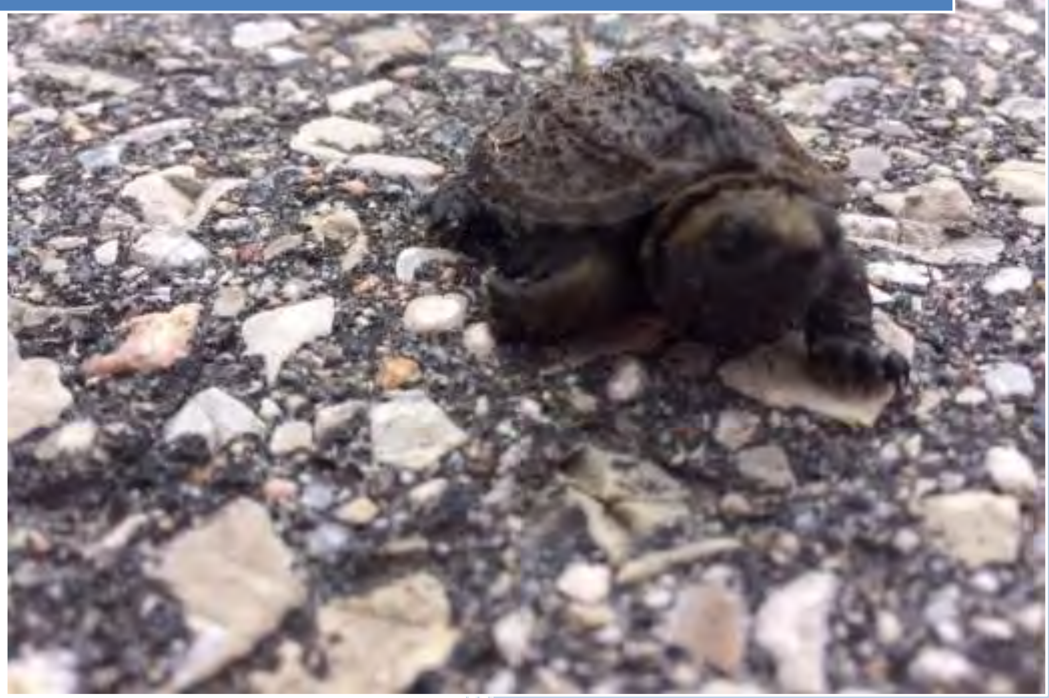
2015

Mapping potential road mortality hotspots for amphibians and reptiles in the Lake Simcoe watershed



Bill Thompson

Lake Simcoe Region Conservation Authority

Introduction

The Lake Simcoe Protection Plan (LSPP; MOE 2009) was developed by the Province of Ontario to coordinate the activities of Provincial, Municipal, and community-based approaches to protect and restore the health of the Lake Simcoe watershed. It sets a number of targets for watershed health, including the maintenance of natural biodiversity and reduction of landscape fragmentation. The LSPP also identifies a number of threats to watershed health, one of the most pressing of which is urban growth and development. The Provincial Growth Plan for the Greater Golden Horseshoe develops population projections for communities in southern Ontario. An assessment of municipal Official Plans developed by municipalities in the Lake Simcoe watershed to address these population projections estimates that urban land use could increase by up to 50% by 2031 (XCG Consultants 2014) (Figure 1).

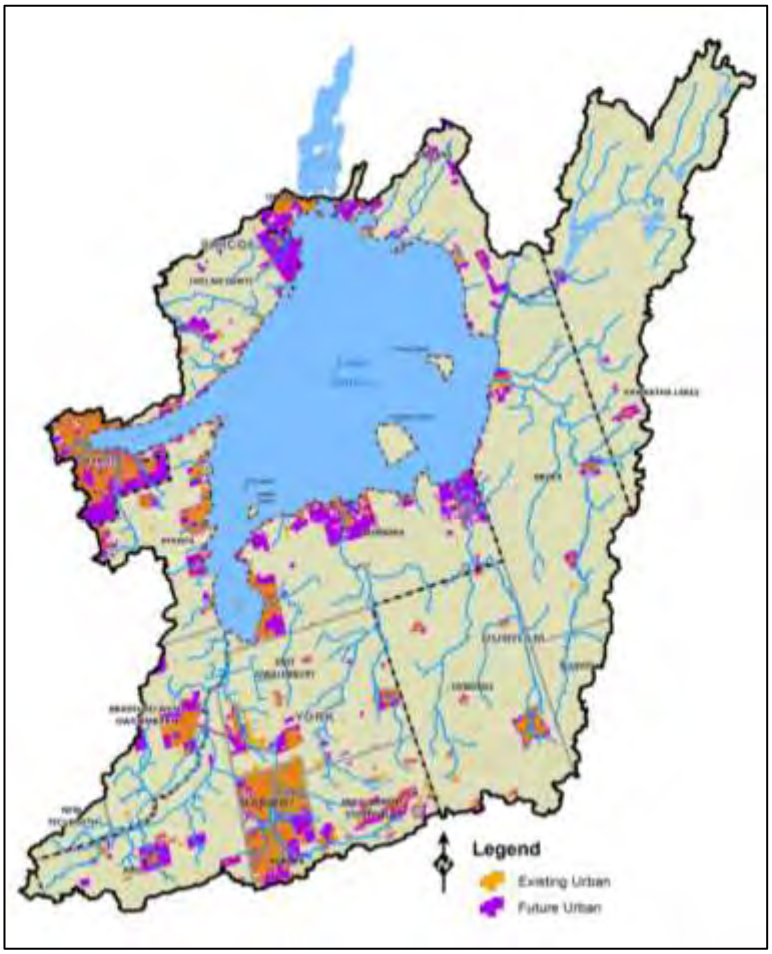


Figure 1. Future urban development in the Lake Simcoe watershed

In order to ensure that natural features are protected while development occurs, the Ministry of Natural Resources and Forestry (MNRF) developed a set of definitions of Key Natural Heritage Features (MNRF 2015). Official plans are to recognize natural areas which meet these definitions, and provide policies for their protection. An assessment by the Lake Simcoe Region Conservation Authority (LSRCA) estimates that over 90% of overall natural heritage cover in the watershed is protected by these and similar policies developed under the Oak Ridges Moraine Plan, Greenbelt Plan, and municipal Official Plans (Figure 2).

Figure 2. Natural features protected by provincial and municipal policies

While this suggests that existing natural features will be largely protected during development, projected land use changes virtually guarantee an increase in the density of the road network, and an increase in the frequency with which roads are located between remaining natural features. Further, as municipal infrastructure is not subject to the *Planning Act*, Key Natural Heritage Feature definitions do not apply to the development of roads and other infrastructure.

Roads can have significant impacts on wildlife communities and the ability of wildlife to move throughout their home ranges. Direct mortality of animals related to roads can be particularly significant for species such as frogs, turtles, and salamanders, which are relatively slow moving but need to travel significant distances from wetland to upland areas to fulfil the requirements of their breeding cycle (Fahrig and Rytwinski, 2009). Even more mobile animals such as mammals (Findlay and Houlahan, 1997) and birds (Kociolek *et al*., 2011) can be subject to increased mortality along roads.

In order to minimize these impacts, subwatershed plans developed by the LSRCA as a requirement of the LSPP recommend that reviewers of Environmental Assessments for municipal infrastructure in the Lake Simcoe watershed give due consideration to the preservation of barrier-free connectivity for wildlife between nearby wetland and upland habitats, including the provision of alternate route configuration, the use of wildlife crossing structures, and/or the use of traffic calming measures in critical locations.

In implementing this recommendation, LSRCA staff have received requests from municipal staff to help predict where and when such concern is merited. In other words, to assist in determining if there are some areas in the watershed where road-associated mortality in amphibians and reptiles is more likely, and if there is some threshold of anticipated traffic volume where transportation planners need to consider the provision of wildlife passage.

A number of different methods to model the movement of wildlife across landscapes, and their resultant exposure to collisions with vehicles, have been developed over the years. Perhaps the simplest is that of Gunson et al. (2012) who calculated a weighted percent cover of land use along roads. Field verification of locations of dead amphibians and reptiles along a road network in southeastern Ontario found a significant relationship between occurrence of road kill and weighted percent cover of land use (Schueler and Gunson 2011; Gunson et al. 2012). While the model of Gunson et al. (2012) has been shown to accurately predict areas where road kill are likely to occur elsewhere in Ontario, it cannot be used to predict movement patterns of wildlife across the landscape. A relatively simple approach to modelling movement across a landscape, known as least-cost path modelling, has also been used to predict priority areas for maintaining or enhancing wildlife corridors in southern Ontario (e.g. Jalava et al. 2001). Least-cost path modelling requires the modeller to define the 'resistance' of different types of land use in their area of interest, and starting and end points for wildlife movement. The model then determines the most likely path of movement from the starting point to the end point, passing through the areas of lowest resistance, given some simple parameters of wildlife movement (Adriaensen et al. 2003). While least-cost path modelling will predict movement corridors across a landscape, it has been criticized for being overly predictive, by identifying only one corridor between two points (Beier et al. 2011). A more recent development in landscape modelling known as landscape resistance modelling (McRae et al. 2008) has been developed to address this criticism. While the input data to landscape resistance models is similar to that of least-cost path models, the model output represents the probability of use of any patch of the landscape by dispersing wildlife. This is seen as being a more realistic description of wildlife movement, and being amenable to further scenario modelling to identify priority areas to increase connectivity with habitat restoration or engineering solutions (Beier et al. 2011).

While most approaches to identifying areas of concern with respect to wildlife-vehicle collisions focus on land use and the structure of the surrounding landscape, traffic volumes on roads bisecting natural areas may also play a significant role. One might expect that the probability of occurrence of collisions between vehicles and wildlife would relate to both the number of animals crossing the road (likely correlated with local land cover), and the number of vehicles on the road. If this is the case, the area of predicted hotspots could be further refined, to focus on roads which support traffic volumes that would be expected to lead to higher rates of wildlife mortality.

The objectives of this study are to test the ability of land cover maps and traffic data to predict areas of wildlife-vehicle collisions hotspots, with the ultimate goal of providing roads planners with maps of areas on which to focus efforts. This has required three steps: 1) different methods of landscape modelling were tested to determine which provides the most accurate predictions of areas of collisions hotspots; 2) the relative influence of traffic volume and land cover on collision probability and frequency was tested, and; 3) the results of these analyses were used to develop maps of hotspot areas for municipalities in the watershed.

Methods

Development of a model to predict areas of high wildlife-vehicle collision probability

Amphibians and reptiles are amongst the most vulnerable to collisions with vehicles as they are slow moving terrestrial species who must move significant distances between different types of habitat to meet their life history needs (Forman and Alexander 1998). In Ontario, road kill is thought to be a significant cause of the decline of these species (Ontario Road Ecology Group and Toronto Zoo 2010). Three candidate models predicting mortality hotspots of amphibians and turtles along roads in the Lake Simcoe watershed were developed following the approaches of Gunson et al. (2012), Adriaensen et al. (2003), and McRae et al. (2008), i.e. the weighted average land cover model, least-cost path approach and the landscape resistance model, respectively.

The weighted average land cover model was developed by following the methods of Gunson et al. (2012), with a few revisions. Briefly the LSRCA land cover GIS database was converted to a grid layer with 20 m resolution, with land cover types converted to a weighting value. Habitats were scored such that all upland forest pixels (ELC community series FOD, FOC, FOM, and CUP) received a score of 50, open water or wetlands (ELC community series BOS, BOT, FEO, FES, FET, MAM, MAS, OAO, SAF, SAM, SAS, SWC, SWD, SWM, and SWT) a score of 100, and all other land cover types were given a score of zero. The GIS software package GRASS was used to calculate average land cover values in a 200 m moving window around each 20 m pixel using the r.neighbors tool. A window size of 200 m was selected by Gunson et al. (2012) based on a literature review of common core habitat sizes for native amphibians and reptiles. The resulting layer of averages, hereinafter called 'Gunson scores', represent a measure of the amount of suitable habitat for amphibians and reptiles within a typical movement landscape for those species.

Least-cost path approaches to modelling require greater parameterization of the model, based on the biology of species of interest. A least-cost path model was developed for common frogs, turtles, salamanders and snakes which occur in the Lake Simcoe watershed, and which move between upland and wetland habitats as part of their breeding cycle (namely snapping turtle, painted turtle, Blanding's turtle, eastern ribbonsnake, blue-spotted salamander, gray treefrog, and wood frog). As with the weighted average approach to modelling, the least-cost path model was based on conversion of the LSRCA land cover layer to a scored raster layer with 20 m resolution. Scores representing the 'resistance' to the movement of these species through various land use types were applied to that raster (Table 1). While greater research on the movement behaviour of study species can be used to develop more precise resistance values, simulations have found that the relative, rather than absolute, weightings of resistance are of key importance (Adriaensen et al. 2003). Published literature on the movement ecology of these species suggests that they may disperse from 200 m to 1 km in their annual breeding migrations (e.g. Semlitsch and Bodie 2003; Boone et al. 2006). A network of potential starting and ending points for movement patterns of wildlife in the watershed were developed by creating centroid points in all wetlands within 200m of a forest (defined as starting points), and all forests within 200 m of a wetland (defined as end points). The r.cost and r.drain functions in GRASS were used to calculate a network of least-cost paths between all 7658 starting and end points, and any paths longer than 1 km were removed from the solution set.

A landscape resistance model was developed for the Lake Simcoe watershed by Walpole (2011), using the same resistance parameters as Table 1. He calculated landscape resistance scores for all 100 m pixels in the Lake Simcoe watershed, based on the probability of that pixel being used by an animal moving between pairs of 30 starting and end points randomly located along the margin of the Lake Simcoe watershed (see also Koen et al. 2014 for more details on the modelling approach).

Table 1. Landscape resistance scores used in least-cost path modelling

Habitat type	LSRCA land cover dataset query	Resistance scores
Forest	Cover = treed	1
Wetland	System = wetland and cover <> treed	1
Open water	System = aquatic	1
Farmland	Landusecode = IAG, NAG, AI, or Cover = shrub or CSCODE = ALO, CUM	100
Developed areas	Landusecode = AA, COM, EST, GC, IND, INS, MOS, RD, URB	1000
Roads and railroads	Landusecode = Rail, Road	10000

Model validation

Three external data sets were used to test the relative ability of these three models to predict where collisions occur in the Lake Simcoe watershed.

Both the Toronto Zoo Adopt-a-Pond program and Ontario Nature's Reptile and Amphibian Atlas are citizen science programs which record the occurrence of frogs, turtles, snakes and salamanders across Ontario. Records collected by these programs in the Lake Simcoe watershed were provided by the MNRF and Ontario Nature, and all occurrences noted as being either 'alive on road' or 'dead on road' were extracted, to form a validation data set composed of 130 records. A second set of 130 random points along the road network was created using the v.random tool in GRASS.

A third validation data set was provided by York Region, representing a summary of all collisions reported to York Region Police on Regional roads between 2008 and 2013. A total of 398 occurrences of collisions with wildlife were extracted from this database and converted to a value of number of collisions per km of road segment per year. While the species of wildlife involved in the collision was not recorded in the database, as these occurrences relate to collisions reported to the police, it is reasonable to expect them to be larger animals (e.g. deer or coyote), rather than the frogs and turtles that the models were parameterized for.

Average annual daily traffic (AADT) data on York Regional roads between 2008 and 2013 was also provided by York Region staff. Average annual daily traffic is estimated for each of York Region's roads with the use of automatic traffic recorders located on Regional roads over a consecutive seven day period. This data is extrapolated to an annual estimate with the use of semi-monthly adjustment factors derived from permanent count stations established on similar roads.

Data analysis

The validation set and random points were buffered by 100 m, and the average score of both the Gunson scores and Walpole's (2011) resistance scores were calculated within the buffer (following the approach of Koen et al. 2014). Comparison of average scores near known occurrences of animals on roads, and the randomly selected locations, was conducted using a t-test. Average Gunson values and Walpole's landscape resistance scores within a 100 m radius of Regional roads where collisions have and have not been reported were similarly compared with the use of a t-test. As the least-cost path corridors represent linear, rather than raster results, the average distance between the known and random locations, and their nearest predicted movement corridor, was tested with the use of a t-test.

A simple test of the influence of traffic volume, without assessing the influence of land cover, on wildlife-vehicle collisions was conducted by conducting a t-test on the average AADT of York Regional roads where collisions have and have not been reported.

The combined influence of land cover and traffic on the probability of a collision between a car and a wild animal was assessed through the use of multiple logistic regression, using both AADT and Gunson scores as independent variables. Their influence on the frequency of collision (i.e. number of collisions per year per kilometer of road) were assessed through the use of multiple linear regression, with standardized partial regression coefficients used to compare the strength of influence of each predictor variable.

Results and discussion

The model based on the approach of Gunson et al. (2012) provides a map of density of wetlands and upland forests in the Lake Simcoe watershed (Figure 3). The average Gunson score within 100 m of locations where frogs or turtles have been recorded on roads (i.e. 33.6) is significantly higher than within randomly located points (t_{258}=3.8, p<0.001) (Figure 4). Similarly, the average Gunson score along Regional roads where collisions have been reported (i.e. 21.6) is significantly higher than along roads where no collisions have been reported (t_{358}=5.32, p<0.0001). As Gunson scores increase, the frequency of collisions between vehicles and wildlife increase as well ($F_{1,401}$ =13.31, p=0.0003). The slightly lower average Gunson scores evidenced in the York Region collision data may represent the fact that the species likely involved in these collisions (e.g. deer, coyote), tend to be more habitat generalists than the frogs and turtles represented in the other data set, so may be more likely to occur in areas with lower amounts of natural heritage cover.

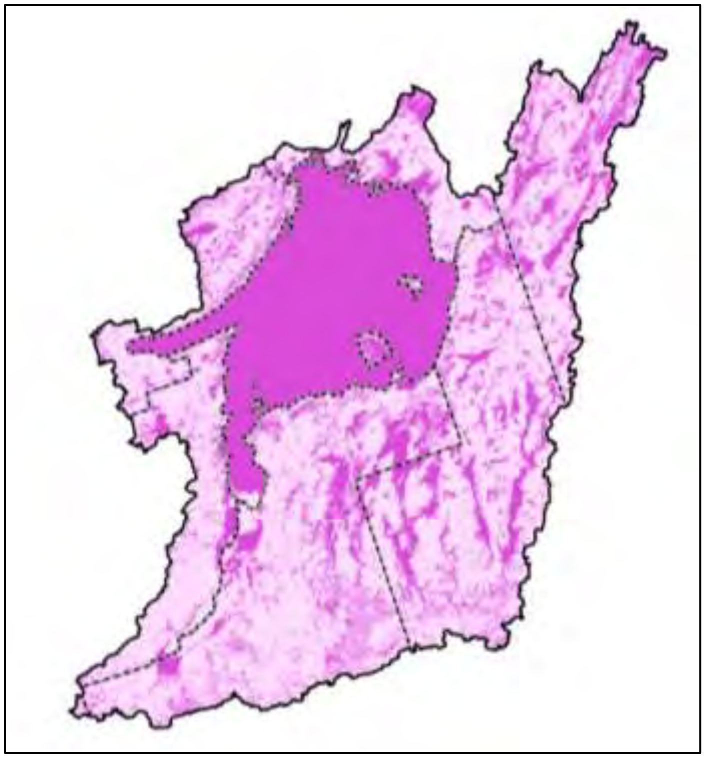


Figure 3. Weighted average land cover, based on methods of Gunson et al. (2012). Darker areas correspond with a greater local cover of upland and wetland or aquatic habitat

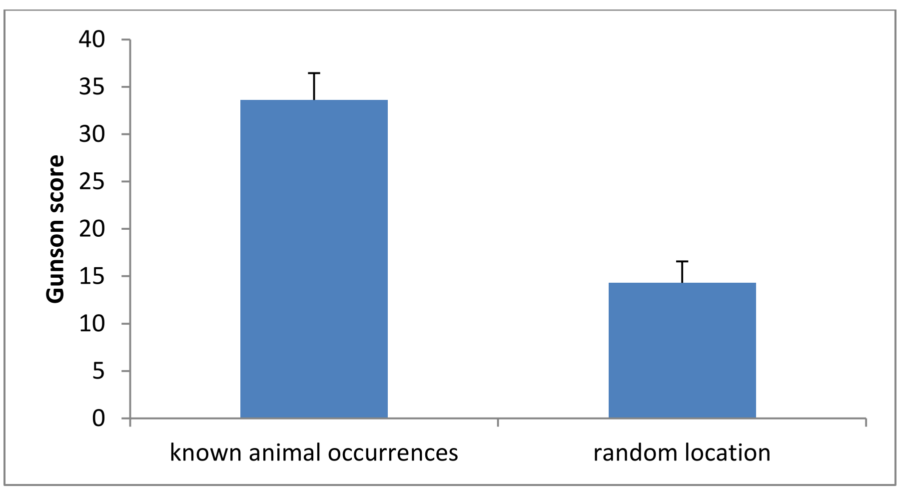


Figure 4. Average weighted land cover scores, in locations where animals have and have not been recorded on roads

The model developed by Walpole (2011) provides a map of the predicted relative 'resistance' to movement of wildlife within the Lake Simcoe watershed (Figure 5); however, there was no significant difference in resistance score within 100 m of known locations of frogs and turtles, and a similar sized set of randomly selected points.

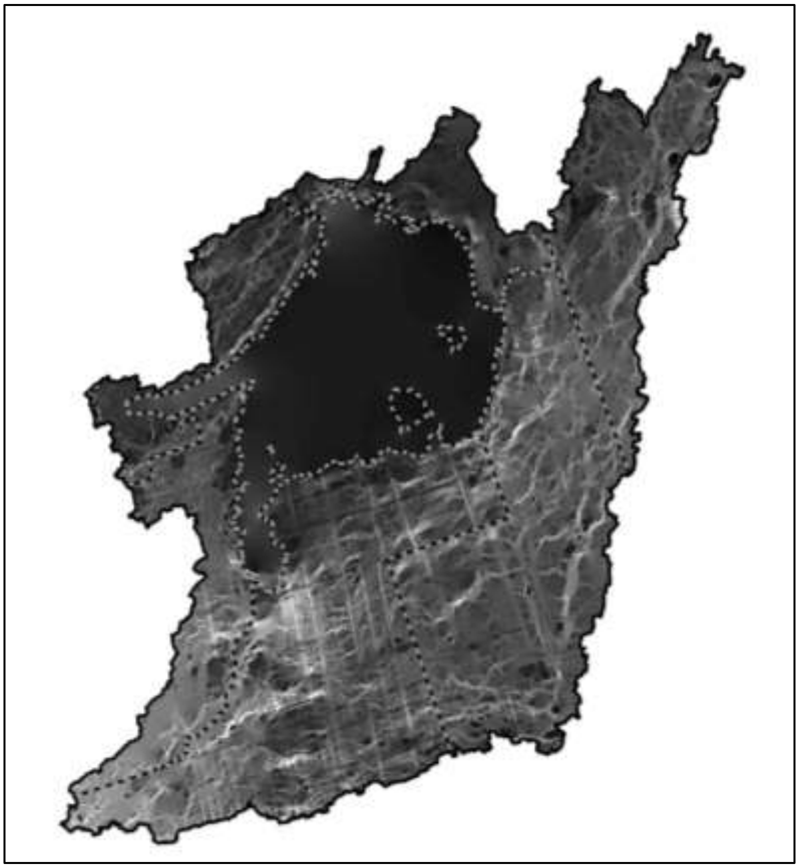


Figure 5. Landscape resistance scores to wildlife movement as calculated by Walpole (2011). Darker colours represent areas with greater resistance

The least-cost path modelling developed a network of predicted wildlife movement corridors in the Lake Simcoe watershed (Figure 6). Locations where frogs or turtles have been observed on roads were significantly closer to these corridors than would be expected, based on random points (t_{144}=3.16, p=0.002), however they occur at an average distance of 750 m from the proposed corridors.

Figure 6. Potential corridors to support local wildlife movement (in red) between remaining natural heritage features (in green) in the Lake Simcoe watershed

These results suggest that both the least-cost path approach (Figure 6) and the weighted average land cover approach (Figure 4) accurately predict where wildlife-vehicle collisions occur in the Lake Simcoe watershed. In fact, the least-cost path corridors and Gunson's hotpots tend to co-occur. However, as the average distance between proposed corridors and noted occurrences of animals on roads (i.e. 750 m) is near the upper end of reported migration distances for many of these species (Semlitsch and Bodie 2003), these corridors may be an overly restrictive set of areas to meaningfully reduce road kill rates. As such, predicted hotspots derived from the weighted land cover approach represent areas where provincial and municipal staff involved with building or maintaining roads should consider mitigating impacts of roads on wildlife. The least-cost path corridors represent a subset of these areas, and may be appropriate locations to focus effort on proactively increasing landscape connectivity, through stewardship and other efforts.

In the absence of assessing the influence of land cover, traffic volumes alone do not predict the probability of collisions with wildlife. There is no significant difference between traffic levels on roads where collisions have been reported, and where they have not (Figure 7). When considered together, logistic regression results indicate that land cover (in the form of Gunson score) significantly ($p<0.0001$)

influences the probability of wildlife-vehicle collisions, but that traffic volume remains non-significantly related to the occurrence of collisions.

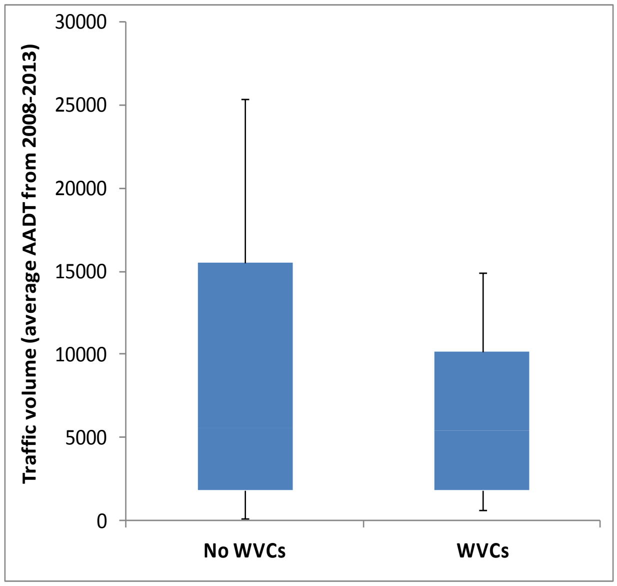


Figure 7. Traffic volume in locations where collisions between wildlife and vehicles (WVCs) have and have not been reported

When considering the number of collisions that occur though, the multiple regression model that includes both land cover and traffic volume significantly predicts collision frequency ($F_{3,399}$ = 8.509, p<0.0001). While traffic volume alone is not a significant predictor in this relationship, it does have a significant (p=0.008) interaction with Gunson score, indicating that traffic volume influences collision frequency in areas of high natural heritage cover.

However, this relationship is negative, suggesting that collisions with wildlife are actually more frequent at low levels of traffic (Figure 8). While this may seem counter-intuitive, other researchers have found similar results. For example, Danks and Porter (2010) found that below 2500 AADT, every additional 500 vehicles per day increased the probability of a collision with a moose in Maine by 57%, but that above 2500 AADT, an increase in traffic volume did not lead to further increases in number of collisions. Working in eastern Ontario, Eberhardt et al. (2013) and Fahrig et al. (1995) found similar negative relationships between traffic volume and number of amphibians killed, suggesting that historic collisions in high traffic areas had reduced local wildlife populations, or that traffic was simply so noisy that it deterred wildlife.

As such, providing wildlife passage options over or under roads, along with fencing to direct wildlife, is critically important when new roads are constructed in potential hotspot areas, where such impacts have not previously occurred. On existing roads, the installation of underpasses or overpasses along with fencing when opportunities arise (i.e. during scheduled road construction) may help local wildlife to recover from the impacts of roads.

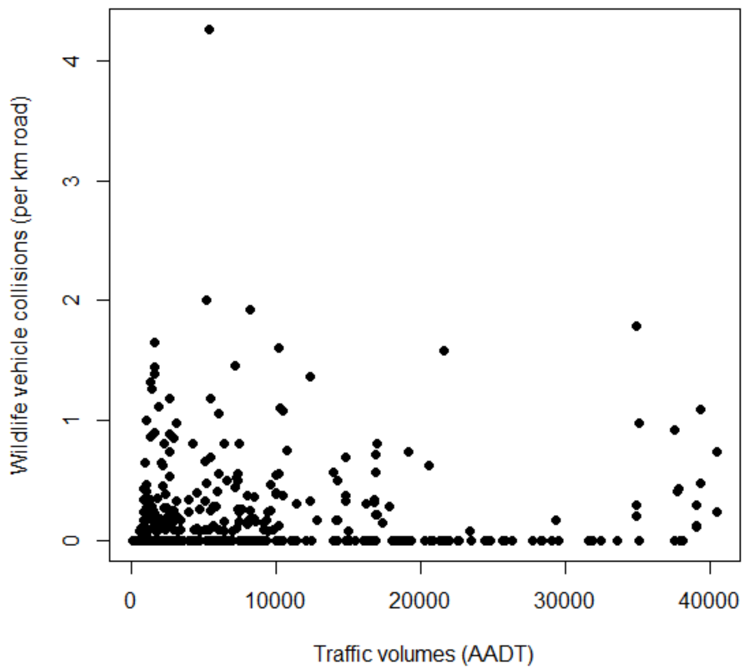


Figure 8. Relationship between traffic volumes and wildlife-vehicle collisions on York Regional roads

It is worth noting however, that AADT as a measure of traffic volume may simply be too coarse to adequately describe the impacts of traffic on wildlife. AADT is an estimate of average daily traffic volumes on a given road. Wildlife movements however are highly non-average in nature. The movement of frogs and turtles from over-wintering to breeding sites is highly dependent on time of year, time of day, and weather conditions (e.g. Obbard and Brooks 1981; Baldwin et al. 2006). If these conditions correspond with periods of higher than average traffic volume (e.g. rush hour or weekend cottage traffic), then AADT may not accurately represent the exposure of wildlife to traffic.

Maps of potential hotspots for collisions between vehicles and frogs or turtles have been developed for all municipalities in the Lake Simcoe watershed, by identifying all areas with a Gunson score greater than 30 (Appendix 1). These hotspots represent 37.3% of the watershed where municipal and provincial roads planners should be most cognizant of the impacts of roads on native biodiversity. Naturally, this model can be expected to have high rates of errors of commission; that is, many areas identified as potential hotspots in this model may not actually be associated with collisions, due to grade differences between the existing or proposed road and the surrounding landscape, or because local wildlife populations are already depressed due to pre-existing road mortality. However, it should also be noted that grade differences do not necessarily alleviate concerns related to wildlife vehicle collisions. In a follow-up to this study, LSRCA staff have begun monitoring mortality levels at several identified hotspots. During the spring turtle migration in 2015, the highest levels of mortality were recorded at a hotspot where an existing bridge provided a grade difference of over 4 m from the river below. As such, neither this mapping, nor cursory examinations of areas where new roads or road reconstruction projects are proposed, are sufficient to address mitigation requirements for roads on wildlife. Rather, proponents for roads or other infrastructure should use the maps in Appendix 1 to determine which areas need further monitoring and evaluation by a qualified field biologist as part of the site planning process.

Works Cited

Adriaensen, F., Chardon, J.P., De Blust, G., Swinnen, E., Villalba, S., Gulinck, H. and Matthysen, E. 2003. The application of 'least-cost' modelling as a functional landscape model. Landscape and Urban Planning 64:233–247.

Baldwin, R.F., Calhoun, A.J.K., and deMayadier, P.G. 2006. Conservation planning for amphibian species with complex habitat requirements: a case study using movements and habitat selection of the wood frog *Rana sylvatica*. Journal of Herpetology 40: 443 – 454.

Beier, P., Spencer, W., Baldwin, R.F., and McRae, B.H. 2011. Toward best practices for developing regional connectivity maps. Conservation Biology 25: 879 – 892.

Boone, R.B., Johnson, C.M., and Johson, L.B. 2006. Simulating wood frog movement in central Minnesota, USA using a diffusion model. Ecological modelling 198: 255 – 262.

Danks, Z.D. and Porter, W.F. 2010. Temporal, spatial, and landscape habitat characteristics of moose-vehicle collisions in western Maine. Journal of Wildlife Management 74: 1229 – 1241.

Eberhardt, E., Mitchell, S. and Fahrig, L. 2013. Road kill hotspots do not effectively indicate mitigation locations when past road kill has depressed populations. The Journal of Wildlife Management 77: 1353 – 1359.

Fahrig, L., Pedlar, J.H., Pope, S.E., Taylor, P.D. and Wegner, J.F. 1995. Effect of road traffic on amphibian density. Biological Conservation 73: 177 – 182.

Fahrig, L. and Rytwinski, T. 2009. Effects of roads on animal abundance: an empirical review and synthesis. Ecology and Society 14: 21.

Findlay C.S. and Houlahan J. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biololgy 11:1000–1009

Foreman, R.T.T. and Alexander, L.E. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29: 207 – 231.

Gunson, K.E., Ireland, D. and Schueler, F. 2012. A tool to prioritize high-risk road mortality locations for wetland-forest herpetofauna in southern Ontario, Canada. North-western journal of zoology 8: 409 – 413.

Jalava, J.V., Riley, J.L., Zammit, A.E., Sorrill, P.J., Holden, T., and Henson, J. 2001. Big Picture applications of bioregional planning in Ontario. Proceedings of the 2001 Parks Research Forum of Ontario.

Kociolek, A.V., Clevenger, P., St. Clair, C.C., and Proppe, D.S. 2011. Effects of road networks on bird populations. Conservation Biology 25: 241 – 249.

Koen, E.L., Bowman, J., Sadowski, C, and Walpole, A.A. 2014. Landscape connectivity for wildlife: development and validation of multispecies linkage maps. Methods in ecology and evolution 5: 626 – 633.

McRae, B. H., Dickson, B.G., Keitt, T.H. and Shah, V.B.. 2008. Using circuit theory to model connectivity in ecology and conservation. Ecology 10:2712–2724.

Ministry of the Environment. 2009. The Lake Simcoe Protection Plan. Queen's Printer for Ontario. Toronto, ON.

Ministry of Natural Resources and Forestry. 2015. Technical definitions and criteria for identifying Key Natural Heritage Features and Key Hydrologic Features for the Lake Simcoe Protection Plan. Queen's Printer for Ontario. Toronto, ON.

Obbard, M.E. and Brooks, R.J. 1981. A radio-telemetry and mark-recapture study of activity in the common snapping turtle, *Chelydra serpentina*. Copeia 3: 630 – 637.

Ontario Road Ecology Group and Toronto Zoo. 2010. A guide to road ecology in Ontario, prepared for the Environment Canada Habitat Stewardship Program for Species at Risk

Schueler, F.W. and Gunson, K.E. 2011. The road ecology circuit in Leeds & Grenville. Trails and Landscape 45:155–160.

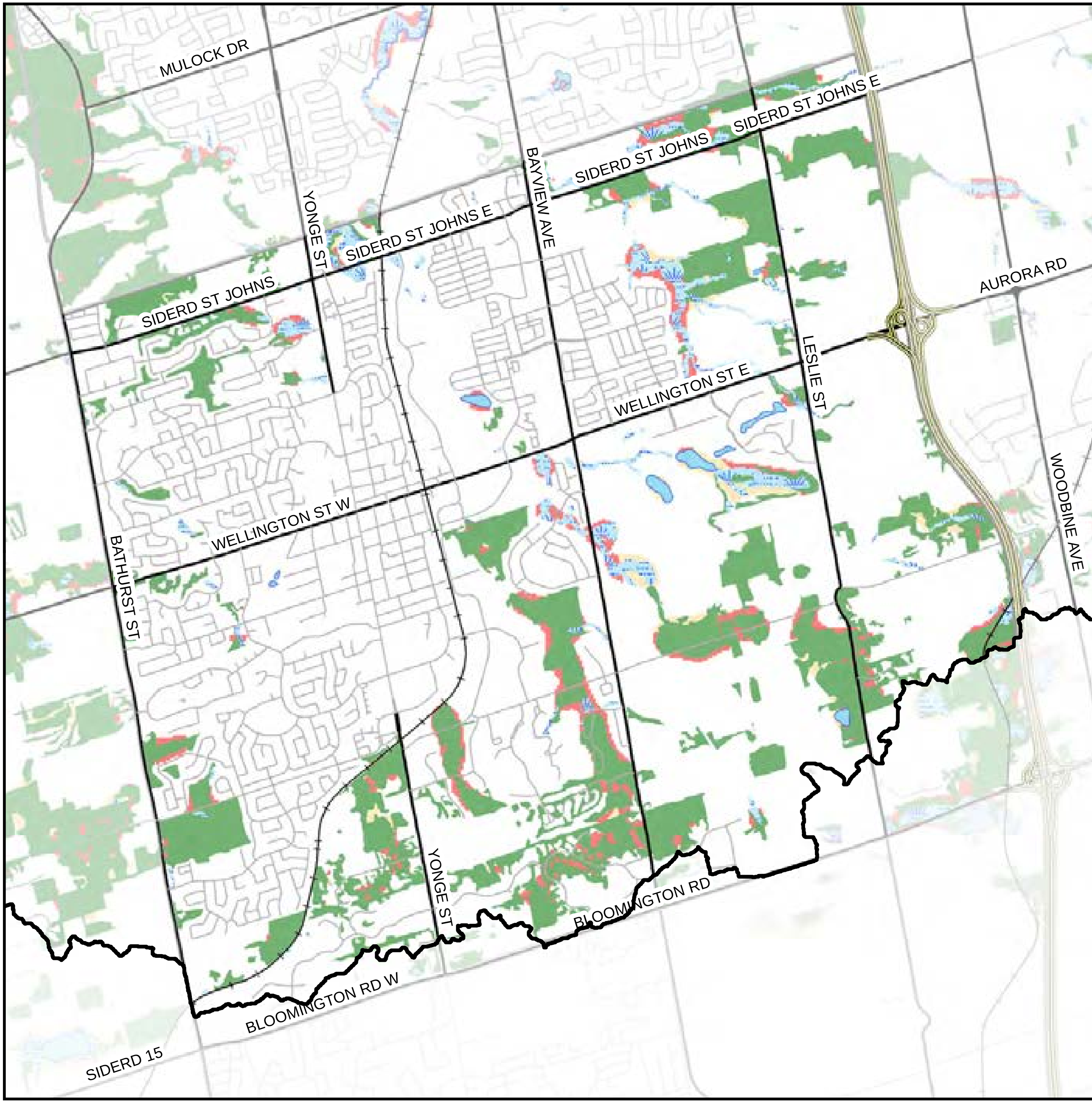
Semlitsch, R.D. and Bodie, J.R. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. Conservation Biology 17: 1219 – 1228.

Walpole, A.A. 2011. Landscape connectivity in the Lake Simcoe watershed, Ontario. First biennial Lake Simcoe Protection Plan Forum.

XCG Consultants Ltd. 2014. Lake Simcoe Phosphorus Offset Program: summary report. Produced for Lake Simcoe Region Conservation Authority.

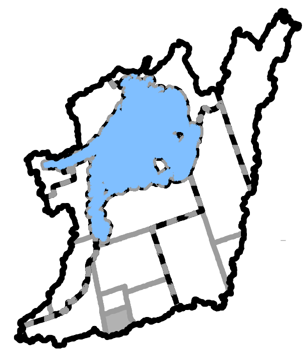
Appendix. Maps of potential hotspots of wildlife vehicle collisions in the Lake Simcoe watershed

Potential wildlife collision hotspots AURORA



Legend

- Local road
- Regional road
- Provincial highway
- Railway
- Roadside hotspots
- Hotspots
- Grassland
- Wetland
- Forest
- Lake



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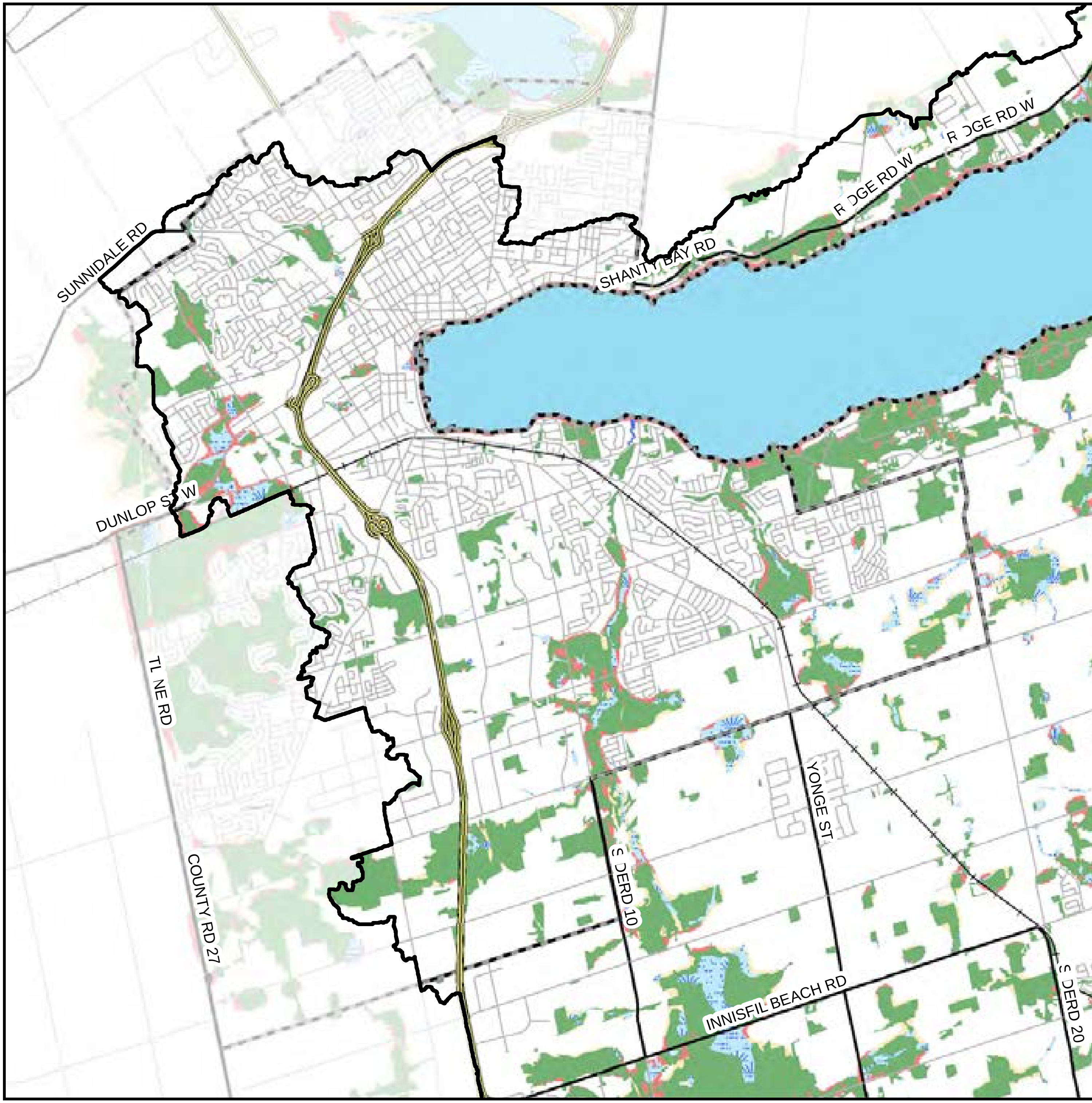
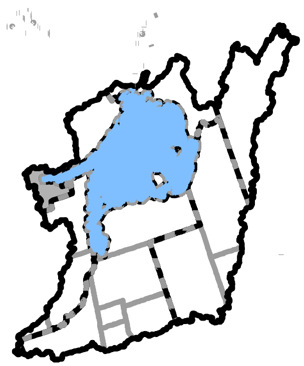


Potential wildlife collision hotspots BARRIE

Legend

- Local road
- Regional road
- Provincial highway
- Railway
- Roadside hotspots
- Hotspots
- Grassland
- Wetland
- Forest
- Lake



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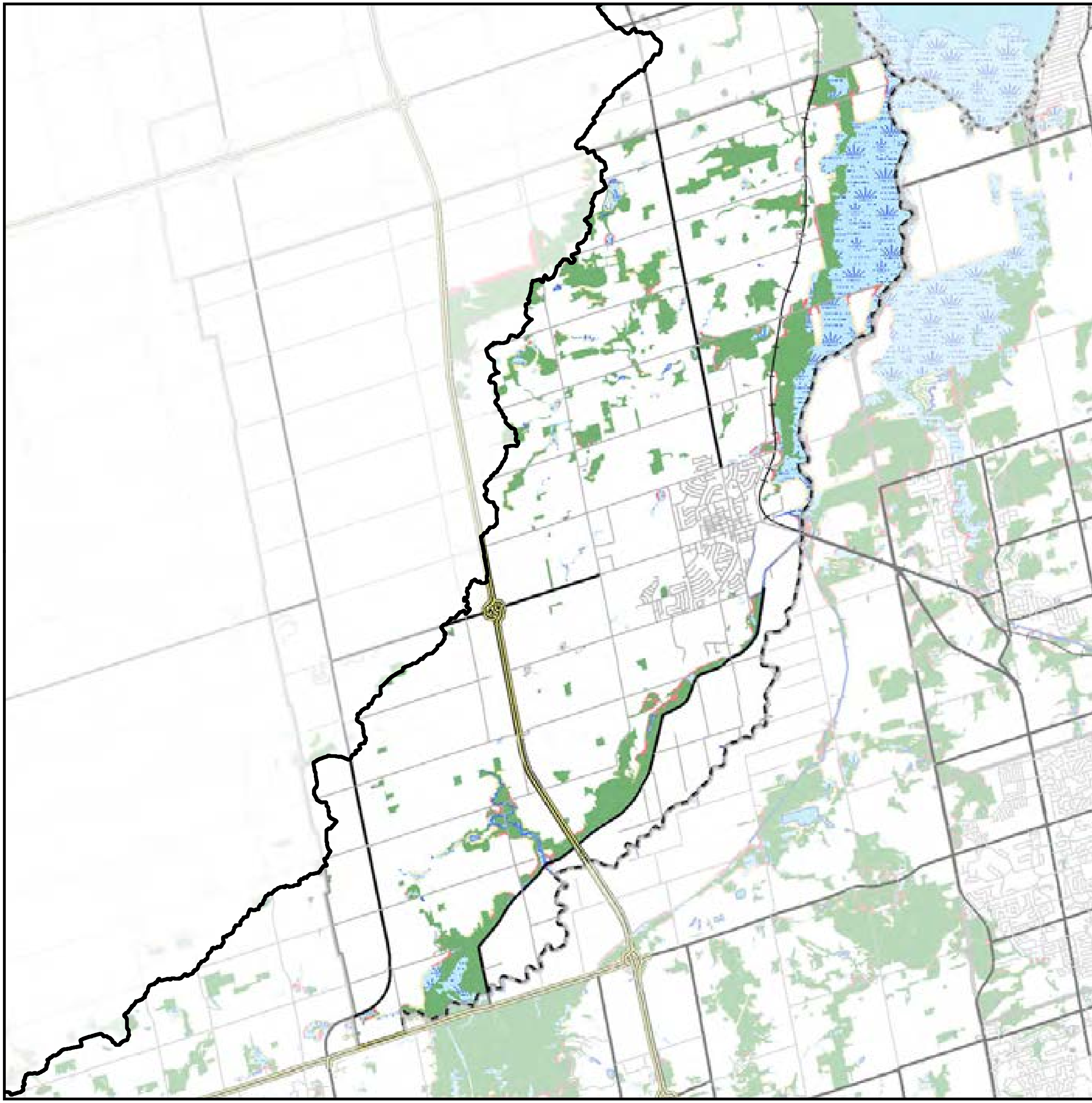
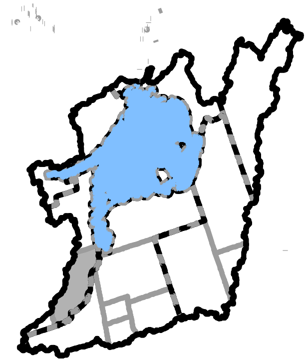


Potential wildlife collision hotspots BRADFORD - WEST GWILLIMBURY

Legend

- Local road
- Regional road
- Provincial highway
- Railway
- Roadside hotspots
- Hotspots
- Grassland
- Wetland
- Forest
- Lake



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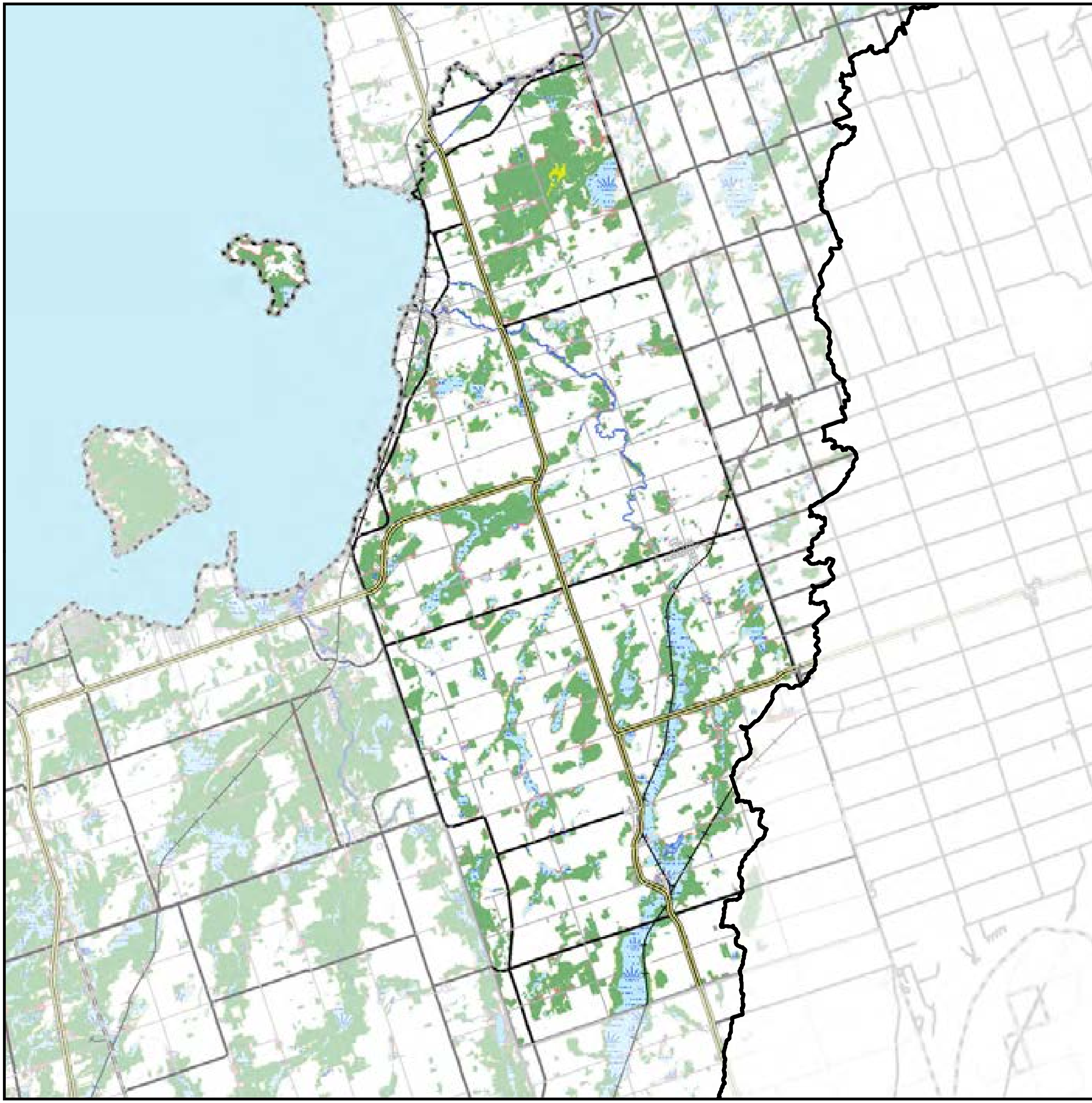
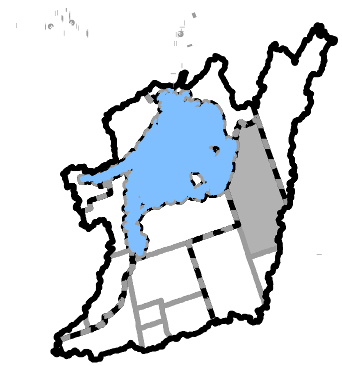


Potential wildlife collision hotspots BROCK

Legend

- Local road
- Regional road
- Provincial highway
- Railway
- Roadside hotspots
- Hotspots
- Grassland
- Wetland
- Forest
- Lake



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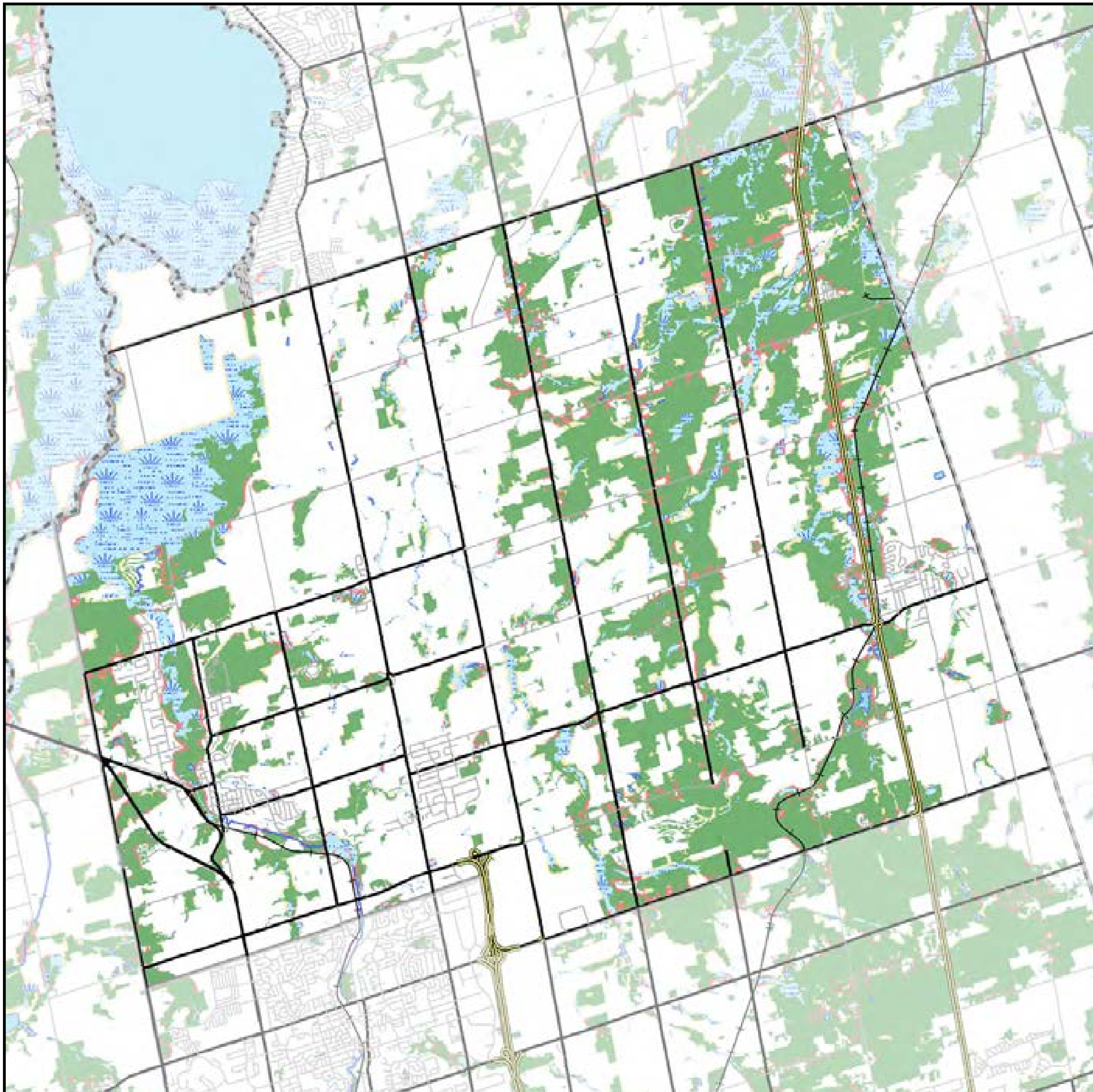
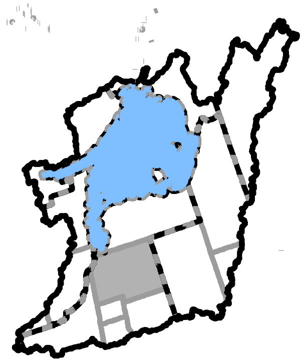


Potential wildlife collision hotspots EAST GWILLIMBURY

Legend

- Local road
- Regional road
- Provincial highway
- Railway
- Roadside hotspots
- Hotspots
- Grassland
- Wetland
- Forest
- Lake



0 1 2 4 Kilometers

N

Lake Simcoe Region conservation authority

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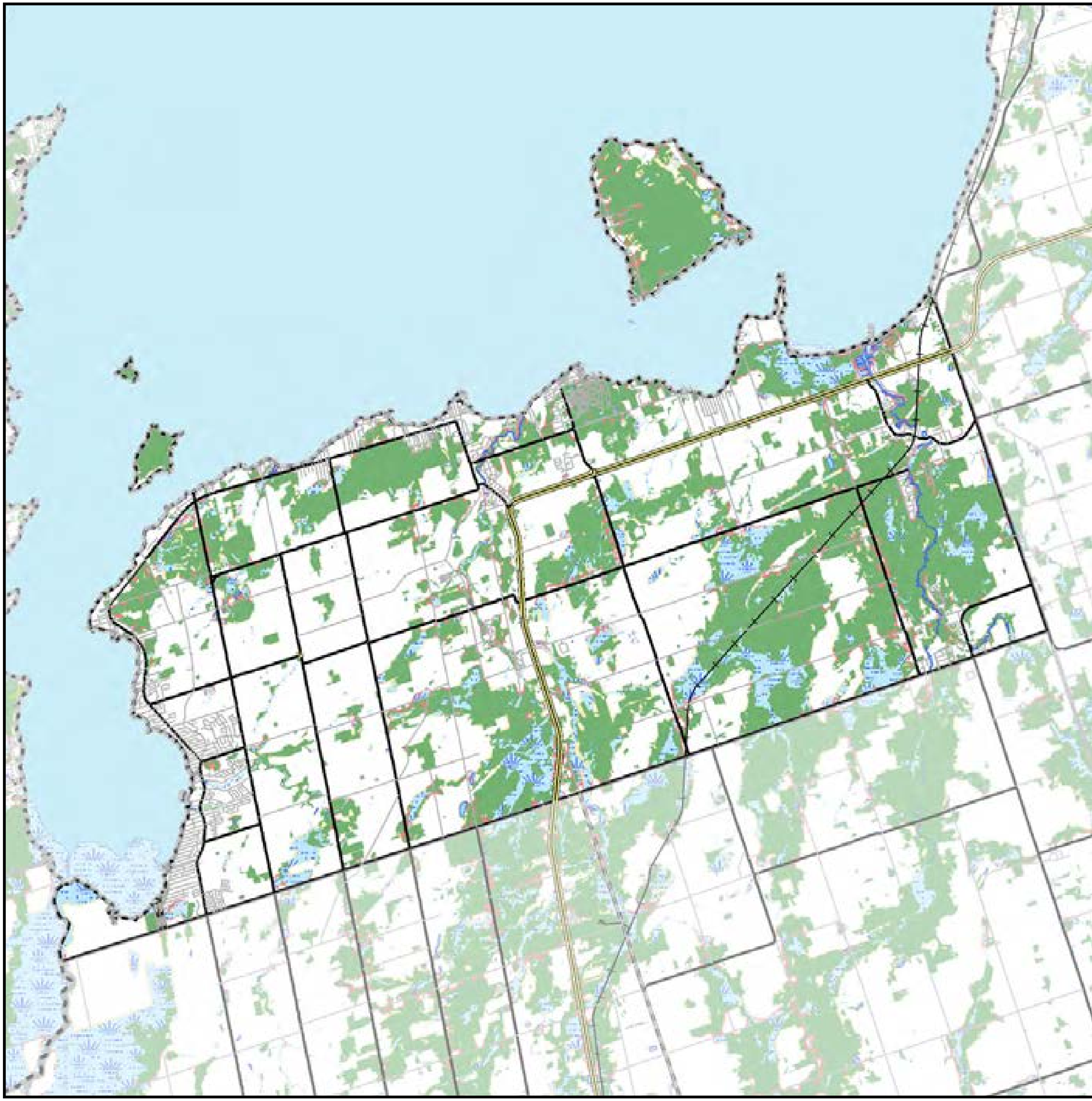
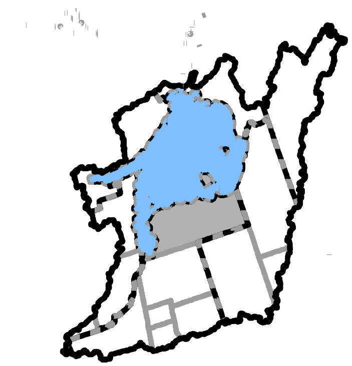
Potential wildlife collision hotspots GEORGINA



Legend

- Local road
- Regional road
- Provincial highway
- Railway
- Roadside hotspots
- Hotspots
- Grassland
- Wetland
- Forest
- Lake



0 1 2 4 6
Kilometers

N

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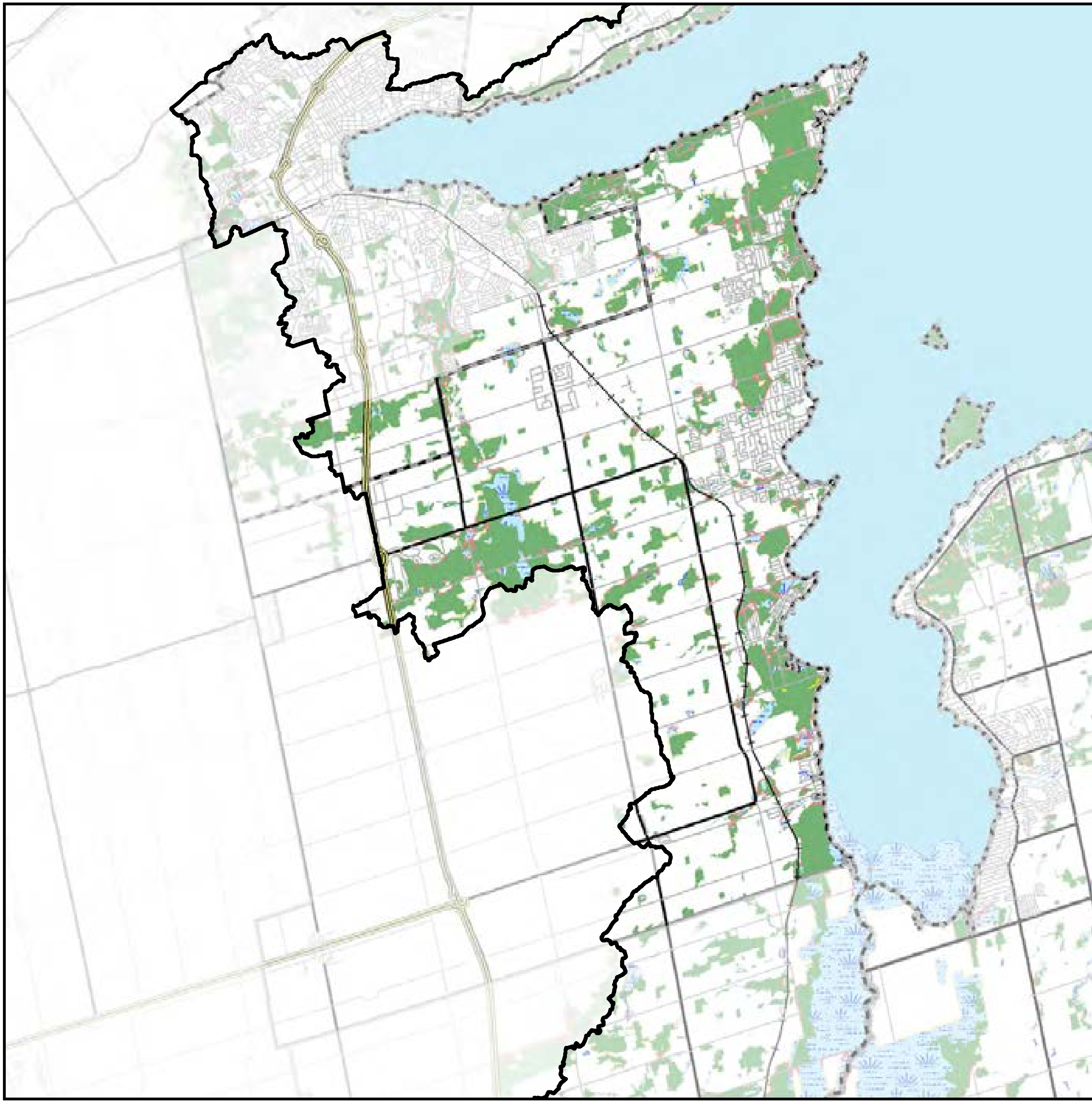
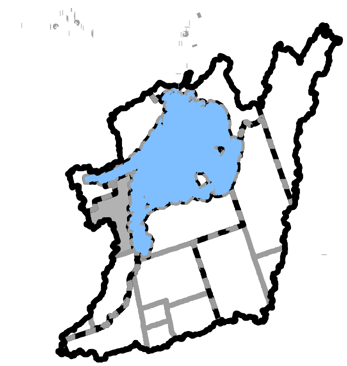
Potential wildlife collision hotspots INNISFIL



Legend

- Local road
- Regional road
- Provincial highway
- Railway
- Roadside hotspots
- Hotspots
- Grassland
- Wetland
- Forest
- Lake



0 1 2 4 6 Kilometers

N

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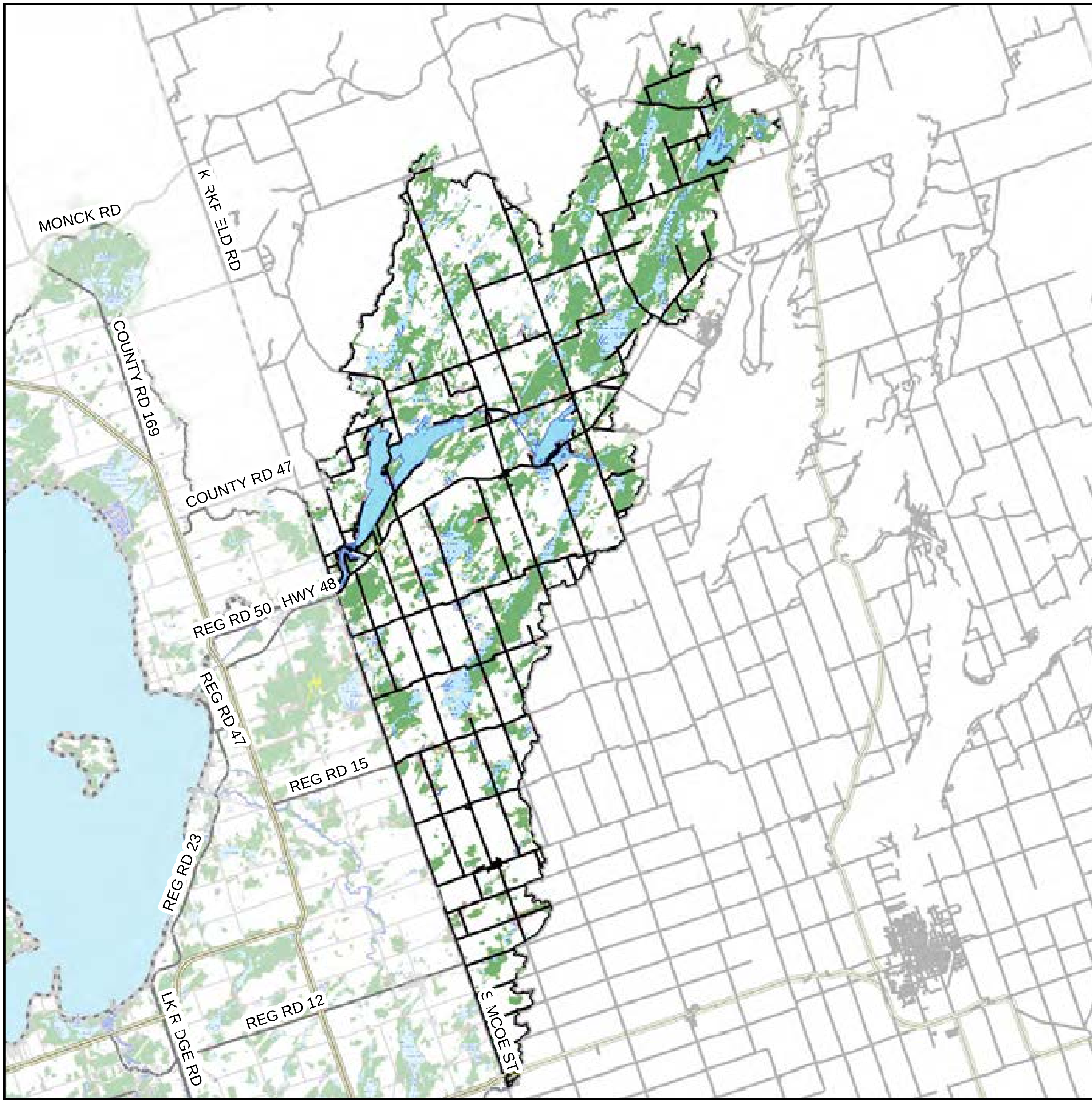
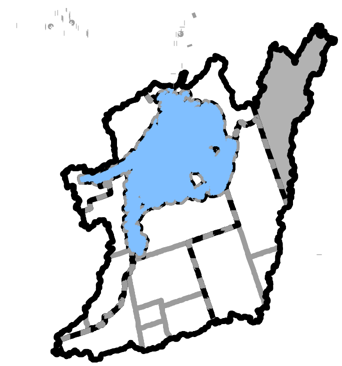


Potential wildlife collision hotspots KAWARTHA LAKES

Legend

- Local road
- Regional road
- Provincial highway
- Hotspots
- Roadside hotspots
- Grassland
- Wetland
- Forest
- Lake



0 1 2 4 6 8 10 Kilometers

N

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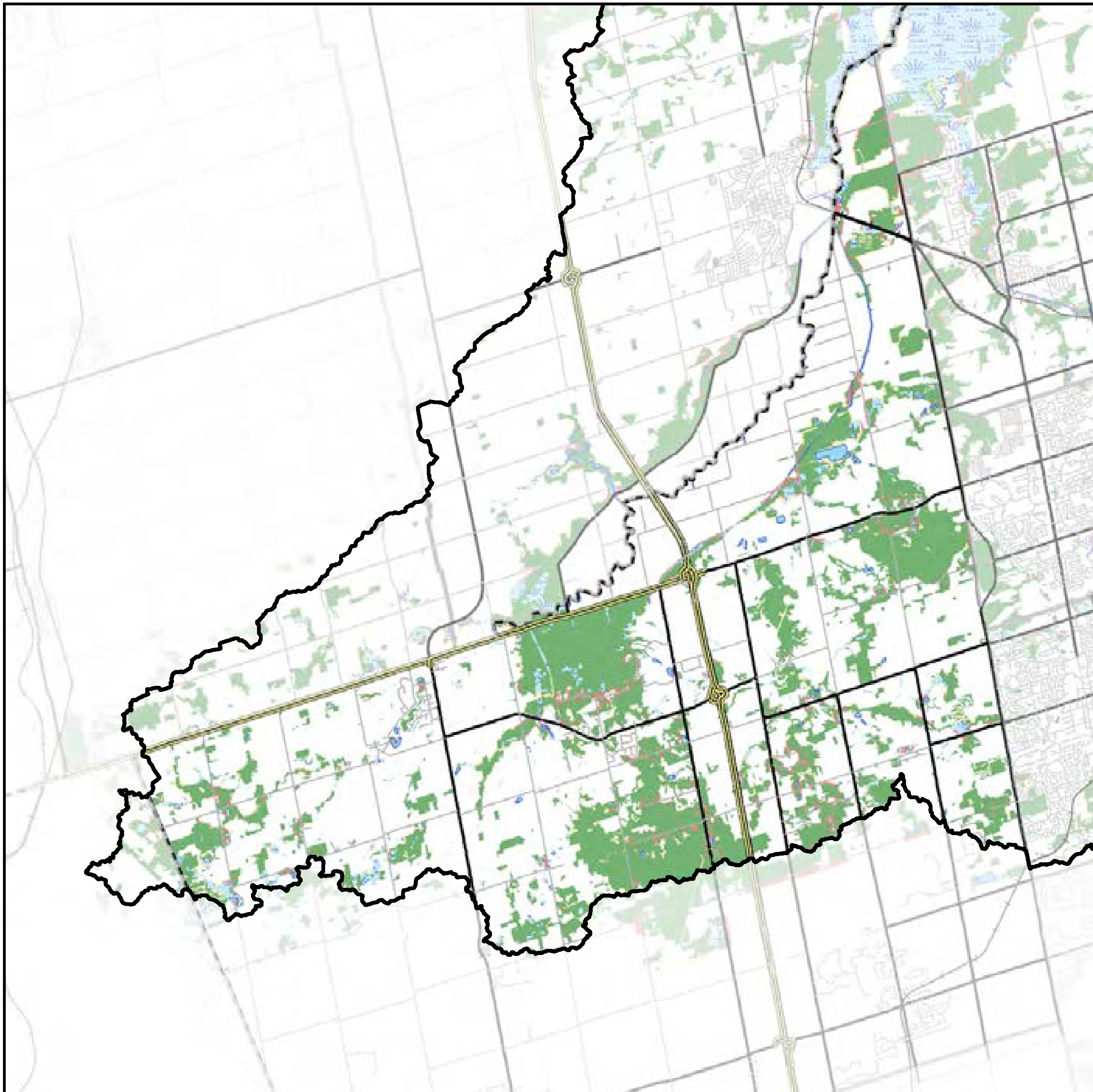
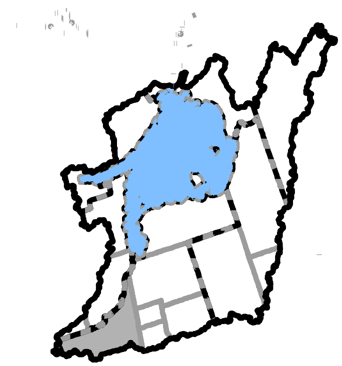


Potential wildlife collision hotspots KING

Legend

- Local road
- Regional road
- Provincial highway
- Railway
- Roadside hotspots
- Hotspots
- Grassland
- Wetland
- Forest
- Lake



0 1 2 4 6 Kilometers

N

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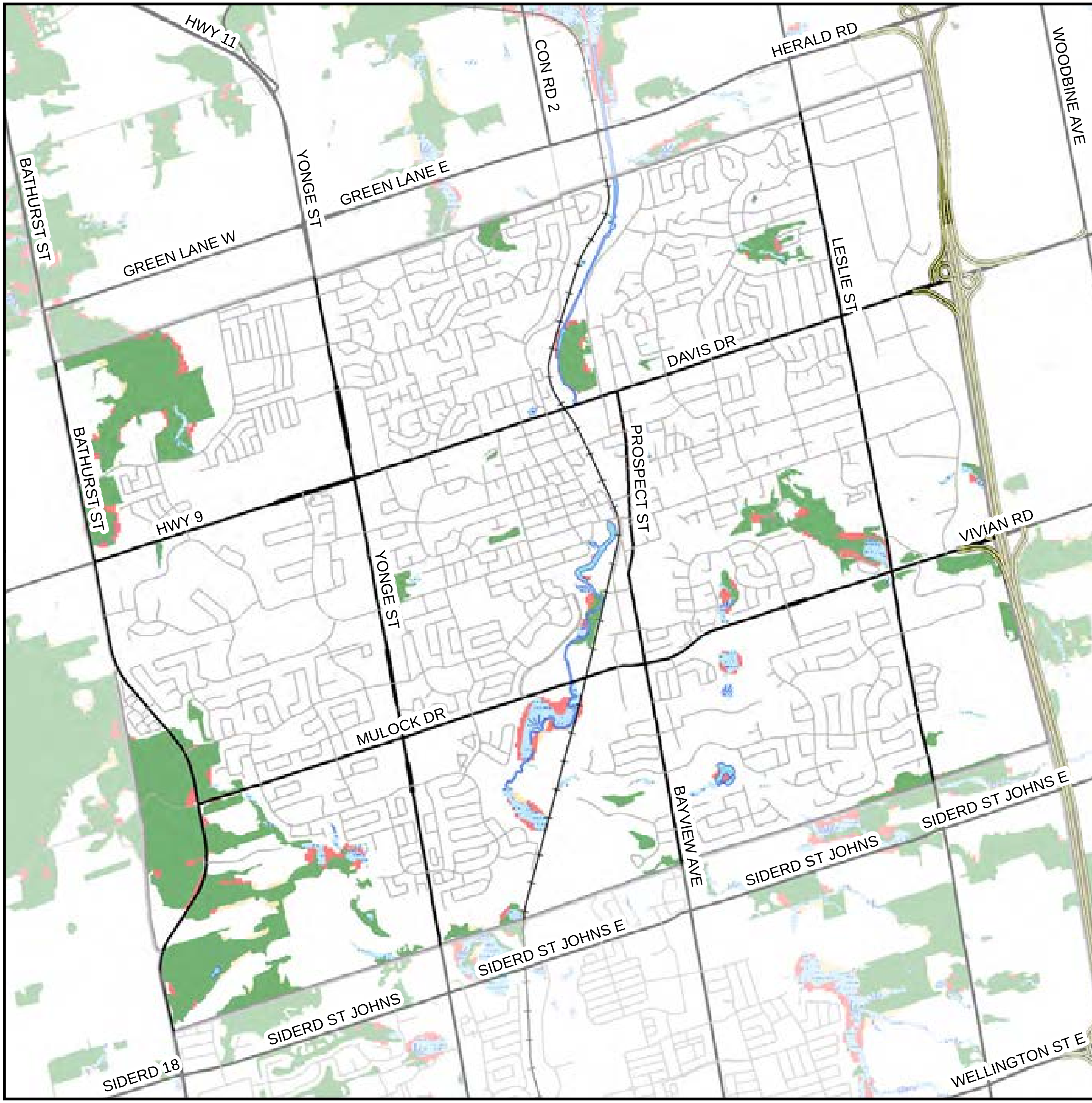
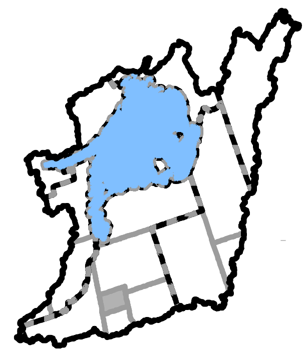


Potential wildlife collision hotspots NEWMARKET

Legend

- Local road
- Regional road
- Provincial highway
- Railway
- Roadside hotspots
- Hotspots
- Grassland
- Wetland
- Forest
- Lake



0 0.5 1 2 Kilometers

N

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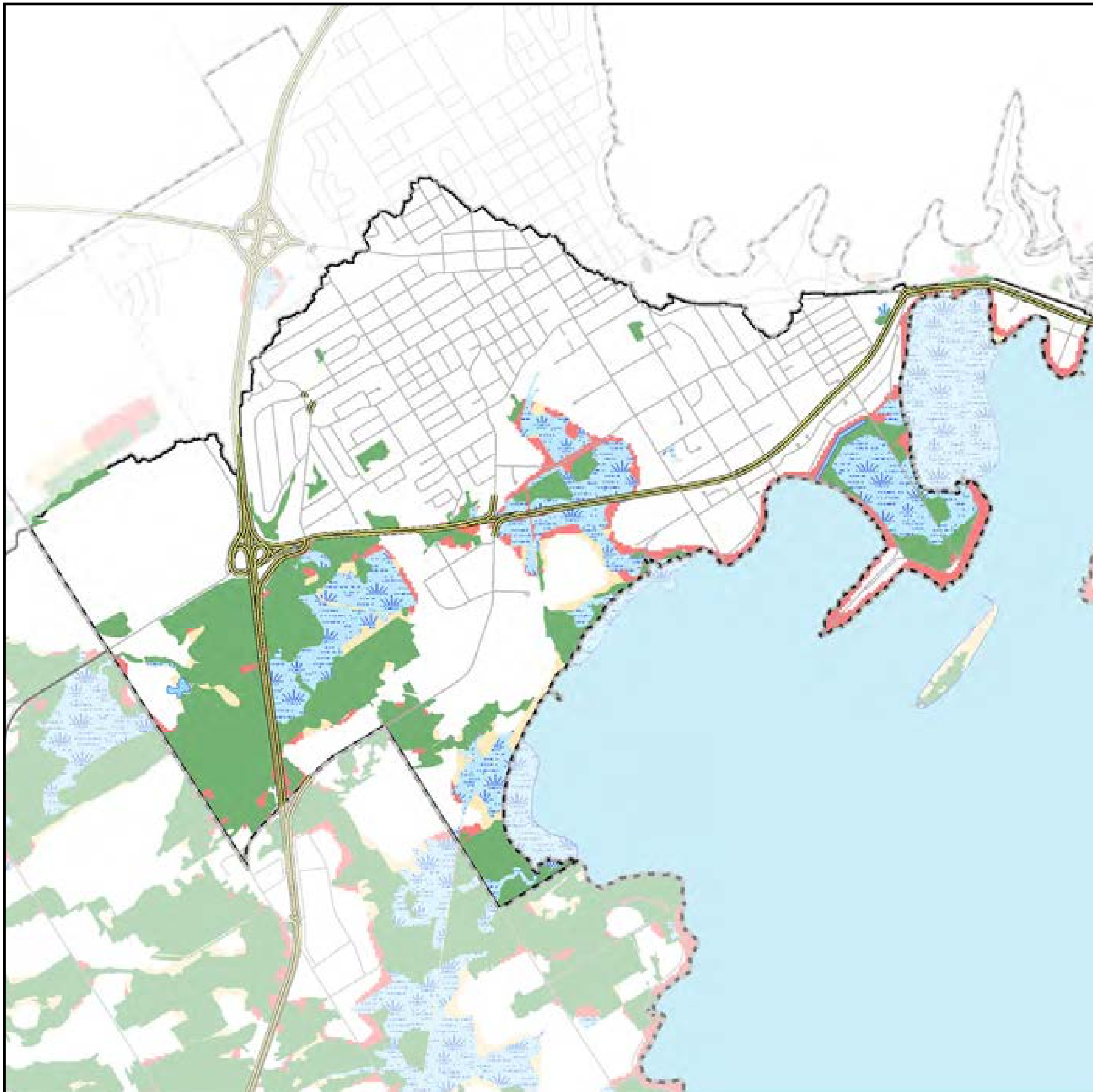
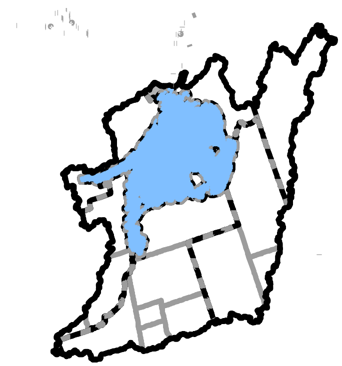


Potential wildlife collision hotspots ORILLIA

Legend

- Local road
- Regional road
- Provincial highway
- Hotspots
- Roadside hotspots
- Grassland
- Wetland
- Forest
- Lake



0 0.5 1 Kilometers

N

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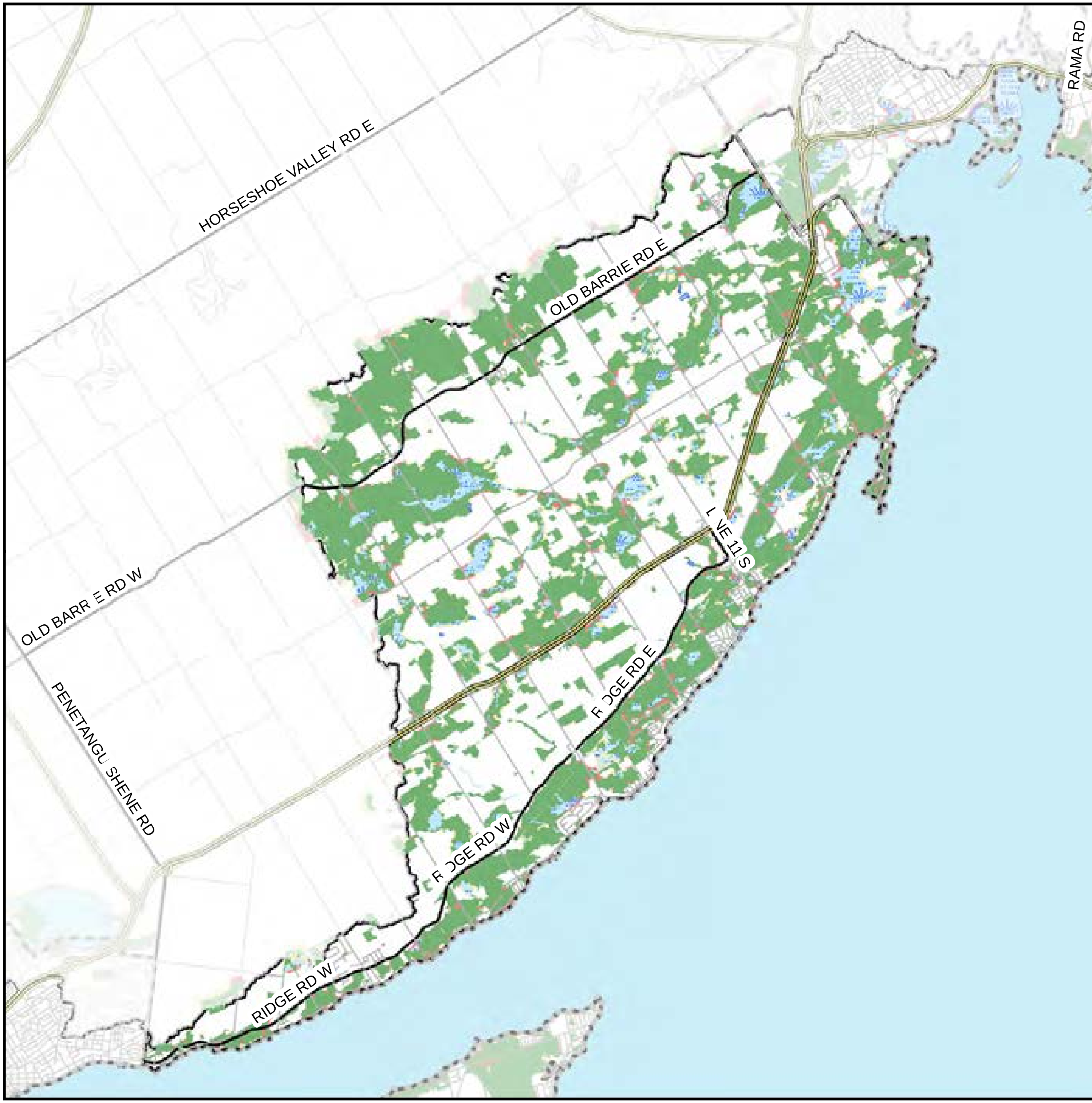
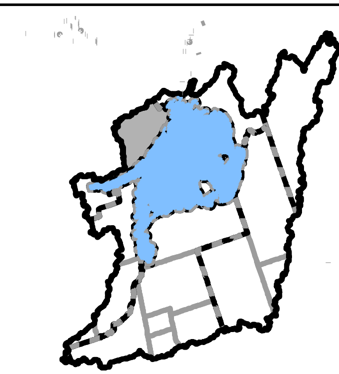


Potential wildlife collision hotspots ORO-MEDONTE

Legend

- Local road
- Regional road
- Provincial highway
- Hotspots
- Roadside hotspots
- Grassland
- Wetland
- Forest
- Lake



0 1 2 4 6 Kilometers

N

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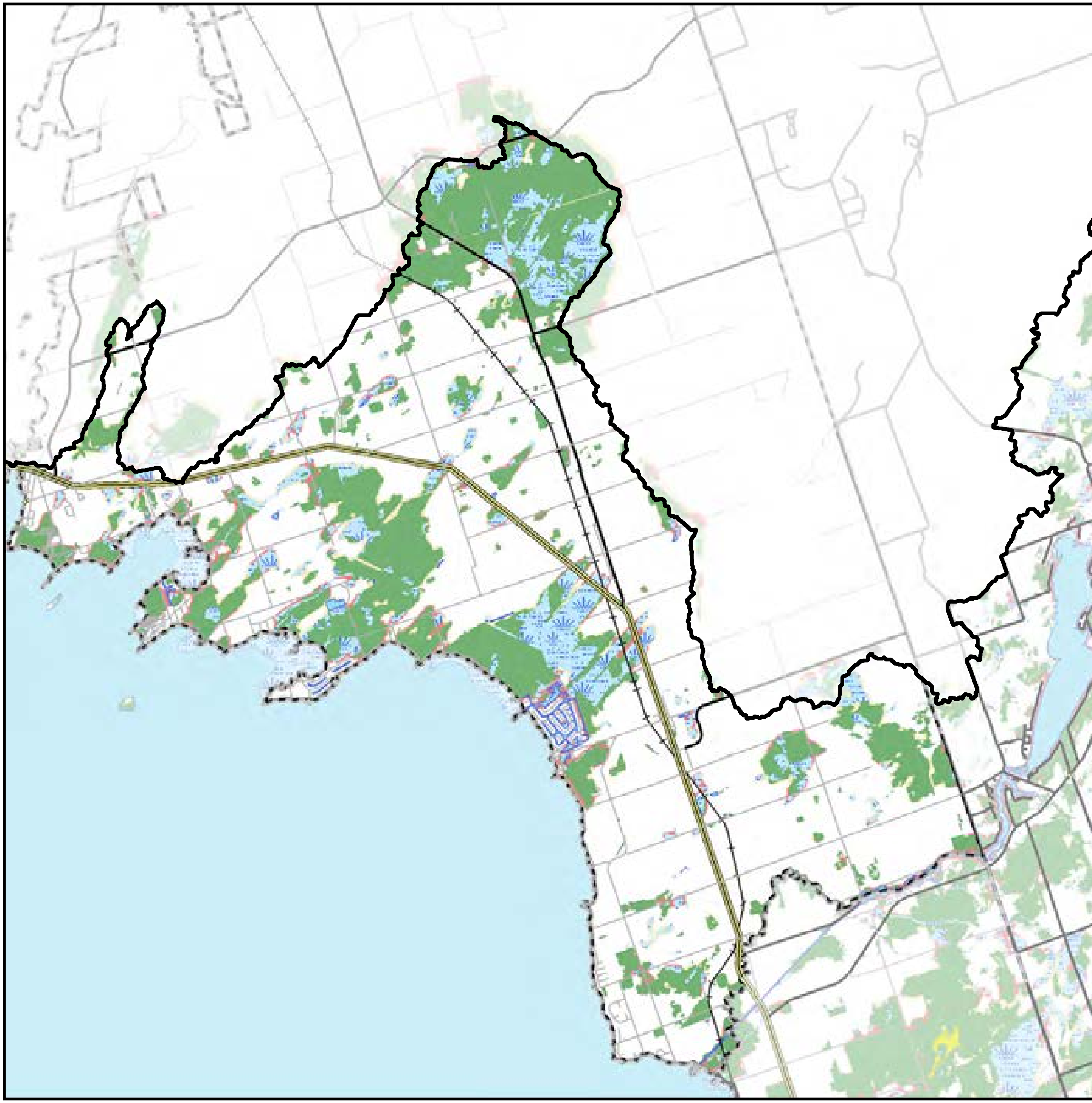
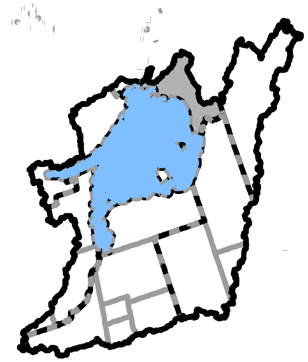


Potential wildlife collision hotspots RAMARA

Legend

- Local road
- Regional road
- Provincial highway
- Railway
- Roadside hotspots
- Hotspots
- Grassland
- Wetland
- Forest
- Lake



0 1 2 4 6 Kilometers

N

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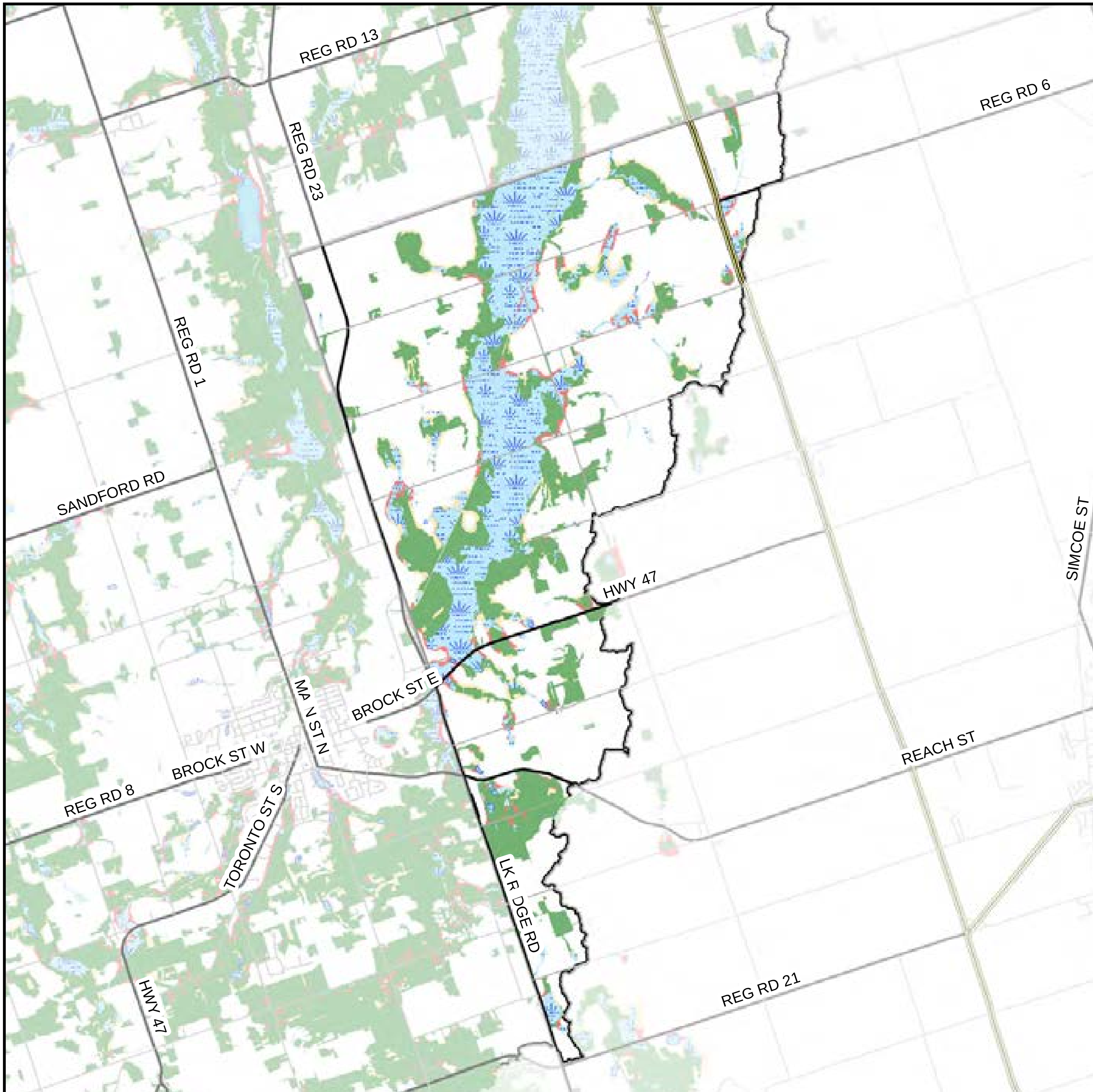
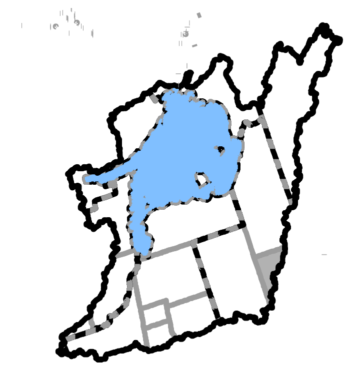


Potential wildlife collision hotspots SCUGOG

Legend



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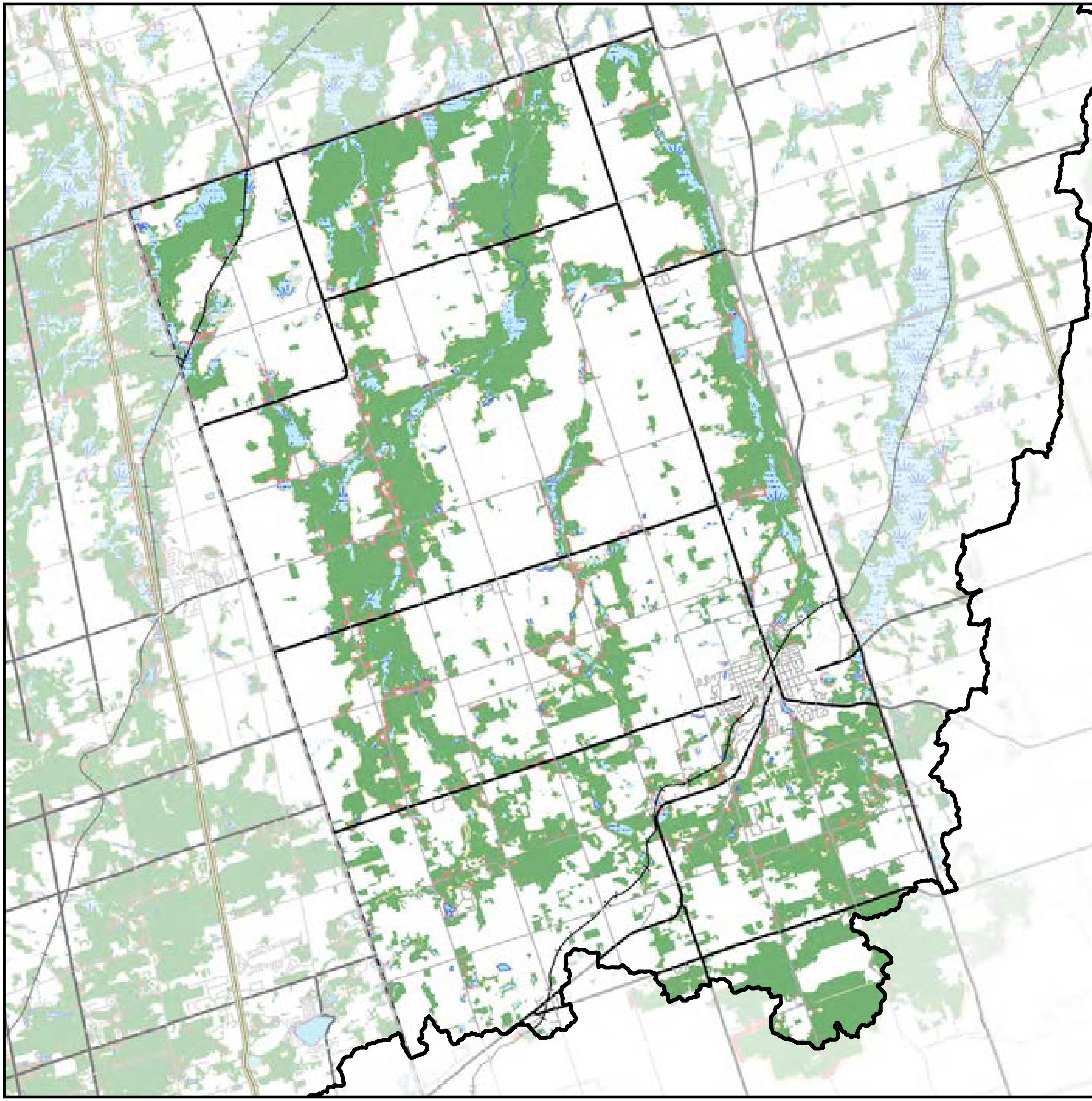
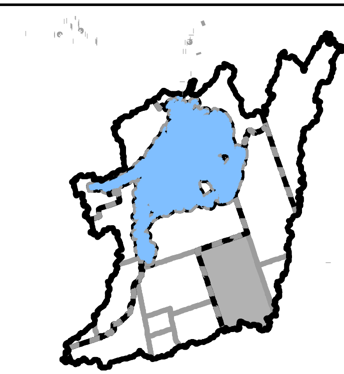


Potential wildlife collision hotspots UXBRIDGE

Legend

- Local road
- Regional road
- Provincial highway
- Railway
- Roadside hotspots
- Hotspots
- Grassland
- Wetland
- Forest
- Lake



0 1 2 4 6 Kilometers

N

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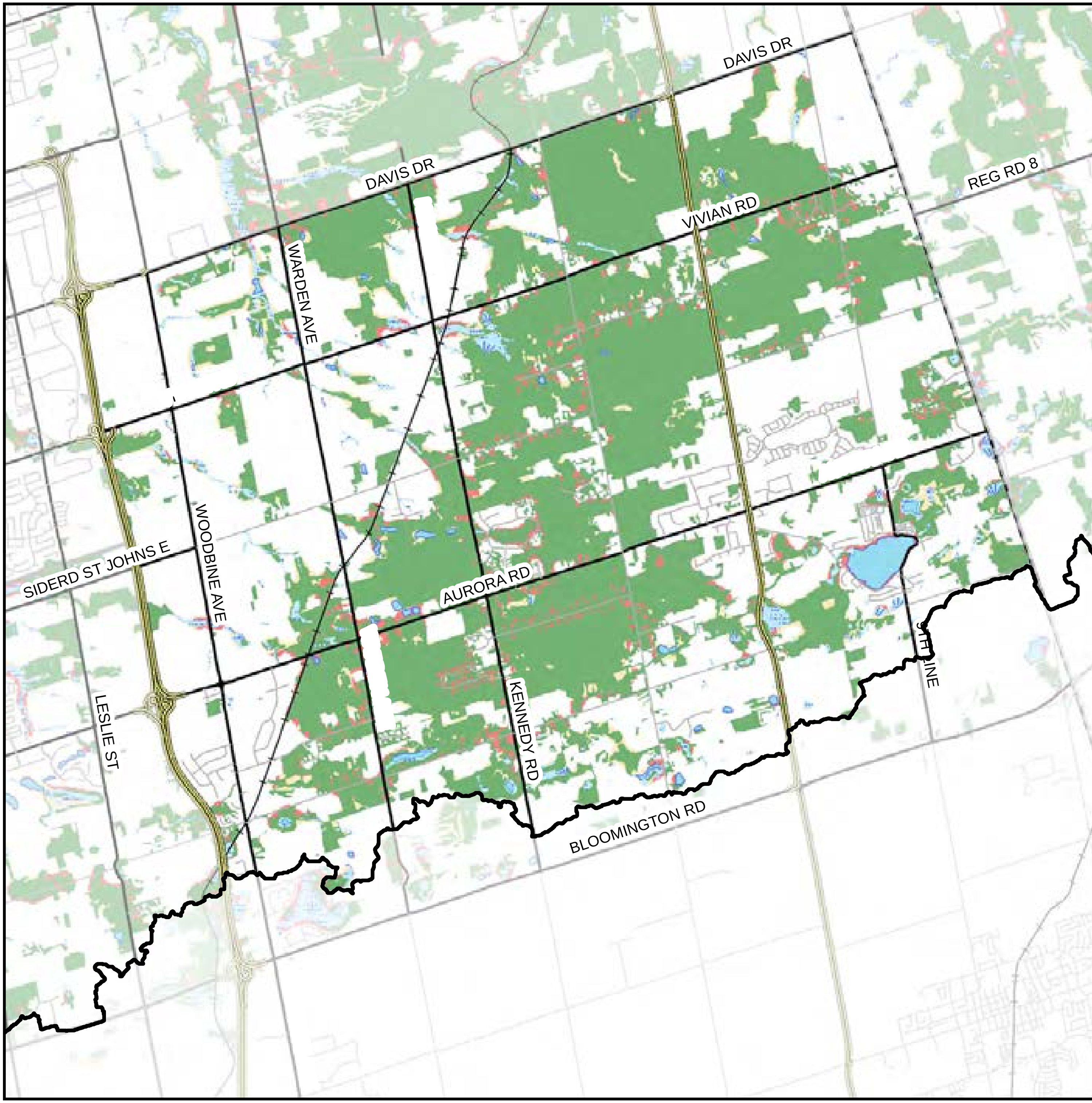
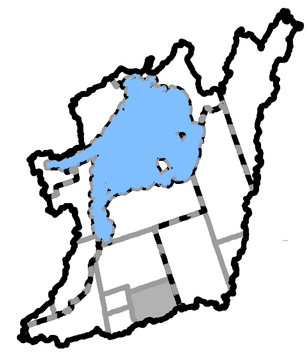
Potential wildlife collision hotspots WHITCHURCH - STOUFFVILLE



Legend

- Local road
- Regional road
- Provincial highway
- Railway
- Roadside hotspots
- Hotspots
- Grassland
- Wetland
- Forest
- Lake



0 0.5 1 2 3 Kilometers

N

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