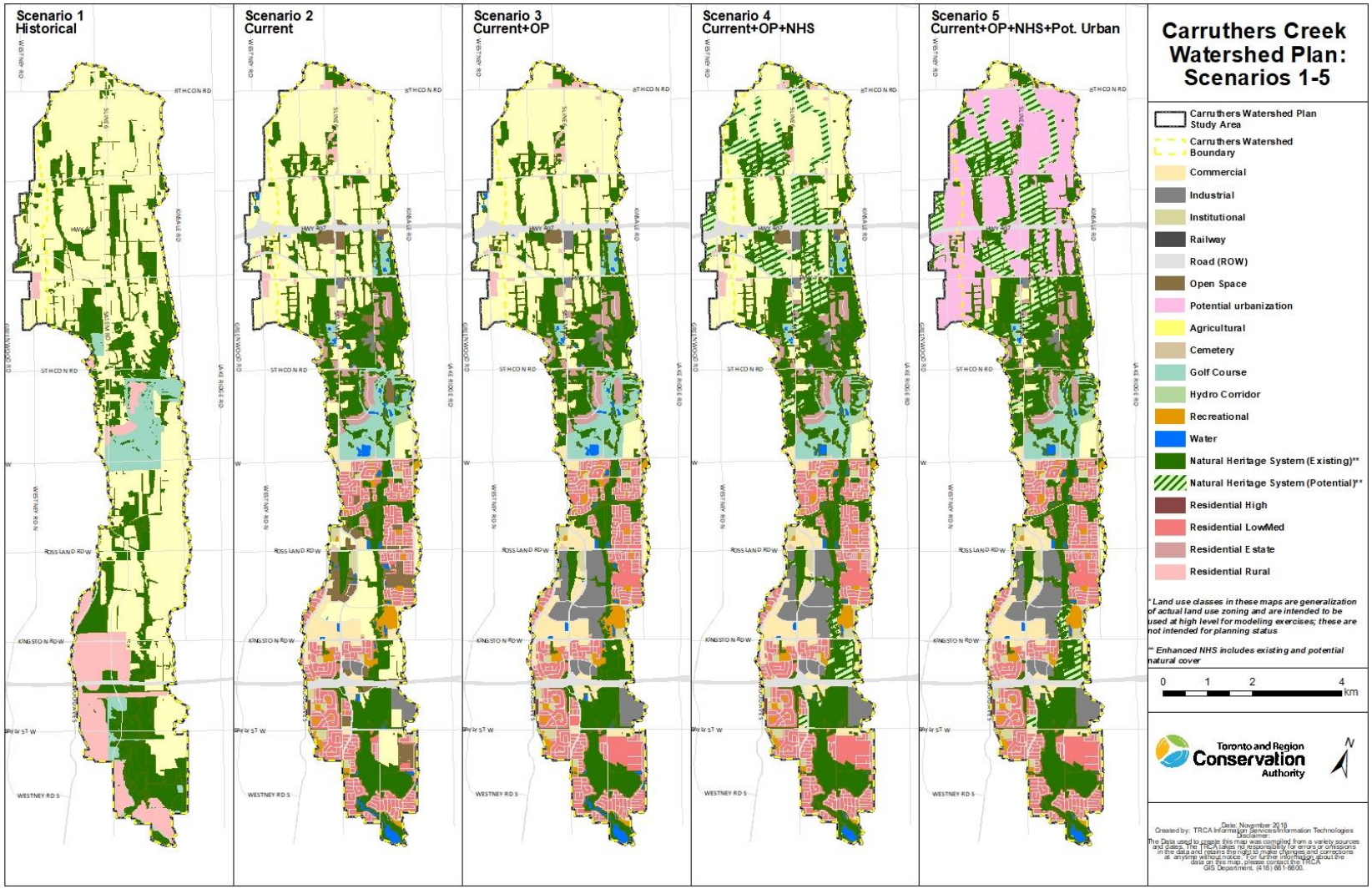
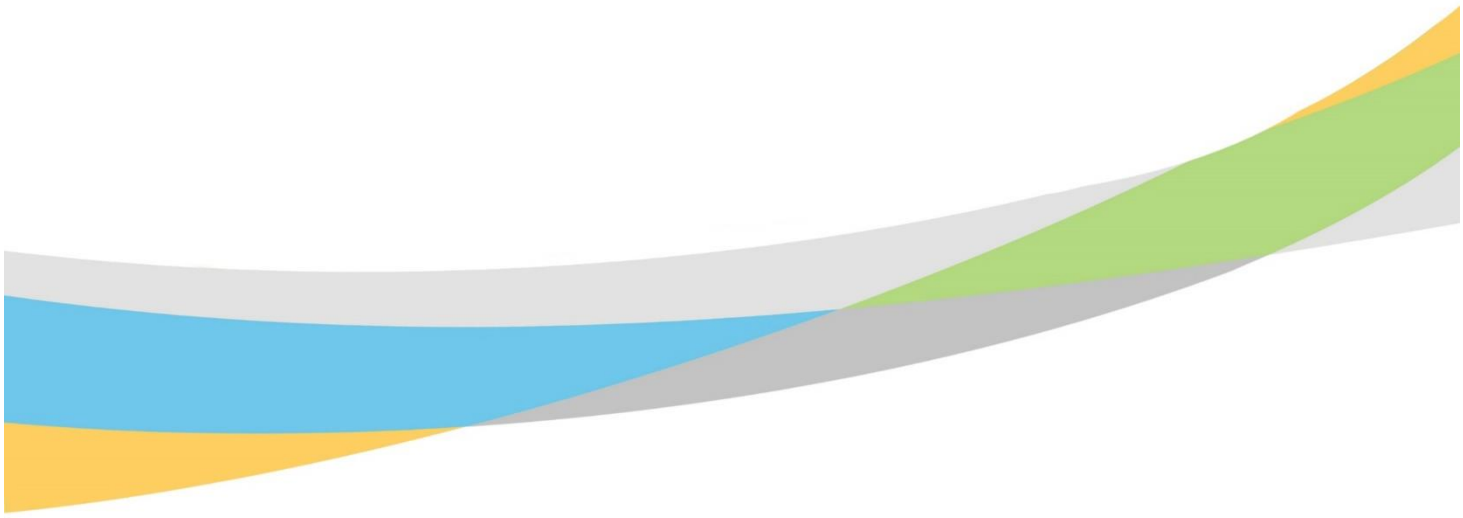


Table A.6.2. Five land use scenarios for the Carruthers Creek watershed depicting (i) Historical (Scenario 1), (ii) Current (Scenario 2), (iii) Current + Official Plan (Scenario 3), (iv) Current + Offical Plan + enhanced Natural Heritage System (Scenario 4), and Current + Official Plan + enhanced Natural Heritage System + Potential Urbanization (Scenario 5)



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