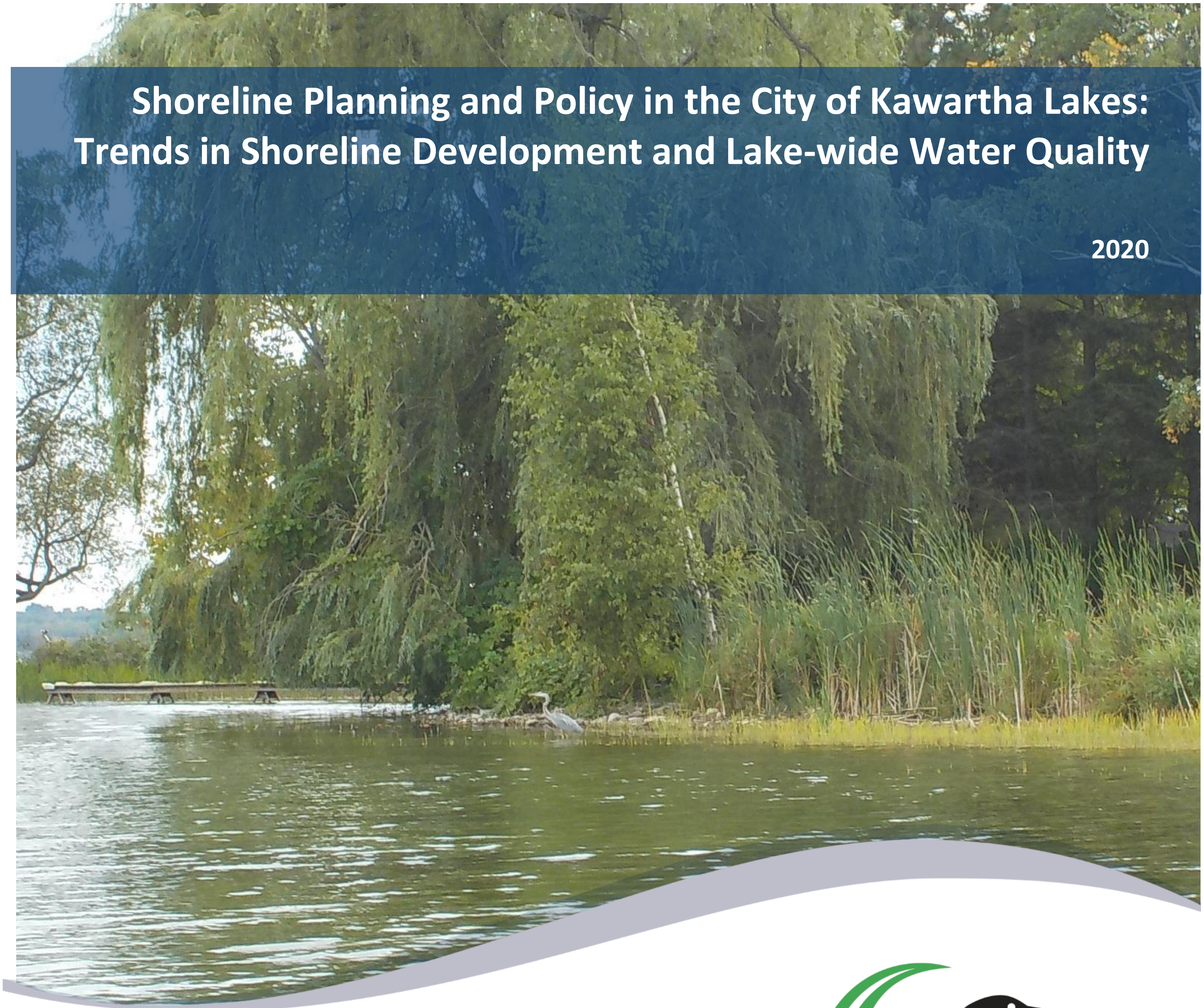
Shoreline Planning and Policy in the City of Kawartha Lakes: Trends in Shoreline Development and Lake-wide Water Quality

2020



KAWARTHA CONSERVATION

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About Kawartha Conservation

Who we are

We are a watershed-based organization that uses planning, stewardship, science, and conservation lands management to protect and sustain outstanding water quality and quantity supported by healthy landscapes.

Why is watershed management important?

Abundant, clean water is the lifeblood of the Kawarthas. It is essential for our quality of life, health, and continued prosperity. It supplies our drinking water, maintains property values, sustains an agricultural industry, and contributes to a tourism-based economy that relies on recreational boating, fishing, and swimming. Our programs and services promote an integrated watershed approach that balance human, environmental, and economic needs.

The community we support

We focus our programs and services within the natural boundaries of the Kawartha watershed, which extend from Lake Scugog in the southwest and Pigeon Lake in the east, to Balsam Lake in the northwest and Crystal Lake in the northeast – a total of 2,563 square kilometers.

Our history and governance

In 1979, we were established by our municipal partners under the *Ontario Conservation Authorities Act*. The natural boundaries of our watershed overlap the six municipalities that govern Kawartha Conservation through representation on our Board of Directors. Our municipal partners include the City of Kawartha Lakes, Region of Durham, Township of Scugog, Township of Brock, Municipality of Clarington, Municipality of Trent Lakes, and Township of Cavan-Monaghan.

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Executive Summary

Lake Management Planning in the City of Kawartha Lakes has affirmed the imperative for enhanced shoreline land use planning being a key tool towards maintaining healthy lakes across the municipality, given the link between healthy lakes and vibrant and healthy communities and economies.

The purpose of this project is to provide a characterization of apparent trends and relationships between shoreline development and water quality in the major lakes across the municipality to provide background information to municipal planners to assist with any efforts in considering enhanced shoreline related planning and policy approaches.

Results indicate that even though negative impacts to lake water quality from shoreline development have been well documented in the scientific literature, and are likely impacting local lakes, significant relationships are not readily apparent in major lakes within the City of Kawartha Lakes with respect to lake-wide nutrient enrichment and other supporting water quality indicators. Given the complex nature of Kawartha Lakes aquatic ecosystems, there are several other overarching factors that likely have a greater influence on lake-wide water quality. Nearshore water quality information is currently lacking, but when available would likely be better able to detect impacts from shoreline development than existing lake-wide water quality information.

The following table summarizes the key findings noted related to trends and relationships between shoreline development and water quality:

Trends in Shoreline Development	Existing: As of 2018, development occupies approximately 45% on average (range 28 to 55%) of the shoreline land area along 120m of each lake.
	Past: From 1988 to 2018, development has increased by approximately 68% on average (range 0 to 342% increase) along the shorelines of each lake.
	Future: Expansion and intensification of existing shoreline development are expected to continue for all lakes into the foreseeable future, however the rate of increase is not clear.
Trends in Lake-wide Water Quality	Existing: Water quality on the study lakes is generally considered moderate-to-good but many lakes experience symptoms of nutrient enrichment, with headwater lakes being more vulnerable to shoreline development impacts.
	Past: Water quality as represented by nutrient enrichment status has improved over the last 30 years, but has remained relatively stable since the 2000's.
	Future: The future trajectory of water quality is not well understood due to the complex nature of lake ecosystems and the lack of data related to water quality projections.
Relationship between Shoreline Development and Water Quality	Existing: There are no obvious relationships between key indicators of shoreline development and lake-wide water quality across the study lakes.
	Past: Significant increases in shoreline development over the last 30 years has not coincided with a general deterioration of lake-wide water quality as indicated by nutrient enrichment.
	Future: Water quality impacts associated with shoreline development are likely more detectable in nearshore waters (as opposed to open lake waters), research into which is currently being undertaken.

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Acknowledgements

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1.0 Introduction

Enhancing and maintaining the natural integrity of shorelines in the City of Kawartha Lakes is a priority objective in the recently completed Lake Management Plans (Kawartha Conservation, 2010-2019), given that developments are concentrated along more than 4,800 km of shorelines within this lake-based municipality.

Shorelines are often referred to as the 'ribbon of life' and are relatively sensitive to development. They provide multiple benefits to the lake ecosystem including filtering contaminants, preventing erosion, and providing fish and wildlife habitat.

Pressures along the shoreline are expected to grow, as waterfront lots are popular retirement destinations for an aging population. Many developments are also transitioning from seasonal holiday cottages to permanent homes. To address development and other related land use impacts to lakes, the Lake Management Plans recommended that enhanced shoreline planning and policy be considered by the City of Kawartha Lakes.

To assist the municipality with these efforts, Kawartha Conservation has undertaken a two-part Shoreline Planning and Policy project. This summary report constitutes the deliverables for part 2 of the project, and focuses on characterizing and identifying relationships between shoreline development and lake-wide water quality, which include:

- research environmental changes in shoreline land use across the City of Kawartha Lakes; and,

- identify linkages between shoreline land use trends and lake health particularly lake-wide water quality.

This background information will be useful for municipal planning staff as they consider various enhanced shoreline policy and planning approaches intended to maintain lake health and good water quality conditions in perpetuity.

Part 1 of the project focused on summarizing Official Plan shoreline policies of several lake-based municipalities in Ontario, and lessons learned from staff implementing them. This information is summarized in a separate publication.

2.0 Review of Background Information

The consequences of shoreline disturbance on lake health are well documented in the scientific literature and can result in reduced ecosystem function and reduced human benefits, for example:

- Water quality: developed shorelines can be a greater source of fecal indicator bacteria than undeveloped shorelines (Hendry and Leggatt, 1982), increases in sodium and chloride are greater in developed lakes that are close to winter-maintained roads (Palmer et al., 2011), and lake capacity models have been developed for certain lakes that predict how the quality of water in a lake will change in response to the addition or removal of shoreline development such as cottages, permanent homes and resorts (Province of Ontario, 2010).

- Fish and Wildlife: alterations to vegetation composition and structure along shorelines can alter aquatic ecosystems for example by changing fish abundance (Taillon and Fox, 2004), changing aquatic invertebrate communities (Edwards et al., 2013), impacting small mammal abundance and activity (Racey and Euler, 1982), and lowering nesting success of birds including Common Loon (Robertson, 1980).

- Socioeconomic: areas of high angling intensity can alter the shoreline environment and contribute to localized pollution and environmental degradation (O'Tool et al., 2009), and water clarity can have a significant effect on lakefront property as results from Ontario indicate that buyers are willing to pay about 2% more for each 0.3 metre increase in water clarity (Clappera and Caudill, 2014).

The shorelines along most of the large lakes in the City of Kawartha Lakes have, for the past 200 or more years, been subject to extensive direct shoreline modifications from development and from other large-scale modifications such as water level regulation, logging, and other activities associated with human colonization of the area. These and other ongoing impacts (e.g., invasive species and climate change) have ultimately, in a cumulative manner, influenced the current state of the lakes and their shorelines.

Literature that examines the impacts and linkages between lake water quality shoreline development specific to the Kawartha Lakes are relatively sparse. Notable research that has been undertaken includes the following:

- In the 1970's the Ontario Ministries of Environment and Natural Resources released a series of technical reports for most major lakes in the municipality and documented elevated fecal indicator bacteria in waters close to dense shoreline developments. This was attributed in large part to poorly functioning local wastewater systems.

- In 2002 Gartner Lee and French Planning examined phosphorus loadings in Sturgeon Lake, as a representative lake of the Kawartha Lakes, and concluded that shoreline land use had negligible impacts to water quality on a lake-wide basis. This is because given phosphorus is fundamental to water quality, shoreline contributions of phosphorus are small in the Kawartha Lakes relative to the total contributions from all sources.

- In the 2010's Kawartha Conservation released a series of Lake Management Plans and Characterization Reports for major lakes in the municipality that provided summaries of existing water conditions, including an estimate of phosphorus loading from shorelines areas (including from septic systems and urban stormwater runoff) relative to all phosphorus contributions.

The current but limited available literature tends to support the notion that shoreline development around a lake tends to impact water quality within the nearshore environment disproportionally more-so than its open waters (e.g., lake-wide). This is supported generally by the findings of this project, as explained in Section 6.0 in this report.

Example of a heavily development shoreline – Washburn Island, Lake Scugog (photo credit: Lou Wise, June 2007)

3.0 Study Area

The study area for this project encompasses most of the large lakes and their respective shorelines in the municipality of the City of Kawartha Lakes (Table 1, Figure 1).

All the lakes are located entirely within this municipality, except for Pigeon Lake (overlaps with Peterborough County, Selwyn Township, and Municipality of Trent Lakes) and Lake Scugog (overlaps with Durham Region and Scugog Township).

These lakes collectively represent approximately 60% of the surface area of all waterbodies in the City of Kawartha Lakes. All are within the management regime of the Trent-Severn Waterway National Historic Site, except for Head Lake and Four Mile Lake. The remaining 40% consist mostly of dozens of smaller lakes and river systems that exist within the northern half of the municipality, and includes the relatively large Lake Dalrymple.

The shoreline area of interest includes all lands around the study lakes that exist 120m inland from their shoreline, including large islands. The 120m distance-from-the-lake was chosen to represent the shoreline area because it is the same terminology often used to define 'adjacent lands' for Natural Heritage and related provincial and municipal land use planning and policy purposes.

These shorelines collectively represent approximately 10% of the length of all rivers and lakes within the City of Kawartha Lakes. The remaining 90% exist mostly along the numerous smaller lakes within the northern half of the municipality, and the numerous rivers that exist across the entire municipality.

Table 1. List of lakes included in the study and associated characteristics. * denotes the shoreline portion within the City of Kawartha Lakes.

	Lake Surface Area (km^2)	Lake Drainage Area (km^2)	Shoreline Length (km)	Shoreline Area – 120m inland from shoreline (km^2)
Balsam Lake	48	1,636	82	8.2
Cameron Lake	15	3,100	29	2.6
Canal Lake	9	256	36	3.5
Four Mile Lake	8	51	22	2.0
Head Lake	9	130	20	2.0
Lake Scugog	68	530	62*	6.8*
Mitchell Lake	3	44	21	1.9
Pigeon Lake	57	5,287	80*	7.1*
Shadow and Silver Lake	4	1,346	28	2.4
Sturgeon Lake	47	4,600	107	11.1

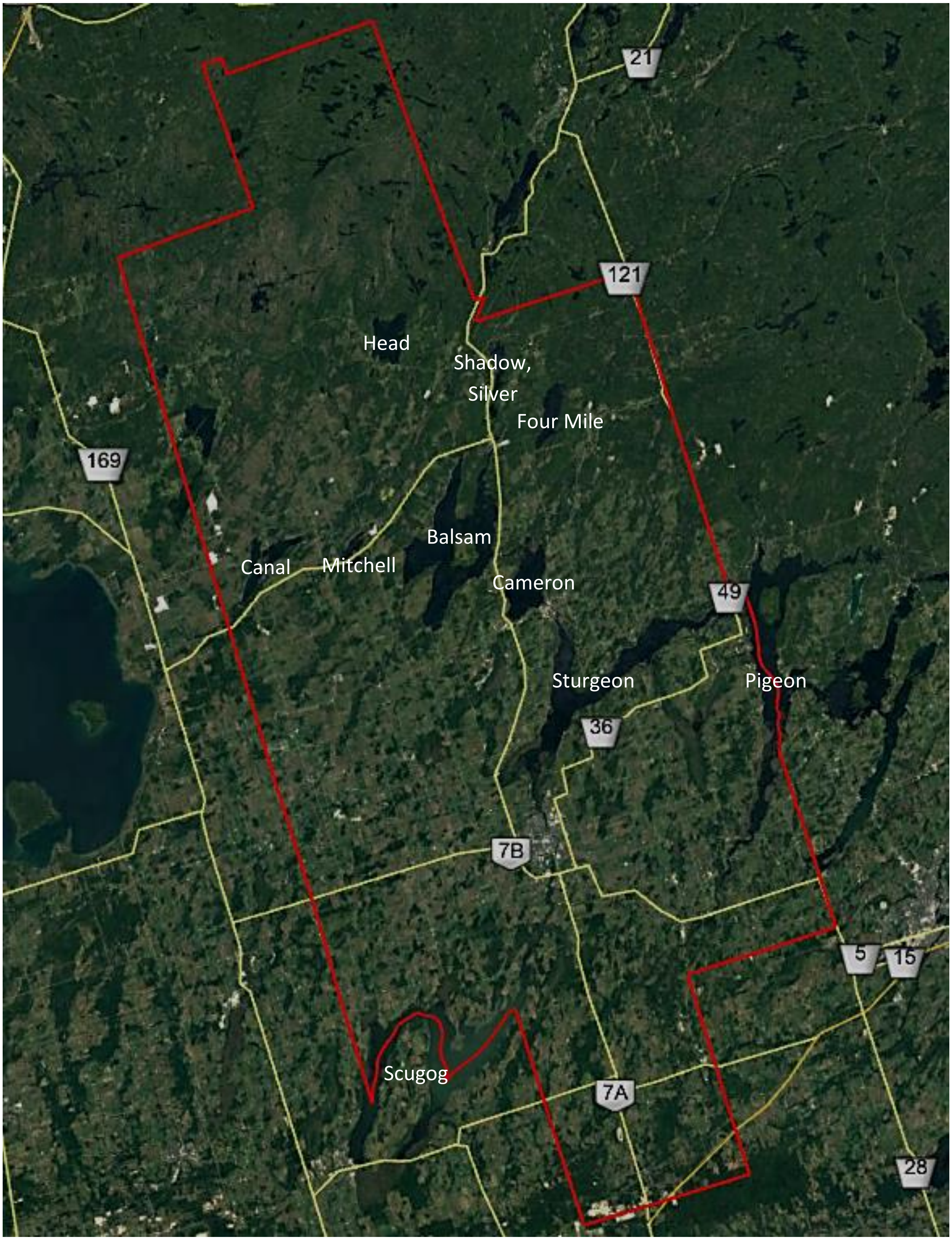

Figure 1. Map of study lakes within the City of Kawartha Lakes.

4.0 General Trends in Shoreline Development

Key Finding: As of 2018, development occupies approximately 45% on average (range 28 to 55%) of the shoreline land area along 120m of each lake.

Shoreline development involves the modification of natural features along a lake to accommodate human uses associated with residential, commercial, and industrial and related activities. It typically means the removal or alteration (sometimes only temporarily, but often permanently) of existing natural features such as forests, wetlands, and grasslands and constructing in-and-among their place roads, buildings, dwellings, retaining walls, utilities, and other structures.

To characterize the current state of shoreline development for the study lakes 2018 aerial imagery was used to identify all the different land use types that exist within 120m from shore. Using Ecological Land Classification (Lee et al., 1998) and related (CVCA, 1998) methodology 27 unique land use types were identified, 5 of which (Rural Development[1], Urban Development[2], Manicured Open Space[3], Active Aggregate[4], and Inactive Aggregate[5]) were grouped to represent shoreline development. Please refer to Appendix B for a list of all land use types and relative percentages for each lake. Supporting indicators used to characterize existing shoreline development include the length of artificial shorelines along the land-water interface (e.g., retaining walls made of steel, concrete, and wood, and manicured lawn edges), and the density of roads within 120m from shore.

Results indicate that development occupies a significant portion of the shorelines of all lakes. Just under half (45%) of the total shoreline area on average for each lake is considered to be in a developed state. Values range from a high of 55% on Cameron Lake to a low of 28% on Mitchell Lake, with almost one-third of the study lakes (Cameron Lake, Head Lake, Balsam Lake) having more development than natural areas (Figure 2). Shorelines identified as agricultural land use exist as a relatively small percentage (3%) on average per lake but can occupy as much as 8 to 10% (Mitchell Lake and Lake Scugog, respectively). Natural areas remain the dominant land use for most lakes, but only slightly ahead of developed areas, accounting for on average 52% for each lake. The remaining natural areas consist primarily of upland forest (27%), lowland forest (18%), marsh wetland (17%).

Artificial edge's account for an average of 16%, and range from 8 to 25%, of the total shoreline length for each lake. Data is lacking for Balsam Lake, Cameron Lake, and Head Lake. Road density averages 6 km/km^2, and range from 4 to 8 km/km^2, along the total shoreline area for each lake.

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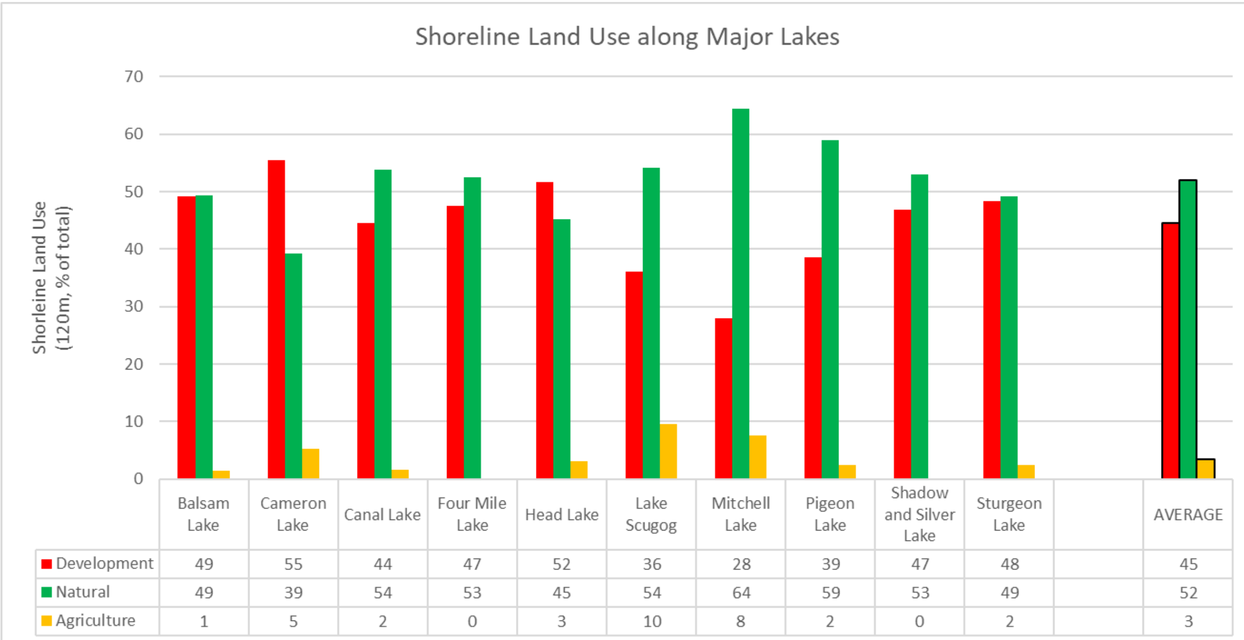
[1] variable, but typically 0.2 ha < area < 2.0 ha containing development not associated with agriculture.
[2] variable, but typically > 5 residential units in an area > 2 ha, generally residential.
[3] regularly maintained, gardens, parks, ski hills, cemeteries, open spaces. >2ha and resulting from or maintained by cultural or anthropogenic-based disturbances.
[4] barren, heavily disturbed open pit or quarry.
[5] surface cover ≥ 25% or barren, currently unused open pit or quarry.



	Balsam Lake	Cameron Lake	Canal Lake	Four Mile Lake	Head Lake	Lake Scugog	Mitchell Lake	Pigeon Lake	Shadow and Silver Lake	Sturgeon Lake		AVERAGE
Development	49	55	44	47	52	36	28	39	47	48		45
Natural	49	39	54	53	45	54	64	59	53	49		52
Agriculture	1	5	2	0	3	10	8	2	0	2		3

Figure 2. Major shoreline land use categories for each lake, as of 2018.

Table 2. Indicators of shoreline development. * denotes City of Kawartha Lakes shoreline only.

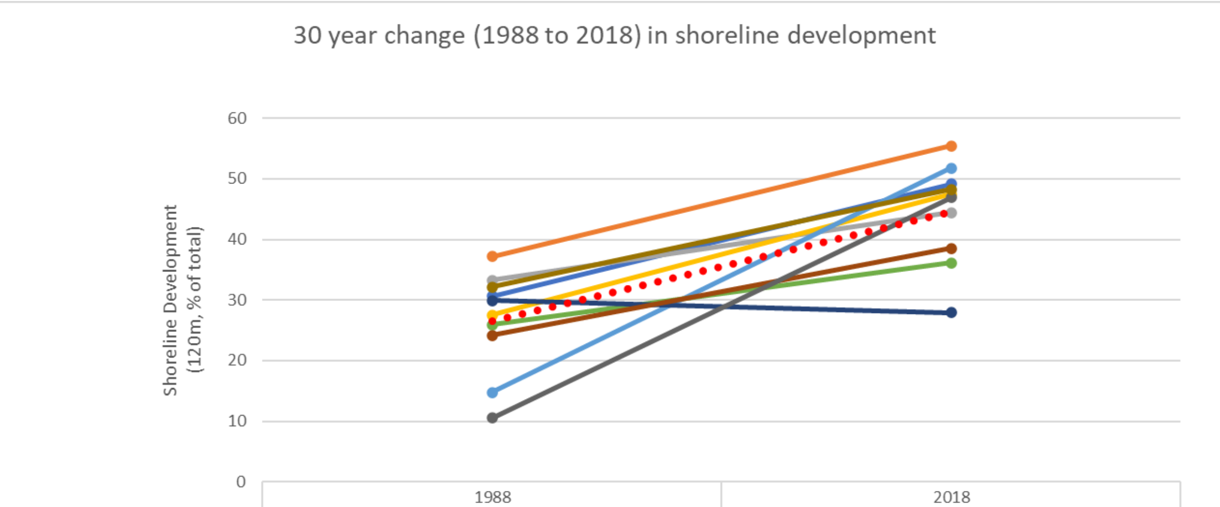
	Developed Shoreline within 120m (% of total area)	**Artificial Water's Edge (% of total length)**	**Road Density within 120m (km/km^2)**
Balsam Lake	49.1	No data	5.3
Cameron Lake	55.5	No data	6.7
Canal Lake	44.5	24.0	4.7
Four Mile Lake	47.5	7.9	7.0
Head Lake	51.8	No data	5.9
Lake Scugog	36.1*	9.0	8.2
Mitchell Lake	27.9	16.0	3.5
Pigeon Lake	38.6*	17.0	7.2
Shadow Lake	46.9	11.4	6.4
Sturgeon Lake	48.3	25.0	5.6
AVERAGE	**44.6**	**15.8**	**6.1**

Key Finding: From 1988 to 2018, development has increased by approximately 68% on average (range 0 to 342% increase) along the shorelines of each lake.

To characterize changes in shoreline development over time, 2018 land use information was compared against 1988 land use information collected using the same Ecological Land Classification and related methodology. Specific locations where development has increased substantially (i.e., greater than 50% increase from 1988 to 2018) along the shoreline of each lake have also been identified by calculating the percent increase within one-hectare grids over the same period.

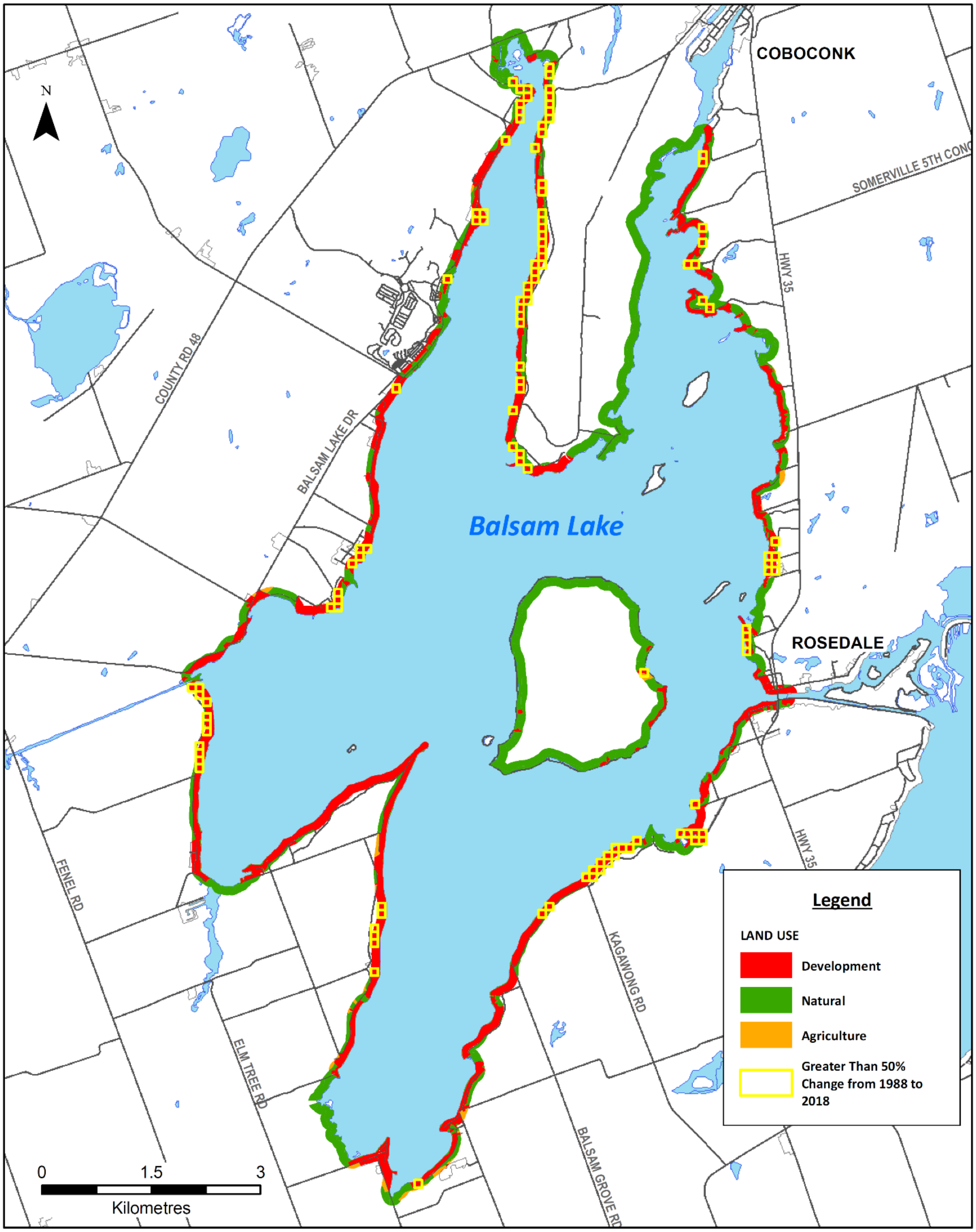
Results indicate that all lakes except Mitchell Lake have experienced significant increases (68% increase on average from 1988 values) in shoreline development over the past 30 years (Figure 3). In 1988 developed areas on average accounted for 27% of the total shoreline area of each lake, which subsequently increased to 45% by 2018. Shadow and Silver Lake and Head Lake experienced the highest increase, quadrupling and tripling their shoreline development areas, respectively. The remaining lakes, except for Mitchell Lake, each experienced approximately a 50% increase over this period.

Developed areas around each lake, as well as the sections that experienced substantial growth, are shown in Figure 4 to Figure 13.



	1988	2018
Balsam Lake	31	49
Cameron Lake	37	55
Canal Lake	33	44
Four Mile Lake	27	47
Head Lake	15	52
Lake Scugog	26	36
Mitchell Lake	30	28
Pigeon Lake	24	39
Shadow and Silver Lake	11	47
Sturgeon Lake	32	48
AVERAGE	27	45

Figure 3. Change in developed shorelines from 1988 to 2018.



SHORELINE LAND USE (120m)

Figure 4. Balsam Lake shoreline land use.

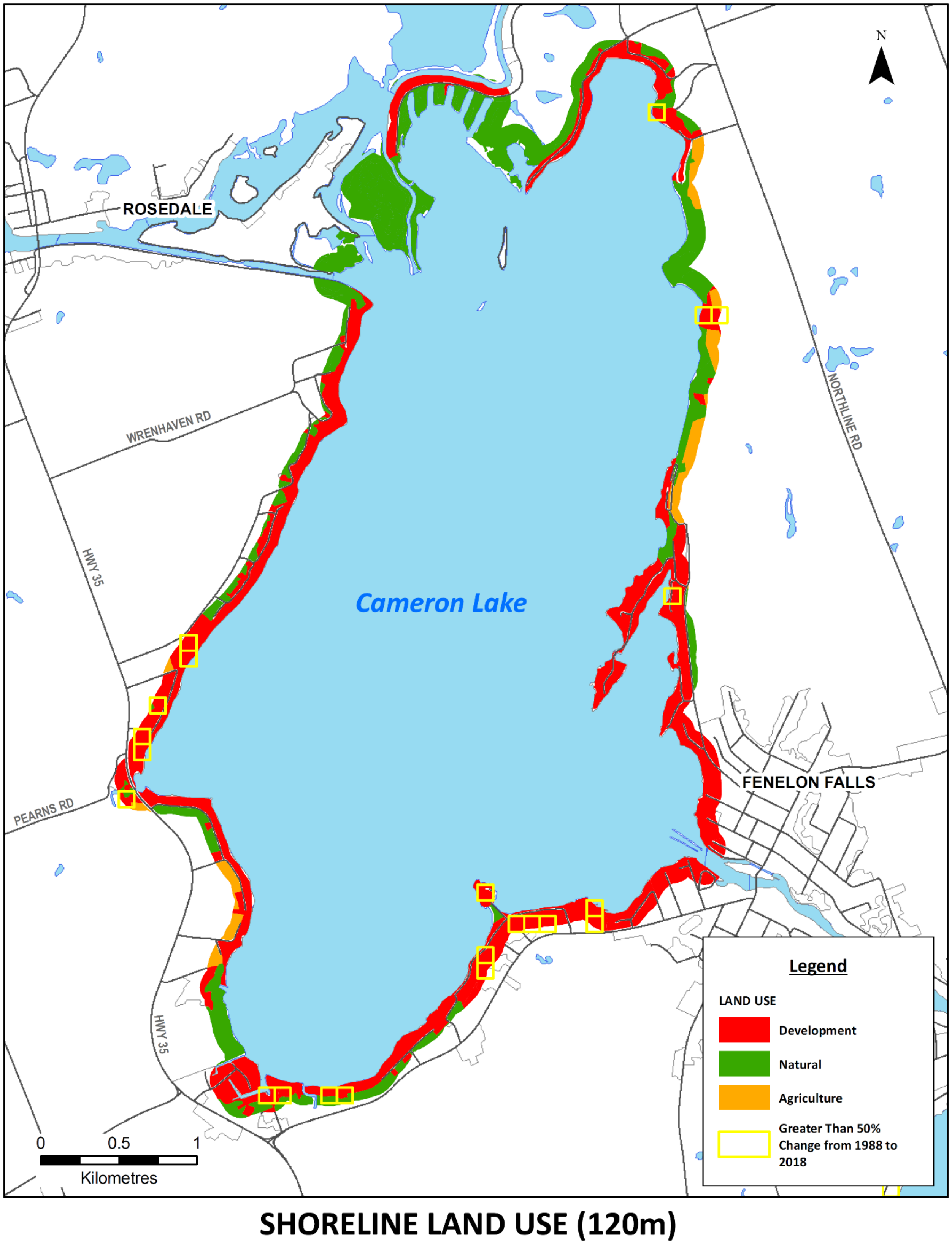


Figure 5. Cameron Lake shoreline land use.

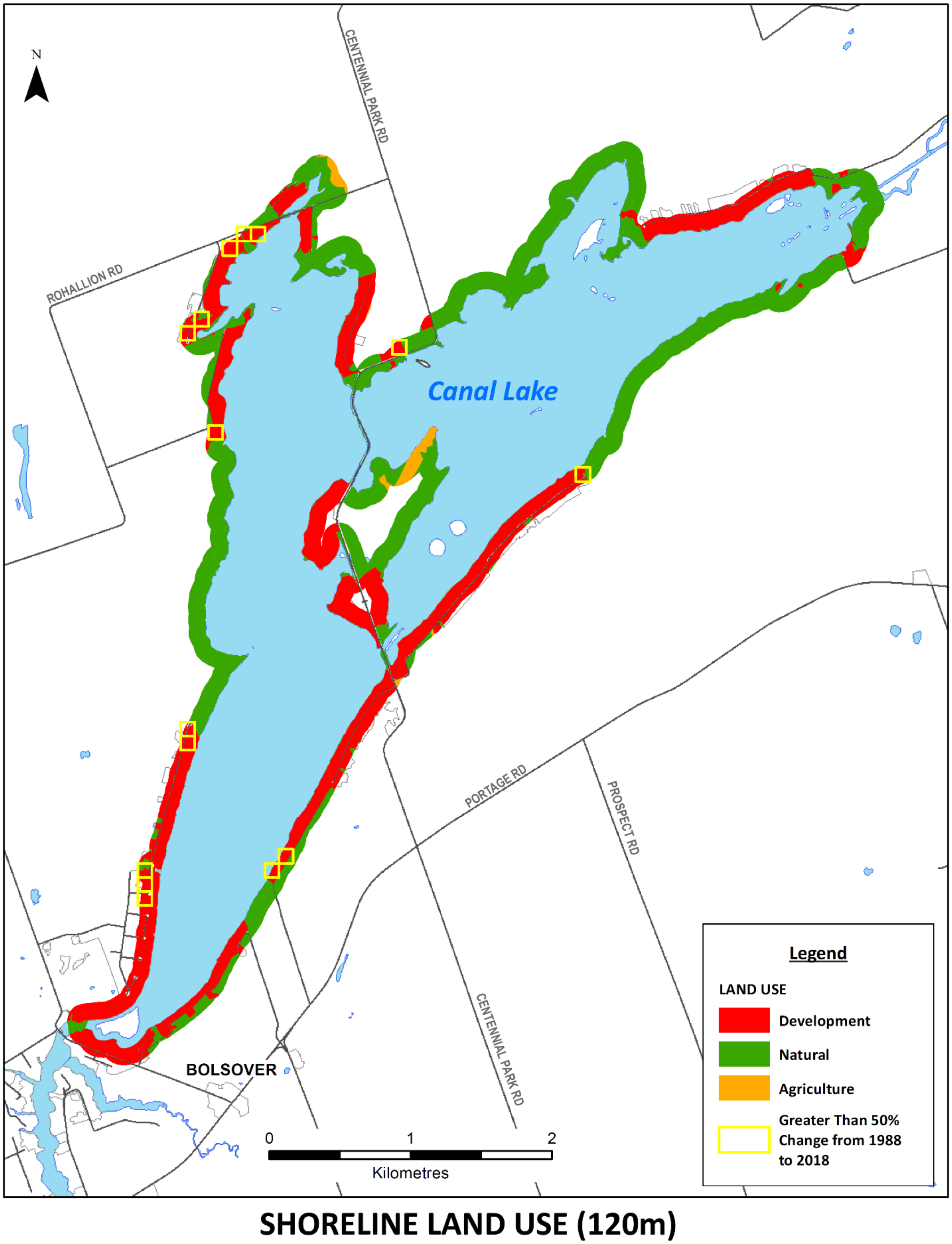
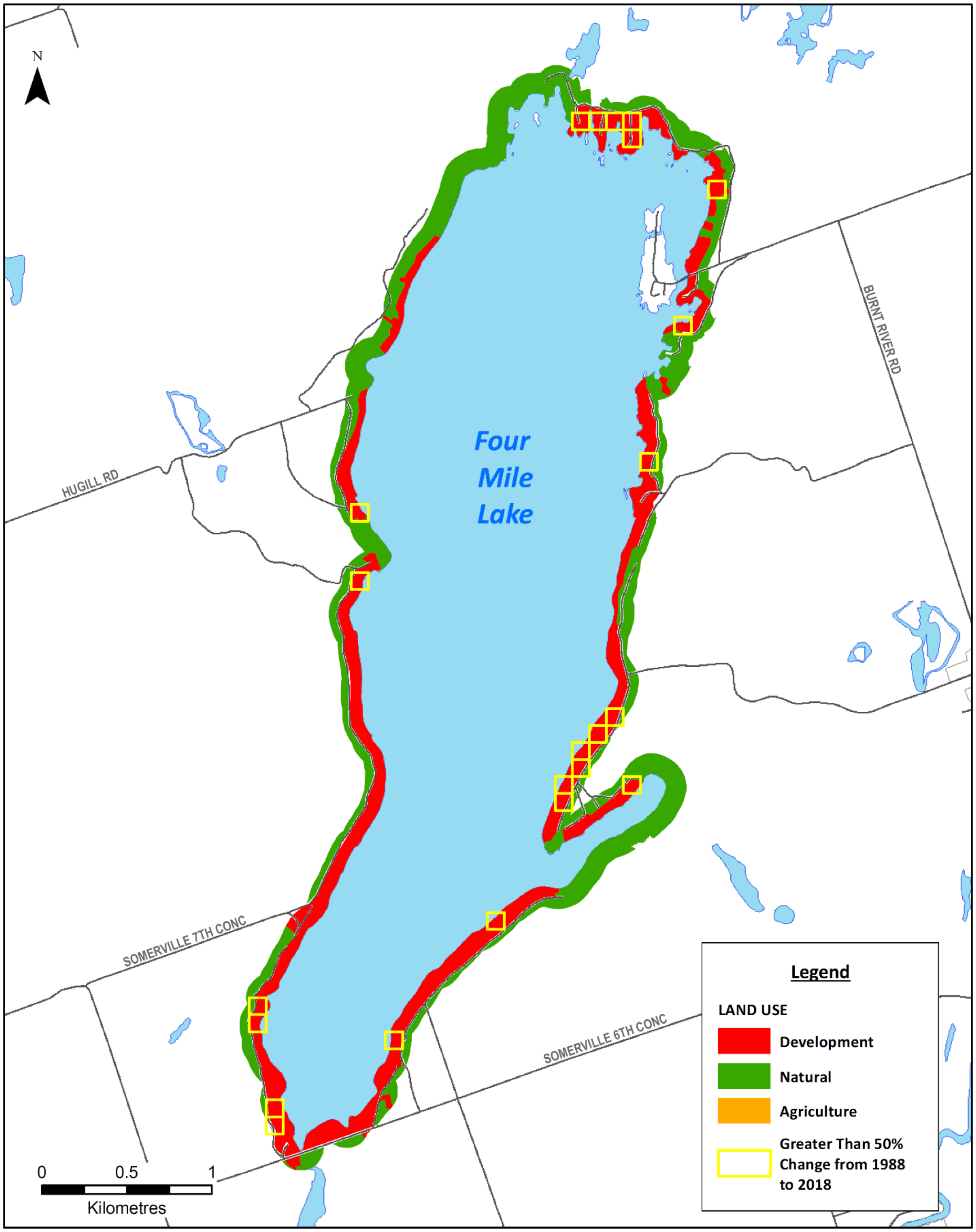
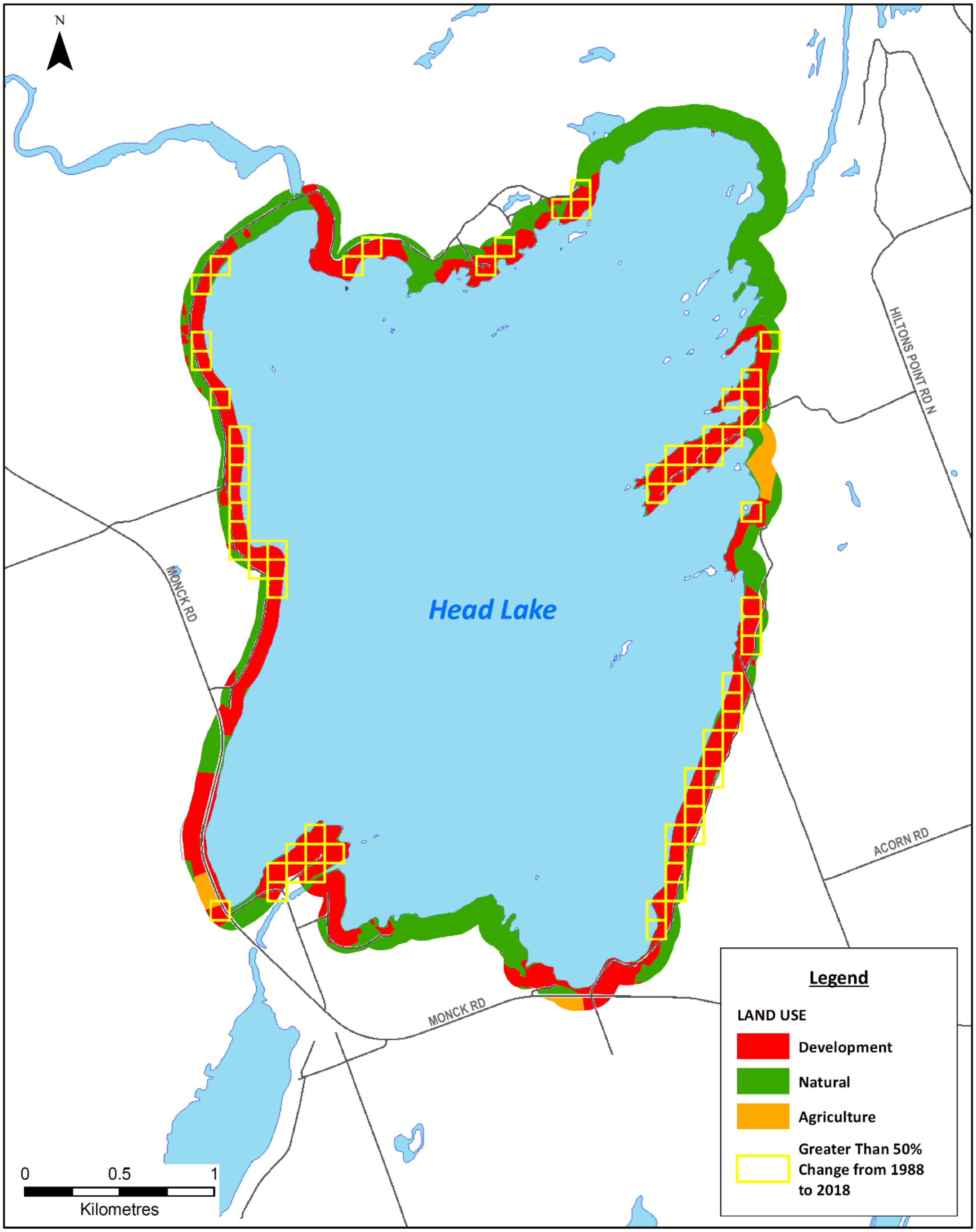


Figure 6. Canal Lake shoreline land use.



SHORELINE LAND USE (120m)

Figure 7. Four Mile Lake shoreline land use.



SHORELINE LAND USE (120m)

Figure 8. Head Lake shoreline land use.

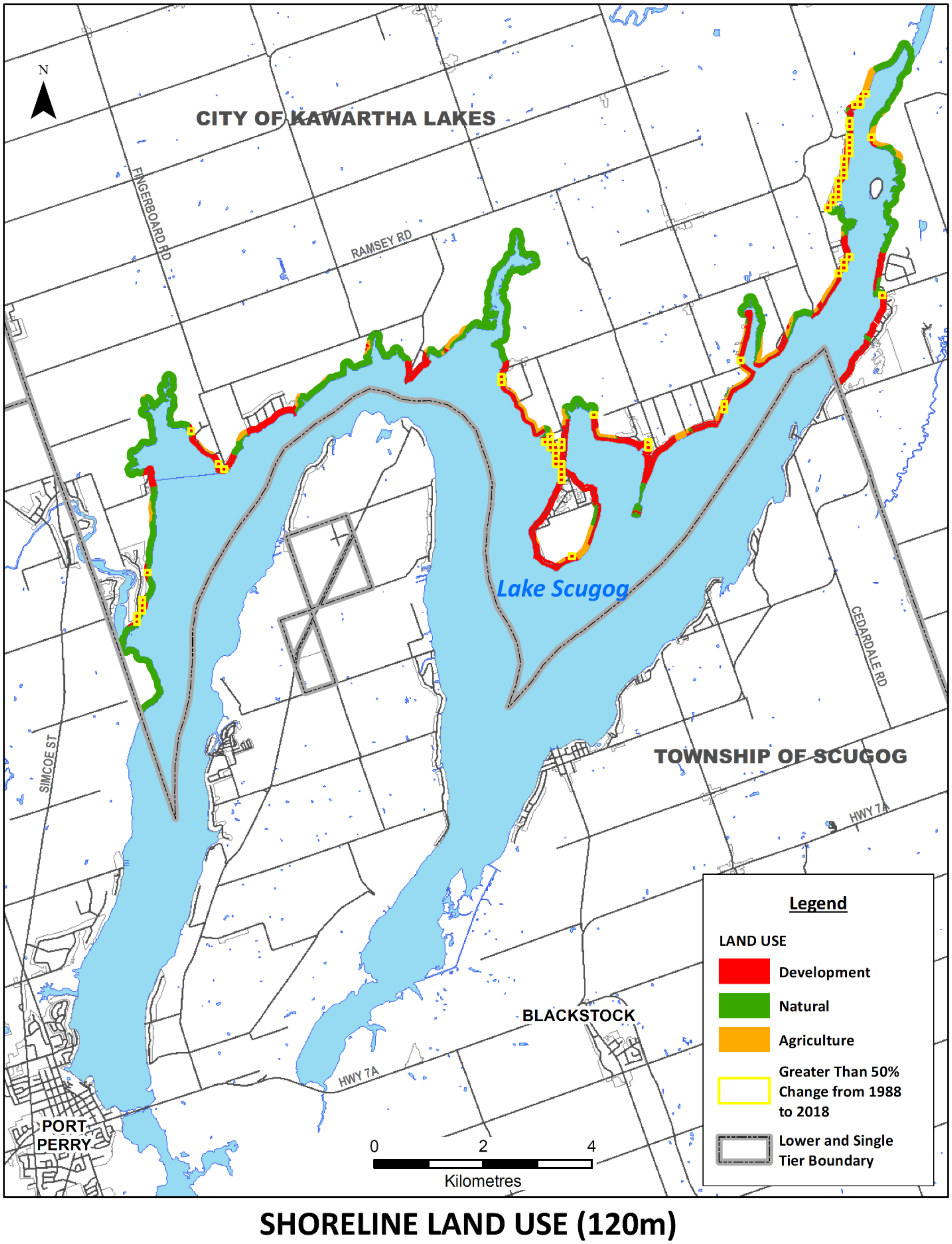


Figure 9. Lake Scugog shoreline land use.

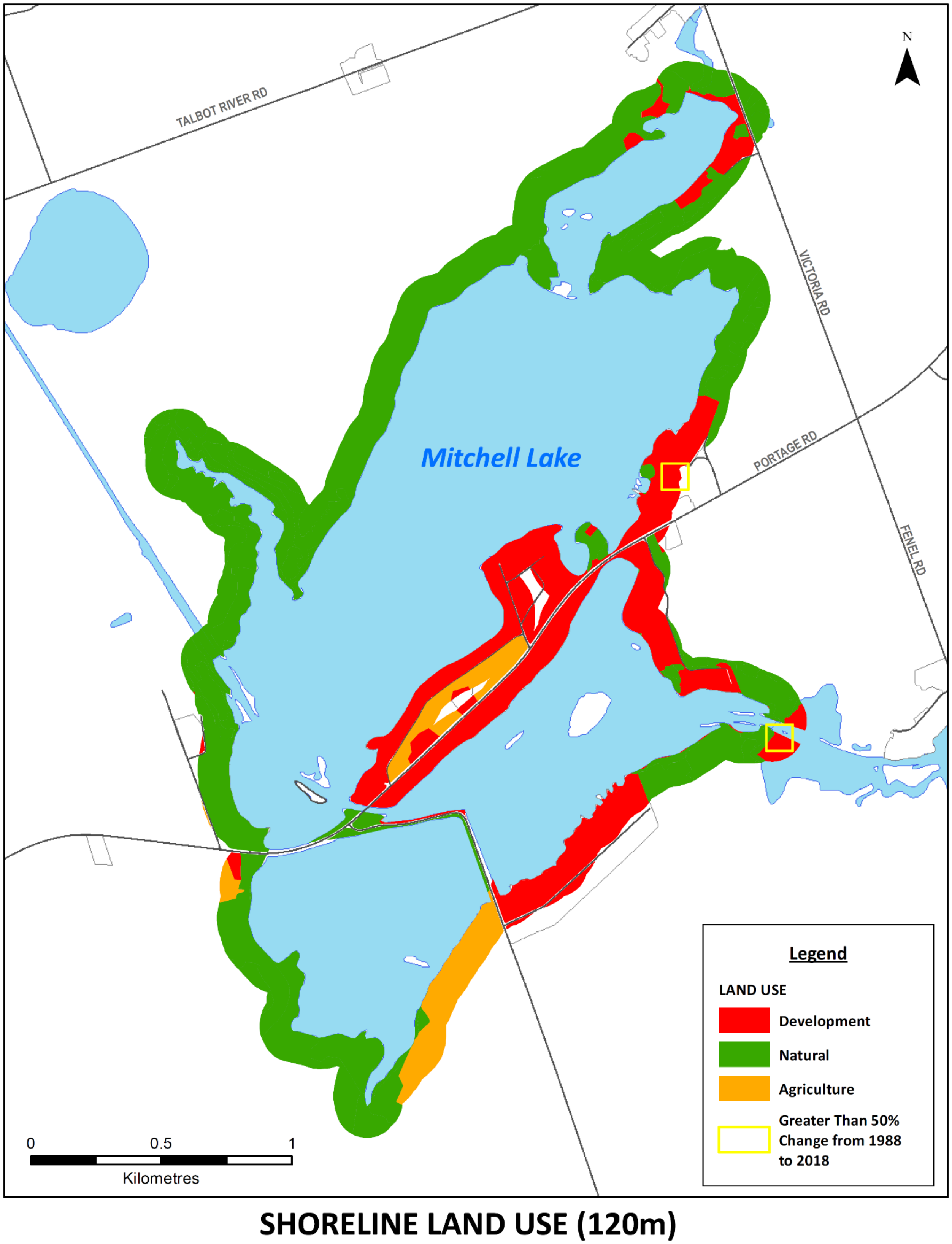
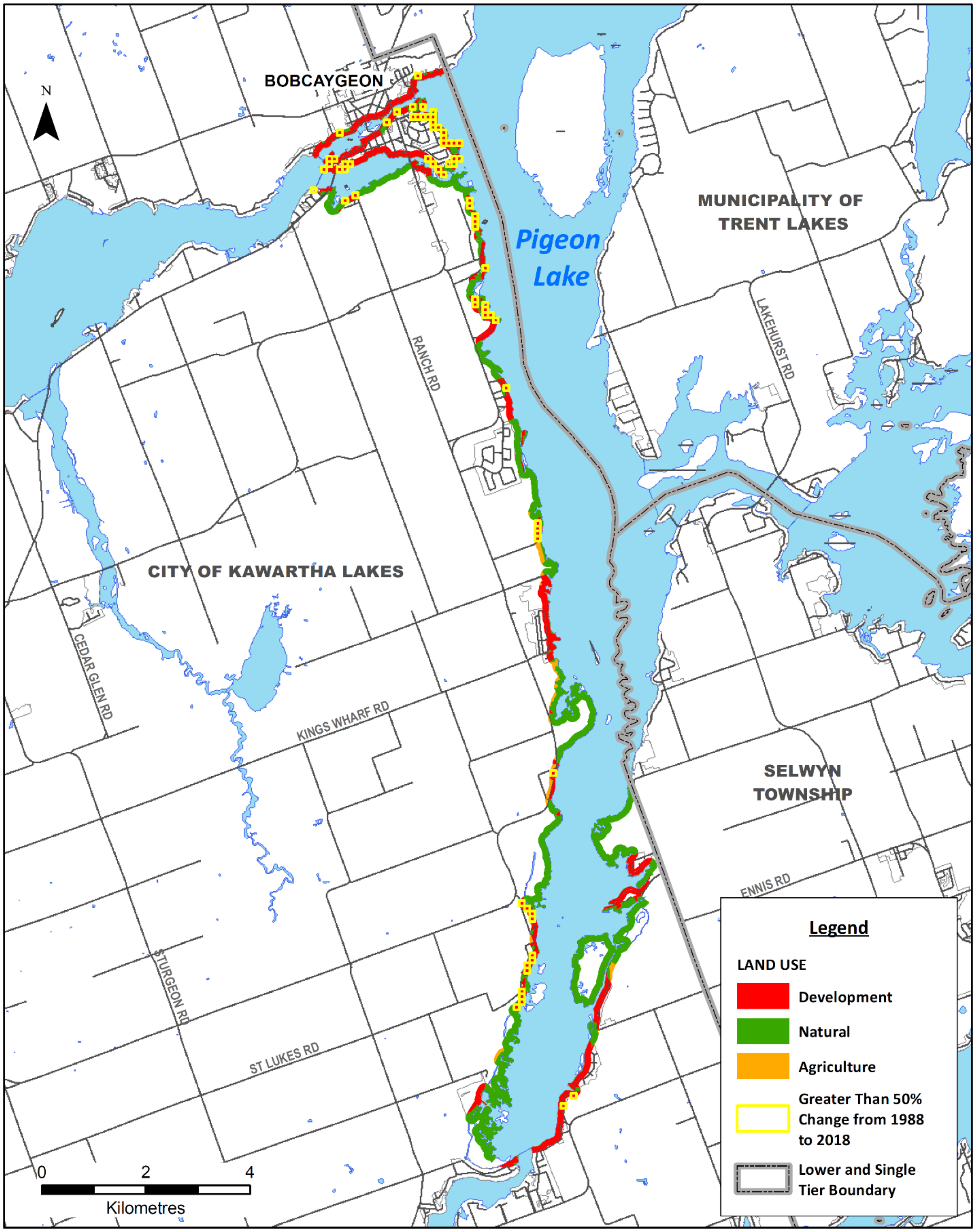


Figure 10. Mitchell Lake shoreline land use.



SHORELINE LAND USE (120m)

Figure 11. Pigeon Lake shoreline land use.

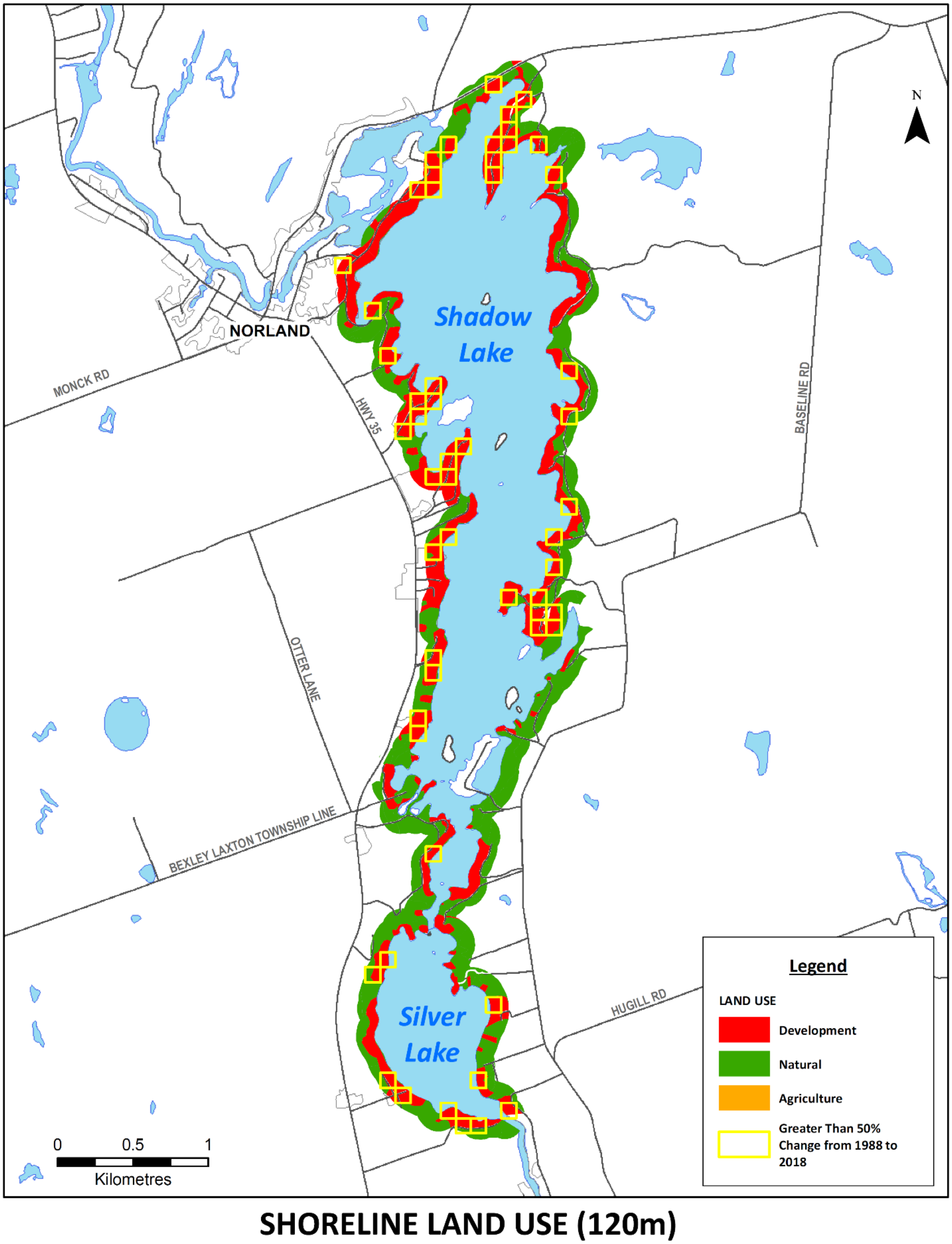


Figure 12. Shadow and Silver Lake shoreline land use.

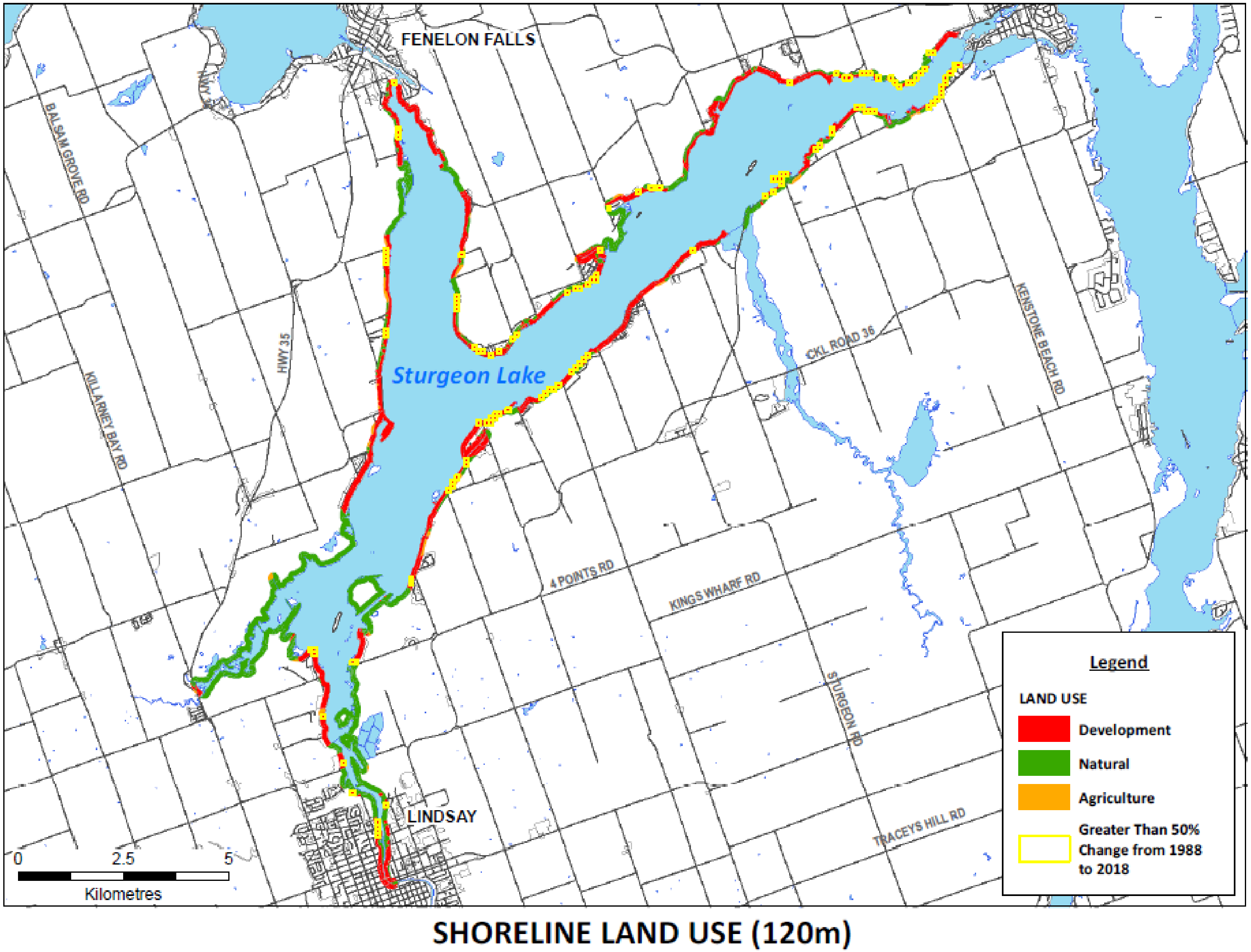


Figure 13. Sturgeon Lake shoreline land use.

Key Finding: Expansion and intensification of existing shoreline development are expected to continue for all lakes into the foreseeable future, however the rate of increase is not clear.

As shown, development along the shorelines around the major lakes in the City of Kawartha Lakes has significantly increased over the past 30 years. Trends in future development however are not as clear given limited information exists related to growth projections specific to shoreline areas. However, if the current trend continues, the lakes will have approximately 65% development within next 30 years.

As highlighted recently by local journalism (Hutchinson, 2019), the City of Kawartha Lakes has been identified as an area for future growth in the provincial Growth Plan. It envisions a permanent population of 100,000 people by 2031 and 107,000 by 2041. As the current population is around 75,500 residents, these growth targets represent a 32 percent increase in population in just over 20 years. This does not consider the seasonal population growth (currently adding about 31,000 residents each year) that will likely also intensify.

Regardless of the lack of data specific to growth around shorelines, it is reasonable to assume that a significant portion of this growth will in fact occur along shoreline areas (Figure 14), given shorelines are growth hotspots as driven by the following key factors:

- Attractive Cottage County: The Kawartha Lakes region, being situated on the Trent-Severn Waterway National Historic Site, remains an attractive tourism and retirement destination for lake-based recreation, living, and cottaging.

- Proximity to Greater-Toronto-Area: The region provides a relatively affordable vacation, retirement, and commuter destination that is particularly accessible (being only one-hour away) for people living in the most-populous and fasted growing urban centre in Canada.

- Covid-19 Pandemic: At least in the near-term, the pandemic has resulted in more human presence, in general, in the municipality. Many residents that might have otherwise worked or vacationed elsewhere have switched their habits (for example, more remote working) thus resulting in enhanced activity in the area, many of which are taking advantage of outdoor lake-based activities.

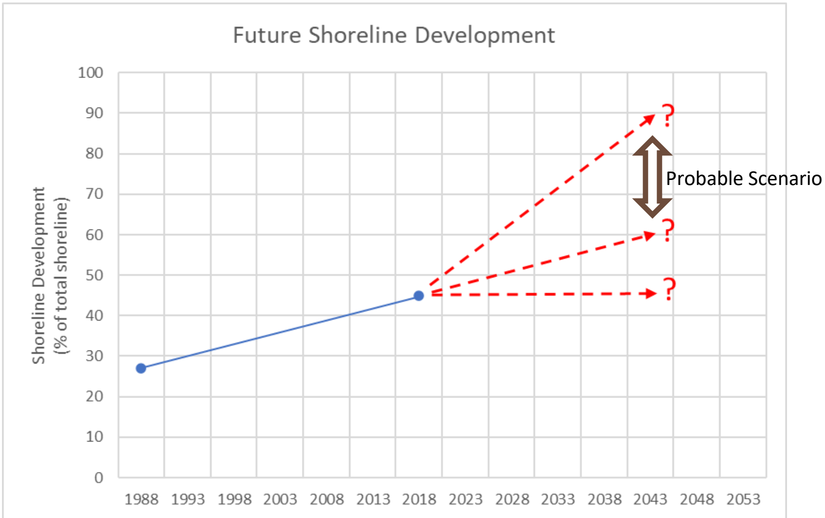


Figure 14. Projections for future shoreline development

5.0 General Trends in Lake Water Quality

Key Finding: Existing water quality on the study lakes is generally considered moderate-to-good but many lakes experience symptoms of nutrient enrichment, with headwater lakes being more vulnerable to shoreline development impacts.

Given the environmental, economic, and socio-cultural benefits that healthy lakes provide to local communities, the imperative for Lake Management Planning (including enhanced shoreline policy) in the City of Kawartha Lakes is driven by the desire to maintain good lake water quality.

Unfortunately, several water quality related issues across numerous lakes were documented in the Lake Management Plans, including periodic blue-green algae outbreaks (e.g., Figure 15), suboptimal habitat in deep basins, frequent public beach closures, and excessive aquatic plant growth. The extent of watershed development (with its primary impact being nutrient enrichment), was considered a major contributing factor in most of these symptoms.

For most of the study lakes nutrient loadings from shoreline sources is a relatively small percentage of total nutrient inputs, with the exception being ‘headwater’ lakes having comparatively low flushing rates. These lakes, which include Lake Scugog, Four Mile Lake, Head Lake, and Mitchell Lake, are noted to be more vulnerable to water quality impacts associated with shoreline development (Figure 16).

To obtain a general representation of lake-wide conditions across the study lakes for the purposes of this project, values for the following water quality indicators were examined: phosphorus, water clarity, and dissolved oxygen.

Results indicate that in general terms across the municipality water quality is considered in a moderate-to-good state as represented by its open water nutrient concentrations (namely phosphorus). Average phosphorus values are 13 ug/L (range from 6 to 20 ug/L) and all lakes meet provincial water quality objectives except for Cameron Lake and Head Lake, with Lake Scugog being just under the threshold (Figure 17).

Supporting water quality indicators examined for each lake include water clarity (as measured by Secchi depth) and dissolved oxygen in the bottom waters (deepest 3 metres) of their deepest basin (Table 3). Water clarity is considered generally good (average of 3.5m) except for Lake Scugog which has notably murkier waters, a typical symptom of nutrient enrichment which can limit aquatic plant growth. Poor dissolved oxygen values have been noted in the deepest basins of Cameron Lake, Shadow and Silver Lake, Four Mile Lake, and Pigeon Lake, another symptom of nutrient enrichment which could limit the availability of habitat for certain sensitive aquatic life.

Figure 15. Blue-green algae outbreaks in Pigeon Lake 2012 (left), Sturgeon Lake 2011 (right).

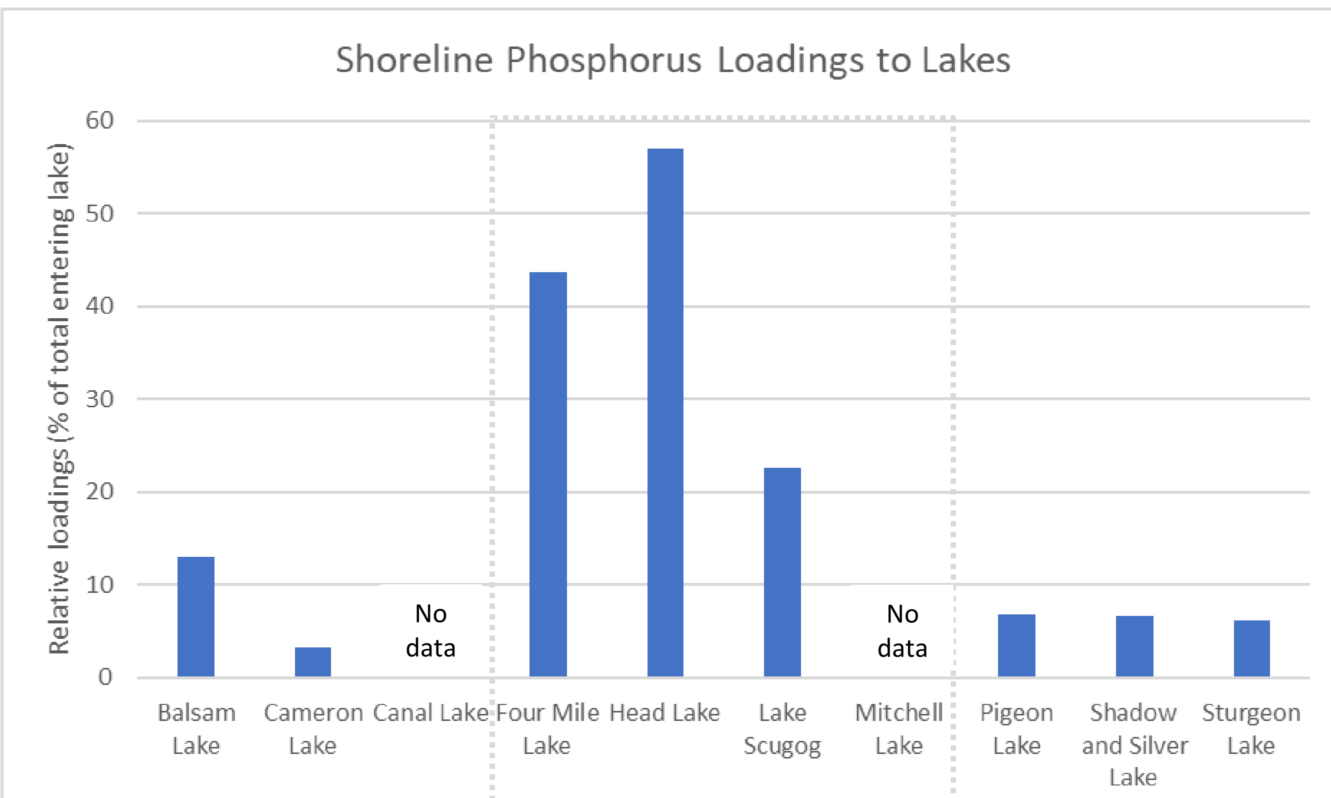


Figure 16. Phosphorus loading contributions from shoreline areas relative to total loadings. Dashed area indicates 'headwater' lakes.

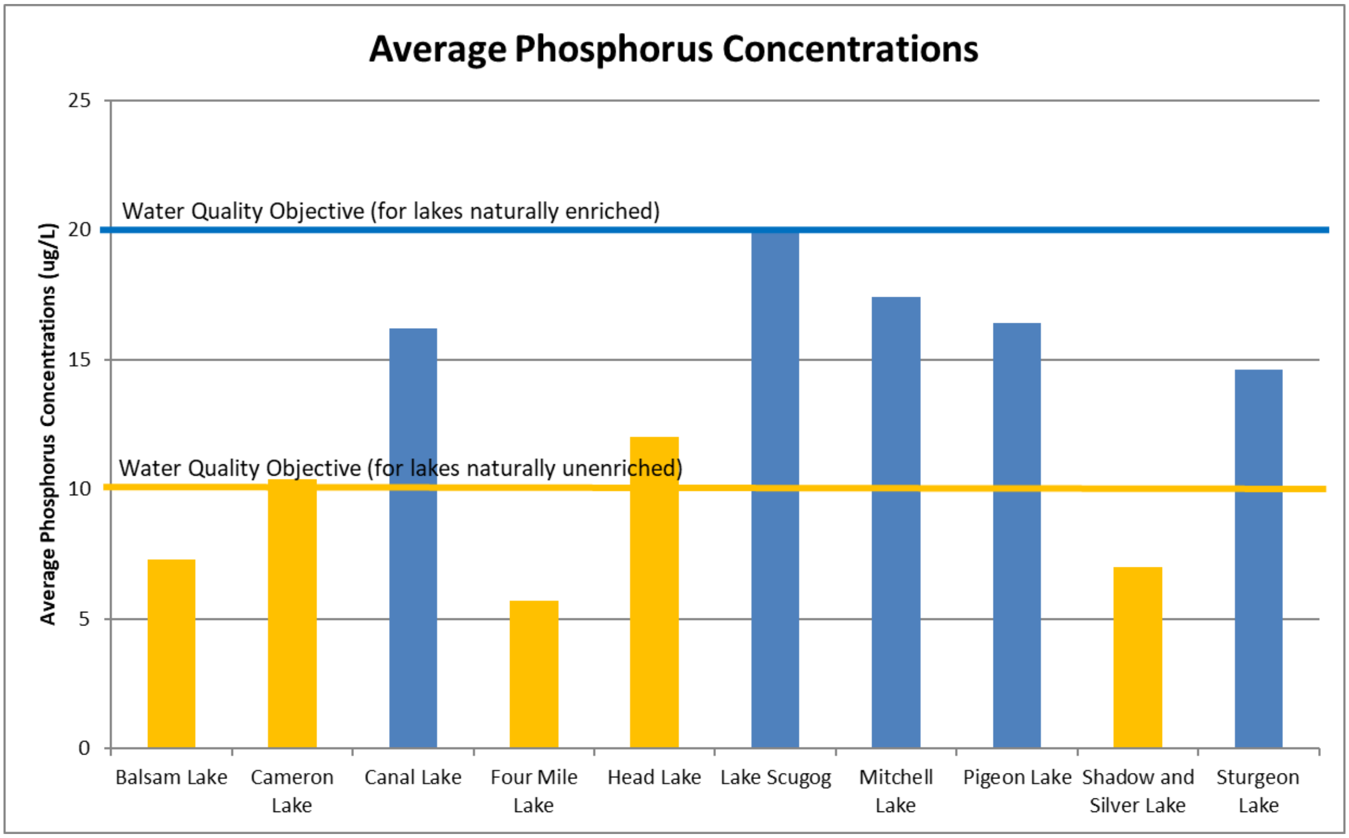


Figure 17. Existing lake-wide phosphorus concentrations in relation to provincial water quality objectives.

Table 3. Indicators of water quality. * denotes relatively poor water quality conditions.

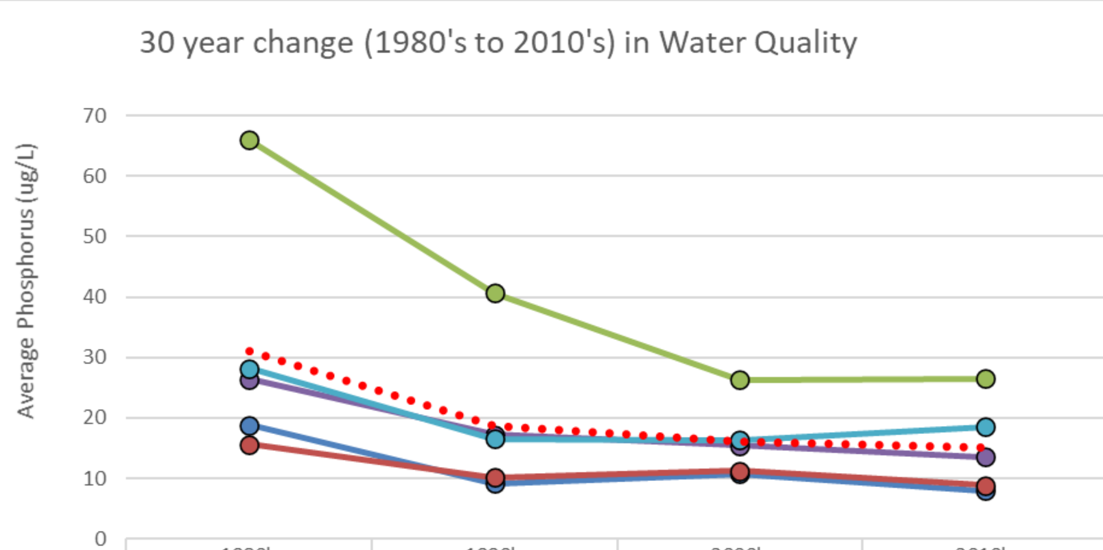
	Total Phosphorus (lake-wide, ug/L)	Water Clarity (depth below surface, m)	Dissolved Oxygen (deep bottom waters, mg/L)
Balsam Lake	7.3	4.3	7.0
Cameron Lake	10.4*	3.3	0.1*
Canal Lake	16.2	2.3	No data
Four Mile Lake	5.7	6.5	2.6*
Head Lake	12.0*	3.3	7.3
Lake Scugog	19.9*	1.3*	7.1
Mitchell Lake	17.4	2.9	No data
Pigeon Lake	16.4	3.3	2.3*
Shadow Lake	7.0	4.6	0.5*
Sturgeon Lake	14.6	3.1	No data
AVERAGE	**12.7**	**3.5**	**3.8**

Key Finding: Water quality as represented by nutrient enrichment status has improved over the last 30 years, but has remained relatively stable since the 2000's.

To characterize general lake-wide water quality changes over time across the municipality, average phosphorus concentrations in samples collected through the Provincial Water Quality Monitoring Network program were used. This data is collected consistently at the outlets of most major lakes and rivers and represent lake-wide conditions in water quality.

Results indicate that there have been water quality changes over the last 30 years in major lakes across the municipality, with the enrichment status of lakes generally improving over time (Figure 18). Average phosphorus values in the 1980's (31 ug/L) were about twice as high as what they are in the most recent decade (15 ug/L). The rate of improvement was highest from the 1980's to 1990's, but has remained relatively stable since the 2000's. This recent 'plateau' of lake conditions has also been documented by the Kawartha Lake Stewards Association (KLSA, 2015).

Factors driving these changes have not been fully documented, but it is generally recognized that improvements in wastewater treatment facilities (particularly those servicing large urban areas), along with the proliferation of zebra mussels (filter feeding organisms) are in large part responsible for the significant reductions in phosphorus recorded during the 1980's and 1990's period.



	1980's	1990's	2000's	2010's
Balsam Lake	19	9	11	8
Cameron Lake	16	10	11	9
Scugog River	66	41	26	27
Sturgeon Lake	26	17	15	14
Buckhorn Lake	28	17	16	19
AVERAGE	31	19	16	15

Figure 18. Trends in phosphorus concentrations over time.

Key Finding: The future trajectory of water quality is not well understood due to the complex nature of lake ecosystems and the lack of data related to water quality projections.

As shown, water quality in the open waters of major lakes in the City of Kawartha Lakes has significantly improved over the past 30 years but has remained relatively stable since the 2010's. Trends in future water quality however are very uncertain because of the various environmental and human-induced variables at play in the Kawartha Lakes.

For example, researchers have recently documented dramatic increases in phosphorus in Lake Scugog due to the rapid proliferation of the invasive aquatic algae Starry Stonewort (Kirkwood, 2020). Climate change is another water quality influencer and has been documented as contributing to increased algal blooms across Ontario lakes (Winter et al., 2011).

In general, there is a lack of available information related to future water quality projections in the Kawartha Lakes. The Lake Management Plans highlighted the urgent need to improve scientific understanding between lake health and the following key stressors: cumulative development along shorelines, climate change, and invasive species in aquatic ecosystems.

Therefore, as illustrated in Figure 19, it is not assured that water quality will remain relatively stable and relatively moderate-to-good for the foreseeable future.

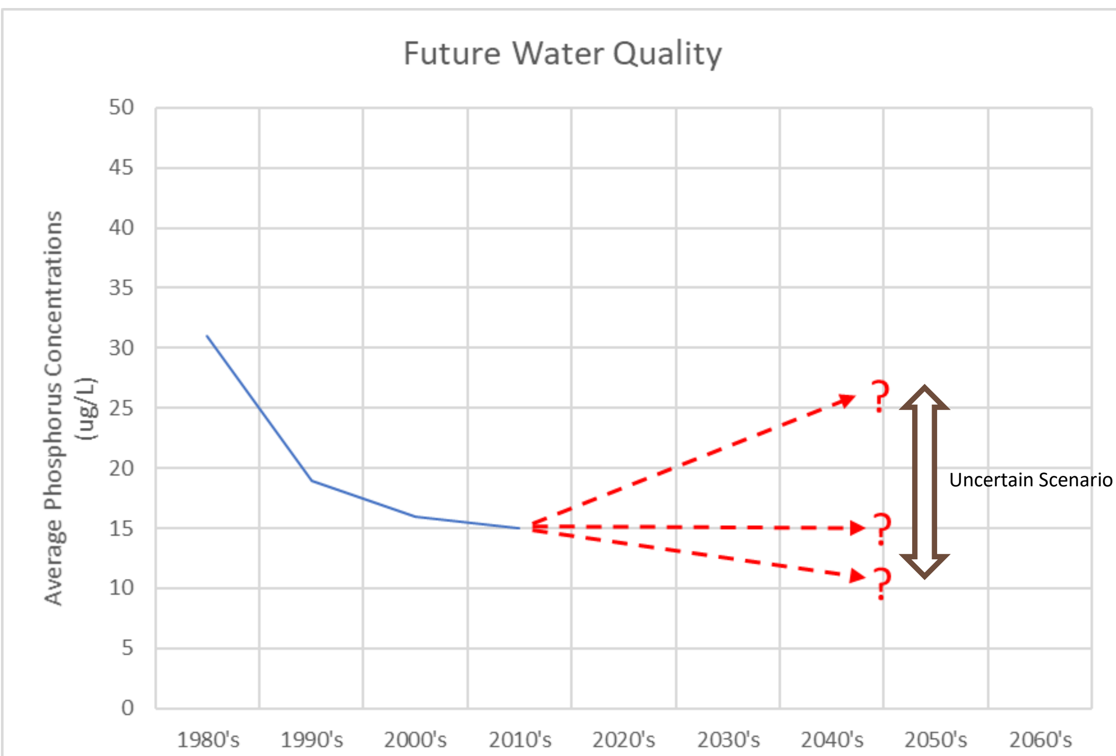


Figure 19. Projects for future water quality conditions.

6.0 Relationships Between Shoreline Development and Lake-wide Water Quality

Key Finding: There are no obvious relationships between key indicators of shoreline development and lake-wide water quality across the study lakes.

To examine if any general relationship exists between shoreline development and water quality conditions in the major lakes, data previously used for characterizing the current state of the lakes (i.e., Table 2 and Table 3) was plotted against each other.

Results indicate no obvious relationship between any of the selected development indicators (developed shorelines, artificial water's edge, and road density) when compared against water quality indicators (phosphorus, water clarity, and dissolved oxygen) across the study lakes (Figure 20). Lakes that have relatively high shoreline disturbance do not necessarily have the poorest water quality, and vice versa lakes having relatively good water quality do not necessarily have the lowest shoreline development.

This finding was also consistent across 'headwater' lakes (Scugog, Head, Four Mile, Mitchell), which are considered more vulnerable to shoreline impacts because of their relatively larger shoreline phosphorus loading contributions. Four Mile Lake, for example, has relatively high amounts of shoreline development but also has good water quality.

The lack of a general relationship with water quality in the study lakes does not mean that shoreline development has inconsequential impacts to water quality. Rather, given that impacts are well documented in the scientific literature, it is more likely that other overarching variables play a stronger role individually or cumulatively alongside shoreline development in determining open lake water quality conditions.

As highlighted by the Lake Management Plans, the following are examples of important driving variables that determine water quality which could potentially 'mask' or reduce the detection of shoreline development impact on lake water quality:

- point-source discharges (e.g., wastewater treatment plants);
- aquatic invasive species (e.g., zebra mussels);
- internal nutrient cycling (e.g., uptake of nutrients by aquatic plants);
- high water flushing rates (e.g., replenishing lakes with 'new' water); and,
- high relative pollutant loading from inflow rivers and streams (e.g., upstream development and agriculture that exists well beyond the shoreline area).

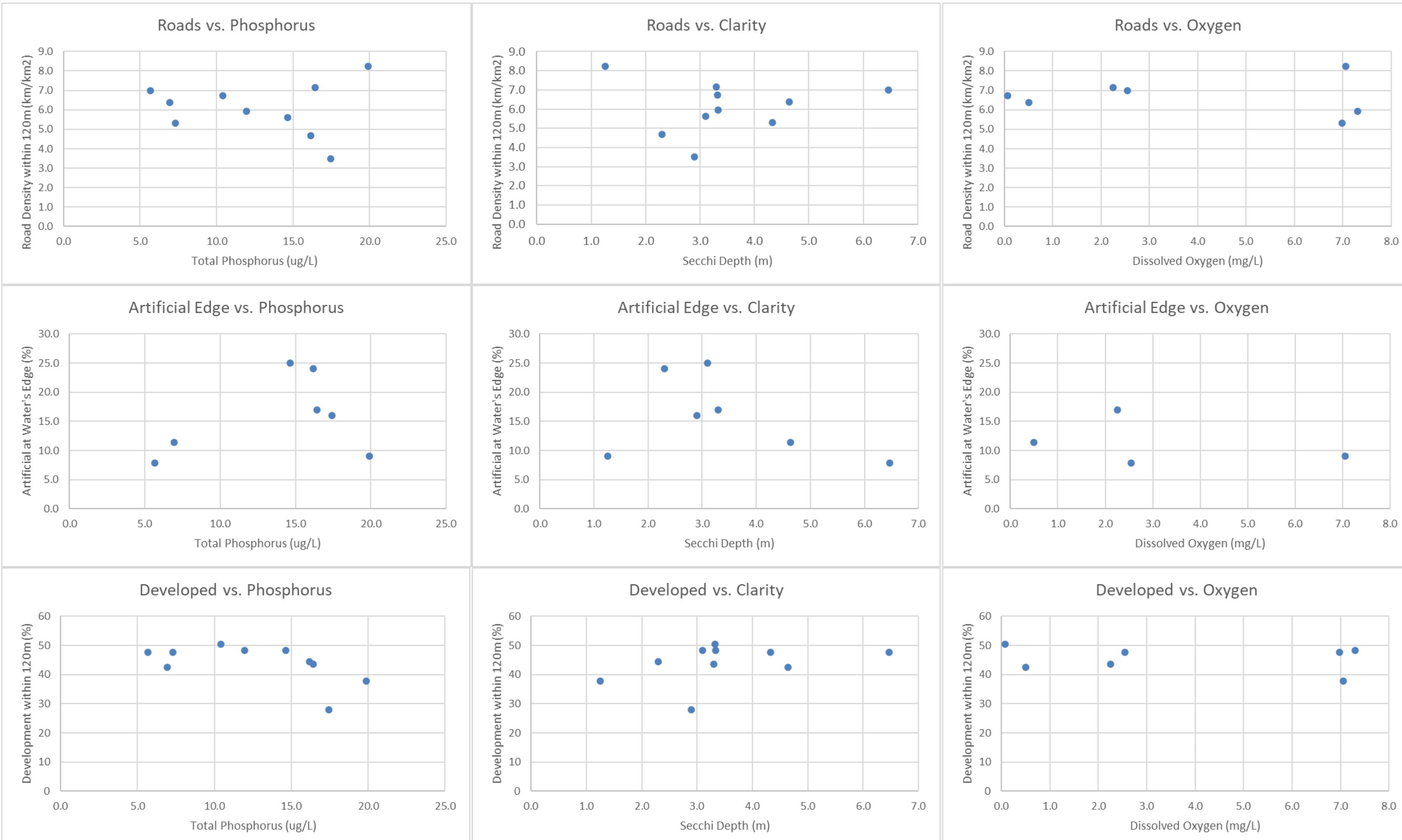


Figure 20. Relationship between indicators of shoreline development and lake-wide water quality.

Key Finding: Significant increases in shoreline development over the last 30 years has not coincided with a general deterioration of lake-wide water quality as indicated by nutrient enrichment.

Available data indicates that over the last 30 years shoreline development around the major lakes increased dramatically while during the same period water quality has improved or remained stable (Figure 21). This suggests in general terms that increases in shoreline development have not yet resulted in significant shifts to poorer water quality, as indicated by nutrient enrichment, across the major lakes in the municipality.

As noted previously, the lack of a general relationship with water quality in the study lakes does not mean that more shoreline development has inconsequential, or even positive, effects on water quality. Although some works associated with increasing development trends may benefit certain aspects of water quality (for example, upgrading inadequate septic systems during property renovation), it is more likely that other environmental and human-induced variables play a stronger role.

Unfortunately, long-term data for water quality indicators other than phosphorus (e.g., water clarity, dissolved oxygen, fecal bacteria, chloride, etc.) and development indicators other than percent developed (e.g., road density, artificial shorelines, etc.) are not readily accessible. These and other applicable data (including biological) might yield better results in terms of identifying relationships.

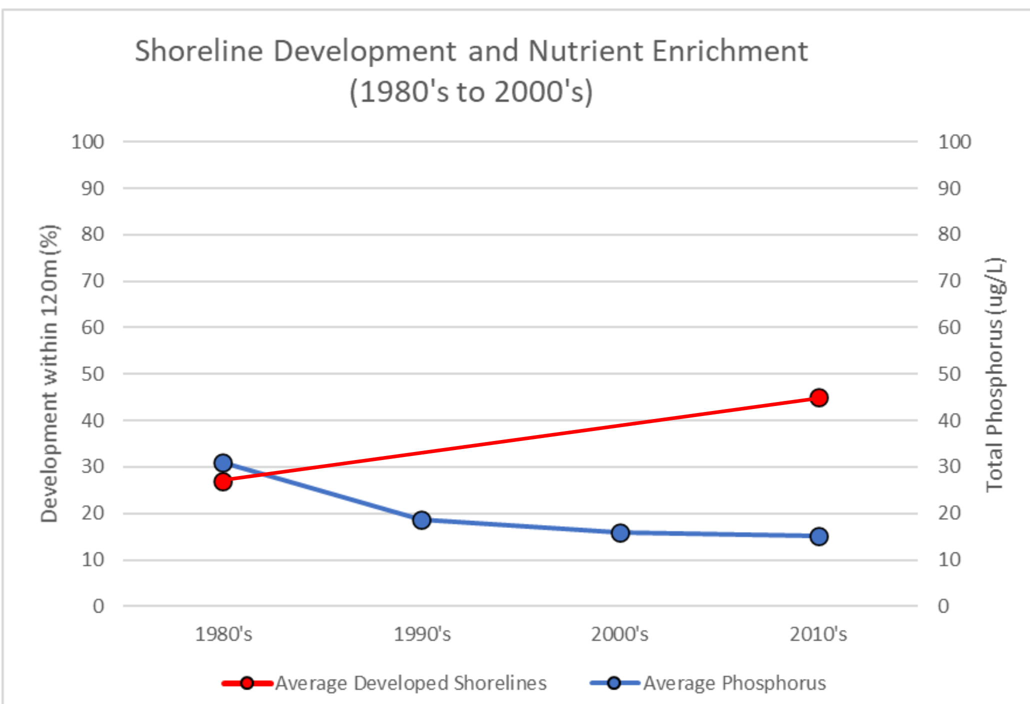


Figure 21. Relationship over time between developed shorelines and phosphorus concentrations.

Key Finding: Water quality impacts associated with shoreline development are likely more detectable in nearshore waters (as opposed to open lake waters), research into which is currently being undertaken.

This report documents that no significant relationship exists between current and 30-year trends in shoreline development and general lake-wide water quality in the major lakes. Traditional water quality data collected in the Kawartha Lakes has primarily focused on obtaining a 'representative' sample of lake-wide conditions as opposed to sampling closer to shore (adjacent to shoreline developments, for example as per Figure 22) and as such comprehensive nearshore data is not readily available at this time.

This gap was noted in the Lake Management Plans, and as such a recommendation was made to conduct research to more accurately identify shoreline sources of nutrients and potential impacts to nearshore areas of the lakes.

Fortunately, lake researchers have begun to recognize that significant opportunities exist to examine water quality along the nearshore, and to expand testing beyond phosphorus to include a broad suite of biological and chemical parametres to increase the chances of detecting a clear signal between water quality and shoreline land use.

At the time of this publication Ontario Tech University in partnership with local community organizations and volunteers, are undertaking a multi-year water quality monitoring program at 60 nearshore locations across most major lakes within the municipality. Results from this research will undoubtedly lead to a better understanding of the impacts of shoreline development on water quality. For example, preliminary findings from nearshore water quality monitoring on Lake Scugog indicate that urban areas are associated with the poorest water quality, development is a key factor in degraded water quality, and that local land-use activities likely play a key role in driving poor water quality conditions (Kirkwood, 2020).

Figure 22. Examples of shoreline development (concrete retaining wall, and manicured lawn), the water quality impacts from which are likely more detectable in adjacent nearshore waters than in the open waters of lakes.

7.0 Summary and Recommendations

This report used data collected from the Lake Management Planning project to examine trends (past, current, and future) and relationships between shoreline development and lake-wide water quality in most of the major lakes across the City of Kawartha Lakes. It represents the most comprehensive review on this topic in the municipality since a study prepared almost 20 years ago by Gartner Lee and French Planning (2002).

Key findings related to trends in shoreline development include:

- As of 2018, development occupies approximately 45% on average (range 28 to 55%) of the shoreline land area along 120m of each lake.
- From 1988 to 2018, development has increased by approximately 68% on average (range 0 to 342% increase) along the shorelines of each lake.
- Expansion and intensification of existing shoreline development is expected to continue for all lakes into the foreseeable future, however the rate of increase is not clear.

Key findings related to trends in lake-wide water quality include:

- Existing water quality of the study lakes is generally considered moderate-to-good but many lakes experience symptoms of nutrient enrichment, with headwater lakes being perhaps more vulnerable to shoreline development impacts.
- Water quality as represented by nutrient enrichment status has improved over the last 30 years, but has remained relatively stable since the 2000's.
- The future trajectory of water quality is not well understood due to the complex nature of lake ecosystems and the lack of data related to water quality projections.

Key findings related to the relationship between shoreline development and lake-wide water quality include:

- There are no obvious relationships between key indicators of shoreline development and lake-wide water quality across the study lakes.
- Significant increases in shoreline development over the last 30 years has not coincided with a general deterioration of lake-wide water quality as indicated by nutrient enrichment.
- Water quality impacts associated with shoreline development are likely more detectable in nearshore waters (as opposed to open lake waters), research into which is currently being undertaken.

Given the fact that shoreline development is ubiquitous across all large lakes in the municipality, and that it has significantly intensified within the recent past and will continue with a high degree of certainty into the foreseeable future, enhanced shoreline planning and policy should remain a priority to mitigate any potential impacts to lake health.

However, given the general lack of supporting evidence available at this time linking shoreline development to degraded lake-wide water quality conditions across the municipality, it is unadvisable to implement strict limitations on development without first obtaining a better understanding of cause and effect.

Results that will be forthcoming from the nearshore water quality monitoring program will provide the best opportunity to detect trends between shoreline development and lake water quality.

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Appendix A: Data availability

Table: Shoreline Development Indicator Data Availability.

Lake Name	Developed shorelines within 120m (Ecological Land Classification – Air photo interpretation)	Artificial shorelines along waters edge (Shoreline Survey by boat)	Road Density within 120m
Balsam Lake	1988, 2018	No data	2020
Cameron Lake	1988, 2018	No data	2020
Canal Lake	1988, 2018	2014	2020
Four Mile Lake	1988, 2018	2016	2020
Head Lake	1988, 2018	No data	2020
Lake Scugog	1988*, 2018	2019	2020
Mitchell Lake	1988, 2018	2014	2020
Pigeon Lake	1988*, 2018	2015	2020
Shadow and Silver Lake	1988, 2018	2017	2020
Sturgeon Lake	1988, 2018	2012	2020

* CKL only.

Table: Water Quality Indicator Data Availability.

Lake Name	Phosphorus concentrations and loading	Water clarity (Secchi depths)	Dissolved Oxygen, in deep basin(s)
Balsam Lake	2010-2012	2011-2014	2012-2013
Cameron Lake	2011-2014	2011-2014	2012-2013
Canal Lake	2011-2014	No data	No data
Four Mile Lake	2012-2015	2014-2016	2014-2016
Head Lake	2013-2015	2015-2017	2015-2016
Lake Scugog	2013-2015	2013-2015	2018
Mitchell Lake	2014-2016	No data	No data
Pigeon Lake	2015-2016	2012-2015	2012-2015
Shadow and Silver Lake	2015-2016	2015-2017	2015-2017
Sturgeon Lake	2013-2015	No data	No data

Appendix B: Ecological Land Classification data 2018

Table: List of land use types along shorelines.

Ecological Land Classification Community Series	Balsam Lake	Cameron Lake	Canal Lake	Four Mile Lake	Head Lake	Lake Scugog	Mitchell Lake	Pigeon Lake	Shadow and Silver Lake	Sturgeon Lake
Active Aggregate*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
Coniferous Forest***	16.57	6.48	7.84	25.52	7.52	1.35	4.71	7.92	8.89	7.24
Coniferous Swamp***	5.66	1.29	3.36	0.36	0.00	2.32	10.25	0.45	2.78	8.08
Cultural Meadow***	2.82	0.93	1.89	0.00	0.20	1.40	2.09	1.08	1.39	5.31
Cultural Savannah***	0.20	0.00	0.00	0.00	0.79	0.01	0.00	0.00	0.00	0.27
Cultural Thicket***	1.26	0.38	18.17	1.12	1.10	0.65	22.26	0.56	0.91	0.67
Cultural Woodland***	1.00	0.11	1.28	4.63	1.78	0.30	0.85	2.05	1.47	0.95
Deciduous Forest***	10.18	2.54	1.30	12.32	11.02	0.73	1.37	1.75	15.62	0.98
Deciduous Swamp***	0.00	2.21	0.29	0.00	4.29	0.05	0.24	0.27	1.00	0.15
Floating Leaved Shallow Aquatic***	0.49	0.00	0.00	0.00	0.50	0.07	0.00	0.00	0.00	0.00
Inactive Aggregate*	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
Intensive Agriculture**	0.83	5.12	0.53	0.00	3.09	6.83	0.46	1.71	0.00	0.96
Manicured Open Space*	0.09	0.48	1.28	0.00	11.00	0.98	0.00	0.25	0.07	1.50
Meadow Marsh***	1.26	6.44	3.10	0.00	1.83	5.05	2.38	10.29	0.01	6.02
Mixed Forest***	3.13	8.80	3.20	6.67	7.44	2.55	6.52	2.65	15.56	4.03
Mixed Shallow Aquatic***	0.18	0.00	0.13	0.00	0.00	0.00	0.44	5.92	0.00	0.00
Mixed Swamp***	1.32	0.00	0.72	0.00	0.00	5.64	0.12	1.83	1.57	0.52
Non Intensive Agriculture**	0.64	0.19	1.13	0.00	0.00	2.80	7.18	0.70	0.00	1.42
Open Beach Bar***	0.09	0.00	1.33	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Open Rock Barren***	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Open Sand Barren***	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Open Water***	2.05	2.32	0.74	0.29	2.82	0.92	0.71	3.84	1.60	0.79
Rural Development*	31.67	45.01	43.19	47.49	40.75	1.27	27.70	13.97	44.70	41.54
Shallow Marsh***	0.63	3.40	2.91	0.46	0.23	21.22	5.98	20.03	0.30	11.55
Submerged Shallow Aquatic***	0.30	0.00	0.92	0.11	0.00	0.00	3.94	0.06	0.00	0.21
Thicket Swamp***	2.29	4.32	6.64	1.03	5.66	11.96	2.61	0.28	1.97	2.48
Urban Development*	17.36	10.00	0.00	0.00	0.00	33.87	0.22	24.33	2.18	5.22
Grand Total	100	100	100	100	100	100	100	100	100	100

* land use considered development.

** land use considered agriculture.

*** land use considered natural.