CanNorth
Canada North Environmental Services Limited Partnership
A First Nation Environmental Services Company

MEEWASIN VALLEY AUTHORITY
NORTHEAST SWALE
MITIGATION PLANNING

Final Report

Prepared by:

Canada North Environmental Services
Saskatoon, Saskatchewan

Prepared for:

Meewasin Valley Authority
Saskatoon, Saskatchewan

Project No. 2287

March 2016

211 Wheeler Street, Saskatoon, Saskatchewan, Canada S7P 0A4
Tel: (306) 652-4432 Fax: (306) 652-4431 Toll Free: 1-844-700-4432 Email: info@cannorth.com
www.cannorth.com
ISO 9001, ISO 14001 and OHSAS 18001 Registered

TABLE OF CONTENTS

LIST OF TABLES iii

EXECUTIVE SUMMARY iv

1.0 Introduction 1
  1.1 Background and Purpose 1
  1.2 Proposed Developments Affecting the Meewasin Northeast Swale 2
    1.2.1 Road Crossings 2
    1.2.2 Residential Development 3
    1.2.3 Trail Development 3

2.0 Ecology of the Northeast Swale 4
  2.1 Existing Habitat and Wildlife Use 4
    2.1.1 Wetland and Riparian Habitat 5
    2.1.2 Open Grassland Habitat 7
    2.1.3 Tree and Shrub Habitat 8

3.0 Urban Development and Wildlife 10
  3.1 Habitat Loss, Connectivity, and Quality 10
  3.2 Direct Mortality 12
  3.3 Altered Behaviour 14

4.0 Mitigation Strategies 17
  4.1 Mitigation Options 17
    4.1.1 Road Design 17
      4.1.1.1 Wildlife Overpasses and Landscape Bridges 18
      4.1.1.2 Wildlife Underpasses 19
      4.1.1.3 Wildlife Exclusion Fencing 23
      4.1.1.4 Diversion Poles and Fencing 24
      4.1.1.5 Wildlife Crosswalks 25
      4.1.1.6 Curb Design 26
      4.1.1.7 Speed Limits and Wildlife Signage 26
      4.1.1.8 Roadway Management Techniques 27
    4.1.2 Lighting 28
      4.1.2.1 Light Sources 29
      4.1.2.2 Light Fixtures 30
    4.1.3 Sound 30
    4.1.4 Urban Planning and Management 31
    4.1.5 Compensation 32
  4.2 Current Mitigation Planning 33
    4.2.1 Road Design 33
    4.2.2 Lighting 33
    4.2.3 Sound 34
    4.2.4 Urban Planning and Management 34
  4.3 Recommended Mitigation Strategies 35
    4.3.1 Road Design 38
      4.3.1.1 Local Roads 39

4.3.1.2 Collector Roads 40
4.3.1.3 Arterial Roads 41
4.3.1.4 Highways 42
4.3.2 Lighting 44
4.3.3 Sound 45
4.3.4 Urban Planning and Management 45
4.3.5 Construction Management 46
5.0 Future Work and Monitoring Requirements 47
6.0 Conclusion 49
7.0 Literature Cited 50

LIST OF TABLES

Table 1. Mammals, reptiles, amphibians, insects, and avian species observed in the Meewasin Northeast Swale and surrounding area.

Table 2. Home ranges, habitat requirements and availability, and expected losses in habitat pre- and post-mitigation for select wildlife groups in the Meewasin Northeast Swale.

Table 3. Summary of available options for mitigation of urban development effects on wildlife for the Meewasin Northeast Swale.

Table 4. Environmental commitment and mitigation summary for the North Commuter Parkway Project, March 2016.

EXECUTIVE SUMMARY

Canada North Environmental Services (CanNorth) was retained by Meewasin Valley Authority (MVA) to provide recommendations on mitigation strategies to reduce the impact of planned developments occurring in or near the Meewasin Northeast Swale (the Swale).

The Swale is a culturally and ecologically significant landscape feature located in the northeast corner of Saskatoon, Saskatchewan and is facing pressure from expanding urban developments. Current development plans include the expansion and development of four potential road crossings through the Swale, including one collector road (Lowe Road), two arterial roads (Central Avenue and the North Commuter Parkway [NCP]), and one highway (Saskatoon Freeway). New residential areas (e.g. Aspen Ridge) as well as existing developments (e.g. Silverspring) are also encroaching on the Swale and will completely border the north and south edges of the Swale in the future. Additional infrastructure, such as trail systems and storm water management systems, will also impact the Swale.

The Swale is characterized by semi-permanent wetlands and riparian habitat, as well as native grassland, cropland, and tree and shrub habitat. This habitat supports a variety of wildlife and plant species, including the 190 birds, 18 mammals, 3 amphibians, 2 reptiles, 20 insects, and 200 plant species that have been documented in the Swale or surrounding area. This includes a number of provincially and federally listed species that are in decline due to a reduction in available wetland and grassland habitat. The Swale also provides habitat for local wildlife movement, especially for species such as amphibians that require riparian corridors for movement.

The types of urban development planned for the Swale have been shown to have significant ecological impacts on wildlife and plant communities. Effects can include habitat loss and fragmentation, reduced habitat quality, reduced connectivity, direct mortality from roadways or other infrastructure, and altered behaviour. Wildlife are particularly sensitive to changes in the light and sound environment, and many wildlife species avoid using habitat adjacent to urban infrastructure. Roadways have been shown to be particularly detrimental to wildlife, and the degree to which a roadway presents a barrier to wildlife movement is largely dependent on the traffic volume. Roads with fewer than 2,500 vehicles per day (vpd) (local roads) have only minimal barrier effects on

wildlife, while increasing barrier effects are found up to 10,000 vpd (collector, arterial roads) where the roadway is considered a complete barrier to wildlife.

The growing recognition of the impact urban development has on wildlife has led to the development of a number of different mitigation strategies. This includes a variety of different wildlife road crossing structures designed to improve habitat connectivity and reduce wildlife-vehicle collisions. Landscape bridges and wildlife overpasses provide above-grade passage and are most effective for large wildlife species, although many species can utilize these crossing structures. Wildlife underpasses provide passage under the roadway, and have variable design and sizing depending upon the target species. Large wildlife underpasses accommodate the greatest variety of wildlife, although some species (e.g. moose) are less likely to use underpasses unless special design elements are in place. Small culvert and tunnel crossings are preferred by smaller wildlife, and specialized design needs to be in place to encourage amphibian crossings. Bridges or drainage culverts can be modified to encourage wildlife use through the addition of walkways or incorporation of upland habitat. There is a wide variety in the costs associated with these crossing structures, with landscape bridges or viaducts being the most expensive (but potentially utilized by the greatest number of species), and smaller structures such as amphibian tunnels being the least expensive (but restrictive to certain wildlife groups). For all crossing structures, fencing specific to the target wildlife group(s) needs to be installed in order to guide wildlife to the crossing structure.

In addition to crossing structures, other roadway modifications have been developed to improve wildlife connectivity and reduce wildlife-vehicle collisions. Installation of diversion poles or fencing near wetlands or areas with high potential for vehicle-bird collisions can help direct birds above the height of traffic. Wildlife crosswalks in conjunction with fencing can provide safer crossing locations for large wildlife, and minor road design modifications such as installing gently sloping curbs and covered storm water drainages can decrease the number of small mammal or amphibian mortalities on the roadway. Roadways that have lower speed limits and signage warning drivers of wildlife may also be suitable in some locations to reduce wildlife-vehicle collisions. Roadway management techniques that reduce roadway salt applications and ensure proper weed management can also be important methods for reducing the effect of roadways on nearby habitat, including water quality.

Available options to reduce the amount of light from urban development includes avoiding the installation of light fixtures where possible, and where necessary, utilizing wildlife friendly lighting. The International Dark Sky Association (IDA) has created the Dark Sky Friendly seal of approval to promote wildlife friendly lighting. No specific light source is required by the IDA as long as the color temperature is below 3,000 K; however, low pressure sodium (LPS) and high pressure sodium (HPS) are still considered the most wildlife friendly. Light emitting diode (LED) can be considered as long as the color temperature is below 3,000 K. The IDA requires that all light fixtures must be either full-cutoff fixtures or fully shielded, so that there is no light emitted above 90 degrees from the light source. More detailed requirements are provided by the Royal Astronomical Society of Canada (RASC) and may be required for areas under consideration for a Nocturnal Preserve or Urban Star Park designation.

Mitigation options for reducing noise include the installation of sound barriers, which can absorb or reflect sound. Noise barriers typically consist of earth berms, solid or transparent walls, or dense vegetation. Reductions in speed limits or road surface design can also minimize the amount of sound emanating from a roadway.

The development guidelines currently recommended by MVA for the Swale includes a number of roadway design features, utilization of Dark Sky Friendly lighting, urban development design features (e.g. the "Greenway"), as well as public education and communication and natural resource management plans. The mitigation strategies recommended by this report largely follow these current development guidelines provided for the Swale. The recommendations provided by this report were developed based on a number of factors. The developments proposed for the Swale have the potential to cause significant negative ecological effects, including a reduction of habitat types that are already rare on the landscape (e.g. wetlands, native grassland). The Swale is also likely utilized for local travel by wildlife species, especially for wildlife groups such as amphibians. Wildlife movement will be greatly restricted due to barrier and edge effects of the proposed developments as well as reduced habitat quality. Large wildlife species, such as deer, may currently utilize the Swale for travel; however, the importance of the Swale for landscape-level migratory movements is limited as the habitat provided by the Swale effectively terminates at the South Saskatchewan River.

Based on these factors, it was important that mitigation for all wildlife species be considered, but primary importance should be placed on protecting the native vegetation *communities in the Swale. The mitigation strategies recommended for each wildlife group (e.g. large mammals, amphibians, birds, etc.) was dependent upon the ability of the Swale to continue to support sustainable populations of each group, given the unavoidable residual effects that will occur (e.g. direct habitat loss, reduced patch sizes, increased human presence). Other factors, such as the estimated severity of effects the proposed development imposes on each wildlife group, the habitat requirements and ability of each wildlife group to migrate or adapt to disturbance, and the presence of rare, sensitive, or at-risk species within each wildlife group were also considered.*

Amphibians, birds, and small to medium-sized mammals were identified as having the greatest potential to maintain sustainable populations in the Swale with the implementation of appropriate mitigation. These wildlife groups also contained a number of species at risk, are largely habitat specialists of grassland and wetlands, are at a high risk of roadway mortality, and play important roles in ecosystem functioning. Therefore, the recommendations for these species included specific measures to prevent reduced habitat quality, mortality, and lost habitat connectivity.

The Swale is unlikely to support large populations of large mammals, as development of the agricultural areas on either side of the Swale will greatly restrict the amount of available habitat in the area. The Swale is unlikely to contain sufficient habitat to continue to support these current populations regardless of the mitigation strategy implemented. However, none of the large mammal species that utilize the Swale are limited in habitat availability outside the city, nor are they considered sensitive, at-risk, or rare species in the province. Therefore, mitigation strategies for large wildlife were largely focused on preventing mortality along the roadways and preventing reductions in habitat quality for the relatively small number of large mammal individuals that may continue to utilize the Swale in the long-term.

Mitigation strategies recommended for all road types include a roadway management plan to reduce salt applications and manage roadside vegetation, installation of fish-friendly culverts where the roadway crosses a potentially fish-bearing waterway, and utilization of Dark Sky Friendly lighting where lighting is required. It is also recommended that no storm water be released directly to the Swale, and should meet pre-defined water quality standards post-treatment. Where possible, storm water treatment footprints should be located outside of sensitive areas. No local roads cross the Swale, but recommendations for this road type include: reduced speed limits (50 km/hr or less), *construction of roadways level with existing topography, signage warning drivers of potential wildlife crossings, clearing of shrub vegetation in the roadway buffer and low growing grasses, installation of bird diverters (poles, trees) in areas with a high risk of bird-vehicle collisions, and curb design to facilitate amphibian and small mammal crossings.*

Due to the high traffic volumes predicted for the proposed collector (Lowe Road) and arterial roads (NCP, Central Avenue) crossing the Swale, supplementary mitigation strategies are proposed in addition to the recommendations provided for local roads. Small culvert crossings and wildlife fencing specific to amphibians and small to medium sized mammals are recommended for the length of these roadways. As drainage culverts will likely be required for cross-road water flow on these roads, modifications such as ledges and walkways or incorporation of habitat outside the high water mark are recommended. Additional crossings should be placed along the length of the road to improve connectivity for amphibians and small to medium-sized mammals (e.g. every 50 m in habitat suitable for amphibians). Temporary road closures during the evening, especially during peak breeding seasons, could also be considered for Lowe Road. Although unlikely and not recommended at this time, if large mammal-vehicle collisions become a safety issue for these roadways in the future, installation of large mammal exclusion fencing along the roadways and wildlife crosswalks at fence ends may be suitable.

Recommendations for the Saskatoon Freeway are tentative as no final design details (location, traffic volume, traffic speed) have been released. However, based on the approximate location and anticipated traffic volume, it has the potential to significantly alter hydrological flows throughout the Swale and reduce habitat connectivity. Therefore, the primary recommendation for this highway is that the design should not affect water levels or flow throughout the Swale. If possible, an open span bridge should be considered for this highway. Incorporation of upland habitat would allow for dry passage of terrestrial wildlife and humans underneath the bridge. If an open span bridge is not selected, the recommended mitigation strategies should follow those proposed for the collector and arterial roads, including the provision of specially designed crossing structures for amphibians and small to medium-sized mammals (e.g. semi-aquatic mammals) and associated wildlife fencing. If underpasses are required for human passage, design elements that promote wildlife use should be incorporated, but these underpasses should not be considered a replacement for the small culvert crossings for *small mammals and amphibians. Installation of diversion fencing/poles or vegetation (trees) near this highway is also recommended to reduce vehicle-bird collisions.*

In addition to roadway mitigation measures, a number of other complementary mitigation strategies are recommended. Lighting in the Swale should be avoided where possible, and where lighting is required, all light sources and fixtures used in or near the Swale should be Dark Sky Friendly, and the guidelines provided by RASC should be followed. Recommended mitigation for sound includes reduced speed limits, installing roadway surfaces that minimize sound, and installation of the "Greenway" to buffer noise from residential areas. Legally binding protection of the Swale, such as bylaws, conservation designations (e.g. Municipal Heritage Site, Environmental Reserve) or easements should also be pursued. The natural resource management plans and public engagement and awareness plans developed by MVA should also be integral to Swale mitigation planning. Construction mitigation strategies for all roadways should also be implemented.

Future work that may be required for urban development mitigation in the Swale may include detailed, road-specific design work to ensure that the recommended structures are placed properly and the design can be incorporated into roadway engineering requirements. Additional biological surveys or habitat assessments may be required to identify key details essential to the design, such as amphibian migration corridors. In addition, any future work should include an opportunity to review the recommendations in light of any significant changes or updates in roadway design (e.g. Saskatoon Freeway).

A detailed monitoring program is critical in order to monitor the effectiveness of the implemented mitigation strategies as well as monitor for changes in the biodiversity or habitat health over time (e.g. species composition, wildlife population sizes, noise and light levels). The study design should ideally follow a BACI (Before-After-Control-Impact) study design, and the data collected from the monitoring program should be analysed on a continuing basis so that mitigation strategies can be optimized as information becomes available.

1.0 INTRODUCTION

1.1 Background and Purpose

Canada North Environmental Services (CanNorth) was retained by Meewasin Valley Authority (MVA) to provide recommendations on mitigation options to reduce the ecological effects of future urban development on MVA-managed properties. One of these properties, the Meewasin Northeast Swale (the Swale), is located in the northeast corner of the City of Saskatoon (COS), a rapidly expanding and developing part of the city. Expansion and development of suburban areas (e.g. Evergreen, Silverspring, Aspen Ridge) are encroaching on the borders of the Swale and will surround the Swale in the future. Three city roadway developments, including the North Commuter Parkway (NCP), are also currently being proposed to bisect the Swale. The Saskatchewan Ministry of Highways and Infrastructure (MHI) has also proposed the development of the Saskatoon Freeway through the Swale.

The Swale is a culturally and ecologically important area that supports a variety of native plants and wildlife, including mammals, birds, amphibians, and reptiles. The developments proposed for the Swale are highly likely to affect local wildlife and plant populations through effects such as habitat loss and fragmentation, road mortality, and altered animal behaviour and movement patterns. As maintaining habitat quality and connectivity is critical to the sustainability of the Swale as a natural area, a number of mitigation strategies, as outlined in the *Northeast Swale Development Guidelines* (Stantec 2012) and the *Northeast Swale Master Plan* (MVA 2015) have been developed.

As development plans that may influence the Swale are developed and finalized, it is important to review the proposed mitigation strategies to ensure that they present the most suitable options for the Swale given all available information. The primary goal of this document is to provide a review and analysis of potential mitigation options that could be utilized in the Swale, including, but not limited to, those described in the Swale management documents (e.g. Stantec 2012; MVA 2015). Based on this review, recommended strategies are provided based on a number of factors, including a thorough review of the proposed developments and design, known information on available habitat and wildlife habitat use of the Swale, and known ecological effects of urban development on wildlife. General strategies to maintain habitat connectivity under urban development pressure will be provided, but particular focus will be placed on how mitigation related to road design and lighting can be utilized to minimize anticipated effects. It is anticipated that although the focus of this report is on the Swale, the recommendations provided here will also be useful for the Small Swale or other MVA properties that are facing similar development pressures.

1.2 Proposed Developments Affecting the Meewasin Northeast Swale

A number of proposed city projects may cause direct or indirect changes to the Swale, including proposed road crossings, development of a trail system within and surrounding the Swale, and residential development along the borders of the Swale. A summary of the proposed developments are provided below, and detailed information can be reviewed in MVA (2015).

1.2.1 Road Crossings

Four road crossings are planned for the Swale and will carry high vehicle traffic volumes (MVA 2015). Two arterial roads with a maximum width of 32 metres will be created, including the NCP and Central Avenue. The NCP will be a four lane undivided arterial road and will cross on the northeast end of the Swale (Stantec 2012). Initial traffic volume predictions for the NCP upon opening are 14,600 to 21,700 vehicles per day (vpd), but may increase to 40,000 to 50,000 vpd depending on overall city growth (COS 2015a). Central Avenue, an existing road on the western edge of the Swale, will be widened and developed into a four-lane divided road, with expected traffic volumes per day reaching 10,000 to 30,000 vpd (Stantec 2012; COS 2015b). Lowe Road (Range Road 3050), another pre-existing road, will be developed into a two lane collector road (expected volume of 1,000 to 15,000 vpd [COS 2015c]) and will have a maximum width of 27 metres (Stantec 2012). MHI is planning the development of the Saskatoon Freeway, which will cross through the Swale northeast of the NCP (MVA 2015). The development of this highway is still in the preliminary planning stage, and thus no timeline, final routing location, or detailed design has been released.

Two existing roads may also require decommissioning. Range Road 3045 cuts through the north end of the Swale, but will no longer be necessary once the NCP and the Saskatoon Freeway have been constructed (MVA 2015). Agra Road also currently runs along the northern border of the Swale, and may not be required for the University Heights 3 residential development; however, this has not yet been finalized (MVA 2015). If this road is not necessary, the existing roadway could be utilized for development of the Greenway (See Section 1.2.3) (MVA 2015). No current plans for decommissioning either road have been developed.

1.2.2 Residential Development

Multiple residential developments already border the edge of the Swale (Silverspring, Evergreen), and plans for additional residential developments that will border the north and south borders are also underway (Aspen Ridge, University Heights 3). Residential homes in these neighborhoods will back onto the proposed Greenway. The number of residents living in neighborhoods bordering the Swale is estimated to increase to approximately 44,000 people once the Aspen Ridge and University Heights 3 areas are developed (COS 2013).

Two storm water management ponds are planned for the Aspen Ridge and University Heights 3 developments (MVA 2015). The footprints of these storm water ponds are currently located within the Swale area but the exact location and design of these systems has not been fully determined.

1.2.3 Trail Development

MVA is proposing the development of the “Greenway” around the border of the Swale to provide a buffer between the Swale and future residential development (MVA 2015). The Greenway will only be created in areas where development has not yet proceeded, including the entire northern edge of the Swale as well as the southeastern edge at the proposed Aspen Ridge residential development boundary (MVA 2015). The Greenway will include an ecological buffer zone, trail zone, and transition zone (MVA 2015). The ecological zone will be 15 m to 20 m wide, and the trail zone and transition zone will range in width from 3 m to 5 m. The trail zone will contain a four season multi-use trail system, and the ecological and transition zones will be planted with native grass species to serve as a buffer between the residential development and the Swale.

In addition to the Greenway, MVA also plans to develop a system of trails, boardwalks, and public amenities throughout the Swale. Trails will be developed to connect entry points along the Greenway to a proposed outdoor staging area and parking lot, picnic sites, interpretive signage, and existing external trails (e.g. Meewasin Trail) (MVA 2015).

2.0 ECOLOGY OF THE NORTHEAST SWALE

The selection of appropriate mitigation strategies is highly dependent on detailed knowledge of the habitat types and wildlife species inhabiting an area (Clevenger and Huijser 2011). The purpose of this section is to provide a brief overview of the ecology of the Swale, including available habitat types and expected wildlife use.

2.1 Existing Habitat and Wildlife Use

The unique ecology and historical significance of the Swale has been recognized for decades (Weichel 1992; MVA 2015). The significant value placed on the Swale is indicative not only of the presence of increasingly rare habitat such as large wetlands and native prairie, but also the relatively unfragmented habitat that the Swale currently provides between different habitat patches in the local landscape. It is likely that the Swale provides local wildlife access routes from the South Saskatchewan River to areas such as the Greater Swale, supporting species movement, recruitment, and dispersal within the local landscape (Golder 2014a; Stantec 2013a).

In addition to providing a connection between habitat patches, the Swale also provides a home for a number of wildlife. Three main habitat types occur within the Swale, including open grassland, aspen shrubland, and wetland and riparian habitat. These habitats, along with their many ecological niches, promote rich plant, insect, and animal communities (Stantec 2013a). A wide variety of wildlife species are known to occur in the Swale, including 190 avian species, 18 mammal species, 3 amphibian species, 2 reptilian species, and 20 insect clades (Table 1) (Gollop 2000; Delanoy 2001; Shadick 2009; Jensen 2009, 2012; Stantec 2013a; MVA 2013). There are also over 200 documented plant species (Stantec 2013a; MVA 2013). Of the species that have been documented in the Swale, a significant proportion has been designated as rare, sensitive, or at-risk either provincially or federally (Table 1). This includes species that have been listed under the federal *Species at Risk Act* (SARA), the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and/or *Migratory Bird Convention Act* (MBCA). The province has also established activity guidelines for sensitive species in Saskatchewan, which includes a large number of the species that have been observed in the Swale (Table 1) (MOE 2015).

The habitat requirements for the variety of species that utilize the Swale are highly variable. Some species depend solely on one habitat type as a collective provider for all requirements including concealment, breeding, and forage. In contrast, other species such as ungulates and some amphibian species require multiple habitat types and have larger home ranges in order to accommodate seasonal migrations, varied diets, and/or breeding (Dietz and Nagy 1976; Kroll 1994; COSEWIC 2009). As knowledge of the home range and habitat requirements of species is necessary to plan effective mitigation, the following sections describe these features for species known to occur within the Swale. A summary of wildlife groups found in the Swale, their habitat requirements and home ranges, estimated changes in available habitat in the Swale pre- and post-disturbance, and projected functional habitat loss is provided in Table 2.

2.1.1 Wetland and Riparian Habitat

The Swale is dominated by a series of wetlands and riparian edges including zones of deep-marsh, shallow-marsh, wet-meadow, and low-prairie (Stantec 2012). Based on the classification system of Steward and Kantrud (1971), the majority of wetlands in the study area have been classified as semi-permanent ponds or lakes (Class IV) dominated by aquatic plants. All semi-permanent wetlands in the Swale were considered ecologically significant, as they provide important functions such as water storage (Stantec 2013a). In addition, these wetlands provide habitat for waterfowl, semi-aquatic mammals, amphibians, native plants, and are also likely rich in benthic invertebrate and crustacean species (Stantec 2012; Stewart 2014).

The semi-permanent wetlands present in the Swale are ideal habitat for the diving ducks and grebes that have been observed in the Swale (*Podiceps* and *Podilymbus* spp.). This includes the horned grebe (*Podiceps auritus*) which has been listed as Special Concern by COSEWIC (COSEWIC 2016). Due to various adaptations to aquatic ecosystems (e.g. legs set well back of equilibrium for enhanced diving and swimming) (Weller 1999), these species are restricted to wetland habitat, and typically nest adjacent to open water (Steward 2014). On expansive wetlands consisting of highly dense emergent vegetation, many colonial birds (e.g. black tern [*Chlidonias niger*], eared grebe [*Podiceps nigricollis*], Franklin’s gull [*Larus pipixcan*]) will establish high-density nesting colonies that are sensitive to disturbance (MOE 2015; Rodewald 2015). These colonies can be extensive, requiring large patch sizes during the breeding season in order to successfully complete nesting (Rodewald 2015). Other sensitive wildlife that utilize semi-permanent wetlands include sand-hill cranes (*Grus canadensis*), great blue herons (*Ardea herodias*), American bitterns (*Botaurus lentiginosus*), and tundra swans (*Cygnus columbianus*).

The shallower ephemeral wetlands and wet-meadow zones are utilized by species such as rails, ducks, wrens, and many other perching birds. In particular, sedge-dominated shallow wetlands and meadows present suitable breeding grounds for yellow rail (*Coturnicops noveboracensis*), which have been federally listed as Special Concern under Schedule 1 of SARA (Naugle et al. 2001; Stantec 2013a; SARPR 2016). In addition, the shorelines, mudflats, or shallow water edges provided by all wetland classes support a variety of shorebird and gull species (over twenty species) that utilize these areas for its rich diversity of insects and crustaceans and as nesting habitat (MVA 2015; Rodewald 2015). This diversity of species includes the red-necked phalarope (*Phalaropus lobatus*), a provincially rare to uncommon species (SKCDC 2015).

The large wetland complexes and uplands in the Swale also present high quality habitat for a variety of amphibian species. Amphibians observed in the area include northern leopard frogs (*Lithobates pipiens*), and barred tiger salamanders (*Ambystoma mavortium*), both of which have federal protection (Stantec 2013a; MVA 2015). Northern leopard frogs are listed on Schedule 1 of SARA as Special Concern, and barred tiger salamanders have been assessed as Special Concern by COSEWIC (SARPR 2016). Although their home range is generally small compared to other wildlife groups, northern leopard frogs require a variety of habitats to complete their life cycle, including deep ponds and springs, creeks, or rivers for overwintering habitat (COSEWIC 2009). Shallow wetlands are required for breeding sites, and moist prairie or wetland margins are required for summer foraging (COSEWIC 2009). This species typically disperses between these habitats through riparian areas or moist grassland, and will return to their breeding site from year to year (Biolinx and E. Wind Consulting 2004; COSEWIC 2009). Barred tiger salamanders use semi-permanent wetlands for breeding, and overwintering typically occurs in small mammal burrows (COSEWIC 2012). Migration to and from sites typically occurs in early spring and late summer and movements generally fall within 250 metres from the aquatic site (COSEWIC 2012). This species also likely shows fidelity to natal ponds (COSEWIC 2012).

Semi-aquatic mammals, such as North American beaver (*Castor canadensis*) and muskrat (*Ondatra zibethicus*) are also important wetland species. Beavers are considered a keystone species due to their role in habitat creation, hydrological processes, and nutrient cycling (Naiman et al. 1986), and muskrat also play an important role in ecosystem function (Clark 1994). Beavers are typically associated with large wetlands with nearby deciduous tree or shrub communities, and although adult beavers have a set territory and home range, juvenile beavers can disperse large distances (average of 8 km to 16 km) (Slough and Sadleir 1977). The home range of an adult beaver is dependent upon the spatial variability of the landscape, but one study found a range of 11 ha to 18 ha (McClintic et al. 2014). Muskrat prefer deep wetlands with sufficient emergent vegetation cover, and rarely venture into terrestrial habitat or leave their home range, even when faced with habitat loss (Ahlers 2015).

2.1.2 Open Grassland Habitat

The Swale contains a variety of upland habitats important for wildlife, including native fescue prairie and cropland (Stantec 2012). The mix of native plant species and cultivated plants provides important nesting and foraging habitat for a number of birds observed in the Swale area. This includes five grassland birds that are listed as species at risk by COSEWIC, some of which are also listed on SARA Schedule 1 (Sprague's pipit [*Anthus spragueii*], loggerhead shrike [*Lanius ludocivianus excubitorides*], bobolink [*Dolichonyx oryzivorus*], common nighthawk [*Chordeiles minor*], short-eared owl [*Asio flammeus*], and burrowing owl [*Speolyto cunicularia*]) (MVA 2013; SARPR 2016). Populations of these bird species are generally decreasing due to habitat loss and fragmentation of native grassland, and some species, such as the burrowing owl, may already be locally extirpated (Gollop 2000). In general, habitat suitability for all these bird species is reduced when livestock activity is intense, when native habitat is harvested as hay, when fires are suppressed, or when grasslands become fragmented by human activities (SARPR 2016). The overall threat of urban development is dependent upon the patch size and vegetation requirements of each species, which can range from 2 ha for bobolink (COSEWIC 2010a) to up 150 ha of shortgrass prairie for Sprague's pipit (COSEWIC 2010b).

The rolling hills, rocky ridges, and dense areas of vegetation also provide locations for mammals and reptiles to establish dens, burrows, or bedding down spots. Medium-sized mammals such as coyotes (*Canis latrans*) will den in the sandy hillsides, under rocks, or within underbrush (Althoff 1980). Coyotes utilize all habitat types during the search for prey, and therefore have a large home range (average 7,597 ha) (Ozoga and Harger 1966). Smaller mammals, such as the striped skunk (*Mephitus mephitis*), prairie long-tailed weasel (*Mustela frenata*), white-tailed jack rabbit (*Lepus townsendii*) and American badger (*Taxidea taxus taxus*) will also utilize the grasslands for cover, feeding opportunities, and acquiring burrows (COSEWIC 2013a; MVA 2013). Badgers are listed by COSEWIC as Special Concern, and are an important component of grasslands as they are a top predator and their abandoned burrows provide habitat for species such as burrowing owls (COSEWIC 2013a). The home range of this species is quite large, ranging from 1,200 to 9,700 ha (COSEWIC 2013a). The size of the badger's home range, as well as their attraction to roadsides (due to increased prey availability) makes badgers highly susceptible to road mortality (COSEWIC 2013a).

Small rodents, including ground squirrels (*Spermophilus* spp.) and various mouse species are the most diverse component of mammalian fauna in grasslands (MVA 2013; Stantec 2013a). These species serve important ecological roles that influence habitat structure and composition such as seed dispersal, consumption and shredding of vegetation, and mixing and aeration of soils (Finch 2005). The home range of species in this group ranges from 0.11 ha to 0.81 ha (City of Edmonton 2010).

2.1.3 Tree and Shrub Habitat

Treed areas in the Swale are dominated by trembling aspen (*Populus tremuloides*) but also contain a number of other deciduous trees and shrubs (Delanoy 2001). This habitat varies in understory density, deadfall, snag abundance, and canopy cover, and provides important functions such as concealment and foraging opportunities for birds and other wildlife (Moorman and Guynn 2001). This habitat supports families such as woodpecker (Picadae), nuthatches (Sittadae), and chickadees (Paridae), as well as species that depend on deadfall and snags to construct nesting cavities and to provide invertebrate food resources (e.g. American kestrel [*Falco sparverius*], tree swallows [*Tachycineta bicolor*]) (Johnston and Holberton 2009). This diversity in structural habitat and prey community composition also supports a host of perching birds that occur within the Swale, as well as bats.

Although neither species have been reported, the Swale may provide suitable habitat for two bat species that occur in the Saskatoon area: little brown myotis (*Myotis lucifugus*) and northern myotis (*Myotis septentrionalis*). Both bats are listed federally as Endangered on Schedule 1 of SARA (SARPR 2016). Bats would primarily use the Swale for foraging habitat, although suitable roosting or maternity colony locations in trees, rock crevices, buildings, or under bridges (COSEWIC 2013b) may exist, especially closer to the South Saskatchewan River, where trees are more abundant. The foraging range of bats does not stray far from the roosting colony, averaging a 200 ha area (COSEWIC 2013b). Distances between roosting trees in a colony can range from 21 m to 926 m, and many females return to the site the following summer (COSEWIC 2013b).

In addition to utilizing treed areas as a travel corridor or refuge, species such as moose (*Alces americanus*) or mule deer (*Odocoileus hemionus*) will browse trees and shrubs for leaves, twigs, and buds (Renecker and Hudson 1992). However, due to seasonal variation in plant and shrub growth, these species have large home ranges (1,215 ha for moose and 285 ha for mule deer), and occupy many different habitats to satisfy nutritional needs (Dietz and Nagy 1976; City of Edmonton 2010). Moose can be frequently seen in wetland habitats foraging on aquatic plants during the summer months (Renecker and Hudson 1992). Forbs and grasses found in native prairie and cropland make up a large part of moose and mule diet in the summer, while fall months will consist of a high forb diet, and high shrub browsing in the winter (Dietz and Nagy 1976).

White-tailed deer (*Odocoileus virginianus*) tend to specialize in their food intake resulting in an even wider range of movement than mule deer (Kroll 1994). The home range for a white-tailed deer varies with sex, age, geography and season, and can range from 79 ha to up to 1,200 ha (Harestad and Bunnel 1979; Kroll 1994). Home ranges for white-tailed deer require browse, cover, and water and therefore require many different habitat types. Edge habitats, such as the Swale or the South Saskatchewan River, can be important travel corridors for this species (Kroll 1994). Ungulates have been observed throughout the Swale area utilizing all habitats and have been observed in trail camera photos in areas close to Central Avenue (MVA 2013; 2015).

3.0 URBAN DEVELOPMENT AND WILDLIFE

Urban developments such as residential neighborhoods and roads place significant pressure on nearby natural habitats. Development, and roads in particular, can fragment habitat (Jacobson 2005) resulting in reduced habitat suitability and connectivity (Bager and Rosa 2011), altered wildlife behaviour and movements (Reijenen and Foppen 2006; Parris 2015), and increased mortality of both wildlife and plants (Huijser and Bergers 2000; Develey and Stouffer 2001). Ultimately, densities of wildlife and plants are negatively influenced by development (Huijser and Bergers 2000; Develey and Stouffer 2001), in particular species that are area sensitive (i.e., require large areas). The following sections further describe the effects of urban development on different wildlife groups, with particular focus on habitats and species that occur within the Swale.

3.1 Habitat Loss, Connectivity, and Quality

Anthropogenic land-use changes can alter wildlife habitats and cause wildlife population declines (Knutson et al. 1999; Trombulak and Frissell 2000). Land-use changes such as road construction and residential development can include a number of different disturbances, including draining and filling of wetlands, sedimentation in important habitats, compaction of soil, alteration of surface hydrology, removal of native plant communities, and increased application of chemicals (e.g. lawn fertilizers, road applications of salt) (Forman and Alexander 1998, Knutson et al. 1999). These changes result in habitat loss, increase the fragmentation of a habitat and the amount of edge habitat, and decrease habitat quality (Forman and Alexander 1998; Trombulak and Frissell 2000). Reductions in habitat quality can be classified through changes in species diversity, reductions in breeding success, and/or changes in home ranges.

Urbanization can result in habitat loss or reduced habitat quality through a number of different mechanisms (Trombulak and Frissell 2000). For example, urbanization can result in the introduction of invasive (exotics, weeds) and generalist species, which can out-compete native species and result in decreased habitat quality (Trombulak and Frissell 2000, Forman et al. 2003). Increased light and noise from the development of roads can result in road edge effects that can extend up to several hundred meters away (Forman and Alexander 1998, Seiler 2002; Berthinussen and Altringham 2012a). These edge effects can have negative consequences including decreased amphibian species richness, and decreases in reproductive success of songbirds (Forman and Alexander

1998; Chace et al. 2003; Eigenbrod et al. 2009). For example, a negative correlation between northern leopard frogs and traffic intensity has been shown to extend up to 1.5 km (Biolinx and E. Wind Consulting 2004).

As a result of reduced habitat quality, home range shifts and functional habitat loss has been documented for numerous wildlife species as they move away from traffic disturbance (vehicles, noise, light, emissions, humans, pollutants) and the habitat is considered lost (Fahrig and Rytwinski 2009). Some species, such as amphibians, are extremely sensitive to changes in water quality changes resulting from road runoff. Runoff from roads contains chemicals, suspended sediment, and salt which can kill aquatic organisms (Newcombe and Jensen 1996). A study of the effects of road salts on amphibians in Nova Scotia found that increased chloride concentrations from de-icing salts excluded salt sensitive species such as spotted salamanders (*Ambystoma maculatum*) and wood frogs (*Lithobates sylvaticus*) (Collins and Russell 2009). Recently, some municipalities have transitioned to new de-icing products (e.g., Caliber M1000, a chemical additive blended with sand and salt) (COS 2016a), which appears to be more toxic than regular salt (Evans and Frick 2001). In addition to salt, increased sediment and nutrient levels in wetlands from runoff events have been shown to cause slower growth and lower survival in tadpoles (Woods 2007). Reduced habitat quality, in conjunction with road mortality, and/or reduced dispersal/recolonization can eradicate local amphibian populations and cause home range shifts (Reh and Sietz 1990; Fahrig et al. 1995; Findlay and Houlahan 1997; Trombulak and Frissell 2000).

Urbanization can also affect bird and mammal populations through reductions in food supply and changes to habitat and landscape structure (Chamberlain and Fuller 2000). One study on breeding grassland birds in the Netherlands revealed a decrease in species richness and nesting density (up to a one third reduction) with disturbance distances up to 3.5 kilometers from roads (Reijnen et al. 1996). A meta-analysis of 234 bird and mammal species found that bird populations declined up to 1 km and mammal populations declined up to 5 km from roads (Benítez López et al. 2010). Aside from vehicular collisions and a learned avoidance of road areas, some bird and small mammal species declines could be due to changes in relative predator abundances. For example, if larger species, such as coyotes, move out of an area due to urban development, populations of small or medium predators may increase (Bateman and Fleming 2011). This can create ecological traps, as the prey of smaller predators are increasingly affected (e.g. reduced waterbird nest success) (Sovada et al. 1995).

Plants also experience edge effects due to colonization by weeds and changes in microclimate (i.e., temperature, dust, water from rain events, surface runoff, soil compaction, and sedimentation). Depressed growth/physical health, or even death may result from pollutants and salt (Fleck et al. 1988). Roadways can create biodeterioration zones up to 200 metres wide due to increased contamination of soils and plants and/or dust deposition near roads; this can result in decreased native plant abundance and increased bare ground and/or invasive plant abundance (Dale and Freedman 1982; Gjessing et al. 1984; Trombulak and Frissell 2000). Aquatic plants face similar consequences from the addition of pollutants and nutrients, and community composition may shift to species more tolerant of roadside conditions (Trombulak and Frissell 2000). Physical habitat loss can also impact wetlands in indirect ways. For example, alterations of the landscape during development can impact surface water runoff and alter shallow groundwater movement, which can enlarge or destroy wetlands and their associated vegetative community (Trombulak and Frissell 2000).

3.2 Direct Mortality

Urban development can cause significant mortality to both plants and animals during construction and usage periods. During construction, when topsoil is stripped and the landscape is prepared for development, slow moving and sedentary wildlife species, such as amphibians (e.g. northern leopard frog, barred tiger salamander), reptiles (e.g. garter snake), small mammals (e.g. meadow mouse), and plants can experience direct mortality (Theobald et al. 1997). Bird nests, including eggs and nestlings, can also be impacted during construction if proper mitigative techniques are not used (i.e., set back restrictions, avoidance time frames). In general, the flight response of some species such as birds and medium and large-sized mammals render them less susceptible to mortality during construction period. However, all forms of wildlife are susceptible to mortality once roads and developments are operational.

Vehicular collisions kill a significant number of wildlife each year (Forman and Alexander 1998) and are a persistent mortality threat (Trombulak and Frissell 2000). The majority of accidents include large mammals like deer, posing a risk to both animals and vehicular traffic (Trombulak and Frissell 2000). However, numerous other species are also killed during vehicular collisions each year, and estimates completed for the United States alone place vertebrate deaths from roadway collisions at over a million per day (Forman and Alexander 1998; Smith et al. 2003; Bishop and Brogran 2013). In

Saskatchewan, around 11,000 deer collisions/fatalities are reported annually (Markewich 2014). Most deer are hit between feeding areas and areas of cover or conservation areas in urban centers (Forman and Alexander 1996). Christie and Nason (2003) analyzed data from deer vehicular collisions and discovered three main trends: 1) most collisions are from 6 p.m. to midnight (44%), most occur on roads with ≥90 km/hr speed limits (82%), and most occurred in the November (breeding/hunting season). Similarly, the Wisconsin Department of Transportation (2001) estimated 41% of all crashes occurred in October/November with second highest occurring in spring (May/June: 16%).

In a recent analysis focused on Canada, Bishop and Brogran (2013) estimated over 13 million birds (3,462 birds/100 km of road) are killed each year in vehicular collisions during the four month period from breeding to fledging. Unlike predators, this form of mortality is not selective based on age, sex, or physical condition, and is thought to contribute to population sinks because these populations only survive by dispersal and immigration (Mumme et al. 2000). Amphibians are particularly vulnerable to mortality near roads given their small size and slow movement (Ashley and Robinson 1996), and road mortality may have a large effect than avoidance (Forman and Alexander 1998). Amphibians such as frogs and salamanders migrate twice a year (in the spring to breeding areas and in the fall to wintering areas) and thus are especially vulnerable in the spring and fall as large numbers move across the landscape (Ashley and Robinson 1996). Thus, the effect of road development on wildlife is often seasonal as most are affected by road crossings during bi-annual movements (City of Edmonton 2010).

Amphibians and other wildlife are attracted to road areas at night due to a warmer microclimate (road heat dissipation) to help with thermoregulation and/or take advantages of foraging opportunities, both of which can lead to increased rates of vehicular collisions (Whitford 1985; Trombulak and Frissell 2000). Consequently, the highest kill rates of amphibians (and the majority of other wildlife species) occur on roads near wetland habitats (Ashley and Robinson 1996; Forman and Alexander 1998). Thus, roads near wetlands pose a significant risk to wildlife. High cumulative road mortality has been shown to reduce local amphibian populations in Ontario (Fahrig et al. 1995). Overall, mortality due to vehicular collisions is a major contributor to the extirpation of rare species near roadways, while other species may persist due to high fecundity or variations in niche availability (Seiler 2002).

Finally, residential development can also lead to problems with house cats, which can significantly influence wildlife populations. In a recent analysis, Blancher (2013) estimated house cats in Canada can kill from 100 to 350 million birds per year. This form of mortality generally peaks during the bird breeding season (May to July) (Blancher 2013). It is likely that predation by cats is the largest single form of mortality to birds in Canada (Blancher 2013; Calvert et al. 2013; Loss et al. 2013). Typically, the most common bird species preyed upon are those that frequent bird feeders (chickadees, house finches) but also those that nest on or near the ground such as grassland nesting birds, waterbirds, and game birds (Blancher 2013). Because the exact diet of house cats is not known, it is plausible they also have a significant impact on other small animals including amphibians, reptiles, and small mammals. It was estimated that cats killed approximately 478 million reptiles, 173 million amphibians, and 12 billion mammals annually in the United States (Loss et al. 2013). Additionally, it has been documented that off-leash dogs can harass and kill wildlife (Forrest and St. Clair 2006). Thus, it is evident human development and its relationship to wildlife mortality can have significant consequences on local populations (Theobald et al. 1997; Calvert et al. 2013; Loss et al. 2013).

3.3 Altered Behaviour

The change in land use from native habitats to roads and neighborhoods can have significant impacts on animal behavior and survival. Ambient light (from street lights and vehicles at night) and noise from roads can disrupt wildlife populations and alter behaviours like vocalization (more frequently, louder, and/or at different times) and foraging bouts, ultimately increasing overall mortality risk (RCEP 2009; Cartwright et al. 2013; Shannon et al. 2015, Parris 2015). Lighting can cause some birds to sing and forage at night, outside of the typical timing for these activities. Although the direct impacts of these altered behaviour patterns on reproduction and population sizes remain unclear, potential effects may include increased energy expenditure and increased predation of individuals and nests. This may be especially problematic as most predatory mammals are nocturnally active (Beier 2005; Parris 2015). Increased ambient lighting can also have severe consequences on mammal populations, given the majority of mammals are nocturnal or crepuscular. Lighting has been shown to reduce activity, movements including dispersal events and use of corridors, foraging success, and potentially increase mortality via predation in nocturnal mammals (Beier 2005). Many mammals reduce activity during full moon periods (0.3 lux) so it is highly feasible that roadways, which are engineered to constantly illuminate between 3 lux and 17 lux will impact mammal populations (Beier 2005). Lighting from roads and vehicle headlights can also disorientate individuals trying to cross the road, increasing the probability of road mortality (Beier 2005).

Glare from artificial lights can also impact wetland habitats of amphibians such as frogs, toads, and salamanders. Artificial lights can disrupt nocturnal breeding choruses and homing to breeding ponds, potentially resulting in reduced reproduction or population sizes (Baker and Richardson 2006; Perry et al. 2008). Further, light pollution can impact physiological performance of amphibians (ability to thermoregulate properly) and increase road mortality as most amphibians become immobile in bright light (Perry et al. 2008). Overall, light pollution has the potential to severely impact wildlife populations (Baker and Richardson 2006; Perry et al. 2008; RCEP 2009).

Roads can also alter behaviour. For example, they may disturb congretory migratory birds such as cranes and geese that use agricultural fields to feed and wetlands to roost (Madsen 1985). Increased disturbance from roads and use of areas for recreation (walking, running, presence of dogs) can cause changes in feeding and activity patterns (Theobald et al. 1997). Birds may be forced to flush off of nests resulting in nest abandonment and/or predation (Hockin et al. 1992), especially as human foot traffic can produce as large of a disturbance as vehicular traffic (Klein 1993). However, habituation can occur to predictable patterns of human movement such as those that are confined to a trail system (Miller et al. 2001; Taylor and Knight 2003).

Sprawl and habitat fragmentation from roads often restrict and channel wildlife movement. In some instances these restricted areas are considered functionally lost habitat as animals cannot access them. Mice and other small mammals have been shown not to cross roads (Oxley et al. 1974; Merriam et al. 1989); additionally roads act as barriers to fish and aquatic mammals (Furniss et al. 1991). Other times, barriers such as fences and roads channel wildlife movements and can, for example, increase local wildlife concentrations such as deer. Increased densities of wildlife such as deer in shrinking green spaces can create conflicts with human residents (eating shrubs, vegetable gardens, spreading Lyme disease, physical attacks on humans) and roads (deer vehicle collisions) (Jones et al. 1986; Rondeau and Conrad 2003; Luers 2013).

The degree to which a road impacts wildlife habitat and movement is partially dependent on the expected traffic volume and speed (City of Edmonton 2010). Roads create what is known as a “barrier” effect which influences species differently (Forman and Alexander

1998). In general, three different road categories exist: local roads have less than 1,000 vpd, collector roads have between 1,000 to 5,000 vpd, and arterial roads have greater than 5,000 vpd (City of Edmonton 2010). Some animals, such as amphibians, may be affected by all types of roads regardless of traffic volume, whereas larger mammals may be less affected by local or collector roads, where traffic volume is less than 2,500 vpd (City of Edmonton 2010; Clevenger and Huijser 2011). All wildlife are deterred by arterial roads, or where traffic volume is exceeds 10,000 vpd (City of Edmonton 2010; Clevenger and Huijser 2011). Forman and Alexander (1998) in their review describe that two-lane roads with moderate traffic volume have negative impacts on amphibians and reptiles, two-lane high speed roads have the most impact on mid- to large-sized mammals, and wide, high speed roads have the most impact on small mammals and birds. Roads with more than 10,000 vpd are essentially a total barrier to wildlife movement, and intermediate traffic volumes are when the most wildlife-vehicle collisions occur (City of Edmonton 2010).

4.0 MITIGATION STRATEGIES

Due to the significant ecological effects of urban development on wildlife and biodiversity as described in Section 3.0, a wide variety of mitigation strategies have been developed. This section first presents all mitigation options that could be utilized for the Swale or similar areas (Section 4.1), followed by a comparison of the recommendations currently presented by MVA (Section 4.2), and the strategies recommended by this review (Section 4.3).

4.1 Mitigation Options

This section presents information on available mitigation strategies that can be used to reduce the impact of road and urban development on habitat quality, connectivity, and biodiversity. Included in this section is a discussion of the potential advantages and disadvantages of each option and the suitability of each option for various scenarios related to the habitat potential of an area, the topography, and the development type (Clevenger and Huijser 2011). High habitat potential areas are defined as critical habitats and important habitat linkages, whereas moderate habitat potential areas do not hold special conservation value but are still suitable for wildlife (Clevenger and Huijser 2011). Low habitat potential areas do not have wildlife habitat potential or very low suitability (Clevenger and Huijser 2011). Details of each mitigation option are also summarized in Table 3. The primary focus of this review is on mitigation options related to overall design (e.g. roadways); however, it is noted that the implementation of mitigation strategies during construction are also extremely important for reducing effects to wildlife. Recommended construction mitigation is presented in Section 4.2.

Where data were available, estimated costs of each structure are included. However, the actual cost of any particular crossing structure is highly dependent upon the actual location, timing of installation (during road construction or after the road is in place), and design requirements. Therefore, the estimates should only be utilized to provide a general understanding of the potential financial costs involved.

4.1.1 Road Design

Most of the larger roadway crossing structures presented below can be modified for human use; however, this is generally not recommended as human presence can be a deterrent for wildlife use (Clevenger and Waltho 2000; City of Edmonton 2010; Clevenger and Huijser 2011). If a multi-use structure is required, various modifications can be included with the crossing structure to minimize the effects of human presence (Clevenger and Huijser 2011).

4.1.1.1 Wildlife Overpasses and Landscape Bridges

The primary above-grade crossing structures include landscape bridges and wildlife overpasses (Clevenger and Huijser 2011). These above-grade structures are utilized for providing landscape continuity and safe passage for wildlife above the roadway. Structurally, landscape bridges and wildlife overpasses are similar, with the main difference being size (Clevenger and Huijser 2011). Landscape bridges are typically larger than wildlife overpasses, with the minimum recommended width for landscape bridges being 70 m to 100 m, versus 40 m to 70 m for wildlife overpasses (Clevenger and Huijser 2011). Continuation of habitat across the structure is important for encouraging wildlife use, thus, vegetation similar to the surrounding landscape is planted, and dense vegetation or earth berms along the edges of the bridge are used to reduce the sight and sounds from the road (Clevenger and Huijser 2011).

There are a number of benefits associated with landscape bridges and overpasses, as demonstrated by their use in high profile areas such as Banff National Park (Clevenger et al. 2009). These benefits include:

- A wide variety of areas may be suitable for these structures, including areas with high or moderate habitat potential where a roadway presents a significant or total barrier to wildlife movement (Clevenger and Huijser 2011). Most topography is suitable for these structures, with the exception of areas where the road bed is raised relative to existing terrain (Clevenger and Huijser 2011).
- Although typically designed with large carnivores and ungulates in mind, with proper design, all wildlife species can utilize this crossing structure (Glista et al. 2009; Clevenger and Huijser 2011; Jones and Pickvance 2013; Healy and Gunson 2014; McGregor et al. 2015).
- Ambient temperature, light, and moisture levels are maintained and these structures are generally more open relative to other structures such as underpasses (Glista et al. 2009; Clevenger and Huijser 2011). These characteristics are important for encouraging wildlife use of the structure (Glista et al. 2009).

- Maintenance requirements are typically limited to initial construction and vegetation establishment and only minimal long-term maintenance should be required (Clevenger and Huijser 2011).
- The overall effectiveness of these structures is generally considered to be high for all wildlife groups, although it may take a couple years for local wildlife to begin using the crossing (Olsson et al. 2007; Clevenger et al. 2009; Glista et al. 2009; City of Edmonton 2010). Large mammals, such as wolves, moose, and elk prefer these structures to underpasses (Clevenger et al. 2009). Although studies are limited (Corlatti et al. 2008), gene flow across these structures has been shown to be sufficient to prevent isolation of populations (Sawaya et al. 2014).

The effectiveness of this strategy comes at a cost. Estimated costs for a wildlife overpass are in the millions of dollars, with available estimates ranging from 1 to 11 million dollars (Huijser et al. 2008; City of Edmonton 2010; CBC 2012; Pallack 2012; Tank 2015). The cost of installing wildlife fencing and jump-outs should also be included in the cost of these structures (See Section 4.1.1.3), as they are necessary to guide wildlife to the overpass and allow trapped wildlife out of the roadway (Dodd et al. 2007). This initial cost for the design and construction is relatively high compared to other mitigation strategies, although the cost of these structures is typically offset by 4.4 deer-vehicle collisions per kilometer per year (Huijser et al. 2007; Glista et al. 2009; Huijser et al. 2009; City of Edmonton 2010). On-going work employing the use of different designs (e.g. parabolic arches vs. conventional straight-edged bridges) or materials (e.g. ARC 2016) will likely decrease the cost of these structures in the future.

An additional consideration for selecting this mitigation option is the potentially larger disturbance area required at the locations where overpasses will be constructed. These structures require an approach on either side, and in level areas, a 5:1 ratio or less slope is recommended (Clevenger and Huijser 2011). This factor may be of importance depending on the habitat quality of the proposed overpass location, as disturbance of native plant communities or wetlands may partially offset the benefits of this structure type.

4.1.1.2 Wildlife Underpasses

Wildlife underpasses include systems such as viaducts, tunnels, or culverts that are designed to allow the passage of wildlife underneath the road. With the exception of viaducts, wildlife underpasses are generally less expensive than overpasses (Huijser et al. 2009) and are used by a variety of wildlife (Lister et al. 2015). These structures are typically recommended for a range of habitat types ranging from high to low quality, and can be utilized in a variety of different terrains, except where the road will be constructed below grade (Clevenger and Huijser 2011).

Extended Bridges/Viaducts

Typically utilized due to the local terrain, extended bridges and viaducts are the largest wildlife underpass systems as they often cross rivers and riparian habitats (extended bridges) or valleys/gorges (viaducts) (Huijser et al. 2007; City of Edmonton 2010). The main difference from standard bridges is that these structures are typically longer than necessary in order to incorporate upland/riparian habitat and allow terrestrial wildlife passage (Huijser et al. 2007; City of Edmonton 2010; Clevenger and Huijser 2011). The actual size of these structures varies widely, depending on the terrain being crossed (e.g. wetland vs. gorge) (Clevenger and Huijser 2011). Benefits associated with these structures include:

- Construction typically results in less ground disturbance relative to other wildlife crossing structures, as they are designed to span sensitive habitat (City of Edmonton 2010; Clevenger and Huijser 2011). These structures can be used as a less destructive option to wildlife underpasses on cut and fill slopes (Clevenger and Huijser 2011).
- The majority of natural habitat is maintained, resulting in minimal revegetation or restoration costs (City of Edmonton 2010). Retaining native vegetation improves plant community connectivity.
- As long as appropriate habitat exists or is restored on either side and under the viaduct, all wildlife species can utilize this crossing structure (Biolinx and E. Wind Consulting 2004; Clevenger and Huijser 2011), and the openness provided by these structures is preferred by larger species (City of Edmonton 2010; USFS 2014).
- The effectiveness of these structures is generally rated as high as animal movement is generally not restricted and habitat connectivity is maintained (Huijser et al. 2007).

No ecological disadvantages for wildlife or plant communities are known for this crossing structure; however, the cost of construction is likely to be a major deterrent in most cases. As estimated by Huijser et al. (2007), a 200 m section can cost between 12 and 24 million dollars. Due to the exceptional cost of these structures, they are typically only utilized where local terrain requires (Liu and Zhou 2003).

Tunnels and Culverts

A wide variety of differently sized and shaped tunnels and culverts are available to provide connectivity for wildlife underneath roadways and can be designed for single wildlife groups (e.g. amphibians) or multiple groups (e.g. City of Edmonton 2010; Clevenger and Huijser 2011).

Large Wildlife Underpasses

A variety of different designs can be used for large animal underpasses, although open span bridges and box culverts are likely to be the most effective (AGFD 2006; City of Edmonton 2010; Clevenger and Huijser 2011; Riley et al. 2014). The minimum recommended height and width of these structures is 4 m by 7 m, and preferably under 60 m in length (AGFD 2006; Clevenger and Huijser 2011; Cramer 2013). Additional design features that encourage use by all species include maximizing the openness and size of the underpass, covering the bottom of the underpass with native soils or using a bottomless culvert, and minimizing roadway noise and light levels (Clevenger and Huijser 2011). Wildlife exclusion fencing is required to guide wildlife to the crossing structure (Clevenger and Huijser 2011). Potential benefits of large wildlife underpasses include:

- Given proper design, the majority of species will utilize an underpass and they are generally considered to be effective (Ng et al. 2004; Huijser et al. 2007; Huijser et al. 2008; Clevenger and Huijser 2011). Even bats have been shown to utilize underpasses for crossing roadways and/or roosting (City of Edmonton 2010; Berthinussen and Altringham 2012b).
- Multiple ecological functions (e.g. water flow, wildlife habitat connectivity) can be served by underpasses that include a water or wetland crossing (Clevenger and Huijser 2011). All wildlife, including terrestrial species, can utilize these

structures if dry passage systems (e.g. ledges at least 2 m wide) are included (City of Edmonton 2010; Clevenger and Huijser 2011).

- The cost of an underpass is highly variable depending on design, but is generally less expensive and requires less ground disturbance than overpasses (City of Edmonton 2010). Estimates compiled by the City of Edmonton (2010) placed the cost of an open span bridge at 55,000 dollars per metre, whereas culvert underpass systems ranged from 70,000 to 500,000 dollars (Huijser et al. 2008; Huijser et al. 2009; City of Edmonton 2010). However, a significantly higher cost (approximately five million dollars) was reported for three underpasses and associated fencing installed in Kootenay National Park (CBC 2013).

Few ecological disadvantages to this type of crossing structure are known. Some species, such as moose or elk, may not utilize this crossing structure due to the reduced visibility and clearance associated with underpasses (City of Edmonton 2010; Clevenger and Huijser 2011). If moose are a priority species, an overpass is recommended unless the structure can be built a minimum of 12 m wide and 4.5 m high (Clevenger 2009; Clevenger and Huijser 2011).

Small to Medium Sized Wildlife Underpasses

Underpasses designed for small to medium-sized wildlife species are typically much smaller than the previously described crossing structures, and can only be utilized by species such as small to medium-sized mammals, reptiles, and amphibians (Clevenger and Huijser 2011). Medium-sized mammal crossing structures typically range between 0.8 m to 3 m wide and 0.5 m to 2.5 m high (Huijser et al. 2008), and small-sized mammal pipe crossings typically range between 0.4 m to 1.2 m in diameter (Huijser et al. 2008; Clevenger and Huijser 2011). These structures can include bottomless arch, metal culverts, or concrete box culverts (Huijser et al. 2008; Clevenger and Huijser 2011). Where culvert systems are utilized for waterflow, a walkway (recommended width of 0.5 m to 0.7 m) along the edge of the culverts can be installed to allow passage of small to medium-sized wildlife species (Huijser et al. 2008; City of Edmonton 2010; Clevenger and Huijser 2011).

As with other crossing structures, these underpasses should be utilized in combination with wildlife exclusion fencing along the roadway to guide wildlife to the crossing and prevent roadway mortalities (Clevenger and Huijser 2011). In addition, as mentioned for large wildlife underpasses, the culvert bottom should be covered with natural materials (e.g. rocks, soil), and the approach to the underpass should be vegetated and appear natural (e.g. no steep slopes) (City of Edmonton 2010; Clevenger and Huijser 2011). Smaller underpasses also need to be placed more frequently along the roadway as the mobility of these species is limited (City of Edmonton 2010).

Although amphibians will utilize standard culvert crossings designed for other wildlife species, special design elements are often included to improve the use of crossing structures by amphibians (Biolinx and E. Wind Consulting 2004). This includes specially designed exclusion fencing and winged entrance walls to guide amphibians to the underpass, as amphibians do not learn the location of these crossing structures and must be guided to them (Biolinx and E. Wind Consulting 2004; City of Edmonton 2010; Clevenger and Huijser 2011). Amphibian crossing structures also need to be placed more frequently than for mammals (every 50 m is recommended), and need to be focused in areas of migration routes (Biolinx and E. Wind Consulting 2004; City of Edmonton 2010). Amphibians are also highly sensitive to changes in environmental conditions, and large diameter culverts or installation of grating on the top of amphibian tunnels is recommended to ensure the environment inside the tunnel is similar to ambient conditions (Clevenger and Huijser 2011). For roads between 30 m and 40 m in width (range estimated for the NCP and other roads in the Swale), the optimal dimensions (width by height) for amphibians ranges from 1.6 m x 1.1 m for a half-round culvert, to 1.75 m x 1.25 m for a box culvert (Huijser et al. 2008).

The cost of installing these structures is also relatively inexpensive but ranges depending upon the size of structure and its design. Small mammals and amphibian tunnels have been estimated at 17,000 dollars to 30,000 dollars per structure for a 20 m wide road (Huijser et al. 2008), while larger structures, such as medium-sized mammal crossings, have been estimated between 30,000 dollars to 180,000 dollars (Huijser et al. 2008).

4.1.1.3 Wildlife Exclusion Fencing

Wildlife exclusion fencing is designed to prevent animals from crossing roadways (Clevenger and Huijser 2011). The specific design of the exclusion fencing needs to made in consideration for specific wildlife species, for example, fencing may need to be buried in some locations to prevent burrowing, and mesh size and height need to be appropriate for each wildlife group (e.g. amphibians vs. ungulates) (Clevenger and Huijser 2011).

Exclusion fencing typically consists of page-wire or chain link fencing for large wildlife, and hardware cloth or welded wire-mesh for smaller mammals and amphibians (Clevenger and Huijser 2011). The height of the fencing is dependent upon the target species, ranging from 2.4 m for large mammals, to 0.6 m for small mammals and amphibians (Clevenger and Huijser 2011). Fencing can often be modified to exclude all wildlife groups (Clevenger and Huijser 2011).

The major benefit to exclusion fencing is that it is extremely effective at preventing wildlife mortalities along the roadway for relatively little cost (35 to 90 dollars per metre) (Clevenger 2011; Dodd et al. 2007; Huijser et al. 2008; City of Edmonton 2010; Clevenger and Huijser 2011). However, as this strategy creates a complete barrier to wildlife movement, wildlife exclusion fencing should only be used in conjunction with crossing structures or to prevent wildlife encounters with specific non-linear dangers (City of Edmonton 2010). In fact, exclusion fencing is a useful, and often required, tool to funnel wildlife towards crossing structures, as some wildlife species cannot “learn” where crossing structures are located (City of Edmonton 2010). Fencing can also be utilized to minimize bird mortalities, as it forces birds (e.g. owls, waterbirds) to fly higher over the roadways above the height of traffic (Jacobson 2005).

Additional costs to wildlife exclusion fencing include regular maintenance to repair tears or gaps, or the inclusion of jump-outs or one-way gates as escape routes for trapped ungulates (City of Edmonton 2010). Adding escape routes can add on an additional 9,000 dollars to 18,000 dollars per structure (Huijser et al. 2008; City of Edmonton 2010).

4.1.1.4 Diversion Poles and Fencing

Diversion poles and fencing are one of the few available technologies for reducing vehicle-bird/bat collisions on bridges and roadways. Diversion structures consist of aluminum poles or chain link fencing that is mounted to the edge of bridges or roadways, in order to direct the flight path of birds and bats above the height of vehicle traffic (Jacobson 2005; City of Edmonton 2010). Vegetation (e.g. trees) can also be utilized as diversionary structures. Although these structures can be utilized on roadways, diversion pole or fencing systems are often used on bridges, as birds often fly over bridges just above the guardrails, directly in line with traffic (City of Edmonton 2010). The height of the diversion system should be designed to direct birds above the height of typical vehicle traffic in the area (e.g. semi-trailers vs. car) (City of Edmonton 2010). No recommendation for pole spacing is available; however, other projects have had success with the installation of bird diverters with spacing of approximately 3.7 m (City of Edmonton 2010). Low diversion fencing or poles or closely spaced reflective markers can also be utilized to prevent collisions with birds of prey, which often fly at the height of vehicles while foraging (Jacobson 2005; City of Edmonton 2010).

These structures are relatively inexpensive (estimated at 50 dollars a pole [City of Edmonton 2010]). If designed appropriately, fencing may be utilized to both divert birds away from the roadway and guide terrestrial wildlife to crossing structures.

4.1.1.5 Wildlife Crosswalks

Wildlife crosswalks channel wildlife to locations along the roadway where there is increased safety for crossing (e.g. reduced speed limit) (City of Edmonton 2010). Wildlife exclusion fencing is used to channel wildlife towards the crossing location and signage is used to warn drivers of the crosswalk (City of Edmonton 2010). These systems can be used in conjunction with animal detection systems so that warning signs can alert drivers to the animal’s presence in real time, thus reducing the risk of a collision (e.g. the “Electro Crosswalk”, Lampman Wildlife Services 2014a). Gates or ramps should also be included near the crosswalk to allow trapped wildlife to escape from the roadway, and systems such as the “Electromat” or cattle guards further prevent animals from being trapped in fenced roadway (Huijser et al. 2008; City of Edmonton 2010; Lampman Wildlife Services 2014b).

A major benefit of this crossing structure is a potentially high level of efficacy in reducing wildlife-vehicle collisions (Huijser et al. 2008). However, this strategy is only effective for large mammals, and the barrier effect of high traffic volume roads is not reduced (Huijser et al. 2008; City of Edmonton 2010). Therefore, this system is only recommended for use on roads where additional mitigation strategies for other wildlife species, such as small mammals or amphibians are in place if necessary (Huijser et al. 2008; City of Edmonton 2010).

An additional benefit to this structure is that estimated costs of wildlife crossing structures are typically much less expensive than wildlife overpass or underpasses. The City of Edmonton (2010) found pricing ranging from 21,000 to 40,000 dollars, but inclusion of an animal detection system increases the cost to an estimated 200,000 dollars.

4.1.1.6 Curb Design

If culverts or other passage structures for amphibians or small mammals are not included in a roadway, strategic curb design can potentially decrease the number of amphibian and small mammal mortalities on a roadway (City of Edmonton 2010). Traditional curb designs, where there is a steep slope between the roadway and curb edge, can often trap species such as salamanders on the roadway, resulting in increased mortality (City of Edmonton 2010). Altering curbs to have a gentle slope (45 degrees or less), or installing ramps or breaks in the curb at regular intervals can provide sufficient passage for these species (City of Edmonton 2010). Covering storm drains or locating them along the centre of the roadway can also reduce mortality and entrapment of small wildlife species (City of Edmonton 2010).

As the cost of implementing a wildlife-friendly curb design is negligible for new road constructions or relatively minimal for pre-existing roads, this strategy can be useful if no other mitigation for these species is in place. However, this strategy would not be recommended for high volume traffic roads where the likelihood of animal mortality is high.

4.1.1.7 Speed Limits and Wildlife Signage

Administrative controls such as speed limits or wildlife signage have also been utilized to increase permeability and reduce the number of wildlife-vehicle collisions, including bird mortalities (City of Edmonton 2010). Speed limit reductions have been shown to reduce large mammal strikes below 72 km/hr, and below 56 km/hr for birds (Huijser and Kociolek 2008; City of Edmonton 2010; Meisingset et al. 2014). In the City of Edmonton, wildlife collisions were between 7 and 17 times higher where speed limits were greater than 50 km/hr compared to areas where speed limits were 50 km/hr or less (City of Edmonton 2010). Improved compliance with speed limit reductions can be enforced with the use of photo radar, and may prove especially useful during times, such as breeding periods, where animals may be less cautious near roadways (City of Edmonton 2010). Reduced speed limits during the evening and nighttime hours have also been utilized to minimize wildlife-vehicle collisions (Huijser et al. 2008). Road closures have also been utilized during sensitive periods such as breeding, migration, or dispersal seasons for species of concern, and can be especially effective for species such as amphibians that migrate en masse (Huijser et al. 2008; Riley et al. 2014).

An advantage of reduced speed limits includes the relatively negligible cost of implementing a speed reduction, especially when implemented during initial road design, as project costs should already include the cost of installing speed limit signage. In addition, this strategy does not prevent wildlife from crossing the road, and given that traffic speed can be equally as important as volume, roads with reduced speed limits may have greater permeability (City of Edmonton 2010). However, the relative improvement in permeability on roadways with high traffic volumes is not likely to be significantly affected by speed limit reductions, and benefits are likely limited to medium to large-sized wildlife. Thus, although reduced speed limits can provide important benefits for relatively little cost, it is unlikely to significantly increase habitat connectivity across roads with high traffic volume, especially for smaller wildlife (City of Edmonton 2010).

In addition to reduced speed limits, driver awareness may also be improved using signage to warn of potential animal crossings (City of Edmonton 2010). This may include permanent diamond-shaped signs, large billboards, or additional warnings attached to speed limit postings (City of Edmonton 2010). Alternative systems such as temporary signs during high wildlife activity periods or interactive signs may be more useful for improving driver awareness (City of Edmonton 2010; Bond and Jones 2013). Animal activated signs that use technology such as video or infrared systems to detect the presence of animals can also prove useful for warning drivers on low volume roads (City of Edmonton 2010). Similar to reduced speed limits, signage can decrease the number of wildlife collisions and increase the permeability of lower volume roads. However, signage is only suitable for large wildlife, and is not likely to be effective at increasing the permeability of roadways in high traffic volume areas (City of Edmonton 2010).

4.1.1.8 Roadway Management Techniques

A number of additional roadway management techniques can also be implemented to improve the wildlife friendliness of a road. As described in Section 3, roadway applications of de-icers and/or gravel can alter the habitat quality of wetlands or adjacent roadway habitat. As it is very difficult to remove chlorides from the environment, the primary recommended mitigation strategy is to avoid the use of de-icer where possible and minimizing the application if necessary (Fay et al. 2013). As described in detail by

Fay et al. (2013), a number of different methods are available to minimize the effects of roadway applications, including:

- administrative controls such as salt management plans, operator education programs, and weather and road forecasting systems;
- alternative chemical applications such as anti-icers (applied prior to ice formation);
- pavement composition that reduces the formation of ice;
- isolation of road drainages from natural areas; and,
- planting of salt-tolerant species for biofiltration around the roadway.

Another roadway management strategy is to ensure that the roadside vegetation is kept low to allow greater visibility of nearby wildlife (Found and Boyce 2011). However, although clearing of shrubs is recommended, planting trees near the roadway can encourage birds to fly over the roadway above traffic, potentially decreasing the number of bird-vehicle collisions (Huijser et al. 2008). Both of these strategies are relatively inexpensive, and can result in improvements to nearby habitat quality as well as reduce the incidences of wildlife collisions.

4.1.2 Lighting

In recognition of the potentially significant effects on lighting on wildlife, a number of organizations have developed guidelines to protect the night sky, including the International Dark-Sky Association (IDA) and the Royal Astronomical Society of Canada (RASC). The main principles promoted by these organizations for light pollution abatement include turning lighting off when unnecessary, minimizing brightness, shielding lighting to focus light only where needed, and minimizing the release of blue light (IDA 2015a; RASC 2015). To promote the use of these principles, the IDA has created the “Dark Sky Friendly” seal of approval for lighting figures that minimize light pollution and effects on wildlife (IDA 2015a). This seal includes requirements for the shielding, distribution, and color temperature of lights (IDA 2015a), and has three main requirements:

- no light can be released above 90 degrees;
- color temperature must be 3,000 K or lower; and,

- fixtures must be mounted at zero degrees with no tilt.

In addition to promoting light pollution abatement solutions, RASC also provides detailed guidelines for areas that may be considered for Nocturnal Preserve (NP) or Urban Star Park (USP) designation (RASC 2015), which the MVA has shown interest in pursuing (MVA 2015). In order to obtain an NP or USP designation, there are a number of requirements that must be observed related to the type and quantity of light allowed in addition to use of Dark Sky Friendly lighting (RASC 2013a; RASC 2013b). Examples of the types of requirements include restrictions on the types of lights that can be utilized for buildings, parking lots, and roadways, and there are also maximum emittance values provided for each structure type (e.g. buildings should generally only emit approximately 1 lux) (RASC 2013a; RASC 2013b).

4.1.2.1 Light Sources

A number of different light sources are currently available for street lighting, including incandescent, high intensity discharge (HID), mercury vapor, metal halide, low pressure sodium (LPS), high pressure sodium (HPS), fluorescent and compact fluorescent lamps, induction lights, and light emitting diode (LED). In Saskatoon, the primary light source is from HPS, although some areas of the city utilize metal halide, and LED lights are being installed in new developments (COS 2016b).

Although the Dark Sky Friendly seal from IDA does not require the use of a certain light source, only light sources with a correlated colour temperature of 3,000 K or lower can receive this seal of approval due to the known negative effects of blue light (Ashdown 2015; IDA 2015a). Therefore, standard clear and daylight metal halide, and cool white fluorescent light sources would not be considered Dark Sky Friendly (IDA 2015b). Some LED lights would also not meet this requirement; however, “warm” LED lights are available (although less energy efficient) and would qualify under the Dark Sky Friendly program (IDA 2015b). In a study completed by Falchi et al. (2011), light sources that produced the least light pollution were LPS, followed by HPS. Metal halide and white LEDs were the worst polluters (Falchi et al. 2011).

4.1.2.2 Light Fixtures

A number of different classifications of light fixtures have been described by the Illuminating Engineering Society of North America (IESNA), including full-cutoff, cutoff, semi-cutoff, and non-cutoff (Lighting Research Centre 2007). These classifications describe the amount of light that is projected above 80 degrees from the light source, which is an indicator of the potential of the light source to produce glare and contribute to light pollution (Lighting Research Centre 2007). Full-cutoff fixtures emit no light above 90 degrees, and not more than 10% above 80 degrees, whereas non-cutoff fixtures do not have any control on the light emitted (e.g. a globe light) (Lighting Research Centre 2007).

In order to be Dark Sky Friendly, light fixtures must be either full-cutoff fixtures or fully shielded, so that there is no light emitted above 90 degrees from the light source (IDA 2015). Nocturnal preserves generally require a more stringent “sharp cutoff” fixture, which requires that no light be emitted above 90 degrees, and less than 2% between 80 and 90 degrees (RASC 2013a). This is with the exception of roadways, where semi-cutoffs (2% uplight) are allowable, but need to be oriented properly to minimize light spill onto the area adjacent to the roadway (RASC 2013a).

In addition to the amount of uplight released, light fixtures can also be categorized based on their light distribution pattern (e.g. Type I to V distribution categories) (SaskPower 2013). The choice of light distribution pattern is primarily based on the location of the light (e.g. Type I, 4 way is used for intersections). RASC recommends that light fixtures on roadways have a Type II distribution pattern, where the majority of light is projected onto the road and not onto areas adjacent to the roadway (RASC 2013a).

Pole height can also influence the light pollution provided by a particular light fixture. RASC (2013) recommends that the light fixtures be mounted no more than six metres above the ground.

4.1.3 Sound

In addition to light pollution, noise emanating from roadways or residential areas can disturb wildlife behaviour, especially for wildlife such as birds or amphibians which rely on vocalizations for breeding and/or defining territories (Parris 2015). A primary method of reducing noise is the installation of noise barriers, which can absorb or reflect roadway noise (FHWA 2001; City of Edmonton 2010). Noise barriers typically consist of earth berms or solid/transparent walls, and can cut reduce noise levels in half (FHWA 2001; City of Edmonton 2010; Clevenger and Huijser 2011). Dense vegetation can also be used, but is generally less effective than berms or solid walls (FHWA 2001). The benefits of berms likely extend beyond noise reduction, as it is thought that berms can also reduce collisions with birds and bats through the redirection of flight paths above the road, and reduce road sight lines from nearby habitat (City of Edmonton 2010).

Earth berms are the preferable type of noise barrier, as solid walls can present a complete barrier to terrestrial wildlife movement and can further the effect of the roadway on habitat fragmentation (City of Edmonton 2010; Clevenger and Huijser 2011). However, earth berms require an increased disturbance footprint along the roadway and would not be suitable if sensitive habitat (e.g. wetland) occurs along the roadway (City of Edmonton 2010). If a solid wall or similar structure is installed, additional mitigation measures, such as under or overpasses should be considered in order to allow wildlife crossings (City of Edmonton 2010).

If construction of a noise barrier is not a practical or recommended solution for a particular location, reduction in speed limits or road surface design can also minimize the amount of sound emanating from a roadway (City of Edmonton 2010). Speed limit reduction can also have a number of other benefits, including reduced wildlife collisions (see Section 4.1.1.7).

4.1.4 Urban Planning and Management

Any decisions regarding the implementation of roadway or other mitigation strategies should be viewed in the context of overall urban and landscape planning. For example, wildlife crossing structures should only be installed in areas where suitable protection of adjacent habitat is in place so that the effectiveness of the crossing structure is not jeopardized (Clevenger 2011). This may include the addition of legally binding designations such as Environmental Reserves, conservation easements, or other conservation zoning agreements (Hess et al. 2014; MVA 2015). Development ordinances can also be utilized for residential, commercial, or industrial developments near to wildlife habitat to ensure that developers are required to follow guidelines that can improve wildlife habitat, such as the inclusion of green spaces or linear corridors (Hess et al. 2014). Specific resource management plans for conservation areas can also help guide the management issues within each conservation area (Hess et al. 2014).

The success of any mitigation strategy can be largely impacted by the public's acceptance and promotion of wildlife areas. Therefore, a well-developed public awareness and education campaign should be included in any mitigation planning (City of Edmonton 2010; Hess et al. 2014). Strict bylaw enforcement should also be a part of the urban management plan to reduce effect such as bird mortalities from domestic pets.

4.1.5 Compensation

In some scenarios, the creation of roadways and other infrastructure will require the clearing and loss of native habitat regardless of the mitigation strategies chosen. One potential mechanism to offset this loss of habitat is through a habitat compensation program. In a compensation plan, habitat is created, reclaimed, and/or protected with the ultimate goal of offsetting lost habitat to ensure no net loss.

A number of different models are available for the establishment of a habitat compensation program, but typically depend on the calculation of debits (lost habitat) compared to credits (habitat gained). Generally, the total area required to compensate the lost habitat is based on the physical land base lost multiplied by the estimated ecological value of the lost habitat (e.g. DECC 2009; Croft et al. 2011; BBOP 2012; Habib et al. 2013). Once the total area required for compensation has been calculated, an area for the compensation is selected. Where possible, land chosen as the offset location should be nearby, and perform a similar ecological function compared to the lost habitat. Regardless of the specific area chosen, it must be protected to prevent future loss.

Potential benefits associated with this strategy are that the overall loss of habitat as a result of a project is minimized or negated, and depending on the location of created habitat, offset habitat may be more likely to maintain its ecological integrity long-term. However, compensation should not be considered as a stand-alone strategy. Mitigation strategies that minimize the environmental effects of a project should always be prioritized, and only residual losses should be dealt with through compensation. No cost estimates were available, as the cost of compensation is highly variable dependent upon the total offset land required, restoration techniques to be utilized, and local land prices.

4.2 Current Mitigation Planning

MVA has published a number of documents that identify mitigation strategies to be utilized for the Swale and other developments (e.g. Stantec 2012; MVA 2015). A brief summary of these mitigation strategies are provided below as a comparison to this report's recommended strategies, which are provided in Section 4.3.

4.2.1 Road Design

A number of mitigation strategies have been proposed by MVA to reduce the impact of road crossings on the Swale, including engineering and administrative controls.

The primary source of habitat connectivity mitigation planning currently proposed for the Swale includes the placement of culverts to facilitate cross-road water and wildlife movement (e.g. small mammals, reptiles, and amphibians) and construction of roads level with existing topography to facilitate large mammal (primarily deer) crossings (Stantec 2012; MVA 2015). Design to including cover (e.g. rocks, vegetation) at the entry points for the culverts has been included to improve usage (Stantec 2012), and planting native vegetation within the road right-of-way has been proposed to prevent the encroachment of non-native species and improve habitat quality (Stantec 2012). Additional administrative controls to improve habitat connectivity include installing a maximum speed limit of 50 km/hr through the Swale at all road crossings, and installing wildlife crossing signage.

A number of different mitigation strategies were also proposed to reduce the overall disturbance during roadway construction, including sharing road crossings with utility crossings such as water mains. A full list of all mitigation strategies proposed for the NCP is provided in Table 4.

4.2.2 Lighting

Saskatoon Light and Power owns and maintains street lights for the City of Saskatoon. The majority of lights in the City utilize HPS; however, in new areas of the City, LED lights with a colour temperature of 4,100 K are standard (COS 2016b). Although no lighting plans have been designed for road crossings in the Swale, COS requires lighting on all roadways be in compliance with the Transportation Association of Canada (TAC)

Guide for the Design of Roadway Lighting (TAC 2006; COS 2015c) as well as approved by COS. It is likely that given the current promotion of LED lights in new developments, LED lighting would also be installed throughout the Swale unless requested otherwise. No specific policies or bylaws on Dark Sky Friendly lighting are currently in place for Saskatoon. However, recent projects indicate the recognition of the need for this lighting. This includes a 2007 pilot project in the Hampton Village residential development that utilized full-cutoff fixtures, and Aspen Ridge's neighborhood design concept that requires Dark Sky Friendly LED street lighting along streets and parks in Aspen Ridge (COS 2014).

Although the Swale must have COS-approved lighting on all roadways, MVA has proposed a number of mitigation strategies to minimize the required lighting in the Swale, including the use of Dark Sky Friendly lighting (See Section 4.1.2). MVA has also proposed that the majority of the Swale be unlit, with the exception of roadways, the Greenway, and the Outdoor Staging Area. Should MVA wish to pursue the Nocturnal Preserve or Urban Star Park designation through RASC, additional lighting requirements as described briefly in Section 4.1.2, and in detail in RASC (2013a; 2013b), would also be required.

4.2.3 Sound

Although the soundscape of a habitat can have important consequences for many species, as described in Section 3, no mitigation strategies for reducing sound levels in or near the Swale have been proposed to date.

4.2.4 Urban Planning and Management

As described in Section 1.2.3, MVA has proposed the development of the "Greenway" which will act as a buffer between the Swale and residential or adjacent land uses (Stantec 2012). In addition to providing a recreational amenity to the local residents, the Greenway will include a storm water management zone to buffer drainage from the surrounding residential areas (COS 2014). Incorporation of linear parks into the development of new residential areas, such as Aspen Ridge, have also been added to encourage the internal absorption of storm water drainage (COS 2014).

A communication plan to inform residents of planned developments near the Swale has also been proposed by COS and MVA (COS 2014; MVA 2015). Future residents of homes backing onto the Greenway will be provided with information on the Swale and the Greenway, including the ecology, function, and importance of these two areas (MVA 2015). This will include information on Nocturnal Preserves and utilization of Dark Sky Friendly lighting or other forms of stewardship (MVA 2015).

4.3 Recommended Mitigation Strategies

The goal of this review is to recommend mitigation strategies to minimize the impact of developments occurring in or near the Swale, such as roads and residential areas. Although the Swale was the primary focus, the recommendations provided can be extrapolated to other similar locations. The recommended strategies were chosen with a goal of selecting the appropriate design, where the design matches the need to protect wildlife and wildlife habitat without over- or under-designing (Clevenger and Huijser 2011). The general principles that were utilized when selecting the recommended strategies included:

- all species and clades were considered;
- the overall network of habitat was considered to ensure that any wildlife crossings chosen did not lead to an “ecological dead-end”; and,
- the selection of a particular mitigation strategy was based on the quality of habitat, topography, and the effectiveness of the strategy (Clevenger and Huijser 2011).

The decision making process followed the guidelines provided by Clevenger and Huijser (2011), City of Edmonton (2010), and AASHTO (2008). The first step in the process was to determine if developments in or near the Swale (e.g. NCP Project) were likely to cause substantial effects to the ecological integrity of the Swale, such as modifying or reducing the quality of habitat necessary for species at risk or preventing the movement of wildlife through a corridor (City of Edmonton 2010). Based on the estimated changes in habitat availability resulting from both direct habitat loss (e.g. clearing for roadways) and the functional loss of habitat (e.g. lost connectivity) (see Table 2), the proposed road and urban developments have a high potential to reduce the habitat quantity and quality in the Swale for plants and all wildlife groups. The decreased quality and patch size resulting from development is particularly important, as the habitat types present in the Swale (fescue grassland, semi-permanent wetlands) are already increasingly rare on the landscape (MVA 2015), and populations of habitat specialists may be disproportionately affected by these developments.

Although no wildlife movement studies or population estimates have been completed, it is likely that the Swale is utilized for local travel by wildlife between the South Saskatchewan River/Peturrson's Ravine and habitat outside the city (e.g. the Greater Swale, agricultural fields), especially for species, such as amphibians, that require riparian or moist habitat for travel. The Swale is also likely utilized for travel by large wildlife, such as deer, although the agricultural area currently north of the Swale is also likely utilized by these species as well. The planned roadways, residential developments, and planned trail system will restrict wildlife movement in the area due to barrier and edge effects as well as reduced habitat quality (see Section 3 and Table 2). Although this area may be used for local wildlife movement, its overall importance at a regional landscape level for large wildlife is likely limited, as the wetland and grassland habitat provided by the Swale effectively terminates at the South Saskatchewan River. The river bank can be utilized for some travel north/south, however, its suitability as a wildlife corridor is relatively limited given the amount of human presence along the riverbank (e.g. trails), and the proximity of the city to the river bank (i.e. it leads animals further into the city). Therefore, no significant alterations to migration patterns of any wildlife are anticipated from the developments planned in or around the Swale.

Given the suitability of the Swale for a wide diversity of species, it was important that mitigation for all wildlife species be considered. Of primary importance was protecting the native vegetation in the Swale, including the wetlands, fescue grassland, and treed/shrub stands, as few wildlife groups could maintain sustainable populations without protection of the native vegetation present in the Swale. The focus of the specific mitigation strategies chosen for each wildlife group (e.g. large mammals, amphibians, birds, etc.) was dependent upon the likelihood of the Swale continuing to support sustainable populations of these groups, given the unavoidable residual effects that will occur (e.g. direct habitat loss, reduced patch sizes, increased human presence). Other factors that were considered in the development of mitigation recommendations for each wildlife group included:

- the probability of each wildlife group being negatively affected by the proposed developments;

- the habitat requirements of each wildlife group, in particular, whether the group contained species that are habitat specialists of native grassland and semi-permanent wetlands, as these species cannot easily migrate or adapt to disturbance due to the low availability of suitable habitat and/or specific habitat requirements;
- the presence of rare, sensitive, or at-risk species within each wildlife group; and,
- the ability of the wildlife groups to disperse or migrate to nearby undisturbed habitat patches.

Based on these factors, the wildlife groups with the greatest potential to maintain sustainable populations in the Swale with the implementation of appropriate mitigation include amphibians, birds, and small to medium-sized mammals. The home ranges and dispersal requirements of these groups are smaller in size, suggesting they could maintain sustainable populations even with the expected losses in habitat or habitat quality resulting from developments. Multiple inhabitants of the Swale belonging to these wildlife groups are species at risk (e.g. northern leopard frogs, horned grebes, bobolinks, badgers), and are largely habitat specialists of grassland and wetlands. These species are also often at the highest risk of roadway mortality (Forman and Alexander 1998) and play important roles in ecosystem function. Implementation of mitigation measures to reduce impacts to these species will also benefit species further up the food chain (e.g. coyotes, hawks) as many of these species are important prey items. Therefore, the recommendations for these species included specific measures to prevent reduced habitat quality, mortality, and lost habitat connectivity.

As the current large mammal populations (deer, moose, coyotes) likely use the Swale as well as the nearby agricultural area as habitat, the development of residential areas on either side of the Swale will greatly restrict the amount of available habitat for large mammals. Once the residential areas have been developed, the Swale is unlikely to contain sufficient habitat to support these populations regardless of the mitigation strategy implemented. Unlike amphibians or other habitat specialists, deer, moose, and coyotes are not limited in habitat availability outside the city, and can more easily disperse to new areas. None of the large mammals that occur within the Swale are considered sensitive, at-risk, or rare species in the province (SKCDC 2015), nor are any important migration routes of these species anticipated to be affected by the proposed development. In addition, as described in Section 3, these species can become hazards and/or nuisances to urban residents. Therefore, the necessity for providing mitigation strategies to maintain large mammal habitat connectivity in the Swale is not warranted.

Mitigation strategies for large wildlife focused on preventing mortality along the roadways and preventing reductions in habitat quality for the relatively small number of individuals that may continue to utilize the Swale in the long term.

The recommended plan for the Swale was based on the need to protect and minimize changes in habitat quality and improve connectivity for both wildlife and hydrological flow. Although the focus was on providing roadway and lighting mitigation options, a number of other complementary strategies are recommended. The recommended mitigation plan includes:

- wildlife friendly road design and crossing structures;
- wildlife friendly lighting;
- a public education and awareness campaign;
- a Swale natural resource management plan;
- a construction environmental management plan, and,
- a long-term monitoring program.

These mitigation strategies are further detailed in the following sections. Note that these recommendations are based on available information, and additional studies may be required to provide more specific design details (e.g. locations of recommended crossing structures).

4.3.1 Road Design

The main goals when selecting roadway design strategies were to: reduce the effect of the road on habitat quality (i.e. water and vegetation), maintain hydrological flows across the roadway, maintain wildlife habitat connectivity where possible, and prevent roadway mortalities. Recommendations are presented by road type, as differences in traffic volume impact the permeability of the roadway, and thus influence the recommended road design and crossing structure selection (Clevenger and Huijser 2011). Although the recommended mitigation strategies may differ by road type, the efficacy of mitigation strategies implemented at one road are highly dependent upon the implementation of mitigation at other roadways. Therefore, in order to maintain connectivity across the entire Swale, it is important that the recommendations be considered collectively.

A number of strategies should be implemented across all road types. A roadway management plan should be in place for all roads, and should include, at minimum, strategies for salt application and roadside vegetation management. This will ensure that roadway management techniques are not having an undue effect on nearby soil and water quality, roadside visibility of wildlife is maximized, and weed species are controlled. Any crossings installed over potentially fish-bearing waterways should be designed to facilitate fish passage (e.g. FHWA 2007). Storm water drainage systems or related infrastructure footprints should be designed to occur outside of sensitive areas where possible, and stormwater should not be released directly to the Swale or sensitive habitat. Any water releases to the Swale should meet pre-defined quality standards that will not impact the water quality of wetlands. In addition, as described in Section 4.3.2, all roadways should utilize wildlife friendly lighting where lighting is required.

4.3.1.1 Local Roads

No local roads are currently planned to cross the Swale, however, a brief discussion of potential recommended strategies for these roads is provided. The barrier effect and expected animal mortality on local roads is relatively minimal due to low traffic volumes (under 2,500 vpd) (Clevenger and Huijser 2011). As wildlife generally move freely over this road type, the majority of crossing structures described in Section 4.1 (e.g. overpasses, underpasses) are not recommended. However, if the road bisects a waterway or wetland, culverts should be installed in order to maintain water flow. Additional mitigation strategies that may be appropriate for this road type when crossing an ecologically sensitive area include:

- reduced speed limits (e.g. 50 km/hr or less);
- construction of roadways level with existing topography;
- signage warning drivers of potential wildlife crossings;
- clearing of shrub vegetation in the roadway buffer and planting native grasses or forbs;
- Use of bird diverters (poles, trees) in areas with a high risk of bird collisions; and,
- curb and stormwater drainage design to facilitate amphibian and small mammal crossings.

4.3.1.2 Collector Roads

One collector road (Lowe Road) is currently planned to bisect the Swale, and may have between 1,000 to 15,000 vpd (COS 2015c). Although the low end of the predicted traffic volume will not be a barrier to wildlife movement, volumes between 2,500 to 10,000 vpd are highly likely to result in wildlife either being killed or repelled by the road (Clevenger and Huijser 2011). Therefore, the recommendations for Lowe Road are dependent upon the likelihood of reaching over 2,500 vpd. If it is unlikely, the recommendations provided above for local roads will be sufficient.

If greater than 2,500 vpd are anticipated, additional mitigation strategies are recommended. Lowe Road crosses approximately 500 metres of the Swale, the majority of which crosses a semi-permanent (Class IV) wetland. As this habitat is suitable for amphibians and small to medium-sized mammals, small culvert crossings and wildlife fencing specific to these groups is recommended for the length of this roadway. As culverts will be required for cross-road water flow near the wetland crossing, it may be possible, depending on the placement of the culverts, to include ledges and walkways that will allow small to medium-sized mammals to utilize these structures for crossing (see Section 4.1.1.2). Alternatively, the culvert size could be increased to incorporate habitat outside the high water mark, allowing for dry passage along the edges of the culvert. Culvert modification is likely to be relatively cost-effective, as the cost of culverts should already be included in the project design. Potential additional costs may include increasing the size of the culvert to include these modifications as well as the cost of ledges/walkways and associated fencing. The likelihood that amphibians would utilize these drainage culverts for crossing is driven by water flow rate through the culvert and the inclusion of moist riparian habitat, with amphibians less likely to utilize culvert crossings with rapid water flow and/or no moist riparian habitat (Patrick et al. 2010).

As crossings for amphibians and small to medium-sized mammal crossings need to be placed along the roadway at shorter intervals than large animal crossings (e.g. every 50 m in habitat suitable for amphibians), additional crossings other than the drainage culverts should be provided along the roadway. The design of these structures should follow the principles outlined in Section 4.1.1.2 and associated references. In particular, spacing and placement are critical aspects to the success of crossing structures, and further work may be required to determine the optimal spacing and placement, based on the home ranges, dispersal requirements, and specific habitat crossed by the roadway (City of Edmonton

2010). In addition, wildlife fencing specific to these amphibians and small to medium sized mammals is required, as the effectiveness of these structures is highly dependent upon the fencing channeling the individuals towards the crossing locations. The height and design of this fencing is not anticipated to impede crossings by large wildlife.

The recommendations provided above for local roads should also be implemented for Lowe Road to mitigate the risk of vehicle collisions with birds and medium to large wildlife (e.g. coyotes, deer, moose) along Lowe Road. Although overpasses or large wildlife underpasses may be suitable for mitigation on roadways with traffic volumes potentially occurring on Lowe Road, they are not recommended for the Swale. Based on the available data and analysis of existing habitat as described above, the Swale is unlikely to host sufficient populations of large mammals to warrant the installation of these structures. As the recommended wildlife fencing installed will not prevent the crossing of these animals, it will still be possible for these animals to cross the roadway, especially outside of peak travel flows (e.g. evening), when these animals may also be the most active and likely to cross the roadway (Christie and Nason 2003). An additional strategy for mitigating large wildlife, as well as benefiting all other species, is the institution of temporary road closures on this road during the evening/night-time hours, especially during breeding seasons. As these hours are outside peak travel times for residents, it is likely that the number of people who will be rerouted to either Central Avenue or the NCP may be minimal. These temporary road closures would benefit all species whose activity periods peak during the evening (e.g. amphibians).

4.3.1.3 Arterial Roads

Two arterial roads will cross the Swale (Central Avenue, NCP). Anticipated traffic volume for these roads ranges from 10,000 to 50,000 vpd (see Section 1.2.1). Even at the lowest anticipated traffic volume, these roads represent a complete barrier to all wildlife movement (Clevenger and Huijser 2011).

Central Avenue is a pre-existing road that crosses predominantly upland habitat (although Petursson's Ravine is nearby), while the NCP crosses primarily riparian and wetland habitat, in addition to a small proportion of uplands. Although the habitat crossed by these two roadways differs, the general recommendations are similar, with only a few exceptions to deal with potential slope stability and hydrological issues for Central Avenue. Recommendations previously provided by Stantec (2012) for Central Avenue should be followed; these include avoiding the clearing of native trees and shrubs, and hydrologically isolating the ravine from surface runoff (Stantec 2012). Further, recommendations provided for collector roads with greater than 2,500 vpd and local roads should be followed for these roads. This includes the provision of small/medium mammal (e.g. rodents, badgers) and amphibian crossings and specific wildlife fencing across the length of the roads at appropriate intervals and locations. Where drainage culverts are required, the modifications described above should be utilized to facilitate wildlife crossings.

Additional mitigation strategies for medium to large-sized wildlife (e.g. coyotes, deer) may be recommended for these roadways, especially the NCP. As with collector roads with greater than 2,500 vpd, the traffic volumes predicted for Central Avenue and the NCP have the potential to act as complete barriers to large wildlife movement and represent scenarios where overpasses or large wildlife underpasses may be considered. However, as described above, based on the available data and analysis of existing habitat, the Swale is unlikely to host sufficient populations of large mammals to warrant the installation of these structures at either of these roadways. Therefore, the recommendations presented above for large wildlife mitigation (e.g. reduced speeds, signage) are also recommended for these roadways. As these roadways are important transportation routes linking communities to the future NCP Bridge, temporary road closures are unlikely to be feasible, but could be considered.

If information becomes available (e.g. detailed wildlife movement/population studies, vehicle collision data) that suggests the creation of Central Avenue and the NCP presents a more significant safety or ecological risk than estimated at present, additional mitigation strategies could be considered and potentially implemented after the roadways are in place. For example, installation of large wildlife specific fencing and wildlife crosswalks at fencing endpoints (see Section 4.1.1.5) may reduce the number of vehicle collisions.

4.3.1.4 Highways

One highway crossing (Saskatoon Freeway) is proposed to cross the Swale northeast of the NCP. MHI has not released the final location and design of the roadway; however, its currently proposed location will require crossing a large open-water section of semi-permanent wetland (MVA 2015). Although traffic volume predictions for this highway were not available, it is estimated that this roadway will host a traffic volume similar to arterial roadways (greater than 10,000 vpd). Therefore, the most significant potential effects resulting from the construction of this highway include altered hydrological flows throughout the Swale and reduced habitat connectivity (Stantec 2012). As altered hydrology can influence habitat characteristics such as wetland sizes, water levels, and vegetation structure, this can have important consequences for habitat availability and wildlife populations within the Swale. Therefore, the primary recommendation for this highway is that the design should minimize effects to water levels or flow throughout the Swale. If possible, the construction of an open-span bridge over the wetland would be recommended to ensure the effects to hydrological flows are minimized.

The wildlife species that may be the most affected by the construction of the highway include amphibians, waterbirds, and semi-aquatic mammals. Depending upon the amount of upland habitat crossed in the Swale, a number of other species (e.g. non-aquatic mammals of all sizes) may also be affected. The construction of an open-span bridge would be the most effective in minimizing the effects to wildlife groups that utilize wetland habitat. Terrestrial wildlife species would also benefit if the bridge is constructed to include a section of upland vegetation on either side of the wetland to allow dry passage underneath the roadway. This dry passage area could also be utilized for passage of humans under the roadway.

If construction of an open span bridge is not possible, the mitigation strategies proposed for collector and arterial roads are recommended for this highway, including the provision of specially designed crossing structures for amphibians and small to medium-sized mammals (e.g. semi-aquatic mammals) and associated wildlife fencing across the length of the road at appropriate intervals and locations. This may include the modification of drainage culverts to allow wildlife passage, as described above. If crossing structures for human passage are required (e.g. an underpass system) these crossing structures should incorporate design elements that will encourage wildlife usage. However, the large underpass systems (e.g. box culverts) that may be required for human usage should not be considered a replacement for the amphibian/small mammals crossings already recommended.

Regardless of the road type constructed for the highway, this area presents a high risk of vehicle collisions with waterfowl. Mitigation options available to reduce this risk are somewhat limited, especially if a speed limit reduction through the Swale is not an option for the highway. Any structures or roadway design that can direct birds to fly above the height of vehicles would be recommended, such as diversion fencing/poles or trees. Although earth berms are likely the most effective at diverting bird pathways (City of Edmonton 2010), installation of diversion fencing/poles or trees near the roadway is recommended over berms due to the much smaller disturbance these structures would have on adjacent wetland habitat.

4.3.2 Lighting

Based on the known ecological effects of lighting on all wildlife and plant species (See Section 3), it is recommended that lighting be avoided where possible, and where lighting is required, all light sources and fixtures used in or near the Swale should be Dark Sky Friendly. All wildlife species benefit from a reduced light environment, and increased light does not reduce vehicle-wildlife collisions (City of Edmonton 2010). In addition, the cost of implementation is likely negligible to relatively low compared to overall project costs and will be limited to any price differences between Dark Sky Friendly lighting and standard lighting choices.

Although use of 4,000 K LED lighting, as promoted for new developments by COS, may result in significant reductions to the City’s electrical requirements, this benefit comes at a cost to wildlife, even if properly shielded. Therefore, the current lighting proposed for new developments by COS would not be considered Dark Sky Friendly and are not recommended for use in or near the Swale. If LED lighting with the appropriate color temperature is available (3,000 K or less), the use of this light source may be recommended, however, prior to the final decision, an analysis of the energy and cost efficiency of low temperature LED lights compared to conventional Dark Sky Friendly light sources (e.g. HPS) should be completed. Consideration should also be placed on ensuring lighting choices would comply with requirements set out by RASC, should MVA wish to pursue an Urban Star Park or Nocturnal Preserve designation. Given the small number of lights required for the Swale relative to the number of COS lights as a whole, it is expected that the small loss of electrical efficiency via use of conventional Dark Sky Friendly light sources would be negligible.

Light fixtures utilized in or near the Swale should be full-cutoff fixtures. RASC (2013a) allows for semi-cutoff fixtures to be utilized along roadways in Nocturnal Preserves, therefore there is some flexibility allowed in street lighting design in Nocturnal Preserves.

However, full-cutoff fixtures should be prioritized wherever street lighting design and engineering allows, and where possible, light fixtures should have a Type II distribution pattern to focus light along the road and not on adjacent land. No non-cutoff fixtures should be allowed in or near the Swale. In addition, no illuminated signage should be allowed in or near the Swale (RASC 2013). It is recommended that internal trails should not be lit, as alternatives such as using a light colored material, painting the edges of the pathway, or using fluorescent markers to reflect ambient light may prove sufficient (RASC 2013). Pole height should also be considered in the lighting design. RASC recommends that pole heights be no taller than six metres along the roadway (RASC 2013). However, pole height should also account for bats or other aerial insectivores that may swoop around street lights and be at risk of being hit by vehicle traffic (City of Edmonton 2010).

The lighting plan for the Swale should also include a community engagement plan, in which adjacent developments to the preserve should be encouraged or required to reduce light pollution, if possible. This engagement plan should include encouraging residents to turn lights off at night, replace outdoor lighting with full-cutoff fixtures, and replace light sources with Dark Sky Friendly options.

4.3.3 Sound

Increased noise within the soundscape of the Swale will be primarily caused by nearby roadways and residential areas. One strategy to minimize noise is to include a buffer between the development and the sensitive area. This strategy has already been incorporated into current recommendations through the creation of the Greenway (MVA 2015). Recommended mitigation strategies for the roadways include reducing speed limits where possible, and reviewing the road surface design to ensure that the materials and design utilized minimizes the creation of road noise. Although sound barriers are an effective method for reducing road noise, these structures are not recommended for the Swale due to the additional disturbance required to install a berm or sound wall. An additional disadvantage to sound walls is the barrier effect it has on wildlife.

4.3.4 Urban Planning and Management

In order for the design strategies recommended above to be fully effective, it is important that a number of management techniques are implemented. This includes:

- Legally-binding protection of the Swale. This may include the installation of bylaws, conservation designations (e.g. Municipal Heritage Site, Environmental Reserve) or easements, or any other legal protections that can be utilized to ensure the long-term protection of the Swale. Potential compensatory actions (see Section 4.1.5) to offset habitat loss from the Swale may include protection of the Greater Swale from future development or incorporation of habitat adjacent to the Swale, as available.
- The establishment of a natural resource management plan that includes burning and grazing to maintain native plant communities. Natural disturbance is an important process in grassland ecosystems, and including these disturbances is necessary to maintain the ecological integrity of the Swale. This report fully supports the plan developed by MVA for the management of the Swale (see MVA 2013; 2015).
- The inclusion of urban design elements such as the proposed “Greenway” to reduce the effects of the nearby residential areas on the Swale.
- Bylaw enforcement and public education programming to ensure that the effect of domestic pets (e.g. cats, dogs) is minimized.
- The inclusion of an ongoing public awareness and education program that includes a targeted awareness program for nearby residents on the ecological value of the Swale. A communication and education program for the Swale has been designed by MVA, the details of which can be reviewed in MVA (2015) and MVA (2013). This report fully supports the development of this education program for the Swale.

The implementation of these management techniques will ensure that the ecological integrity is maintained to the extent possible, and that sustainable populations of wildlife and plants will continue to utilize the Swale.

4.3.5 Construction Management

Roadway construction will be a major disturbance for the Swale. A number of mitigation strategies have been developed to minimize the effects of construction on the Swale through various approval and permitting processes for the NCP, as presented in Table 4. This report recommends the implementation of all identified mitigation strategies.

5.0 FUTURE WORK AND MONITORING REQUIREMENTS

Effective placement of crossing structures requires considerable thought and consideration of the home range and dispersal requirements of the target species, as well as habitat in the local area and the likelihood of various areas being utilized by different wildlife (City of Edmonton 2010). Therefore, if the recommendations presented in Section 4.3 are accepted or to be utilized for the Swale, detailed, road-specific design work should be completed to ensure that the recommended structures are placed properly and the design can be incorporated into roadway engineering requirements. Additional biological surveys or habitat assessments may be useful to identify key details essential to the design, such as amphibian migration corridors. In addition, any future work should include an opportunity to review the recommendations in light of any significant changes or updates in roadway design (e.g. Saskatoon Freeway).

Once mitigation strategies have been designed and installed, it is recommended that a detailed monitoring program be established (Clevenger and Huijser 2011). Implementation of a well-designed monitoring program for the Swale will provide a reliable means of estimating the success of implemented mitigation strategies, and can provide valuable information for future developments. The study design and methodology used for a monitoring program depends largely on the overall initial goals of the mitigation strategy (Clevenger and Huijser 2011). For this program, two main objectives were identified. The first objective was to maintain habitat connectivity across roadways. Therefore, one of the focuses of the mitigation plan should be to assess the effectiveness of crossing structures on habitat connectivity and wildlife movement. The second objective was to maintain the ecological integrity of the Swale, and the monitoring program should examine for changes in the biodiversity or habitat health/quality of the Swale over time (e.g. species composition, wildlife population sizes, noise and light levels) (MVA 2013; 2015).

A number of different strategies have been developed to monitor the effectiveness of roadway mitigation strategies, and crossing structures in particular (e.g. Clevenger and Huijser 2009, City of Edmonton 2010; Clevenger and Huijser 2011). Evaluation of the effectiveness of a crossing structure (or roadway) should include estimating not only how many times wildlife use the crossing or roadway, but also the number of times an animal approached but did not cross (City of Edmonton 2010). A large number of technologies are available to monitor crossing structures and roadways, including road kill data collection, snow tracking, installation of sand or ink beds, hair collection devices, radio telemetry, and infrared cameras (City of Edmonton 2010). Clevenger et al. (2009) found that remote cameras were the most cost-effective for monitoring crossing structures; however, these devices are generally only effective for monitoring medium to large species (Clevenger and Huijser 2011). Monitoring devices that are useful for smaller animals include track pads, where the animal first walks over a layer of soot followed by contact paper, leaving a track behind (Clevenger and Huijser 2011). These devices are relatively low cost, although labour costs need to be included for the pickup, replacement, and analysis of the track plates (Clevenger and Huijser 2011). The choice of technology recommended for the Swale will be dependent upon the final mitigation design as well as available funding.

Monitoring for changes in biodiversity, wildlife populations, and habitat health/quality will require the development of a suite of standardized biological surveys that can be completed over time, and should ideally follow a BACI (Before-After-Control-Impact) study design. Therefore, the biological program should be implemented as soon as possible to allow for pre- and post-disturbance comparisons. A potentially suitable control area may be the Greater Swale. The data collected from the monitoring program should be analysed on a continuing basis so that mitigation strategies can be optimized as information becomes available. This may be especially important for roadways that are implemented in phases, allowing for design modifications to be made to future road crossings based on knowledge gained from previous road developments.

Components that should be incorporated as part of the monitoring program include measurements of biodiversity, noise, and light levels (MVA 2015). In particular, the study should be designed to estimate changes in habitat quality and quantity, as well as species composition and/or population numbers of both plants and wildlife over time. Standardized protocols should be developed in order to obtain consistent, reliable data between years, and should include the establishment of permanent sampling locations. Including standardized protocols such as rangeland health estimates may also allow citizen scientists to be involved in the data collection, thereby lessening the time and financial costs associated with the monitoring program. Selection of focal species for study (e.g. species of high priority) may also lessen the time and financial costs of the monitoring program.

6.0 CONCLUSION

The Swale is a culturally and ecologically important area due to the presence of rare habitat types and species. In addition to providing a number of ecological functions, the Swale provides an important opportunity for city residents to interact and learn about Saskatchewan ecosystems. Therefore, it was important when designing mitigation recommendations that the biological integrity of the Swale be maintained to the extent possible in consideration of planned developments. These recommendations were based on available information, scientific literature, and professional opinion, but should be reviewed if any changes to the proposed developments are required or additional relevant information becomes available.

7.0 LITERATURE CITED

Ahlers, A. 2015. Habitat selection, survival, and disease risk of semiaquatic mammals in a highly altered landscape. PhD Thesis, University of Illinois, Urbana, Illinois, U.S.A.

Althoff, D.P. 1980. Den and den-site characteristics of coyotes (*Canis latrans*) in southeastern Nebraska. Transactions of the Nebraska Academy of Sciences VIII: 9-14.

American Association of State Highway and Transportation Officials. 2008. Wildlife and roads decision guide. Website: http://environment.transportation.org/ environmental_issues/wildlife_roads/decision_guide/pdf/decision_guide.pdf. Accessed January 22nd,2016.

Animal Road Crossing (ARC). 2016. New materials: Can exploring new materials change how we engineer our highways? Website: http://arc-solutions.org/new-materials/. Accessed January 7th, 2015.

Arizona Game and Fish Department (AGFD). 2006. Guidelines for culvert construction to accommodate fish and wildlife movement and passage. Arizona Game and Fish Department, Habitat Branch.

Ashdown, I. 2015. Color temperature and outdoor lighting. All things lighting: Relevance in illumination engineering. Website: http://agi32.com/blog/2015/07/ 07/color-temperature-and-outdoor-lighting/. Accessed January 4th, 2015.

Ashley, E. P. and J. T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field Naturalist 110:403-412.

Bager, A. and C. A. Rosa. 2011. Influence of sampling effort on the estimated richness of road-killed vertebrate wildlife. Environmental Management 47:851–858.

Baker, B. J. and J. M. L. Richardson. 2006. The effect of artificial light on male breeding-season behaviour in green frogs, *Rana clamitans melanota*. Canadian Journal of Zoology 84:1528-1532.

Bateman, P. W. and P. A. Fleming. 2012. Big city life: Carnivores in urban environments. Journal of Zoology 287:1-23.

Beier, P. 2006. Effects of artificial night lighting on terrestrial mammals. *In* Ecological consequences of artificial night lighting. C. Rich and T. Longcore (Eds). Island Press, Washington. pp. 19-42.

Bendel, P. and G. Therres. 1999. Proximity of waterbird colonies to development in Maryland. Proceedings of the Annual Conference of Southeast. Assocation of Fish and Wildlife Agencies 53:425-43.

Benítez-López, A., R. Alkemade, and P. A. Verweij. 2010. The impacts of roads and other infrastructure on mammal and bird populations: a meta-analysis. Biological Conservation 143:1307-1316.

Benson, J. F., P. J. Mahoney, and B. R. Patterson. 2015. Spatiotemporal variation in selection of roads influences mortality risk for canids in an unprotected landscape. Oikos 124:1664-1673.

Berthinussen, A. and J. Altringham. 2012a. The effect of a major road on bat activity and diversity. Journal of Applied Ecology 49:82-89.

Berthinussen, A. and J. Altringham. 2012b. Do bat gantries and underpasses help bat cross roads safely? PLoS ONE 7(6): e38775. doi:10.1371/journal.pone.0038775

Biolinx Environmental Research Ltd. (Biolinx) and E. Wind Consulting. 2004. Best management practices for amphibians and reptiles in urban and rural environments in British Columbia. Prepared for the B.C. Ministry of Water, Land, and Air Protection. Nanaimo, B.C., Canada.

Bishop, C. A. and J. M. Brogan. 2013. Estimates of avian mortality attributed to vehicle collisions in Canada. Avian Conservation and Ecology 8(2):2.

Blancher, P. 2013. Estimated number of birds killed by house cats (*Felis catus*) in Canada. Avian Conservation and Ecology 8(2):3.

Bond, A. and D. Jones. 2013. Wildlife warning signs: Public assessment of components, placement, and designs to optimise driver response. Animals 3: 1142-1161.

Business and Biodiversity Offsets Program (BBOP). 2012. Resource paper: No net loss and loss-gain calculations in biodiversity offsets. BBOP, Washington, D.C.

Calvert, A. M., C. A. Bishop, R. D. Elliot, E. A. Krebs, T. M. Kydd, C. S. Machtans, and G. J. Robertson. 2013. A synthesis of human-related avian mortality in Canada. Avian Conservation and Ecology 8(2):11.

Canadian Broadcasting Corporation (CBC). 2012. Ontario builds first bridge for animals near Sudbury. Website: http://www.cbc.ca/news/canada/sudbury/ontario-builds-first-bridge-for-animals-near-sudbury-1.1148087. Accessed January 15th, 2016.

Canadian Broadcasting Corporation (CBC). 2013. Wildlife underpasses installed at Kootenay National Park. Website: http://www.cbc.ca/news/canada/calgary/

wildlife-underpasses-installed-at-kootenay-national-park-1.1872120. Accessed January 19th, 2015.

Cartwright, L. A., D. R. Taylor, D. R. Wilson, and P. Chow-Fraser. 2014. Urban noise affects song structure and daily patterns of song production in red-winged blackbirds (*Agelaius phoeniceus*). Urban Ecosystems 17:561-572.

Chamberlain, D. E., and R. J. Fuller. 2000. Local extinctions and changes in species richness of lowland farmland birds in England and Wales in relation to recent changes in agricultural land-use. Agriculture, Ecosystems & Environment 78:1-17.

Chace, J. F., J. J. Walsh, A. Cruz, J. W. Prather, and H. M. Swanson. 2003. Spatial and temporal activity patterns of the brood parasitic brown-headed cowbird at an urban/wildland interface. Landscape and Urban Planning 64:179–190.

Christie, J. S. and S. Nason. 2003. Analysis of vehicle collisions with moose and deer on New Brunswick arterial highways. *In:* The 31st Annual Conference of the Canadian Society for Civil Engineering, Moncton, New Brunswick. pp. 11.

City of Edmonton. 2010. Wildlife passage engineering design guidelines. Prepared by Stantec Consulting Ltd. for the City of Edmonton Office of Natural Areas. Edmonton, Alberta.

City of Saskatoon (COS). 2013. University Heights sector plan. Planning and Development Branch, City of Saskatoon. Saskatoon, Saskatchewan.

City of Saskatoon (COS). 2014. Aspen Ridge neighborhood concept plan. City of Saskatoon: Saskatoon Land, Victory Majors Investments Corporation, and Cindercrete Products. Saskatoon, Saskatchewan.

City of Saskatoon (COS). 2015a. North Commuter Parkway and Traffic Bridge replacement projects. Website: https://www.saskatoon.ca/business-development/major-projects/current-projects/north-commuter-parkway-traffic-bridge-replacement-projects. Accessed January 7th, 2015.

City of Saskatoon (COS). 2015b. Traffic studies. Website: https://www.saskatoon.ca/moving-around/driving-roadways/managing-traffic/traffic-studies. Accessed January 7th, 2015.

City of Saskatoon (COS). 2015c. City of Saskatoon new neighborhood design and development standards manual: Section 8 transportation system. City of Saskatoon. Saskatoon, Saskatchewan.

City of Saskatoon (COS). 2016a. Improvements to snow and ice program- made better winter roads. Website: https://www.saskatoon.ca/news-releases/improvements-snow-ice-program-%E2%80%93-made-better-winter-roads. Accessed January 6th, 2016.

City of Saskatoon (COS). 2016b. Street lighting: Street light information. Website: https://www.saskatoon.ca/services-residents/power-water/saskatoon-light-power/street-lighting. Accessed December 17th, 2015.

Clark, W. 1994. Habitat selection by muskrats in experimental marshes undergoing succession. Canadian Journal of Zoology 72: 675-680.

Clevenger, A. and N. Waltho, 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology 14(1): 47-56.

Clevenger, A., A. Ford, and M. Sawaya. 2009. Banff wildlife crossings project: Integrating science and education in restoring population connectivity across transportation corridors. Final report to Parks Canada Agency, Radium Hot Springs, British Columbia, Canada. 165 pp.

Clevenger, T. 2011. Planning considerations for wildlife passage in urban environments: Best practice guideline. Prepared for the Government of Alberta Transportation. Edmonton, Alberta.

Clevenger, A. and M. Huijser. 2011. Wildlife crossing structure handbook design and evaluation in North America. Publication No. FHWA-CFL/TD-11-003. U.S. Department of Transportation. Lakewood, Colorado, U.S.A.

Collins, S. J. and R. W. Russell. 2009. Toxicity of road salt to Nova Scotia amphibians. Environmental Pollution 157:320-324.

Corlatti, L., K. Hacklander, and F. Frey-Roos. Ability of wildlife overpasses to provide connectivity and prevent genetic isolation. Conservation Biology 23(3): 548-556.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2009. COSEWIC assessment and status report on the northern leopard frog (*Lithobates pipiens*) in Canada. Ottawa vii + 69 pp. Website: www.sararegistry.gc.ca/status/status_e.cfm. Accessed December 14th, 2015.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2010a. COSEWIC assessment and status report on the bobolink (*Dolichonyx oryzivorus*) in Canada. Ottawa ix + 42 pp. Website: www.sararegistry.gc.ca/status/status_e.cfm. Accessed January 20th, 2016.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2010b. COSEWIC assessment and status report on the Sprague’s pipit (*Anthus spragueii*) in Canada. Ottawa ix + 34 pp. Website: www.sararegistry.gc.ca/status/status_e.cfm. Accessed January 20th, 2016.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2012. COSEWIC assessment and status report on western tiger salamander (*Ambystoma mavortium*) in Canada. Ottawa xv + 63 pp. Website: www.sararegistry.gc.ca/status/status_e.cfm. Accessed January 4th, 2016.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2013a. COSEWIC assessment and status report on the American badger (*Taxidea taxus)* in Canada. Ottawa ix + 63 pp. Website: www.sararegistry.gc.ca/status/status_e.cfm. Accessed January 27th, 2016.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2013b. COSEWIC assessment and status report on the little brown myotis (*Myotis lucifugus)*, northern myotis (*Myotis septentrionalis*), tri-colored bat (*Perimyotis subflavus*) in Canada. Ottawa xxiv + 93 pp. Website: www.sararegistry.gc.ca/status/status_e.cfm. Accessed January 20th, 2016.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2016. COSEWIC's wildlife species assessment. Website: http://www.cosewic.gc.ca/eng/sct0/index_e.cfm. Accessed January 2016.

Cramer, P. 2013. Design recommendations from five years of wildlife crossing research across Utah. Proceedings of the 2013 International Conference on Ecology and Transportation.

Croft, C., T. Zimmerling, and K. Zimmer. 2011. Conservation offsets: A working framework for Alberta. Alberta Conservation Association. Sherwood Park, Alberta.

Dale, J. M. and B. Freedman. 1982. Lead and zinc contamination of roadside soil and vegetation in Halifax, Nova Scotia. Proceedings of the Nova Scotian Institute of Science 32:327-336.

Delanoy, L. 2001. Vegetation and wildlife survey of the Northeast Swale near Saskatoon. Saskatoon, SK. Meewasin Valley Authority. Saskatoon, Saskatchewan.

Department of Environment, Climate Change, and Water New South Wales. (DECC). 2009. The science behind biobanking. Department of Environment, Climate Change, and Water New South Wales, Sydney, Australia.

Develey, P. F. and P. C. Stouffer. 2001. Effects of roads on movements by understory birds in mixed-species in Central Amazonian Brazil. Conservation Biology 15(5): 1416-1422.

Dietz, D.R. and J.G. Nagy. 1976. Mule deer nutrition and plant utilization. *In* Mule deer decline in the west. Symposium Proceedings, Utah State University, Logan, USA. pp. 71-78.

Dodd, N., J. Gagnon, S. Boe, and R. Schweinsburg. 2007. Role of fencing in promoting wildlife underpass use and highway permeability. In: Proceedings of the 2007 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina University, Raleigh, North Carolina, USA, pp. 475-487.

Eigenbrod, F., S. J. Hecnar, and L. Fahrig. 2009. Quantifying the road-effect zone: threshold effects of a motorway on anuran populations in Ontario, Canada. Ecology and Society 14: 24. Website: http://www.ecologyandsociety.org/ vol14/iss1/ art24/.

Evans, M. and C. Frick. 2001. The effects of road salts on aquatic ecosystems. National Water Research Institute Contribution Series No. 02–308. Saskatoon, Canada.

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

Fahrig, L. and T. Rytwinski. 2009. Effects of roads on animal abundance: an empirical review and synthesis. Ecology and Society 14(1):21.

Falchi, F., P. Cinzano, C. Elvidge, D. Keith, and A. Haim. 2011. Limiting the impact of light pollution on human health, environment, and stellar visibility. Journal of Environmental Management 92(10): 2714-2722.

Fay, L., X. Shi, and J. Huang. 2013. Strategies to mitigate the impacts of chloride roadway deicers on the natural environment: National cooperative highway research program synthesis 449. Prepared by the Western Transportation Insitute for the Transportation Research Board. Washington, D.C.

Federal Highway Adminstration (FHWA). 2001. Keeping the noise down: Highway traffic noise barriers. Website: https://www.fhwa.dot.gov/environment/noise/ noise_barriers/design_construction/keepdown.pdf. Accessed January 8th, 2015.

Federal Highway Administration (FHWA). 2007. Design for fish passage at roadway-stream crossings: Synthesis report. Publication No. FHWA-HIF-07-033. U.S. Department of Transportation, Federal Highway Administration. McLean, Virginia.

Finch, D. M., Editor. 2005. Assessment of grassland ecosystem conditions in the Southwestern United States: wildlife and fish—volume 2 Gen. Tech. Rep. RMRS-GTR-135-vol. 2. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 168 p.

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

Fleck, J. E., L. J. Ross, and K. Hefner. 1988. Endosulfan and chlorthal-dimethyl residues in soil and sediment of Monterey County. State of California, Department of Food and Agriculture, Division of Pest Management, Environmental Protection and Worker Safety, Branch of Environmental Monitoring and Pest Management. Website: http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh8806.pdf.

Forman, R. T. 1998. The ecological road-effect zone for transportation planning and Massachusetts highway example. In Proc. Int. Conf. Wildlife and Transportation, Rep. FL-ER-69-98, ed. GLEvink, P Garrett, DZeigler,J Berry. Florida Dep. Transp. Tallahassee, FL.

Forman, R. T. and L. E. Alexander. 1998. Roads and their major ecological effects. Annual review of ecology and systematics 207-C2.

Forman, R. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter. 2003. Road ecology: Science and solutions. Island Press, Washington, D.C.

Forrest, A. and C. C. S. Clair. 2006. Effects of dog leash laws and habitat type on avian and small mammal communities in urban parks. Urban Ecosystems 9:51-66.

Found, R. and M. Boyce. 2011. Predicting deer-vehicle collisions in an urban area. Journal of Environmental Management 92 (10): 2486-2493.

Furniss, M. J., T. D. Roelofs and C. S. Yee. 1991. Road construction and maintenance. American Fisheries Society Special Publication 19:297-323.

Gjessing, E., E. Lygren, L. Berglind, T. Gulbrandsen, and R. Skanne. 1984. Effect of highway runoff on lake water quality. Science of the Total Environment 33:245-257.

Glista, D., T. DeVault, and J. DeWoody. A review of mitigation measures for reducing wildlife mortality on roadways. Landscape and Urban Planning 91:1-7.

Golder Associates. 2014a. Technical proposal for the City of Saskatoon- North Commuter Parkway project. Prepared by Golder Associates for the City of Saskatoon. Saskatoon, Saskatchewan.

Golder Associates. 2014b. North Commuter Parkway Project- Technical proposal addendum. Submitted to the Environmental Assessment Branch, MOE. Regina, Saskatchewan.

Gollop, B. 2000. Northeast Swale. *In* P. Jonker, and B. Gollop (Eds.), A guide to nature viewing sites in and around Saskatoon, revised edition. pp. 55-59. Saskatoon Nature Society. Saskatoon, SK:

Habib, T., D. Farr, R. Schneider, and S. Boutin. 2013. Economic and ecological outcomes of flexible biodiversity offset systems. Conservation Biology 27: 1313-1323.

Harestad, A. and F. Bunnel. 1979. Home range and body weight- a reevaluation. Ecology 60(2): 389-402.

Healy, A. and K. Gunson. 2014. Reducing wildlife collisions: What is working in northeastern Ontario. Conference proceedings of the 2014 conference of the Transportation Association of Canada. Montreal, Quebec.

Hess, G., C. Moorman, J. Thompson, and C. Larson. 2014. Chapter 12: Integrating wildlife conservation into urban planning. In: Urban Wildlife Conservation: Theory and Practice. DOI 10.1007/978-1-4899-7500-3_12.

Hockin, D., M. Ounsted, M. Gorman, D. Hill, V. Keller and M. A. Barker. 1992. Examination of the effects of disturbance on birds with reference to its importance in ecological assessments. Journal of Environmental Management 36:253-286.

Huijser, M. P. and P. J. Bergers. 2000. The effect of roads and traffic on hedgehog (*Erinaceus europaeus*) populations. Biological Conservation 95:111-116.

Huijser, M., A. Kociolek, P. McGowen, A. Hardy, A. Clevenger, and R. Ament. 2007. Wildlife-vehicle collision and crossing mitigation measures: A toolbox for the Montana Department of Transportation. Prepared by the Western Transportation Institute for the State of Montana Department of Transportation. Helena, Montana.

Huijser, M. and A. Kociolek. 2008. Wildlife-vehicle collision and crossing mitigation measures: A literature review for Blaine County, Idaho. Prepared for the Board of Blaine County Commissioners. Hailey, Idaho.

Huijser, M., P. McGowen, A. Clevenger, and R. Ament. 2008. Wildlife-vehicle collision reduction study: Best practices manual. Prepared by the Western Transportation Institute for the Federal Highway Administration. McLean, Virginia, U.S.A.

Huijser, M., J. Duffield, A. Clevenger, R. Ament, and P. McGowen. 2009. Cost-benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada: A decision support tool. Ecology and Society 14(2): 15.

International Dark-Sky Association (IDA). 2015a. Fixture seal of approval. Website: http://darksky.org/fsa/. Accessed January 4th, 2015.

International Dark-Sky Association (IDA). 2015b. The promise and challenges of LED lighting: A practical guide. International Dark Sky Association. Tuscan, Arizona.

Jacobson, S. L. 2005. Mitigation measures for highway caused impacts to birds. In USDA Forest Service general technical report PSWGTR-191, Vol. I and II. C. J. Ralph and T. D. Rich (Eds). United States Department of Agriculture and Forest Service, Washington, D.C., USA. pp. 1043–1050.

Jensen Ecosystems Services (Jensen). 2009. Species at risk survey for North East Swale within Meewasin Valley, September 15-21, 2009. Report prepared for the Meewasin Valley Authority. Saskatoon, Saskatchewan.

Jensen Ecosystems Services (Jensen). 2012. Bird survey for North East Swale within Meewasin Valley, May 1 to June 2, 2012. Report prepared for the Meewasin Valley Authority. Saskatoon, Saskatchewan.

Johnston, J.C. and R.L. Holberton. 2009. Forest management and temporal effects on food abundance for a ground-foraging bird (*Catharus guttatus)*. Forest Ecology and Management 258(7):1516-1527.

Jones, P. H., B. A. Jeffrey, P. K. Watler and H. Hutchon. 1986. Environmental impact of road salting - State of the art. Ontario Ministry of Transport and Communication. MTC No. RR237. pp. 53.

Jones, D. and J. Pickvance. 2013. Forest birds use vegetated fauna overpass to cross multi-lane road. Oecol.Aust.17: 42-51.

Klein, M. L. 1993. Waterbird behavioral responses to human disturbances. Wildlife Society Bulletin 21:31-39.

Knutson, M. G., J. R. Sauer, D. A. Olsen, M. J. Mossman, L. M. Hemesath and M. J. Lannoo. 1999. Effects of landscape composition and wetland fragmentation on frog and toad abundance and species richness in Iowa and Wisconsin, USA. Conservation Biology 13:1437-1446.

Kroll, J.C. 1994. A practical guide to producing and harvesting white-tailed deer. Institute for White-tailed Deer Management and Research Centre for Applied Studies in Forestry. Nacogdoches, Texas.

Lampman Wildlife Services. 2014a. Wildlife mitigation products: Electro Crosswalk. Website: http://www.lampmanwildlifeservices.com/electro-crosswalk. Accessed January 8th, 2015.

Lampman Wildlife Services. 2014b. Lampman Electromat: Product information sheet. Website: http://www.lampmanwildlifeservices.com/usercontent/ /Lampman_Electromat.pdf. Accessed January 19th, 2015.

Lister, N-M., M. Brocki, and R. Ament. 2015. Integrated adaptive design for wildlife movement under climate change. Frontiers in Ecology and Environment 13(9): 493-502.

Lighting Research Centre. 2007. Lighting answers: What are the IESNA cutoff classifications? Website: http://www.lrc.rpi.edu/programs/nlpip/lightinganswers/lightpollution/cutoffClassifications.asp. Accessed January 5th, 2015.

Liu, R. and D. Zhao. 2003. Evaluation of best management practices for mitigating impacts of highways on stream and wildlife ecology: First progress report. Auburn, Alabama, U.S.A.

Loss, S. R., T. Will and P. P. Marra. 2013. The impact of free-ranging domestic cats on wildlife of the United States. Nature Communications 4:1396.

Luers, M. 2013. Update: Can we de-ice our roads without hurting wildlife? *In* Crossing Paths. Washington Department of Fish & Wildlife. Olympia, Washington Website http://wdfw.wa.gov/living/crossing_paths/2013_archive.html. Accessed January 4th, 2016.

Madsen, J. 1985. Impact of disturbance on field utilization of pink-footed geese in West Jutland, Denmark. Biological Conservation 33:53-63.

Markewich, C. 2014. By the numbers: wildlife collisions in Saskatchewan. Website: http://cjme.com/article/192066/numbers-wildlife-collisions-saskatchewan. Accessed January 12th, 2016.

McClintic, L., J. Taylor, J. Jones, R. Singleton, and G. Wang. 2014. Effects of spatiotemporal resource heterogeneity on home range size of American beaver. Journal of Zoology 293: 134-141.

McGregor, M. S. Wilson, and D. Jones. 2015. Vegetated fauna overpass enhances habitat connectivity for forest dwelling herpetofauna. Global Ecology and Conservation 4: 221-231.

Meewasin Valley Authority. 2013. Northeast Swale resource management plan. Meewasin Valley Authority. Saskatoon, Saskatchewan.

Meewasin Valley Authority. 2014. Letter of approval re: North Commuter Parkway, File#50.14.627. Letter addressed to CIMA. Saskatoon, Saskatchewan.

Meewasin Valley Authority. 2015. Meewasin Northeast Swale master plan. Meewasin Valley Authority. Saskatoon, Saskatchewan.

Meisingset, E., L. Loe, O. Brekkum, and A. Mysterud. 2014. Targeting mitigation efforts: The role of speed limit and road edge clearance for deer-vehicle collisions. Journal of Wildlife Management. DOI: 10.1002/jwmg.712

Merriam, G., M. Kozakiewicz, E. Tsuchiya and K. Hawley. 1989. Barriers as boundaries for metapopulations and demes of *Peromyscus leucopus* in farm landscapes. Landscape Ecology 2:227-235.

Miller, S. G., R. L. Knight and C. K. Miller. 2001. Wildlife responses to pedestrians and dogs. Wildlife Society Bulletin 29:124-132.

Moorman, C.E. and D.C. Guynn, Jr. 2001. Effects of group-selection opening size on breeding bird habitat use in a bottomland forest. Ecological Applications. 11(6):1680-1691.

Mumme, R. L, S. J. Schoech, G. E. Woolfenden, and J. W. Fitzpatrick. 2000. Life and death in the fast lane: demographic consequences of road mortality in the Florida Scrub-Jay. Conservation Biology 14:501–512. Website: http://dx.doi.org/10.1046/j.1523-1739.2000.98370.x

Naiman, R., J. Melillo, and J. Hobbie. 1986. Ecosystem alteration of boreal forest streams by beaver (*Castor canadensis*). Ecology 67(5): 1254-1269.

Naugle, D.E., R.R. Johnson, M.E. Estey, and K.F. Higgins. 2001. A landscape approach to conserving wetland bird habitat in the prairie pothole region of eastern South Dakota. Wetlands. 21(1):1-17.

Newcombe, C. P. and J. O. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16:693-727.

Ng, S., J. Dole, R. Sauvajot, S. Riley, and T. Valone. 2004. Use of highway undercrossings by wildlife in southern California. Biological Conservation 115 (2004): 499-507.

Olson, M., P. Widen, and J. Larkin. 2007. Effectiveness of a highway overpass to promote landscape connectivity and movement of moose and roe deer in Sweden. Landscape and Urban Planning, doi:10.1016/j.landurbplan.2007.10.006.

Oxley, D., M. B. Fenton and G. R. Carmody. 1974. The effects of roads on populations of small mammals. Journal of Applied Ecology 11:51-59.

Ozoga, J. J., and E. M. Harger. 1966. Winter activities and feeding habits of northern Michigan coyotes. Journal of Wildlife Management 30:809-818.

Pallack, B. 2012. Cost estimates balloon for Oro Valley wildlife crossings. Website: http://arc-solutions.org/article/cost-estimates-balloon-for-oro-valley-wildlife-crossings/. Accessed January 15th, 2015.

Patrick, D., C. Schalk, J. Gibbs, and H. Woltz. 2010. Effective culvert placement and design to facilitate passage of amphibians across roads. Journal of Herpetology 44(4): 618-626.

Parris, K. M. 2015. Ecological impacts of road noise and options for mitigation. *In* Handbook of Road Ecology. R. van der Ree, D. J. Smith and C. Grilo (Eds). John Wiley & Sons, Ltd, Chichester, UK. doi: 10.1002/9781118568170.ch19

Perry, G., B. W. Buchanan, R. N. Fisher, M. Salmon and S. E. Wise. 2008. Effects of artificial night lighting on amphibians and reptiles in urban environments. Urban Herpetology 3:239-256.

Reh, W. and A. Seitz. 1990. The influence of land use on the genetic structure of populations of the common frog *Rana temporaria*. Biological Conservation 54:239-249.

Reijnen, R., R. Foppen and H. Meeuwsen. 1996. The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. Biological Conservation 75:255-260.

Reijnen, R. and R. Foppen. 2006. Impact of road traffic on breeding bird populations. *In* The ecology of transportation: Managing mobility for the environment. J. L. Davenport (Ed). Springer, Dordrecht, The Netherlands. pp. 255-274.

Renecker L.A. and R.J. Hudson. 1992. Habitat and forage selection of moose in the aspen-dominated boreal forest, central Alberta. Alces 28:189.

Riley, S., J. Brown, J. Sikich, C. Schoonmaker, and E. Boydston. Chapter 15: Wildlife friendly roads: The impacts of roads on wildlife in urban areas and potential remedies. In: Urban wildlife conservation: Theory and practice. DOI 10.1007/978-1-4899-7500-3_15.

Rodewald, P. (Editor). 2015. The birds of North America, Cornell Laboratory of Ornithology, Ithaca, NY. Website: http://bna.birds.cornell.edu/BNA/.

Rondeau, D., and J. M. Conrad. 2003. Managing urban deer. American Journal of Agricultural Economics 85:266-281.

Royal Astronomical Society of Canada (RASC). 2013a. Guidelines for outdoor lighting in nocturnal preserves (RASC-NP-GOL). Royal Astronomical Society of Canada.

Royal Astronomical Society of Canada (RASC). 2013a. Guidelines for outdoor lighting in urban star parks (RASC-USP-GOL). Royal Astronomical Society of Canada.

Royal Astronomical Society of Canada (RASC). 2015. Municipal bylaws. Website: http://rasc.ca/sample-bylaw. Accessed January 4th, 2015.

The Royal Commission on Environmental Pollution (RCEP). 2009. Artificial light in the environment. London, United Kingdom.

Saskatchewan Conservation Data Centre (SKCDC). 2015. Taxa list for vertebrates. Regina, Saskatchewan. Website: http://www.biodiversity.sk.ca/SppList/verts.pdf.

Saskatchewan Ministry of Environment (MOE) Environmental Assessment Branch (EAB). 2014. Re: City of Saskatoon- North Commuter Parkway project, EAB File #: 2014-011. Letter addressed to City of Saskatoon. Regina, Saskatchewan.

Saskatchewan Ministry of Environment (MOE). 2015. Saskatchewan activity restriction guidelines for sensitive species. Fish and Wildlife Branch. Regina, Saskatchewan.

SaskPower Corporation (SaskPower). 2013. Standard engineering practice section 4: Roadway lighting design guide. SaskPower. Regina, Saskatchewan.

Sawaya, M. S. Kalinowski, and A. Clevenger. 2014. Genetic connectivity for two bear species at wildlife crossing structures in Banff National Park. Proceedings of the Royal Society B 281: 20131705.

Seiler, A. 2002. Effects of infrastructure on nature. *In* COST 341. Habitat fragmentation due to transportation infrastructure. The European Review. European Commision. Directorate-General for Research. Brussels, Belgium. pp. 31-50.

Shadick, S. 2009. NE Swale bird survey report. Report submitted to the MVA, June, 2009.

Shannon, G., M. F. McKenna, L. M. Angeloni, K. R. Crooks, K. M. Fristrup, E. Brown, and S. McFarland. 2015. A synthesis of two decades of research documenting the effects of noise on wildlife. Biological Reviews. DOI: 10.1111/brv.12207.

Slough, B. and R. Sadleir. 1977. A land capability classification system for beaver (*Castor canadensis* Kuhl). Canadian Journal of Zoology 55: 1324-1335.

Smith, H. T., R. M. Barry, R. M. Engeman, S. A. Shwiff, W. J. B. Miller. 2003. Species composition and legal economic value of wildlife road-kills in an urban park in Florida. Florida Field Naturalist 31:53-58.

Sovada, M. A., A. B. Sargeant, and J. W. Grier. 1995. Differential effects of coyotes and red foxes on duck nest success. Journal of Wildlife Management 59:1-9.

Species At Risk Public Registry (SARPR). 2016. Species list. Environment Canada. Website: http://www.sararegistry.gc.ca/species/default_e.cfm.

Stantec Consulting Ltd (Stantec). 2012. Northeast Swale development guidelines. Prepared for the City of Saskatoon Planning and Development Branch, Community Services Department. Saskatoon, Saskatchewan.

Stantec Consulting Ltd (Stantec). 2013a. North Commuter Parkway- Baseline terrestrial and aquatic field studies, and heritage resource impact assessment. Prepared by Stantec Consulting Ltd. for the City of Saskatoon. Saskatoon, Saskatchewan.

Stantec Consulting Ltd (Stantec). 2013b. North central/North east natural screening study, City of Saskatoon. Draft report prepared for the City of Saskatoon. Saskatoon, Saskatchewan.

Stewart, R.E., Jr. 2014. Technical aspects of wetlands as bird habitat. United States Geological Survey Water Supply Paper 2425. Website: water.usgs.gov/nwsum/WSP2425/birdhabitat.html. Accessed January 4th, 2016.

Stewart, R.E. and H.A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildlife Service, Washington, D.C., USA. Resource Publication 92. 57 pp.

Tank, P. 2015. Mayor wants to explore animal bridge in swale. Website: http://thestarphoenix.com/news/local-news/mayor-wants-to-explore-animal-bridge-in-swale. Accessed January 15th, 2015.

Taylor, A. R. and R. L. Knight. 2003. Wildlife responses to recreation and associated visitor perceptions. Ecological Applications 13:951-963.

Theobald, D. M., J. R. Miller and N. T. Hobbs. 1997. Estimating the cumulative effects of development on wildlife habitat. Landscape and Urban Planning 39:25-36.

Transportation Association of Canada (TAC). 2006. Guide for the design of roadway lighting. Transportation Association of Canada. Ottawa, Ontario.

Trombulak, S. C. and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

United States Forest Service (USFS). 2014. Glenn highway extended bridge for moose. Website:http://www.fs.fed.us/wildlifecrossings/casehistories/other/GlennHighway.php. Accessed January 15th, 2015.

Vogel, W. O. 1989. Response of deer to density and distribution of housing in Montana. Wildlife Society Bulletin 17:406-413.

Weichel, B. 1992. Inventory of natural areas remaining in the vicinity of Saskatoon. Saskatoon Natural History Society. Saskatoon, SK.

Weller, M.W. 1999. Wetland birds: habitat resources and conservation implications. Cambridge University Press.

Whitford, P. C. 1985. Bird behavior in response to the warmth of blacktop roads. Transactions of the Wisconsin Academy of Sciences Arts and Letters 73:135-143.

Wisconsin Department of Transportation. 2001. Motor vehicle-deer crashes in 2001. Website: http://www.wistatedocuments.org/cdm/singleitem/collection/p267601coll4/id/5904/rec/16. Accessed January 6th, 2016.

Woods, S. L. 2007. Tadpole sediment interactions of the western toad, *Bufo boreas*, in a temperate-lentic system. M.Sc. thesis. Department of Forestry, University of British Columbia, Vancouver, British Columbia.

TABLES

LIST OF TABLES

Table 1. Mammals, reptiles, amphibians, insects, and avian species observed in the Meewasin Northeast Swale and surrounding area.

Table 2. Home ranges, habitat requirements and availability, and expected losses in habitat pre- and post-mitigation for select wildlife groups in the Meewasin Northeast Swale.

Table 3. Summary of available options for mitigation of urban development effects on wildlife for the Meewasin Northeast Swale.

Table 4. Environmental commitment and mitigation summary for the North Commuter Parkway Project, March 2016.

TABLE 1

Mammals, reptiles, amphibians, insects, and avian species observed in the Meewasin Northeast Swale and surrounding area.

Scientific Name	Common Name	Federal			Provincial	Provincial or Federal Activity Restriction Guidelines			
		COSEWIC Status	SARA Status	Schedule	SKCDC Rank	Setback Distance (m) - Medium Disturbance	Setback Distance (m) - High Disturbance	Restricted Area	Restricted Activity Dates
Mammals									
Alces alces	Moose	-	-	-	S4	-	-	-	-
Blarina brevicauda	Northern short-tailed shrew	-	-	-	S5	-	-	-	-
Canis latrans	Coyote	-	-	-	S5	-	-	-	-
Castor canadensis	American beaver	-	-	-	S5	-	-	-	-
Lepus townsendii	White-tailed jack rabbit	-	-	-	S4	-	-	-	-
Mephitis mephitis	Striped skunk	-	-	-	S5	-	-	-	-
Microtus pennsylvanicus	Meadow vole	-	-	-	S5	-	-	-	-
Mus musculus	House mouse	-	-	-	SNA	-	-	-	-
Mustela frenata	Prairie long-tailed weasel	-	-	-	S3S4	-	-	-	-
Odocoileus hemionus	Mule deer	-	-	-	S4	-	-	-	-
Odocoileus virginianus	White-tailed deer	-	-	-	S4	-	-	-	-
Ondatra zibethicus	Muskrat	-	-	-	S5	-	-	-	-
Spermophilus franklinii	Franklin's ground squirrel	-	-	-	S5	-	-	-	-
Spermophilus richardsonii	Richardson's ground squirrel	-	-	-	S5	-	-	-	-
Spermophilus tridecemlineatus	Thirteen-lined ground squirrel	-	-	-	S5	-	-	-	-
Sylvilagus nuttallii	Nuttall's cottontail	Not at Risk	-	-	S4	-	-	-	-
Taxidea taxus taxus	American badger	Special Concern	-	-	S3	-	-	-	-
Thomomys talpoides	Northern pocket gopher	-	-	-	S5	-	-	-	-
Reptiles and Amphibians									
Ambystoma mavortium	Western tiger salamander	Special Concern	-	-	S5	-	-	-	-
Lithobates pipiens	Northern leopard frog	Special Concern	Special Concern	Schedule 1	S3	200	500	Ponds used for breeding, living or hibernating	April 1 to October 31
Pseudacris maculata	Boreal chorus frog	-	-	-	S5	-	-	-	-
Thamnophis radix	Plains garter snake	-	-	-	S5	-	-	-	-
Thamnophis sirtalis parietalis	Red-sided garter snake	-	-	-	S5	-	-	-	-
Insects									
Braconidae	Parasitic wasp	-	-	-	-	-	-	-	-
Cantharidae	Soldier beetle	-	-	-	-	-	-	-	-
Celastrina ladon	Spring azure blue	-	-	-	-	-	-	-	-
Chironimidae	Non-biting midge	-	-	-	-	-	-	-	-
Colias philodice	Common sulphur	-	-	-	-	-	-	-	-

TABLE 1

Mammals, reptiles, amphibians, insects, and avian species observed in the Meewasin Northeast Swale and surrounding area.

Scientific Name	Common Name	Federal			Provincial	Provincial or Federal Activity Restriction Guidelines			
		COSEWIC Status	SARA Status	Schedule	SKCDC Rank	Setback Distance (m) - Medium Disturbance	Setback Distance (m) - High Disturbance	Restricted Area	Restricted Activity Dates
Culicidae	Mosquito	-	-	-	-	-	-	-	-
Dermacentor variabilis	Dog tick	-	-	-	-	-	-	-	-
Enodia anthedon	Northern pearly eye satyr	-	-	-	-	-	-	-	-
Everes amyntula	Western tailed blue	-	-	-	-	-	-	-	-
Formicidae	Ant	-	-	-	-	-	-	-	-
Ichneumonidae	Parasitic wasp	-	-	-	-	-	-	-	-
Lepidoptera	Moth	-	-	-	-	-	-	-	-
Lycadeides idas	Northern blue	-	-	-	-	-	-	-	-
Odonata	Nymphal dragonfly	-	-	-	-	-	-	-	-
Pieris rapae	Cabbage white	-	-	-	-	-	-	-	-
Syrphidae	Hover fly	-	-	-	-	-	-	-	-
Tachinidae	Fly	-	-	-	-	-	-	-	-
Tenthrididae	Saw flies	-	-	-	-	-	-	-	-
Vanessa cardui	Painted lady thistle	-	-	-	-	-	-	-	-
Zygoptera	Damselfly	-	-	-	-	-	-	-	-
Birds									
Cranes and Rails									
Fulica americana	American coot	Not at Risk	-	-	S5B	-	-	-	-
Grus canadensis	Sandhill crane	-	-	-	S2B,S4M	-	-	-	-
Porzana carolina	Sora	-	-	-	S5B	-	-	-	-
Doves and Pigeons									
Columba livia	Rock pigeon	-	-	-	SNA	-	-	-	-
Zenaida macroura	Mourning dove	-	-	-	S5B	-	-	-	-
Ducks, Geese and Swans									
Anas acuta	Northern pintail	-	-	-	S5B,S5M,S4N	-	-	-	-
Anas americana	American wigeon	-	-	-	S5B,S5M,S2N	-	-	-	-
Anas clypeata	Northern shoveler	-	-	-	S5B,S5M	-	-	-	-
Anas crecca	Green-winged teal	-	-	-	S5B,S5M,S2N	-	-	-	-
Anas cyanoptera	Cinnamon teal	-	-	-	S4B,S4M	-	-	-	-

TABLE 1

Mammals, reptiles, amphibians, insects, and avian species observed in the Meewasin Northeast Swale and surrounding area.

Scientific Name	**Common Name**	**Federal**			**Provincial**	**Provincial or Federal Activity Restriction Guidelines**			
		COSEWIC Status	**SARA Status**	**Schedule**	**SKCDC Rank**	**Setback Distance (m) - Medium Disturbance**	**Setback Distance (m) - High Disturbance**	**Restricted Area**	**Restricted Activity Dates**
Anas discors	Blue-winged teal	-	-	-	S5B,S5M	-	-	-	-
Anas platyrhynchos	Mallard	-	-	-	S5	-	-	-	-
Anas strepera	Gadwall	-	-	-	S5B,S5M,S2N	-	-	-	-
Anser albifrons	Greater white-fronted goose	-	-	-	S5M	-	-	-	-
Aythya affinis	Lesser scaup	-	-	-	S5B,S5M,S3N	-	-	-	-
Aythya americana	Redhead	-	-	-	S5B,S5M,S2N	-	-	-	-
Aythya collaris	Ring-necked duck	-	-	-	S5B,S5M	-	-	-	-
Aythya marila	Greater scaup	-	-	-	S5M	-	-	-	-
Aythya valisineria	Canvasback	-	-	-	S5B,S5M,S2N	-	-	-	-
Branta canadensis	Canada goose	-	-	-	S5B,S5M,S2N	-	-	-	-
Branta hutchinsii	Cackling goose	-	-	-	S5B	-	-	-	-
Bucephala albeola	Bufflehead	-	-	-	S5B,S3M,S1N	-	-	-	-
Bucephala clangula	Common goldeneye	-	-	-	S5B,S3M,S3N	-	-	-	-
Chen caerulescens	Snow goose	-	-	-	S5M	-	-	-	-
Clangula hyemalis	Long-tailed duck	-	-	-	S4M	-	-	-	-
Cygnus columbianus	Tundra swan	-	-	-	S5M	-	-	-	-
Oxyura jamaicensis	Ruddy duck	-	-	-	S5B	-	-	-	-
Rhodostethia rosea	Ross's gull	Threatened	Threatened	Schedule 1	SNA	400	400	Nesting colony	May 1 to July 15
Grebes									
Aechmophorus occidentalis	Western grebe	-	-	-	S5B	200	200	Nesting colony	May 15 to July 15
Podiceps auritus	Horned grebe	Special Concern	No Status	No Schedule	S5B	200	200	Nesting colony	May 15 to July 15
Podiceps grisegena	Red-necked grebe	Not at Risk	-	-	S5B	200	200	Nesting colony	May 15 to July 15
Podiceps nigricollis	Eared grebe	-	-	-	S5B	200	200	Nesting colony	May 15 to July 15
Podilymbus podiceps	Pied-billed grebe	-	-	-	S5B	200	200	Nesting colony	May 15 to July 15
Herons and Bitterns									
Ardea herodias	Great blue heron	-	-	-	S3B	1000	1000	Nesting colony	April 1 to July 31
Botaurus lentiginosus	American bittern	-	-	-	S4B	150	350	Nest site	May 1 to July 31

TABLE 1

Mammals, reptiles, amphibians, insects, and avian species observed in the Meewasin Northeast Swale and surrounding area.

Scientific Name	Common Name	Federal			Provincial	Provincial or Federal Activity Restriction Guidelines			
		COSEWIC Status	SARA Status	Schedule	SKCDC Rank	Setback Distance (m) - Medium Disturbance	Setback Distance (m) - High Disturbance	Restricted Area	Restricted Activity Dates
Kingfishers									
Megaceryle alcyon	Belted kingfisher	-	-	-	S5B,S5M	-	-	-	-
Loons									
Gavia immer	Common loon	Not at Risk	-	-	S5B	-	-	-	-
Nighthawks									
Chordeiles minor	Common nighthawk	Threatened	Threatened	Schedule 1	S4B,S4M	100	200	Nest Site	May 1 to August 31
Owls									
Asio flammeus	Short-eared owl	Special Concern	Special Concern	Schedule 1	S3B,S2N	300	500	Nest site	March 25 to August 1
Athene cunicularia	Burrowing owl	Endangered	Endangered	Schedule 1	S2B	300 {200} [200]	500	Nest site	April 1 to July 15 {July 16 to October 15} [October 16 to March 31]
Bubo virginianus	Great horned owl	-	-	-	S5	-	-	-	-
Bubo scandiacus	Snowy owl	Not at Risk	-	-	S5N	-	-	-	-
Surnia ulula	Northern hawk owl	Not at Risk	-	-	S3B,S5N	400	400	Nest sie	March 1 to July 15
Partridges, Pheasants and Grouse									
Perdix perdix	Gray partridge	-	-	-	SNA	-	-	-	-
Phasianus colchicus	Ring-necked pheasant	-	-	-	SNA	-	-	-	-
Tympanuchus phasianellus	Sharp-tailed grouse	-	-	-	S5	400	400	Lek	March 15 to May 15
Pelicans and Cormorants									
Pelecanus erythrorhynchos	American white pelican	Not at Risk	-	-	S3B	1000	1000	Nesting colony	April 1 to July 31
Phalacrocorax auritus	Double-crested cormorant	Not at Risk	-	-	S4B	1000	1000	Nesting colony	April 1 to July 31
Perching Birds									
Acanthis flammea	Common redpoll	-	-	-	S4	-	-	-	-
Agelaius phoeniceus	Red-winged blackbird	-	-	-	S5B	-	-	-	-
Ammodramus bairdii	Baird's sparrow	Special Concern	No status	No schedule	S4B	-	-	-	-
Ammodramus leconteii	Le Conte's sparrow	-	-	-	S4B	-	-	-	-
Ammodramus nelsoni	Nelson's sparrow	Not at Risk	-	-	S5B	-	-	-	-
Ammodramus savannarum	Grasshopper sparrow	-	-	-	S4B	-	-	-	-
Anthus rubescens	American pipit	-	-	-	S5N	-	-	-	-
Anthus spragueii	Sprague's pipit	Threatened	Threatened	Schedule 1	S3B	200	250	Nest site	April 21 to August 31
Bombycilla cedrorum	Cedar waxwing	-	-	-	S5B	-	-	-	-

TABLE 1

Mammals, reptiles, amphibians, insects, and avian species observed in the Meewasin Northeast Swale and surrounding area.

Scientific Name	**Common Name**	**Federal**			**Provincial**	**Provincial or Federal Activity Restriction Guidelines**			
		COSEWIC Status	**SARA Status**	**Schedule**	**SKCDC Rank**	**Setback Distance (m) - Medium Disturbance**	**Setback Distance (m) - High Disturbance**	**Restricted Area**	**Restricted Activity Dates**
Bombycilla garrulus	Bohemian waxwing	-	-	-	S4B	-	-	-	-
Calcarius lapponicus	Lapland longspur	-	-	-	S4N	-	-	-	-
Calcarius ornatus	Chestnut-collared longspur	Threatened	Threatened	Schedule 1	S5B	100	200	Nest site	May 1 to July 31
Cardellina pusilla	Wilson's warbler	-	-	-	S5B	-	-	-	-
Catharus fuscescens	Veery	-	-	-	S5B	-	-	-	-
Catharus guttatus	Hermit thrush	-	-	-	S4B	-	-	-	-
Catharus minimus	Gray-cheeked thrush	-	-	-	S4B	-	-	-	-
Catharus ustulatus	Swainson's thrush	-	-	-	S5B	-	-	-	-
Chondestes grammacus	Lark sparrow	-	-	-	S5B	-	-	-	-
Cistothorus palustris	Marsh wren	-	-	-	S5B	-	-	-	-
Cistothorus platensis	Sedge wren	Not at Risk	-	-	S5B	-	-	-	-
Coccyzus erythropthalmus	Black-billed cuckoo	-	-	-	S5B	-	-	-	-
Contopus sordidulus	Western wood-pewee	-	-	-	S5B	-	-	-	-
Corvus brachyrhynchos	American crow	-	-	-	S5	-	-	-	-
Corvus corax	Common raven	-	-	-	S5	-	-	-	-
Cyanocitta cristata	Blue jay	-	-	-	S5	-	-	-	-
Dolichonyx oryzivorus	Bobolink	Threatened	No Status	No Schedule	S5B	200	200	Nest site	May 1 to August 31
Dumetella carolinensis	Gray catbird	-	-	-	S5B	-	-	-	-
Empidonax alnorum	Alder flycatcher	-	-	-	S5B,S5M	-	-	-	-
Empidonax minimus	Least flycatcher	-	-	-	S5B,S5M	-	-	-	-
Eremophila alpestris	Horned lark	-	-	-	S5B,S5M,S5N	-	-	-	-
Euphagus carolinus	Rusty Blackbird	Special Concern	Special Concern	Schedule 1	S4B	150	300	Nest site	May 1 to July 31
Euphagus cyanocephalus	Brewer's blackbird	-	-	-	S5B	-	-	-	-
Geothlypis philadelphia	Mourning warbler	-	-	-	S5B	-	-	-	-
Geothlypis trichas	Common yellowthroat	-	-	-	S5B	-	-	-	-
Haemorhous mexicanus	House finch	-	-	-	S5N	-	-	-	-
Haemorhous purpureus	Purple finch	-	-	-	S5B	-	-	-	-

TABLE 1

Mammals, reptiles, amphibians, insects, and avian species observed in the Meewasin Northeast Swale and surrounding area.

Scientific Name	**Common Name**	**Federal**			**Provincial**	**Provincial or Federal Activity Restriction Guidelines**			
		COSEWIC Status	**SARA Status**	**Schedule**	**SKCDC Rank**	**Setback Distance (m) - Medium Disturbance**	**Setback Distance (m) - High Disturbance**	**Restricted Area**	**Restricted Activity Dates**
Hirundo rustica	Barn swallow	Threatened	No Status	No schedule	S5B,S5M	100	100	Nest site	May 1 to August 1
Icterus galbula	Baltimore oriole	-	-	-	S5B	-	-	-	-
Junco hyemalis	Dark-eyed junco	-	-	-	-	-	-	-	-
Lanius excubitor	Northern shrike	-	-	-	S1B,S4N	-	-	-	-
Lanius ludovicianus excubitorides	Loggerhead shrike	Threatened	Threatened	Schedule 1	S3B	250	400	Nest site	May 1 to August 15
Melospiza georgiana	Swamp sparrow	-	-	-	S5B,S5M	-	-	-	-
Melospiza lincolnii	Lincoln's sparrow	-	-	-	S5B	-	-	-	-
Melospiza melodia	Song sparrow	-	-	-	S5B	-	-	-	-
Mniotilta varia	Black-and-white warbler	-	-	-	S5B	-	-	-	-
Molothrus ater	Brown-headed cowbird	-	-	-	S5B	-	-	-	-
Oreothlypis celata	Orange-crowned warbler	-	-	-	S5B	-	-	-	-
Oreothlypis peregrina	Tennessee warbler	-	-	-	S5B	-	-	-	-
Poecile atricapillus	Black-capped chickadee	-	-	-	S5	-	-	-	-
Parkesia noveboracensis	Northern waterthrush	-	-	-	S5B	-	-	-	-
Passer domesticus	House sparrow	-	-	-	SNA	-	-	-	-
Passerculus sandwichensis	Savannah sparrow	-	-	-	S5B	-	-	-	-
Passerella iliaca	Fox sparrow	-	-	-	S5B	-	-	-	-
Petrochelidon pyrrhonota	Cliff swallow	-	-	-	S5B,S5M	-	-	-	-
Pheucticus ludovicianus	Rose-breasted grosbeak	-	-	-	S5B	-	-	-	-
Pheucticus melanocephalus	Black-headed grosbeak	-	-	-	S4B	-	-	-	-
Pica hudsonia	Black-billed magpie	-	-	-	S5	-	-	-	-
Pipilo maculatus	Spotted towhee	-	-	-	S5B	-	-	-	-
Plectrophenax nivalis	Snow bunting	-	-	-	S5N	-	-	-	-
Pooecetes gramineus	Vesper sparrow	-	-	-	S5B	-	-	-	-
Progne subis	Purple martin	-	-	-	S5B,S5M	-	-	-	-
Quiscalus quiscula	Common grackle	-	-	-	S5B	-	-	-	-
Regulus calendula	Ruby-crowned kinglet	-	-	-	S5B	-	-	-	-

TABLE 1

Mammals, reptiles, amphibians, insects, and avian species observed in the Meewasin Northeast Swale and surrounding area.

Scientific Name	Common Name	Federal			Provincial	Provincial or Federal Activity Restriction Guidelines			
		COSEWIC Status	SARA Status	Schedule	SKCDC Rank	Setback Distance (m) - Medium Disturbance	Setback Distance (m) - High Disturbance	Restricted Area	Restricted Activity Dates
Regulus satrapa	Golden-crowned kinglet	-	-	-	S4B	-	-	-	-
Riparia riparia	Bank swallow	Threatened	-	-	S5B,S5M	-	-	-	-
Sayornis phoebe	Eastern phoebe	-	-	-	S5B,S5M	-	-	-	-
Sayornis saya	Say's phoebe	-	-	-	S5B,S5M	-	-	-	-
Seiurus aurocapilla	Ovenbird	-	-	-	S5B	-	-	-	-
Setophaga coronata	Yellow-rumped warbler	-	-	-	S5B	-	-	-	-
Setophaga magnolia	Magnolia warbler	-	-	-	S5B	-	-	-	-
Setophaga palmarum	Palm warbler	-	-	-	S5B	-	-	-	-
Setophaga petechia	Yellow warbler	-	-	-	S5B	-	-	-	-
Setophaga striata	Blackpoll warbler	-	-	-	S5B	-	-	-	-
Setophaga tigrina	Cape may warbler	-	-	-	S4B	-	-	-	-
Setophaga ruticilla	American redstart	-	-	-	S5B	-	-	-	-
Sialia currucoides	Mountain bluebird	-	-	-	S5B	-	-	-	-
Sitta canadensis	Red-breasted nuthatch	-	-	-	S5	-	-	-	-
Spinus pinus	Pine siskin	-	-	-	S5	-	-	-	-
Spinus tristis	American goldfinch	-	-	-	S5B	-	-	-	-
Spizella arborea	American tree sparrow	-	-	-	S5B	-	-	-	-
Spizella pallida	Clay-coloured sparrow	-	-	-	S5B	-	-	-	-
Spizella passerina	Chipping sparrow	-	-	-	S5B	-	-	-	-
Stelgidopteryx serripennis	Northern rough-winged swallow	-	-	-	S5B	-	-	-	-
Sturnella neglecta	Western meadowlark	-	-	-	S5B	-	-	-	-
Sturnus vulgaris	European starling	-	-	-	SNA	-	-	-	-
Tachycineta bicolor	Tree swallow	-	-	-	S5B,S5M	-	-	-	-
Toxostoma rufum	Brown thrasher	-	-	-	S5B	-	-	-	-
Troglodytes aedon	House wren	-	-	-	S5B	-	-	-	-
Turdus migratorius	American robin	-	-	-	S5B	-	-	-	-
Tyrannus tyrannus	Eastern kingbird	-	-	-	S5B,S5M	-	-	-	-

TABLE 1

Mammals, reptiles, amphibians, insects, and avian species observed in the Meewasin Northeast Swale and surrounding area.

Scientific Name	Common Name	Federal			Provincial	Provincial or Federal Activity Restriction Guidelines			
		COSEWIC Status	SARA Status	Schedule	SKCDC Rank	Setback Distance (m) - Medium Disturbance	Setback Distance (m) - High Disturbance	Restricted Area	Restricted Activity Dates
Tyrannus verticalis	Western kingbird	-	-	-	S5B,S5M	-	-	-	-
Vireo gilvus	Warbling vireo	-	-	-	S5B	-	-	-	-
Vireo olivaceus	Red-eyed vireo	-	-	-	S5B	-	-	-	-
Vireo solitarius	Blue-headed vireo	-	-	-	S5B	-	-	-	-
Xanthocephalus xanthocephalus	Yellow-headed blackbird	-	-	-	S5B	-	-	-	-
Zonotrichia albicollis	White-throated sparrow	-	-	-	S5B	-	-	-	-
Zonotrichia leucophrys	White-crowned sparrow	-	-	-	S5B	-	-	-	-
Zonotrichia querula	Harris' sparrow	-	-	-	S5B	-	-	-	-
Raptors									
Accipiter cooperii	Cooper's hawk	Not at Risk	-	-	S4B,S2M,S2N	400	400	Nest site	April 1 to July 31
Accipiter striatus	Sharp-shinned hawk	Not at Risk	-	-	S4B,S4M,S2N	-	-	-	-
Buteo jamaicensis	Red-tailed hawk	Not at Risk	-	-	S5B,S5M,S1N	-	-	-	-
Buteo lagopus	Rough-legged hawk	Not at Risk	-	-	S4M,S4N	-	-	-	-
Buteo swainsoni	Swainson's hawk	-	-	-	S4B	-	-	-	-
Cathartes aura	Turkey vulture	-	-	-	S2B,S2M,S2N	-	-	-	-
Circus cyaneus	Northern harrier	Not at Risk	-	-	S5B,S4M,S2N	-	-	-	-
Falco columbarius	Merlin	Not at Risk	-	-	S4B	-	-	-	-
Falco peregrinus anatum	Peregrine falcon	Special Concern	Threatened	Schedule 1	S1B,S4M,S2N	500	1000	Nest site	April 1 to Augut 15
Falco sparverius	American kestrel	-	-	-	S5B,S5M,S1N	-	-	-	-
Haliaeetus leucocephalus	Bald eagle	Not at Risk	-	-	S5B,S4M,S4N	750	1000	Nest site	March 15 to July 15
Pandion haliaetus	Osprey	-	-	-	S4B,S3M	1000	1000	Nest site	May 1 to August 15
Shorebirds and Gulls									
Actitis macularius	Spotted sandpiper	-	-	-	S5B,S5M	-	-	-	-
Bartramia longicauda	Upland sandpiper	-	-	-	S5B,S5M	-	-	-	-
Calidris alba	Sanderling	-	-	-	S4M	-	-	-	-
Calidris bairdii	Baird's sandpiper	-	-	-	S5M	-	-	-	-
Calidris himantopus	Stilt sandpiper	-	-	-	S5M	-	-	-	-
Calidris melanotos	Pectoral sandpiper	-	-	-	S5M	-	-	-	-

TABLE 1

Mammals, reptiles, amphibians, insects, and avian species observed in the Meewasin Northeast Swale and surrounding area.

Scientific Name	Common Name	Federal			Provincial	Provincial or Federal Activity Restriction Guidelines			
		COSEWIC Status	**SARA Status**	**Schedule**	**SKCDC Rank**	**Setback Distance (m) - Medium Disturbance**	**Setback Distance (m) - High Disturbance**	**Restricted Area**	**Restricted Activity Dates**
Calidris minutilla	Least sandpiper	-	-	-	S4B,S4M	-	-	-	-
Calidris pusilla	Semipalmated sandpiper	-	-	-	S4M	-	-	-	-
Charadrius semipalmatus	Semipalmated plover	-	-	-	S1B,S5M	-	-	-	-
Charadrius vociferus	Killdeer	-	-	-	S5B	-	-	-	-
Chlidonias niger	Black tern	Not at Risk	-	-	S4B	400	400	Nesting colony	May 1 to July 15
Chroicocephalus philadelphia	Bonaparte's gull	-	-	-	S4B,S4M	400	400	Nesting colony	May 1 to July 15
Gallinago delicata	Wilson's snipe	-	-	-	S5B	-	-	-	-
Larus californicus	California gull	-	-	-	S5B,S5M	-	-	-	-
Larus delawarensis	Ring-billed gull	-	-	-	S5B,S5M	-	-	-	-
Leucophaeus pipixcan	Franklin's gull	-	-	-	S4B,S4M	400	400	Nesting colony	May 1 to July 15
Limnodromus griseus	Short-billed dowitcher	-	-	-	S1B,S4M	-	-	-	-
Limnodromus scolopaceus	Long-billed dowitcher	-	-	-	S5M	-	-	-	-
Limosa fedoa	Marbled godwit	-	-	-	S5B,S5M	-	-	-	-
Phalaropus lobatus	Red-necked phalarope	Special Concern	-	-	S4B,S3M	-	-	-	-
Phalaropus tricolor	Wilson's phalarope	-	-	-	S5B,S5M	-	-	-	-
Pluvialis dominica	American golden-plover	-	-	-	S5M	-	-	-	-
Pluvialis squatarola	Black-bellied plover	-	-	-	S4M	-	-	-	-
Recurvirostra americana	American avocet	-	-	-	S5B,S5M	-	-	-	-
Tringa flavipes	Lesser yellowlegs	-	-	-	S5B,S5M	-	-	-	-
Tringa melanoleuca	Greater yellowlegs	-	-	-	S5B,S5M	-	-	-	-
Tringa solitaria	Solitary sandpiper	-	-	-	S5B,S4M	-	-	-	-
Tringa semipalmata	Willet	-	-	-	S5B,S4M	-	-	-	-
Woodpeckers									
Colaptes auratus	Northern flicker	-	-	-	S4	-	-	-	-
Picoides pubescens	Downy woodpecker	-	-	-	S5	-	-	-	-
Picoides villosus	Hairy woodpecker	-	-	-	S5	-	-	-	-
Sphyrapicus varius	Yellow-bellied sapsucker	-	-	-	S5B,S5M	-	-	-	-

[1] Species identified by Gollop 2000; Delanoy 2001; Shadick 2009; Jensen 2009, 2012; Stantec 2013; MVA 2013.

TABLE 2

Home ranges, habitat requirements and availability, and expected losses in habitat pre- and post-mitigation for select wildlife groups in the Meewasin Northeast Swale.

Wildlife Species Group	Home Range (ha)	Habitat Requirements	Current Habitat Availability in Swale (ha)[1]	Direct Loss (ha)[2]	Estimated Potential Road/Edge Effect[3]	Estimated Functional Habitat Loss[4]	Estimated Habitat Loss after Mitigation[5]
Plants	-	Various	311	8	Up to 200 m	Moderate	Low
Large mammals (ungulates)	79 to 1,215	Tree/shrub areas, open grassland/cultivated areas, riparian edges	222	3.3	Up to 100 m to 5,000 m	High	High
Medium-sized mammals	1,200 to 9,700	Open grassland/ cultivated areas	222	3.3	Up to 100 m to 5,000 m	High	Moderate
Semi-aquatic mammals	11 to 18	Semi-permanent and permanent wetlands	89	4.7	No data (likely minimal)	Low	Low
Small rodents and mammals	0.11 to 0.81	Tree/shrub areas, open grassland/cultivated areas, riparian edges	222	3.3	Up to 10 m	Moderate	Low
Amphibians/reptiles	0.06	Moist grassland, riparian areas, open wetland	311	8	Up to 1,500 m	High	Moderate/Low
Grassland bird species	150	Grassland	222	3.3	Up to 300 m to 3,500 m	High	High
Waterbirds	1 to 20	Grassland, riparian areas, open wetlands	89	4.7	Up to 25 m to 700 m	Moderate	Low
Bats	200	Tree/shrub areas, open grassland, riparian areas, wetlands	311	8	Up to 1,600 m	Moderate	Moderate

[1] Total available habitat in the Swale = 311 ha, Total upland habitat = 222 ha, Total wetland habitat= 89 ha, based on Stantec (2013b), Figure A9.

[2] Estimated based on the construction/widening of three roadways (Central Avenue, Lowe Road, and the North Commuter Parkway). Road width was estimated at 60 m to incorporate additional clearing required for construction. No estimates of habitat loss for the Saskatoon Freeway are included as no final design or footprint was available.

[3] Distance that road or edge effects have been shown to affect wildlife groups due to reduced habitat quality or connectivity, direct mortality, or altered behaviour (e.g. avoidance). Values based on Bendel and Therres (1999), Benítez López et al. (2010), Benson et al. (2015), Berthinussen and Altringham (2012a), Forman (1998), Forman and Alexander (1998), Reijnen et al. (1996), and Vogel (1989) (see Section 3).

[4] Estimated range of expected habitat loss (Direct and functional loss) without implementation of any mitigation strategies (Low habitat loss = 0 to 30%, Moderate = 29 to 59%, High= 60 to 100%)

[5] Estimated range of expected habitat loss (Direct and functional loss) with implementation of mitigation strategies specific to the wildlife group potentially available for the Swale (Low habitat loss = 0 to 30% habitat, Moderate= 29 to 59% habitat, High= 60 to 100%)

TABLE 3

Summary of available options for mitigation of urban development effects on wildlife for the Meewasin Northeast Swale.

Impact Type	Animal Group(s)	Mitigation	Key Design Features	Estimated Cost[1]	Benefits/Advantages	Drawbacks/Disadvantages	Current Recommendations	Recommended by this Report
Roadways	All mammals, amphibians, reptiles	Landscape bridge/ Wildlife overpass	- Facilitates movement of animals above the road. - Vegetated to continue habitat over the structure. - Wildlife fencing used to guide wildlife to the structure and berms or dense vegetation planted to minimize view and sound of roadway. - Range in width from 40 m to 100 m.	$1 to $11 million	- A wide variety of areas are suitable for these structures, with the exception of road beds that are raised relative to the terrain. - Can facilitate the movement of all animal groups, especially if small pools or ponds are created on the overpass. - Ambient environmental conditions are maintained. - Overall effectiveness of this structure is high. - Low maintenance once established.	- Expensive, but cost typically offset by 4.4 deer-vehicle collisons per kilometer per year. - Physically large structure that can increase the disturbance footprint of a roadway.	-	-
		Extended bridge/Viaduct	- Allow passage of wildlife underneath the roadway. - Typically utilized due to the local terrain and are longer than necessary to incorporate upland or riparian habitat and allow wildlife passage. - Extended bridges incorporate upland habitat when crossing riparian or watercrossings. - Viaducts typically cross valleys or gorges.	$12 to $24 million	- Construction results in less ground disturbance relative to other crossing structures. - Majority of native habitat is retained, resulting in minimal revegetation and restoration requirements. - All wildlife species can utilize this crossing structure as long as suitable habitat exists under the structure and on either side. - Preferred crossing structure for large wildlife species. - Overall effectiveness of this structure is high.	- Expensive, so only typically utilized where local terrain requires.	-	-
		Large wildlife underpass	- Below grade passage designed for large wildlife (although most species can utilize these structures). - Variety of different designs can be utilized (box culverts, open span bridges) depending on target species. - Ledges or walkways can be added to culverts or bridges to allow dry passage for wildlife. - More open structures are preferred by wildlife- the recommended height and width is 4 m by 7 m. - Bottom of crossing is covered with native soils and entrances are vegetated. - Wildlife fencing used to guide wildlife to crossing structure.	Open span bridge: $55,000 per metre Tunnel systems: $70,000 to $500,000	- Can facilitate the movement of all animal groups. - Overall effectiveness of this structure is high. - Multiple ecological functions can be served by underpass (e.g. water flow). - Can create bat roosting habitat. - Low maintenance once installed. - A wide variety of areas are suitable for these structures, with the exception of roads that are constructed below grade.	- Expensive, although less so than wildlife overpasses and extended bridges/viaducts. - Some large wildlife (e.g. moose) will not use these structures unless it is built especially large (12 m wide and 4.5 m high).	-	-
	Small and medium-sized mammals, amphibians, reptiles	Small to medium-sized wildlife underpass	- Smaller underpasses designed specifically for small to medium-sized wildlife, including amphibians. - Ledges or walkways can be added to culverts to allow dry passage for wildlife. - Crossings are designed to maintain ambient conditions (e.g. natural light, substrate). - Wildlife fencing utilized to direct wildlife to crossing structures, and winged walls can be used at either end of the tunnel to direct amphibians towards natural habitat. - Size and type of culvert built is dependent on target species, ranges from 0.4 m to 3 m. - Bottom of crossing is covered with native soils and entrances are vegetated.	Small mammal/amphibian crossings: $17,000 to $30,000 Medium mammal crossings: $30,000 to $180,000	- Effective at preventing roadway mortalities of target species. - Relatively low maintenance once in place.	- Large wildlife species can not use these structures. - Placement and spacing extremely important for use by wildlife.	*	*
	All mammals, amphibians, reptiles	Exclusion fencing	- Roads are fenced to prevent animals from crossing the road. - Wildlife fencing is designed specifically for target species (e.g. mesh size and height). - Can be paired with escape routes for trapped ungulates (e.g. jump-outs, one-way gates).	Fencing: $35 to $90 per metre Escape routes: $9,000 to $18,000	- Prevents animals from crossing roads at undesireable locations and thus significantly reduces roadway mortalities. - Effective at guiding animals towards crossing structures. - Relatively inexpensive.	- Reduces habitat connectivity unless paired with crossing structures or other mitigation. - Needs regular maintenance.	-	*
	Birds	Diversion poles/fencing	- Aluminum poles or chain link fencing mounted on the edge of roadways or bridges to direct the flight path of birds above the height of traffic. - Closely spaced reflective markers can be used to prevent collisions with birds of prey.	$50 per pole	- Reduces the potential for bird-vehicle collisions. - Relatively inexpensive.	- Effectiveness has not been studied.	-	*
	Large mammals	Speed limits, signage, reflectors	- Speed limits are reduced to improve detectibility and response time for traffic. - Signage to improve awareness. Signs can be animal-activated, warning drivers in real-time about wildlife crossings. - Photo radar to encourage drivers to slow down.	-	- Reduces number of wildlife-vehicle collisions. - Relatively inexpensive.	- No barriers preventing animals from crossing road (not completely effective at eliminating wildlife-vehicle collisions). - Does not mitigate animals that are repelled from crossing the roadway. - Effectiveness is limited for small wildlife.	*	*
		Crosswalks	- Animals are directed to an appropriate location for crossing through fencing and drivers are warned of high potential wildlife crossing. - Can be utilized with an animal detection systems to detect presence of large animals and warns oncoming traffic through signage. - Cattle guards or escape routes provided to prevent animals becoming trapped on roadway.	$21,000 to $40,000 (no detection system) $200,000 (with detection system)	- Reduced wildlife-vehicle collisions due to increased awareness and improved recognition of animal crossing hazard over basic signage.	- Potentially expensive and will not mitigate animals that are repelled by the roadway. - Effectiveness is limited for small mammals.	-	-

TABLE 3

Summary of available options for mitigation of urban development effects on wildlife for the Meewasin Northeast Swale.

Impact Type	Animal Group(s)	Mitigation	Key Design Features	Estimated Cost[1]	Benefits/Advantages	Drawbacks/Disadvantages	Current Recommendations	Recommended by this Report
Roadways	Small mammals, amphibians	Curb design	- Curbs are designed to have a ramp/break or gentle slope to facilitate movement over the curb. - Installation of screens over large storm drains.	-	- Relatively inexpensive. - Useful for low traffic volume roads where risk to wildlife is low.	- Not effective for high volume roadways where risk of mortality is high.	-	*
Light	All mammals, amphibians, reptiles, birds	Dark Sky Friendly lighting	- Lights should be avoided where possible or used sparingly and turned off when unnecessary. - Where lights are used, lights have color temperature of 3000 K or less, must be shielded, and no light must be released above 90 degrees.	-	- Effective for all wildlife species. - Relatively inexpensive.	- None known.	*	*
Sound	All mammals, amphibians, reptiles, birds	Noise barriers	- Barriers to prevent travel of road noise into adjacent habitat. - Include structures such as earth berms, solid or transparent walls, or dense vegetation. - Reduced speed and road surface design can also cut down on road noise.	-	- Effective for all wildlife species.	- Wall systems can be a barrier to wildlife movement and need to be used in conjunction with other mitigation strategies. - Creation of earth berms can increase width of disturbance required for roadway and are not recommended next to sensitive habitat.	-	-

[1] Note that estimated costs are based on data provided in the literature (See Section 4.1) and are highly variable depending on the location, timing of installation, and actual design.

TABLE 4

Environmental commitment and mitigation summary for the North Commuter Parkway Project, March 2016.

Valued Component	Potential Impact[1]	Environmental Commitment/Mitigation	Source	Project Schedule Time Frame
Soils	Disturbance to soil profile; increased erosion	Disturbed areas will be recontoured and reclaimed to pre-disturbance and/or stable profile. If required, seeding will be used to prevent erosion and promote site stabilization	Golder 2014a.	Construction
		Steep, irregular, or slumped terrain will be avoided as much as possible. Changes to slope profile will be minimized where possible.	Stantec 2012; Golder 2014a.	Construction
		Topsoil shall be stripped and stockpiled for later use in reclamation, and will be replaced under dry conditions. Special removal/storage measures are required in the presence of saline soils.	Stantec 2012; Golder 2014a.	Construction
		Work is to take place under dry conditions where possible to prevent rutting.	Golder 2014a	Construction
		Creation of hard, impervious surfaces should be minimized.	Stantec 2012; Golder 2014a.	Construction
	Soil erosion	Erosion control devices will be installed as necessary where soil erosion occurs. An environmental monitor will monitor the site for erosion.	Golder 2014a	Pre-construction; Construction
		Erosion control structures shall be constructed as early as is practicable to maximize the entrapment of silt.	Stantec 2012; Golder 2014a.	Pre-construction; Construction
		Runoff should be directed to vegetated areas.	Stantec 2012.	Construction
	Addition of deleterious substances to soils	Soils shall be properly remediated in the event of a spill.	Golder 2014a.	Construction
Vegetation	Impact to rare plants	Additional rare plant surveys (early, late, and mid-season) must be conducted, and results must be reported to the EAB and MOE (*Completed in 2014).*	Golder 2014b; Golder 2014a; MOE 2014.	Pre-construction
		Should rare plants be located during the construction phase, measures to avoid or mitigate impacts will be developed in consultation with MOE.	MOE 2014; Golder 2014a.	Construction
		Vehicles and construction activities will be restricted to the ROW or designated access routes. Existing corridors will be used where possible.	Stantec 2012; Golder 2014a.	Construction
	Loss/alteration of vegetation communities	Disturbance to grassland habitat will be confined to as small an area as possible.	Stantec 2012; Golder 2014a.	Construction
		Topsoil in grassland areas will be salvaged and used during reclamation to preserve the seed-bank.	Golder 2014a.	Construction
		Vegetation recovery in grassland areas will be monitored during the next two growing seasons or as required until vegetation has re-established.	Golder 2014a.	Construction
	Residual impact and alteration of vegetative communities	Appropriate vegetation, including certified seed mixes, will be used for reseeding and erosion control. Seed mixes should be selected in consultation with the MVA.	Stantec 2012; Golder 2014a.	Post-construction
		Grassland habitat will be re-seeded with native plants, including grasses and low shrubs. Selected vegetation must take wildlife safety into account and be salt-tolerant.	Stantec 2012; Golder 2014a.	Post-construction
		Site reclamation activities should start as soon as is feasible after construction.	Stantec 2012; Golder 2014a.	Post-construction
		Monitoring of reclamation success should continue until the ROW and disturbed lands are revegetated; erosion control devices shall remain in place until disturbed areas are stable.	Stantec 2012; Golder 2014a.	Post-construction
	Spreading of noxious and/or nuisance weed species	Equipment will be cleaned prior to entry into the Project area and between sections of the ROW.	Stantec 2012; Golder 2014a.	Pre-construction/Construction
		Stockpiled soil should be covered with tarps during long-term storage to reduce weed growth.	Stantec 2012.	Construction
		Irruptions of weed species occurring as a direct result of the Project will be addressed with reasonable control measures.	Golder 2014a.	Construction; Post-construction

TABLE 4

Environmental commitment and mitigation summary for the North Commuter Parkway Project, March 2016.

Valued Component	Potential Impact[1]	Environmental Commitment/Mitigation	Source	Project Schedule Time Frame
Wetlands	Addition of deleterious substances to wetlands	Sediment and erosion controls shall be placed to prevent addition of silt to wetlands and waterbodies.	Stantec 2012; Golder 2014a.	Construction
		Contractors will adhere to safe storage, handling, and fuelling practices (e.g., secondary containment, usage of spill trays, fuel storage, equipment laydowns and fuelling at 100 m or more from watercourses or waterbodies).	Stantec 2012; Golder 2014a.	Construction
		Equipment must be free of fluid leaks. An Emergency Response plan will outline procedures in case of spills.	Golder 2014a	Construction
	Alteration/disturbance to wetlands	Physical disturbance to riparian areas and wetland edges will be minimized, particularly in the river valley and swales.	Golder 2014a.	Construction
		Temporary work spaces will be restricted adjacent to wetland areas in order to minimize disturbance	Golder 2014a; MOE 2014.	Construction
	Changes to Project footprint hydrology	Adequate footprint drainage will be maintained, including implementation of proper drainage structures. Natural drainage patterns shall not be altered, particularly in the Small Swale and Northeast Swale areas.	Golder 2014a; MOE 2014.	Design; construction
		A stormwater model and management plan should be developed for the Northeast Swale and adjacent lands, with consideration for natural water level fluctuations.	Stantec 2012.	Design
		Storm water retention ponds should be constructed for the Northeast Swale to facilitate filtration of storm water; these shall preferably be constructed in previously-disturbed areas.	Stantec 2012.	Construction
		Culverts should be inspected regularly to ensure unimpeded flow of water.	Stantec 2012.	Construction; Post-construction
Wildlife	Disturbance to active bird nests	Vegetation clearing should occur outside the most sensitive timing window (early April to late August) for nesting migratory birds to prevent destruction of nests, eggs, or offspring	Stantec 2012; Golder 2014a.	Construction
		Pre-construction surveys will be conducted if construction occurs in summer months. Located nests will be avoided with an appropriate setback distance (early April to late August).	Golder 2014a; MOE 2014.	Pre-construction
	Disturbance to nocturnal wildlife	Project will adhere to dark sky compliance guidelines (MVA) see City of Saskatoon (2013).	Stantec 2012; Golder 2014a.	Design
	Habituation of animals to humans	Human-wildlife conflict will be minimized through good housekeeping and waste disposal procedures. Contractors shall avoid wildlife encounters, and site-appropriate speed limits will be implemented during construction.	Golder 2014a.	Construction
	Habitat loss and disturbance to northern leopard frog (a federally listed amphibian species)	If northern leopard frogs are present prior to or during construction, MOE will be notified and appropriate mitigation measures will be determined. These may include: collection and translocation of individuals to nearby suitable habitat, changing the timing of construction in specific areas, or installing amphibian barriers to prevent movement onto the ROW.	Golder 2014a; Golder 2014b.	Pre-construction; Construction
		Additional northern leopard frog surveys will be conducted prior to construction. Mitigation strategies will be employed in consultation with MOE if wildlife sensitivities or concerns are identified.	Golder 2014a; MOE 2014.	Pre-construction
		Pre-construction frog surveys will occur immediately before construction in areas with high habitat potential.	Golder 2014b.	Pre-construction
		Use of temporary workspaces will be restricted in areas of high habitat potential for northern leopard frogs.	Golder 2014b.	Construction
		Clearing of topsoil or vegetation near wetlands will occur outside the sensitive timing windows for northern leopard frogs.	Golder 2014b.	Construction
		Work on open excavations will occur in a timely manner to prevent mortality of northen leopard frogs, which may enter excavations and be crushed or dessicated.	Golder 2014a.	Construction
		Employment of environmental monitors will be required in areas of high habitat potential for northern leopard frogs.	Golder 2014b.	Construction
	Disturbance to listed or sensitive wildlife species	If a conflict with a listed species is identified during construction, work will cease in the immediate area until appropriate mitigation measures can be implemented.	Golder 2014a.	Construction
		Adherence to provincial/federal activity restriction guidelines, the Species at Risk Act, and other provincial and federal legislation will be required (MOE 2014).	Golder 2014a; MOE 2014.	Construction

TABLE 4

Environmental commitment and mitigation summary for the North Commuter Parkway Project, March 2016.

Valued Component	Potential Impact[1]	Environmental Commitment/Mitigation	Source	Project Schedule Time Frame
Sensitive habitat	Impact to native habitats in the Northeast Swale	Swale crossings will conform with the Northeast Swale Development Guidelines and the Northeast Swale Resource Management Plan.	MVA 2014.	All phases
		Transportation crossing corridors be shared with utility crossings, to limit disturbance to habitat.	Stantec 2012.	Design/Construction
		All construction activities should be confined to the ROW and designated equipment storage and laydown areas. Previously disturbed areas adjacent to ROW should be used for storage/laydown on advisement of the environmental monitor.	Stantec 2012.	Construction
		An environmental monitor should be on site during construction on the Northeast Swale for kick off, during environmentally sensitive activities, and for regular inspections (every 2 days).	Stantec 2012.	Construction
		All construction debris should be removed as quickly as possible for disposal.	Stantec 2012.	Post-construction
		A buffer zone surrounding the Northeast Swale should be implemented with appropriate vegetation and barriers to control designated land use, vegetation communities, wildlife usage, and hydrological function.	Stantec 2012.	Design; Construction
		Where possible, streams, floodplains, wetlands and other desirable wildlife habitat should be preserved.	Stantec 2012.	All phases
	Impact to hydrological function at NCP	Culverts should allow for natural flow, and should not prevent movement of fish and other wildlife; culvert should include natural cover.	Stantec 2012.	Design/Construction
	Impact to sensitive habitat during RR 3045 Decommissioning	Backhoes should avoid entering wetlands (except the bucket).	Stantec 2012.	Construction
		Wetland slopes should be contoured similar to the slopes adjacent to the old road.	Stantec 2012.	Construction
		Wetland disturbance should be confined to the old ROW.	Stantec 2012.	Post-construction
		Disturbed wetlands should be left to naturally revegetate.	Stantec 2012.	Post-construction
		The old road bed should be reclaimed to native species using techniques approved by the MVA, or repurposed for access to interpretive sites under MVA guidance.	Stantec 2012.	Post-construction
		Decommissioning should be scheduled for the late summer to fall period.	Stantec 2012.	Post-construction
		All road material should be removed from the swale by truck as quickly as feasible; no stockpiles should be constructed on undisturbed land.	Stantec 2012.	Construction
	Impact to sensitive habitat at Central Avenue (near Peturrson's Ravine)	Changes to groundwater flow should be monitored as pertinent to unique and/or endangered species in the ravine.	Stantec 2012.	Design/Construction
		Floodplain slopes, side slopes (>5%), and other desirable wildlife habitat should be avoided.	Stantec 2012.	Design/Construction
		Steep, irregular, or slumped terrain should be avoided where possible, particularly areas along the eastern bank of the South Saskatchewan River. Changes to slope profile and/or slope stability should be minimized.	Stantec 2012.	Design/Construction
		Surface flow should not be altered significantly, and surface flow over the top of the bank should not adversely affect the stability of key ecological areas.	Stantec 2012.	Design/Construction
		Peturrson's Ravine should be hydrologically isolated from potentially contaminated surface run off.	Stantec 2012.	Construction
		Presently disturbed areas should be used as an alternative to disturbing new habitat when possible.	Stantec 2012.	Design/Construction
		Clearing of native woody vegetation should be avoided where possible	Stantec 2012.	Design/Construction
Heritage resources	Disturbance to archaeological sites	Avoidance of the two archaeological sites recorded during HRIA, north of the proposed ROW (Stantec 2013a); provided that these features are avoided the Project has been approved to proceed per section 63 of *The Heritage Property Act*	Golder 2014a.	Pre-construction
		Should archaeological materials or features be encountered during construction, all work in the immediate area will cease and appropriate mitigation measures will be implemented in consultation with the HCB .	Golder 2014a.	Construction

[1] Potential impacts have been defined as those that are likely to occur based on previously identified issues and assessments of the Project area (Technical reports, regulatory approvals etc.), and is not a comprehensive list of all possible impacts.