1.0 Introduction

1.1 Background

Population and employment projections suggest that urban development could increase by 50% in the Lake Simcoe watershed by 2041. This shift from rural and natural heritage features, to urban land use can have significant impacts on Ontario's native biodiversity. With increased development comes the need for more transportation infrastructure, which can significantly impact wildlife habitat.

The impacts of roads on wildlife communities generally fall into four categories:

Habitat Degradation

- Invasive species
- Road use contaminants (salt, chemicals from vehicles)
- Light and noise
- Human presence
- Edge effects

Habitat Loss

- Direct removal of habitat by the road footprint
- Removal of breeding habitat, food sources, hibernacula, etc.
- Greater impact on species with a large home range

Reduced Habitat Connectivity

- Barriers to movement
- Some species attempt to cross; some will not or cannot
- Reduced gene flow between populations, impairing their resilience

Wildlife Injury or Mortality

- Vehicle-wildlife collisions (VWCs)
- Dependent on traffic volume, speed, visibility, etc.
- Impacts vary for different species
- Landscape features and road design affect rates of VWCs

1.2 Reptiles and amphibians are the hardest hit

Reptiles (turtles, snakes and lizards) and amphibians (frogs, toads and salamanders) are among those species most at risk from roads. Their life history characteristics require them to migrate between various habitats throughout the year to reach the habitat features they need to survive and reproduce (e.g. mates and breeding or hibernation sites). They are also slow-moving and difficult to see on roads.

In Ontario, almost half of the native species of reptiles and amphibians have been designated 'At Risk' either provincially or federally. This includes all of the native turtle species, and road mortality has been identified as one of the major causes of their decline.

While roads are dangerous to slow-moving reptiles, they also present an opportunity to bask on the warm asphalt, and sandy road shoulders provide ideal nesting habitat for turtles. However, using roads

for these purposes can result in road mortality, injury or nest damage through vehicle-wildlife collisions and routine road maintenance activities (e.g. shoulder grading or mowing).

1.3 Purpose of the guide

This guide was created to assist project managers in incorporating road ecology best management practices (BMPs) into road design, with a focus on using ecopassages to improve habitat connectivity and reduce vehicle-wildlife collisions. Due to their particular susceptibility to roads, as mentioned above, the guide focusses on mitigating impacts on reptile and amphibians. Numerous other guides outline mitigation measures for other groups of wildlife; see Appendices A and B for these resources.

2.0 Road ecology best management practices

Transportation infrastructure is important to support our growing population and the movement of people and goods. So while it's impossible to stop building roads or railways, they can be designed and built in ways that minimize their impacts on wildlife.

Road ecology is the interaction of roads and vehicles with the environment. The incorporation of road ecology best management practices (BMPs) into road design can help build infrastructure that mimics the natural environment and minimizes the disruption of natural processes. Achieving this requires the integrated efforts of transportation planners, policy-makers, engineers and ecologists.

The Ontario Ministry of Transportation has drafted an Environmental Guide for Mitigating Road Impacts to Wildlife (MTO, 2017a), which outlines wildlife mitigation measures which can be incorporated into different stages of road design and operational practices. These are listed in order of preferred options:

1) Avoidance – Plan for a route that avoids and/or minimizes impacts on wildlife and ecosystems, including avoiding and buffering road alignments from natural habitat during the Environmental Assessment or preliminary design stage. Planning infrastructure projects close together (e.g. roads and rail) can minimize the amount of habitat affected.

2) Mitigation – Identify and implement a suite of mitigation approaches (BMPs) in the road design for habitat protection and facilitating wildlife movement. These measures should be cost-effective, properly located, and sensitive to anticipated future land use changes bordering the road.

3) Habitat creation and offsetting – Strategies such as wetland substrate salvage, topsoil salvage, habitat creation or improvements (on and off the right-of-way), and more ecologically-based road vegetation management can benefit wildlife and soften habitat impact.

4) Monitoring – Evaluate whether a mitigation strategy for wildlife is effective and strive to determine if wildlife populations are affected by the mitigation, and which designs work best.

Ecopassages are a road ecology mitigation BMP designed to assist wildlife in safely crossing roads, working to minimize road mortality, while increasing habitat connectivity. This guide focusses on implementing wildlife ecopassages as a mitigation measure for reptiles and amphibians; however it is only one of many potential BMPs that can be incorporated into road design and maintenance.

A list of general BMPs for road design, construction, operation and maintenance for reptiles and amphibians is presented in Table 1, and was adapted from the Credit Valley Conservation Fish and Wildlife Crossing Guidelines (CVC, 2017). This list is not exhaustive and the resources in Appendices A and B provide additional BMPs.

It doesn't have to be expensive!

There are a broad range of relatively low-cost solutions to mitigating road effects on wildlife, especially when they are factored into the capital costs of a road project

Best management practices (BMPs) for road design and construction, operation and maintenance phases for reptiles and amphibians

Improving Habitat Connectivity and Reducing Vehicle-Wildlife Collisions

Road Design:

- Avoid building roads near natural heritage features, and where not avoidable, design new roads near the edges of habitat (as opposed to directly through) to reduce fragmentation and potential need for crossings.
- Group linear infrastructure projects together where possible
- Install traffic calming measures (e.g. speed bumps, rumble strips, roundabouts), wildlife crossing signs, and/or animal-vehicle detection systems.
- Incorporate sloped and roughened curbs along roadsides in areas with salamanders and turtles to prevent animals from being trapped in the ROW.
- Modify infrastructure (i.e. curbs, drainage grates, culverts, Jersey barriers) to facilitate wildlife movement.

Construction, Operation and Maintenance:

- Implement seasonal road closures during times of wildlife migration.
- Develop and promote public awareness and education campaigns.
- Wildlife awareness or crossing signage may be placed along roads that bisect habitat.
- Manage roadside vegetation to ensure that drivers and wildlife have a clear field of view.
- Inspect wildlife exclusion fences periodically for damage that could affect the integrity of the fence or allow passage of wildlife. Inspections should occur following spring melt and heavy rain events; this is especially important when using temporary geotextile fencing.
- Ongoing monitoring and maintenance of crossing structures and fencing post-construction, with adaptive management implemented as needed
- In the event that a wildlife rescue is needed, MNRF should be contacted to obtain a Wildlife Scientific Collector's permit

General Road Ecology Considerations

Road Design:

- Minimize footprint of road and length of culverts where feasible.

- Install noise barriers (e.g. soil berms or solid walls) to minimize disturbance to adjacent natural areas.
- Avoid or minimize artificial lighting adjacent to natural areas and wildlife corridors, unless required for human safety. If lighting is required, use downcast and directional options that avoid unnecessarily broadcasting light to the natural area.
- During design, light-sensitive areas (e.g. wetlands with breeding amphibians) should be mapped in order to inform the appropriate placement (or avoidance) of lighting fixtures.
- Consider constructing habitat features beyond the footprint of the road (eg. turtle nesting habitat and snake hibernacula).

Construction, Operation and Maintenance:

- Protect the existing habitat during the construction of the road and crossing structure through adequate erosion and sediment control using biodegradable materials
- Avoid use of salt for winter road maintenance near natural heritage features, especially those adjacent to watercourse crossing structures (i.e. bridges, culverts)
- Provide habitat creation/ offsetting at nearby location if impacts cannot be avoided
- Temporary fencing should be installed along road embankments/shoulders where work is proposed and around stockpiles of gravelly and sandy substrate to prevent turtles from nesting from late May to early July.
- Avoid grading road shoulders during the following turtle nesting and incubation periods:
- Turtle nesting: late May to early July.
- Nest incubation: June to September.
- Do not use fine wire or plastic mesh netting where snakes are present because they are easily entangled and killed in the material.
- Be aware of wildlife moving along roadsides during mowing operations. Where possible, conduct a walk-through to flush out any wildlife before mowing along the roadside.

3.0 Incorporating wildlife ecopassages into the road design process

Opportunities to implement road ecology BMPs occur both when new roads are being designed, and when existing roads are undergoing works (e.g. widening, reconstruction, culvert/bridge replacement, or installation of new barriers).

The recommended process for planning wildlife crossing projects

Step 1 – Identify and prioritize road sections that could negatively impact connectivity or increase mortality of reptile and amphibian populations.

Step 2 – Consult with relevant stakeholders, including conservation authorities, municipalities, and provincial ministries (eg. MTO, MNRF) to determine regulations/permit requirements and to obtain relevant available data.

Step 3 – Identify the species in the area that will be affected by the road project, including potential species at risk. Design a strategy to aid as many species as possible without inadvertently impacting other species.

Step 4 – Design and determine the location of mitigation measures such as crossing structures and fencing by combining ecological, engineering and hydrologic data.

Step 5 – Plan the construction process, considering timing to avoid active wildlife periods, temporary mitigation measures, sediment and erosion control and other relevant aspects of project planning.

Step 6 – Develop a monitoring and maintenance plan to evaluate the effectiveness of the mitigation measures and ensure their ongoing function.

3.1 Identify and prioritize road sections for mitigation

New or proposed road alignments that pass through natural heritage features may benefit from wildlife crossing structures or other road ecology BMPs to preserve habitat connectivity. The LSRCA's Natural Heritage System and Restoration Strategy (LSRCA, 2018a) can help guide project managers in identifying these areas. Additionally, the LSRCA has developed mapping of locations where reptiles and amphibians are more likely to be affected by roads (LSRCA, 2015), and these 'hotspot' maps can be a starting point in identifying areas to incorporate road ecology BMPs. These documents area available on the LSRCA website and hotspot GIS map layers can be obtained by contacting the LSRCA.

The Ontario Reptile and Amphibian Atlas (Ontario Nature, 2018) collects data of these wildlife on roads and is another potential source of road hotspot information.

Future uses of adjacent lands should always be considered when planning mitigation projects. If lands are flagged for future development, they may not be an appropriate ecopassage site in the long term.

3.2 Stakeholder consultation and permitting

Pre-consultation with regulatory agencies at the project outset can identify road ecology opportunities, applicable regulations, policies, and permit requirements. It can also assist in identifying budget implications upfront while improving construction phasing requirements. Ongoing consultation throughout the project can assist with the timely review of submissions, provide available data and scope any required studies.

When planning an ecopassage project, we recommend following these steps to assist in the process:

1. A pre-consultation process is undertaken with LSRCA Planning and Development and/or Regulations staff and interested Regional or Local Municipal staff
2. Available background data (flora/fauna, natural heritage systems, floodplain, hazards etc.) is obtained from agencies such as LSRCA, MNRF, MECP, and Regional and Local Municipalities
3. Surveys are conducted to demonstrate in-depth knowledge of existing conditions (Ecological Land Classification, wetland evaluations, breeding birds and amphibians, road mortality counts, etc.)
4. An assessment is undertaken to determine impacts, crossing selection, alternatives, mitigation measures and monitoring
5. Reporting is completed prior to detailed design

Consultation with local landowners and naturalist groups can provide a source of information and potential volunteers to support monitoring. Garnering early public support of a mitigation project can greatly improve its success and increase general acceptance of road ecology projects.

3.3 Construction planning

Timing of projects should consider sensitive local species and their breeding seasons as shown below in Table 1. These periods are approximate and vary depending on seasonal weather patterns.

Table 1. Approximate sensitive activity periods for reptiles and amphibians in Ontario

Wildlife Group	Sensitive Activity	Approximate Time Period
Turtles	Nesting season	Mid-May to July
Turtles	Hatchling emergence	Mid-August to mid-October
Amphibians	Breeding season	Spring (usually March to June)
Snakes	Emergence from hibernation and breeding	Spring

The Ontario MNRF has also developed timing windows for in-water works to avoid critical spawning periods for fish species.

Another important element of construction planning is erosion and sediment control (E&SC) measures. Applying E&SC best management practices protects adjacent waterbodies from inputs of sediment which can negatively impact fish and wildlife habitat (GGH Conservation Authorities, 2006).

4.0 Wildlife ecopassage design

Properly-designed ecopassages exclude wildlife from the roadway with fencing, which instead directs them to the crossing structure to safely pass over or under the road. In this way, the threat of roads to wildlife and drivers is minimized, and the connectivity between habitats is maximized.

4.1 Crossing structures

For reptiles and amphibians, crossings are generally located under roadways and can consist of a retrofit of existing infrastructure (e.g. drainage culvert) or a purpose-built structure (e.g. a reptile tunnel). In all cases, the crossing system should be designed to enable passage of as many species as possible.

4.1.1 New Crossing Structures

When new roads are being built or existing roads are being rehabilitated or reconstructed, opportunities to install wildlife crossing structures are presented. Depending on the landscape and drainage requirements, crossing structures may not vary much from standard culverts and bridges. Adjustments such as increasing the openness ratio, incorporating a dry passage option, installing a secondary passage structure, or incorporating a grate to improve lighting may achieve wildlife connectivity needs. Table 2 outlines the general types of crossing structures with some associated considerations for each.

Table 2. Ecopassage types and design considerations (adapted from MNRF 2016)

Crossing Type	Design Considerations
Box Tunnel	• Traditionally used for drainage, but can also be modified specifically for amphibian/reptile passage • Tunnels up to 3 m wide or high typically made from precast concrete • Maximum recommended tunnel length of 25 m • Can be open-top or open-grate, open-bottom, or variation of these • Embed tunnels to enable effective fish passage
Arch / Round Tunnel	• Arch tunnels have natural bottoms and are recommended for tunnels ≥ 1.5 m diameter • Round tunnels work well in aquatic conditions for turtles and semi-aquatic snakes. • In terrestrial conditions, round tunnels should be filled 0.3-0.4 m with local soil/debris to create a level crossing surface. • Recommended design for arch tunnels are slightly larger than box tunnels to compensate for the loss of openness as a result of tunnel shape
Large Underpass	• Larger multi-species crossing structures ≥ 3 m wide such as tunnels and bridges, viaducts or overpasses that are generally not prefabricated or precast. • Possible to maintain natural landscape if road is tunneled or elevated (e.g. a viaduct). • Consider when tunnel length will exceed 25 m. • Multi-species strategy for large and small animals.

Openness ratio refers to the amount of light visible at the end of a crossing structure and determines the permeability or attractiveness of a structure for wildlife to cross through. Section 4.3 provides some general guidelines for desired openness ratios. It is calculated as the cross sectional area of the structure entrance (m) divided by its length (m) as shown below:

Box Culvert = (Height X Width) / Length
Corrugated Steel Pipe (CSP) = (πr^2) / Length *

*where π= 3.14 and r= radius of

4.1.2 Retrofitting existing infrastructure

Where existing roads are not scheduled for upgrades but wildlife road mortality is a concern, existing infrastructure (eg. box culverts, large CSPs or bridges) can be retrofitted to facilitate wildlife passage. When considering retrofits, an assessment of the permeability and openness ratio of the structure should first be completed (Kintsch and Cramer, 2011).

Some options for retrofits include installing a dry bench within a culvert to allow for passage of non-aquatic species, removing beaver bafflers or other obstructions, installing wildlife exclusion fencing to direct animals to the structure, and/or adding habitat structures such as turtle nesting beaches, snake hibernacula or salamander boards.

4.2 Fencing

Crossing structures without associated fencing have been shown to be ineffective at reducing wildlife road mortality (Rytwinski et al., 2016). Fencing acts to restrict wildlife access to roadways while

maintaining connectivity across habitats by guiding them towards ecopassages to safely cross under or over the roads. Wildlife exclusion fencing can reduce wildlife road mortality by up to 80% (LSRCA, 2018b). Fencing can also be used as a stand-alone measure to prevent vehicle-wildlife collisions along roads where connectivity is not a concern (e.g. suitable habitat is only on one side of the road).

Several options are available for fencing material and their use depends on the target species. In general, solid permanent material (e.g. concrete, aluminum, plastic), or hardware cloth with ¼ inch mesh or less has been the most effective for excluding reptiles and amphibians. Some available options are shown in Appendix B. Where feasible, construct fencing to exclude as many species as possible.

Fence ends should be designed to deter wildlife from walking around the fence to access the roadway. This can be achieved by extending the fence beyond the natural heritage feature and away from the road in a curved U-shape design. This way, animals are directed back towards the crossing structure.

Ensure that fencing is strong enough to withstand winter conditions, is placed far enough from the road to avoid damage from road maintenance activities, is taller than the spring high water level, and that there are escape ramps for animals trapped in the roadway. Other considerations for fencing design and maintenance are outlined in Section 4.3 below, as well as in MNR (2013) and MNRF (2016).

4.3 Ecopassage and fencing recommendations for reptiles and amphibians

The following guidelines for the design and construction of reptile and amphibian ecopassages were adapted from CVC, 2017.

Openness ratio

- Turtles: recommend ≥0.25, but no less than 0.1
- Amphibians and snakes: recommend ≥0.1, but no less than 0.07

Crossing Structure Dimensions

- Recommend width and height both ≥1m, but no less than 0.5m
- Length ideally less than 25m

Placement/ Spacing of Crossing Structures

- Ideally aligned with predictable movement paths (e.g. annual migration routes)
- Structures should be no more than 50-100m apart for amphibians (depending on migration radius of species) and 150-300m apart for reptiles

Substrate within Crossing Structure

- For dry culverts, install natural substrate with some cover (e.g. native soil, leaf litter, branches, debris, sod) to provide refuge from predators
- Many species prefer/require moist substrate
- Avoid large rocks and rip-rap
- If medium-large sized stone is required, fill interstitial spaces with material appropriate for wildlife footing

Approach to Crossing Structure

- Natural cover but not obstructing entrance
- Minimal/low growing vegetation to maintain clear path and line-of-sight

Fencing

- Solid permanent material (e.g. concrete, aluminum), Animex, ACO or equivalent fencing, or hardware cloth with ¼ inch mesh or less
- Height 0.4-1.2m, depending on jumping/climbing ability of the target species. Recommended minimum height of 30cm for salamanders, 60cm for turtles and 100cm for snakes, frogs and toads
- Include a curved design or a 15cm wide lip along the top edge angled away from the road at 45° to prevent animals from climbing over
- Bottom of fence buried 10-20cm
- Fence should extend 100m on each side of crossing structure and ends should curve back
- Cloth or plastic can be attached to the bottom of chain link fencing

Other Considerations

- Ambient light, temperature, moisture conditions maintained where possible; can be facilitated by incorporating slots/grates (however this could allow road contaminants like salt into the ecopassage)
- Utilize cover structure (i.e. brush piles) at entry and exit of structure while ensuring clear line of sight through the structure is maintained
- Steel is not a desirable material for structures due to its conductivity, which makes it cold during the spring migratory period
- Polymer concrete maintains temperature and moisture conditions
- Turtles prefer crossings with standing water or moderate flow
- Back-fill at road-side of fence to provide an escape route for animals

5.0 Monitoring and long-term maintenance

5.1 Monitoring

Monitoring the effectiveness of wildlife crossing structures is important to determine how well road mitigation measures are working and to identify any potential issues with the design.

An ideal monitoring program is comprised of a **before-after-control-impact design (BACI)** (for example, refer to LSRCA, 2018b). This includes collecting data before and after the ecopassage has been installed, at both mitigation sites and at control sites where there has been no mitigation. This allows researchers to determine with confidence whether a parameter of interest (e.g. road mortality rates, use of ecopassages, population size) has in fact changed, and if it can be attributed to the BMP. Where possible, up to three years of pre- and post-mitigation monitoring is ideal to measure changes in the ecological response, and to rule out any changes due to yearly environmental variation.

A monitoring program can include **road mortality surveys**, which can be conducted by walking, biking or driving along the site. The method used will depend of the road type and traffic conditions and should consider human safety. Mortality surveys should be conducted regularly in order to identify all road-killed individuals since amphibians can quickly degrade on busy roads. The 'Wildlife on Roads' Handbook (Gunson and Schueler, 2018) provides helpful tips for observing different wildlife groups on roads.

Trail cameras are also useful for monitoring wildlife ecopassages or created habitat structures to determine usage by target species. Cameras which are capable of taking motion-detected and time-lapse photos in day and night are the most effective at capturing a wide range of species. Fencing, rocks or other materials can be used to funnel wildlife past the camera to ensure that they are captured. The

use of cameras requires frequent site visits to change batteries and memory cards, as well as time to review the numerous photos they generate, but can be extremely useful in determining the effectiveness of crossing structures and other site features.

Other methods of monitoring reptile and amphibian activity at an ecopassage site include **pitfall traps, mark-recapture, radio-telemetry, and passive data loggers/PIT tag readers**. The applicability of each method depends on the research question, available resources, and the species of interest. A summary of these methods, as well as advantages and disadvantages of each are available in MNRF (2016).

5.2 Maintenance

Maintenance of ecopassages and associated fencing is an often overlooked aspect of road ecology projects; however a lack of maintenance can compromise the structure's function. Maintenance and clearing of culvert debris, fence repairs, cutting back vegetation and repairing erosion / wash-outs are all required to ensure the integrity and proper functioning of ecopassages. A thorough inspection of ecopassages and fencing should occur in early spring following snowmelt to enable any repairs prior to the sensitive activity periods of wildlife (refer to Table 2), followed by ongoing regular inspections.

It is important to assign responsibility and associated budget to maintain ecopassages early in the project design so there is no lag time in implementing a maintenance program. Maintenance should be ongoing throughout the structure's lifespan.

The Ontario Ministry of Transportation has developed a best practices manual for protecting species at risk (including reptiles and amphibians) during road maintenance activities. This manual applies to routine road maintenance as well as ecopassages and wildlife exclusion fencing (MTO, 2017b).

6.0 Lessons Learned

Through the completion of a pilot turtle passage project, the LSRCA has learned some lessons regarding the implementation of wildlife ecopassages, which might be beneficial to others undertaking similar projects. These include:

1. Consider road ecology and conduct pre-consultation early in the road design process.
2. Project design may need to be revised to meet applicable permits and regulations (from municipalities, MTO and/or the LSRCA).
3. Conduct site meetings with those responsible for road maintenance to ensure that any roadside fencing is installed entirely out of the way of any and all road maintenance activities. This will avoid any damage to the fencing from standard road maintenance machines (eg. graders, mowers, snow plows, etc.).
4. Use the tallest fencing possible to exclude as many species as possible.
5. Don't underestimate the amount of time and labour required to install exclusion fencing.
6. Plan ahead for the long-term maintenance of ecopassages and fencing and include it in the project budget. Consider who will be responsible, how often it will be inspected / maintained and what may need to be done (eg. cutting vegetation, fence repairs, clearing culverts, etc.).
7. Order extra fencing, posts or other ecopassage materials to store and have on hand for repairs.
8. If monitoring ecopassages with wildlife cameras, ensure that they are securely attached to permanent fixtures and if possible hidden from view to avoid any theft.

9. Consult and inform nearby landowners on the project and its purpose early on in the process. Interested landowners may volunteer to keep an eye on the site and report any wildlife observed. In some cases they may also volunteer to assist with regular site monitoring.
10. Volunteers will require special considerations (e.g. training, supervision, high visibility clothing).
11. Seek out advice from others in the field, including the conservation authority and the Ontario Road Ecology Group – there is a lot of knowledge and experience available.

7.0 Summary and further information

Considering the effects of roads on the natural environment during the road design process and incorporating road ecology BMPs can reduce the negative impacts of roads on wildlife as well as human health and safety. Early consultation with relevant agencies can greatly improve the efficiency of the project and develop cross-organizational and interdisciplinary relationships.

As roads and other infrastructure continue to expand throughout the watershed and beyond, consideration of road ecology principles can become 'business as usual'. From simple retrofits to dedicated wildlife infrastructure, various options are available. Monitoring and maintenance of any road ecology project is integral to its success.

For further information and resources on road ecology BMPs, including template municipal policies, refer to Appendix A or the LSRCA Road Ecology webpage. For more information on this guide or road ecology in general, please email info@LSRCA.on.ca.

Appendix A – References

Credit Valley Conservation. 2017. CVC Fish and wildlife crossing guidelines. 32 pp.

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Appendix B – Resources

***Note: LSRCA does not endorse any specific products, and only presents some currently available products for informational purposes.**

ACO Wildlife. http://www.acowildlife.us/index.html

Animex Wildlife Mitigation Solutions. https://animexfencing.com

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