

# **Lessons Learned: Terry Fox Drive Wildlife Guide System intended to reduce road kills and aid the conservation of Blanding's Turtle (*Emydoidea blandingii*).**

Proceedings, Transportation Association of Canada, September 2014.

**Shawn R. Taylor<sup>1</sup>, Nicholas Stow<sup>2</sup>, Caleb Hasler<sup>3</sup>, Kevin Robinson<sup>3</sup>.**

<sup>1</sup>*Dillon Consulting Limited, 1155 East Service Road, Unit 14, Oakville, ON, CAN*

<sup>2</sup>*City of Ottawa, Land Use and Natural Systems, 110 Laurier Ave W., Ottawa, ON, K1P 1J1 CAN*

<sup>3</sup>*Dillon Consulting Limited 177 Colonnade Rd S., Suite 101, Ottawa, ON K2E 7J4*

## **Abstract**

To mitigate the effects of a new roadway through sensitive forests and wetlands of the South March Highlands in Ottawa, a series of four wildlife-only culverts were installed along with another six hydraulic culverts carrying watercourses. Terry Fox Drive is a four-lane arterial road that fragments wildlife habitat and created a physical barrier to existing wildlife movements between habitats. Several species of mammals, reptiles and amphibians, along with a local population of Blanding's turtle, an endangered species, was at risk of increased road mortality from traffic. The Wildlife Guide System (WGS) integrates ten long box culverts (1.2 m X 1.8 m X ~50 m), three 0.60 m square catch-basin 'skylights' in each, 907 m of 0.80 m high armour-stone guide walls and 1.2 m high containment fencing throughout the 2.1 km forested section. Guide walls and fencing included 40 cm overhangs slanted towards the habitat to avoid turtles from scaling the barrier. Galvanized, welded wire fencing fabric with 50 mm X 100 mm openings was used on 75 mm diameter steel posts. A level railway crossing remains the only gap in the WGS where animals can access the road. Camera traps were used over a three year study period, immediately following construction, to determine if local wildlife was using the WGS. Road mortality was assessed on Terry Fox Drive and five other nearby roads. Over the three-year period, culverts were monitored for 42,799 hours and a total of 6,033 animals were observed representing 24 species. Frogs, raccoons and rabbits were the most common users, but also fisher, porcupine, skunk, long-tailed weasel, turtles and coyote were observed. Ten Blanding's turtles passed through the culverts, two in 2011 and eight in 2013. Over the same period however, two Blanding's turtles were killed by vehicles at the level railway crossing and two near unmaintained sections of the fencing. Over all species, of the ~70 road kills reported, about 1/3 were on Terry Fox Drive near the level crossing. The results suggest that the WGS, at a cost of \$958K effectively mitigate road impacts on wildlife and is useful as a mitigation tool for reducing impacts to slow-moving animals like Blanding's turtle. We have learned that the armour stone walls degrade quickly (partly due to theft) and may be unsustainable in an urban setting. Shorter, poured concrete walls would perform better, for longer periods, be safer, and the fencing would be easier to be tied in. The fencing design was good, but requires maintenance to ensure holes and damages are repaired. Cutting grass behind the fence on slopes is problematic for the maintenance crew. The addition of skylights was an inexpensive addition that although untested, appears to be effective at reducing the 'tunnel effect' that effect animal movements.

\* Corresponding Author: email [staylor@dillon.ca](mailto:staylor@dillon.ca)

## Introduction

The 2010 expansion of 5.2 km of Terry Fox Drive (TFD) in the City of Ottawa (City) between Richardson Sideroad (RSR) and March Road required a lengthy provincial Class Environmental Assessment as a route planning study and preliminary design (Dillon, 2003). Subsequently, during the detailed design and permitting, the Canadian Environmental Assessment Act (CEAA) process was triggered due to the federal stimulus funding the City received, and a necessary request for authorization under the Fisheries Act of Canada to relocate a small branch of Shirley's Brook. The legitimacy of the Class EA (Dillon, 2003) was challenged in Ontario Superior court by public opponents to the project, in part due to the length of time (>5 years) between the Class EA approval and construction start-up. The challenge was unsuccessful as the lapse period had been changed to 10 years in 2006 in the most recent Class EA guidelines for Municipal Consulting Engineers Association (Ontario Superior Court, 2010). The City of Ottawa therefore completed the environmental assessment on behalf of Infrastructure Canada and Fisheries and Oceans (Dillon 2010a). Final approvals and permits were received in April 2010, construction proceeded immediately and the road was operational by July 2011.

To complete the CEAA effects analysis with current natural heritage data, fieldwork was conducted in 2009 to identify the flora and fauna of the South March Highlands and surrounding Carp River lowlands. This involved inventories of fisheries, breeding birds, amphibians, reptiles, mammals, forest cover, wetlands and vegetation. The data put the proposed road infrastructure into context against the provincial and federal species at risk (SAR) legislation and other legislation protective of the ecological and hydrological functions of the impacted area. Identified at-risk species included one herbaceous plant (American Ginseng), one tree (Butternut), one bird (Blue Winged Warbler) and one reptile (Blanding's Turtle), of which conventional construction mitigation was able to reduce the residual and cumulative effects to acceptable levels for all but the reptile (Dillon, 2010 a). The road design required the removal of roughly 10.5 ha of forest and wetlands habitat in the South March Highlands, fragmenting existing habitats, disrupting traditional wildlife movement corridors and creating the new hazard of road kill to previously isolated communities of wildlife. Blanding's turtle (*Emydoidea blandingii*), a federally endangered Species at Risk (SAR) (COSEWIC, 2005), were found in the area and because of the potential for impacts to individual turtles and their habitat, long-term mitigation of the construction phase and roadway operations was necessary. A detailed mitigation strategy was proposed (Dillon, 2010 b) that involved the installation of wildlife passages, field research of the population dynamics of Blanding's turtle, and monitoring to assess the effectiveness of the wildlife passages in reducing the risk and incidence of road mortalities.

Beneath the 5.8 km new section of Terry Fox Drive, four terrestrial (TCV) culverts (Plate 1) were installed along with six hydraulic culverts (CV) carrying watercourses (Figure 1). Concrete box culverts, each 0.9 m tall X 1.8 m wide X 52 m long were installed with the invert at grade. Nine of ten culverts were fitted with three, equally spaced modified catch basins, to provide 'skylights' every 13 m, and reduce the tunnel effects common with small box culverts (Brudin *et al*, 2003; Clavenger and Waltho, 2000). The other was an arch culvert that did not require skylights as it provided a larger opening at either end and retained water throughout the year. Bottom substrates were added to all culverts: cobblestone in the hydraulic culverts, ¾" clear gravel in two of the terrestrial culverts, and organic soil and logs in the other

two terrestrial culverts. To assist with directing animals into the culverts, 907 m of armour stone guide walls flank the culverts through the wetlands and bottomlands (Plate 1), averaging 45 m per side. A gap between the fencing and treeline is intentional, and meant to be maintained free of woody vegetation while shrubs planted at each open end, are meant to provide cover for moving animals and attract them to the openings.



**Plate 1. Box culvert with armour stone guide walls on each side. With 30 cm of substrates covering the bottom, the opening is 60 cm tall X 120 cm wide. The 25 cm overhanging lip is meant to stop animals from scaling the walls.**



**Plate 2. Terminal ends of the fencing at a bike trail opening were wrapped backwards to avoid escapes. Top panels were angled back 45° as some turtles can scale fences using their beak and claws.**

In addition to the armour stone walls, galvanized, welded wire fencing, with the top 40 cm angled towards the habitat (Plate 2), and the bottom 40 cm entrenched, extends for 2.1 km on either side of the road throughout the forested areas of the Terry Fox Drive Right of Way. The fence fabric provides vertical openings 50 mm wide X 100 mm tall, sized to inhibit all turtles larger than new hatchlings from passing, yet open enough to pass wind and snow loads. Finer mesh, with 10 mm hexagonal openings, was applied to the bottom 300 mm of the fence through the most exposed wetlands. Fence terminal ends wrap back on themselves (Plate 2), encouraging the animals to turn back and cross at the culverts. An at-grade level crossing of the Nepean-Arnprior rail line caused a 15 m wide gap in the fencing system, but otherwise the fence and guide walls encloses the road on both sides of the four-lane arterial through all of the forested section.

Habitat loss and road mortality are the two most significant threats to Blanding's turtle and most wildlife in Ontario. Road ecology is the study of road networks on ecosystems and road ecologists aim to advise best management solutions to reduce the negative impacts of road networks on ecosystems. Several large structures to pass large mammals like elk, deer and moose have been installed on major highways across Canada and United States in recent years, generally with good results (Smith, 2003; MTO, 2005; Brudin 2003; Clavenger and Waltho, 2000). Overpasses or large underpasses may be necessary for large mammals (Clavenger and Waltho, 2000), but smaller underpass culverts can be used for many smaller mammals, amphibians and reptiles (Woltz *et al*, 2008; Aresco, 2005) in urban or pastoral areas. The collective results so far have clearly shown that although there are factors that influence use, the culverts or overpasses are frequently used by wildlife (Clavenger and Waltho, 2000; Smith, 2003), but use does not necessarily equate to the effectiveness of a crossing structure in preserving the viability of adjacent wildlife populations (Van der Grift et al, 2012).

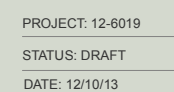
The Wildlife Guide System (WGS) constructed in Ottawa is one of the first in Ontario to be implemented as part of new road construction through virgin territory, rather than retrofitted into an existing roadway. During the detailed design of Terry Fox Drive, the urban section, vertical profile, stormwater management system, clearing procedures and construction methods were altered significantly to reduce the overall footprint. There was less loss of regulated wetland, less forest habitats cleared, less rock blasting, and the adjacent habitats and animals were protected during construction. Residual habitat fragmentation, loss of interior forest conditions and long-term barrier effects were unavoidable and these impacts were therefore offset with the WGS. The WGS was designed to reduce the impacts on individual animals, allowing them to move freely back and forth beneath the road with a lower risk of vehicle strikes.

As part of the construction of new roads, few scientific researchers have the access, funding and forethought to assemble sufficient before-and-after data on wildlife populations, movement patterns and migration corridors. Van der Grift et al (2012) laid out a nine-step research structure to evaluate the effectiveness of road mitigation measures during roadway planning, yet since then have had little real-time examples from which to support their conclusions. In the case of Terry Fox Drive, other than a single winter tracking study, little wildlife data was collected beforehand by the City. The location of the wildlife passage culverts identified during the final design stage of the environmental assessment, was based on the literature of the South March Highlands (Brunton 2004; Glenside 2001), topography, previous suggestions, the literature and an understanding of animal movement. The pre-development population sizes and movement patterns were therefore unknown prior to road construction, and leaves a gap in our understanding of the impacts of the new road.

## **Objectives**

The primary objective of implementing the WGS as part of the new transportation corridor, was therefore to reduce road mortalities, ameliorate habitat fragmentation, offset the barrier effects and







maintaining the population viability of wildlife in the area. This project was different from others that used large overpasses or underpasses, as it incorporated relatively small culverts, with less than optimal-sized openings. The value of providing wildlife passage for anything but large mammals has not previously been part of the dialogue in Canada, although that is changing in recent years with the advent of Road Ecology.

The objectives of this three year, post-construction study were therefore to assess the use of the culverts by local wildlife species, to assess road kill mortalities for local wildlife species, and to aid in the development of wildlife passage technology. Large mammals, although white tailed deer are present in the area, were not the target species. The primary target species was the Blanding's turtle population of the South March Highlands, however important secondary species include the meso-mammals, small mammals, amphibians and other reptiles for the sake of wildlife conservation management. The WGS was an expensive addition to the Terry Fox Drive infrastructure, at a cost of roughly \$958,000 to Canadian taxpayers, so a primary objective has been to learn as much as possible from this real-time field experiment, and to disseminate the information to road ecology practitioners.

## **Methods**

The WGS monitoring project was designed as a stand-alone, multi-year evaluation of the usefulness of the fencing, guide walls and culverts installed along and beneath TFD for passing wildlife. Monitoring was conducted in 2011 through 2013, during the late spring to mid fall months when most wildlife are active. In 2013, monitoring was extended into the winter to assess wildlife passage during frozen conditions.

Mounted trail cameras traps (NightXplorer NX80HD Infrared Trail Cameras) were installed in ten culverts to monitor wildlife passage. Cameras were put into steel protective cases and were bolted to the upper inside obvert surface of each culvert (Plate 3) 15 m into the mouth, where sunlight from the skylights would aid in wildlife recognition. Cameras were set to record an image every minute as it was expected that all animals would take at least one minute to traverse the culverts and cold blooded animals would not automatically trigger the infrared sensors. Batteries and memory cards were swapped out every two weeks. Every two weeks, roughly 18,500 - 20,000 images per camera were scanned with software that would detect a change in the pixels between frames and highlight images requiring evaluation (Scouting Assistant Professional, Version 1.5.3.2, by Chasingame Outdoors). Images were visually assessed for animals and records kept for species, date, time, temperature and direction of travel. Terry Fox Drive and five nearby major roads were patrolled twice weekly to collect roadkill statistics to determine the background mortality rates of local roads.



	
<p><b>Plate 3. NightXplorer NX80HD mounted in locked protective steel case hanging from the inside top of the concrete culverts.</b></p>	<p><b>Plate 4. High definition daylight photo of a wildlife-only culvert, with skylight providing illumination over the topsoil substrate, stocked with random log assemblies.</b></p>

Sound level recordings were measured in two locations (TCV1, TCV4; 15 min average db) with a decibel meter, 10 m from the road centreline, over a 24 hour period in October 2011, shortly after the road was opened to traffic. Timestamps on each photographic image were recorded, and classified over the 24 hour clock, which allowed charting of time of travel for all observed species.

The WGS study was done in parallel with a Blanding's turtle population, distribution and range study, which used mark and recapture techniques to estimate the population size, and radio-telemetry to track the movements of tagged turtles in the South March Highlands (SMH) and Kizell Drain Wetland areas. An estimated population of 99 adults was determined for the areas surrounding the Terry Fox Drive extension. Field studies were conducted between 2010 and 2013 throughout the duration of the active period (May – November) and positions of overwintering turtles were also determined through radio telemetry tracking during the winter. The tracking studies are relevant to the WGS because it demonstrates the use of the culverts by Blanding's turtles, which may not be picked up on the cameras. Furthermore, population modelling suggests that one adult female mortality per year (e.g., vehicle strike) has a significant negative effect on population size.

Six roads surround or pass through the South March Highlands. These roads were patrolled three times weekly during the active season to identify carcasses of possible road mortalities that had occurred. Including Terry Fox Drive (TFD), Huntmar Drive (HD), Old Carp Road (OCR), Goulbourn Forced Road (GFR), Richardson Side Road (RSR) and Second Line Road (SLR) were patrolled. Numbers were tallied for each year, and grouped for the three year period to identify trends.



Within the arc prescribed by Terry Fox Drive, urban development is planned to occur over the next several years, converting many wild areas to residential units, roads and commercial enterprises. Outside the curve, the South March Highlands are owned by the City of Ottawa and planned to be preserved in its natural state. The wildlife culverts therefore allow wildlife to egress from a relatively dangerous area, to one of greater safety and security as development encroaches.

## Results and Discussion

### Observations per unit of Effort

During each field season, the cumulative number of hours the culverts were monitored (effort) were recorded. Cameras were removed each year before winter, and replaced in late spring, yet water levels in the culverts stopped us from reinstalling them all at the same time. Observations per unit of effort (OpE) were calculated to determine if our total effort and number of observations were consistent across the three years. Depending on environmental conditions, each year the number of monitoring hours, and therefore the number of images and confirmed observations varied proportionally (Table 1). Over the three year study, there were 6,033 observations of animals either in, or moving through the culverts. Efforts in 2012 and 2013 were similar.

Table 1. Inter-Year Observations per Effort 2011-2013

Year	Hours Monitored (Effort)	Observations	Observations per Effort
2011	7182	783	0.11
2012	15711	2391	0.15
2013	19906	2859	0.14

Comparing between culverts, Table 2 may suggest which culverts are better placed to provide a movement conduit for wildlife. A bias exists however, between the wet hydraulic culverts (CV) placed on creeks when compared with the dry terrestrial wildlife-only culverts (TCV), strategically placed along pre-existing observed wildlife pathways. The number of observations per effort for the wildlife-only culverts demonstrate consistently high number of observations when compared to the hydraulic and wildlife culverts.

**Table 2. Comparison of Observations per Effort over Three Years**

<b>Culvert</b>	<b>Type of Culvert</b>	<b>2011 Hours Monitored</b>	<b>2011 Observations</b>	<b>2011 Observations per Effort</b>	<b>2012 Hours Monitored</b>	<b>2012 Observations</b>	<b>2012 Observations per Effort</b>	<b>2013 Hours Monitored</b>	<b>2013 Observations</b>	<b>2013 Observations per Effort</b>	<b>Average Observations per Effort</b>
CV3a	Hydraulic & Wildlife	577	15	0.03	1048	134	0.13	1605	261	0.16	<b>0.11</b>
CV3b	Hydraulic & Wildlife	642	78	0.12	1101	268	0.24	1841	281	0.15	<b>0.17</b>
CV3c	Hydraulic & Wildlife	655	44	0.07	850	87	0.10	1363	183	0.13	<b>0.10</b>
CV4	Hydraulic & Wildlife	867	70	0.08	1789	307	0.17	2133	402	0.19	<b>0.15</b>
CV5 Arch	Hydraulic & Wildlife	522	64	0.12	1336	183	0.14	904	69	0.08	<b>0.11</b>
CV6	Hydraulic & Wildlife	726	62	0.09	1393	259	0.19	2219	284	0.13	<b>0.13</b>
TCV1	Wildlife	807	127	0.16	1946	350	0.18	2668	457	0.17	<b>0.17</b>
TCV2	Wildlife	754	70	0.09	2184	340	0.16	2204	459	0.21	<b>0.15</b>
TCV3	Wildlife	811	169	0.21	1777	246	0.14	2451	316	0.13	<b>0.16</b>
TCV4	Wildlife	821	84	0.10	2287	217	0.09	2518	147	0.06	<b>0.09</b>

### **Species Richness and Diversity**

Species richness over the three year study was quite consistent and we feel that all species that may have been expected to use the culverts did in fact do so. Unknown species (UK), due to blurred or overly dark images, account for a significant number of observations, 265 in 2013, yet have been included in this data set as they are indicative that the culverts are being used by an animal, we just aren't aware of the species. Twenty four (24) species were observed in 2013, of which frogs, racoon and muskrat were the three most numerous. These results are consistent across all three seasons, in that frogs, racoons, muskrat and porcupine are the most frequent users, with frogs making up 35-40% of all observations annually.

Results for CV5, the arch culvert are skewed from the norm as the camera traps could not record animals in the water, so only exposed animals would be observed and recorded.

**Table 3. Total Confirmed Wildlife Observations during the 2013 Field Season**

Species	CV3a	CV3b	CV3c	CV4	CV5	CV6	TCV1	TCV2	TCV3	TCV4	Species Total
BR	0	0	0	0	0	3	1	2	2	0	8
BS	2	0	0	0	0	0	0	1	0	0	3
BT	0	0	0	0	0	7	0	1	0	0	8
BV	4	9	1	0	0	1	0	10	1	0	26
CM	0	0	0	0	0	0	1	0	0	0	1
DS	0	0	5	0	4	2	0	0	0	0	11
FG	104	150	131	35	6	145	92	278	86	41	1068
FS	1	0	0	0	0	5	33	1	6	0	46
FX	0	0	0	0	0	0	1	0	0	0	1
GH	2	9	0	0	0	0	0	1	0	0	12
GR	0	0	0	2	0	0	4	0	0	0	6
LW	0	0	0	0	0	4	2	15	1	2	24
MR	1	56	35	0	1	3	0	0	0	0	96
MS	1	0	0	17	0	5	15	9	5	6	58
PP	0	0	0	1	0	4	24	1	30	30	90
PS	0	1	0	0	0	0	0	2	0	0	3
PT		0	0	0	0	1	0	0	0	0	1
RC	132	5	0	345	0	73	163	82	138	34	972
RS	0	0	0	0	0	0	82	2	0	11	95
SK	0	0	0	0	0	0	1	0	2	0	3
SL	3	0	0	0	0	1	0	0	0	0	4
SN	5	0	0	0	0	0	5	22	1	6	39
SQ	0	0	0	0	0	0	11	0	0	0	11
ST	0	0	0	0	0	4	0	4	0	0	8
UK	6	51	11	2	58	26	22	28	44	17	265
<b>Culvert Total</b>	<b>261</b>	<b>281</b>	<b>183</b>	<b>402</b>	<b>69</b>	<b>284</b>	<b>457</b>	<b>459</b>	<b>316</b>	<b>147</b>	<b>2859</b>

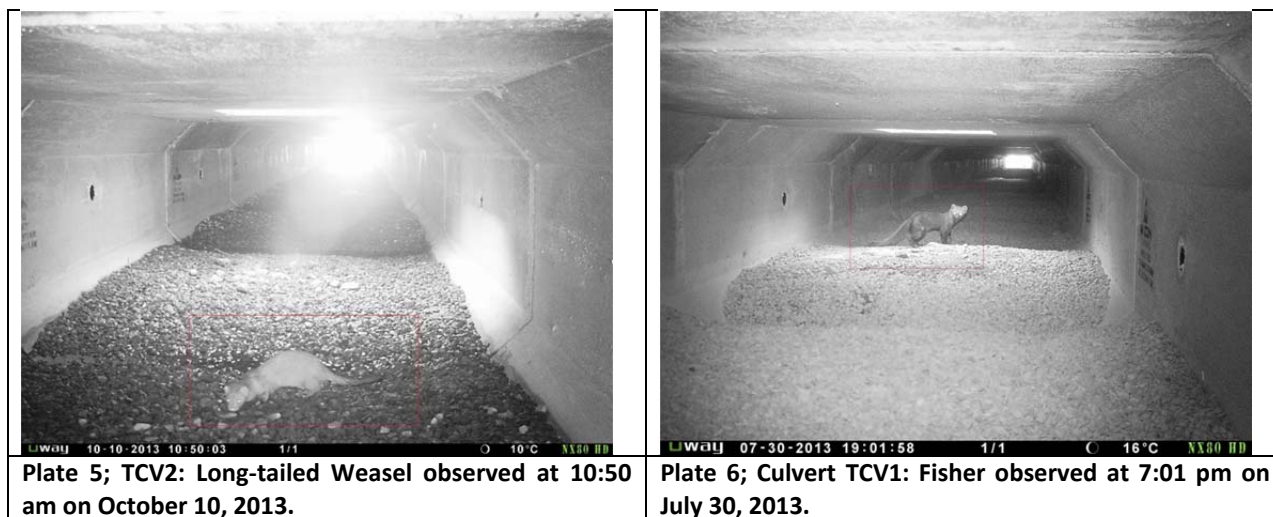
Abbreviations: BR = Brown Rat (*Rattus norvegicus*); BS = Bird Species (*Aves* spp); BT = Blanding's Turtle (*Emydoidea blandingii*); BV = American Beaver (*Castor canadensis*); CM = Eastern Chipmunk (*Tamias striatus*); DS = Duck Species (*Anatidae* spp); FG = Frog (*Rana* spp); FS = Fisher (*Martes pennanti*); FX = Red Fox (*Vulpes vulpes*); GR = Great Blue Heron (*Ardea herodias*) GR = Groundhog (*Marmota monax*); LW = Long-tailed Weasel (*Mustela frenata*); MR = Muskrat (*Ondatra zibethicus*) MS = Mouse (*Muridae* spp); PP = North American Porcupine (*Erethizon dorsatum*); PT = Painted Turtle (*Chrysemys picta*); RC = Northern Raccoon (*Procyon lotor*); RS = Rabbit Species (*Leporidae* spp); SK = Striped Skunk (*Mephitis mephitis*); SL = Salamander Species (*Ambystoma* spp); SN = Snake Species (*Colubridae* spp); SQ = Eastern Gray Squirrel (*Sciurus carolinensis*); ST = Common Snapping Turtle (*Chelydra serpentina*); UK = Unknown Species

Relatively high numbers of secretive mammal species such as Long-Tailed Weasel (24 obs. - Plate 5), Fisher (46 obs. - Plate 6) and Porcupine (90) were found in the culverts. Certain species clearly selected some culverts over others as shown in Table 3, presumably as they were sited along their normal travel routes and game trails. Often these were observed in the culverts during mid-day at a time when traffic noise and vibrations were high.

The culverts were also used by other unexpected animals. Great Blue Heron were observed 12 times feeding in culvert CV3B located on a tributary to the Carp River. Bats and some birds regularly flew through the culverts and were recorded by the camera traps.

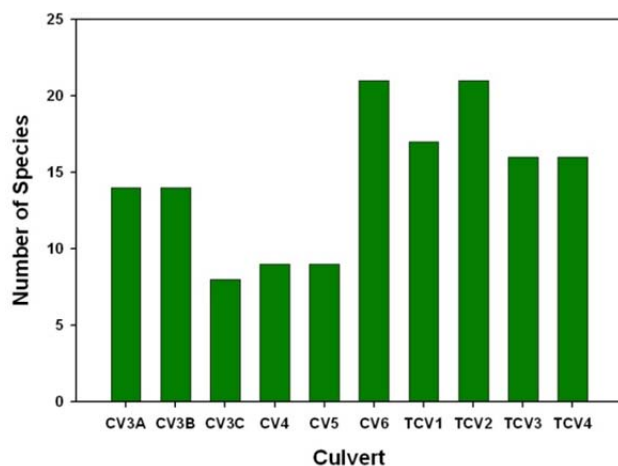
Several images record reptiles (i.e., snakes, common snapping turtle, painted turtle and Blanding's turtle) basking below the skylights in the warm sun.

Two movements of Blanding's turtle through the culverts were observed in 2011, with no observations in 2012. Tracking data had indicated that movements across the road had been made during these periods, but they were not observed on the cameras. During 2013 however, eight (8) observations were made of Blanding's turtles using the culverts. Use of CV5, the 5 m arch culvert is quite possible without being observed on the camera traps, and is a recognized limitation of this monitoring method.



### Inter Culvert Comparison

Based on the data assembled from 2011- 2013, the data was aggregated to represent general trends across the ten culverts, plotted by the number of species and taxa.



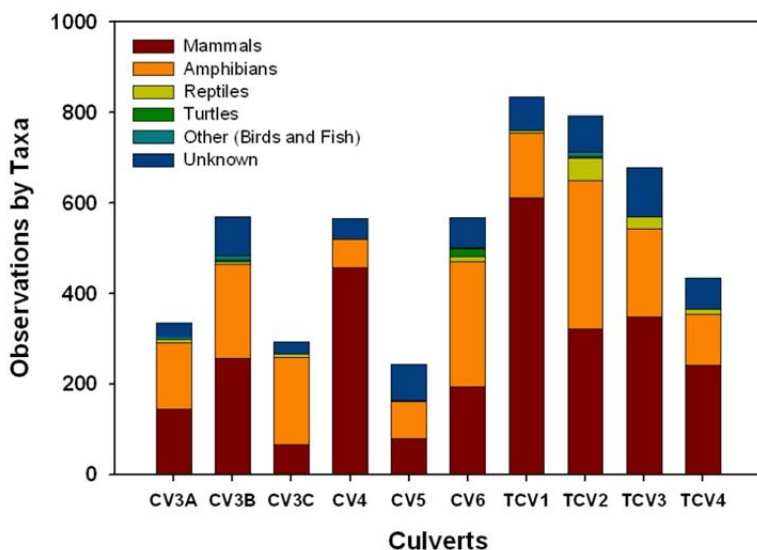
**Figure 2. Three year comparison of culvert preference by species.**

The TCV series of culverts that were installed specifically for wildlife passage, consistently saw the highest number of species movements (Figure 2), peaking with TCV2, a semi-wet culvert that saw 20 species. Comparable to this was CV6, a hydraulic culvert on East Shirley's Brook, which also saw 20 species moving along the natural stream corridor. Surprisingly, CV5, the large arch culvert on West Shirley's Brook had one of the lowest species counts, but considering that water fills the culvert throughout most of the year, which may have deterred some land

mammals, and many movements within the creek water may not have been observable.



Figure 3 represents culvert preferences by taxonomic group based on the total number of observations for each group. Culvert CV4 is a relatively dry tributary set at the edge of the forest and was heavily used by mammals but few amphibians and no reptiles were observed here. There are few desirable wet habitats on the downstream side of culvert CV4, so there would be no need for semi-aquatic animals to use this corridor.



**Figure 3. Three year comparison of culvert preference by taxonomic group.**

Significant numbers of amphibians passed through all other culverts and are the most numerous of all taxa observed.

The highest number of observations over three years were made in culvert TCV1, located on the ridge line 'saddle' where animal movements were predicted during the planning and design phase of Terry Fox Drive. Mammals, amphibians and other were recorded here in large numbers. No reptile movements were recorded in TCV1 along the saddle corridor. For turtles, this result is consistent with the 3 year radio tracking studies of Blanding's turtle (Dillon 2013b).

Results such as this have been blended into the management recommendations of the Blanding's turtle Conservation Needs Assessment (Dillon 2013a).

In contrast, the lower valley locations between distinct wetlands, TCV2 & TCV3 saw between 700-800 movements over the three year period. There were higher numbers of small mammals, amphibians and reptiles, including Blanding's turtle here in comparison to the upland culverts. These culverts are placed between wetlands (TCV2) or on a moist valley (TCV3). No distinct watercourses pass through either culvert, but both sides are seasonally moist to wet, with dense riparian vegetation communities on either side of the road. Hydraulic culvert CV6 on the more distinct tributary, East Shirley's Brook, had nearly 600 movements from the three largest taxa as well as turtles, however mammal movements were lower than average. Combined, these results suggest that mammals prefer the drier crossings, particularly when located on moist valleys, either along ridgelines or in the lowlands.

### Time of Travel

This study has also analyzed time of travel, to determine if the noise and vibration related to the daily fluctuation in traffic patterns influenced animal passaged in the WGS. Figure 4 represents the time of travel data for all observations per hour during 2013. Several observations record movements during the daylight hours, but overall, it is apparent from the data that early morning evening, and late night

are the primary movement periods. These periods offset the noise profiles, suggesting that the normal periods of movement avoid the peak travel periods.

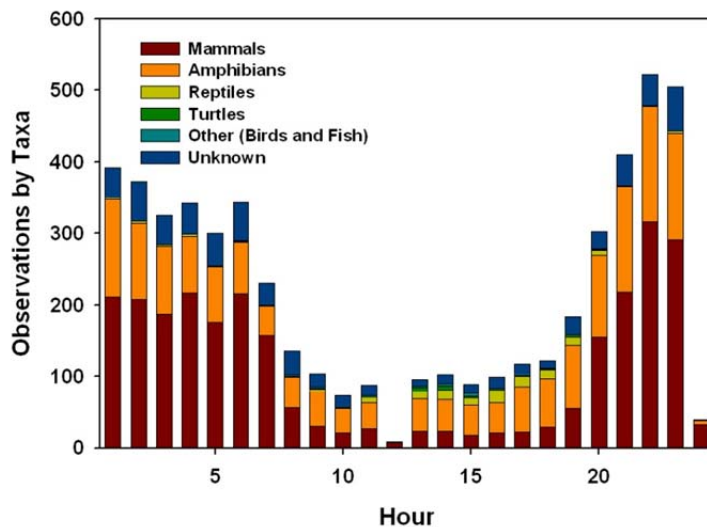
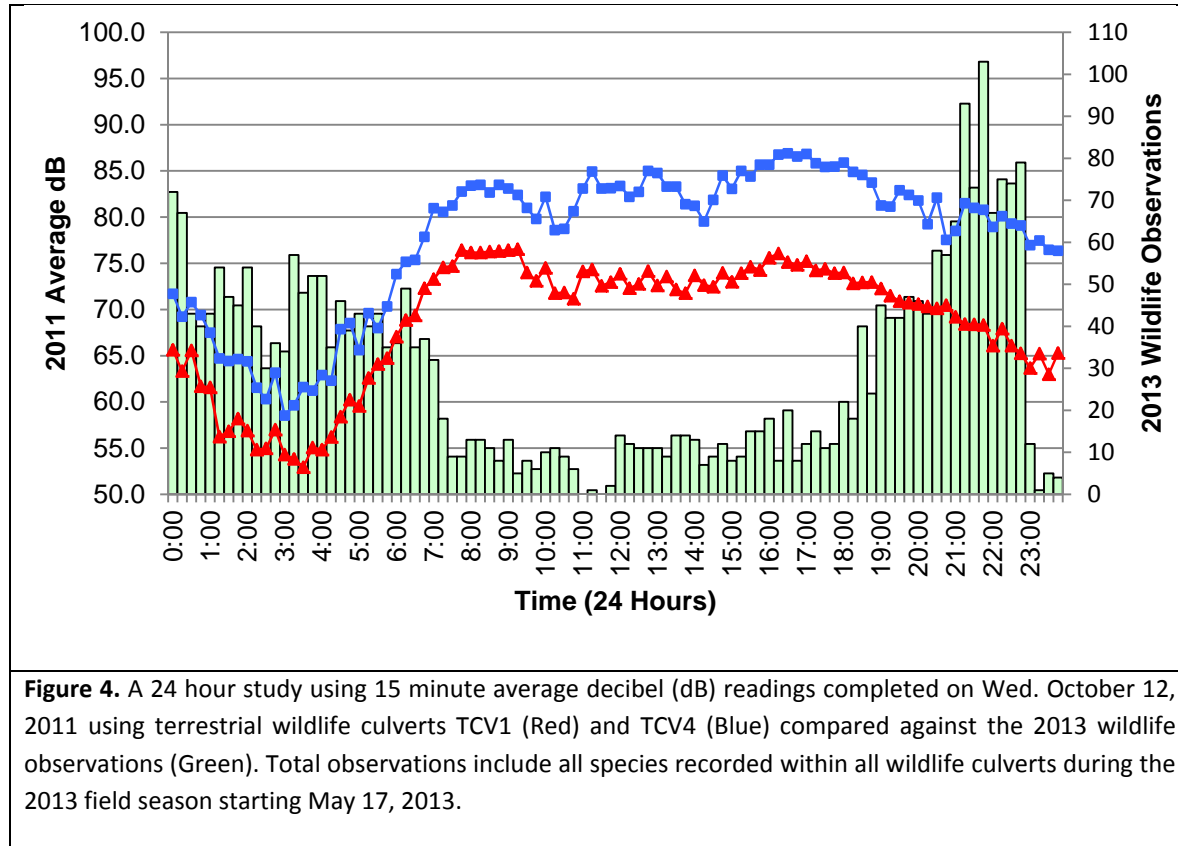


Figure 5 represents the number of movements by taxonomic group by time of day (diel), where zero hour is 12:00 midnight. Mammals clearly move more during the night time hours, when traffic movements are minimal.

Noise recording in 2011 demonstrated that although there was a morning and late afternoon commuter peak, traffic volumes remained relatively high throughout the day. These results seem to demonstrate that most of the mammals move when traffic noise is

lowest, particularly avoiding the mid-day period. These results mirror the natural

rhythms' seen in some wild animals, as they are seldom observable in the field during daytime when they rest, but are much more active at night, however amphibians and reptiles are equally active during the day and would be expected to move in the daylight. A higher percentage of amphibians and reptiles do continue to move through the culverts during the daytime, when their predators are least active.

#### **Intra Road Mortality Comparison**

Regular patrols to record road mortality were completed approximately three times a week along the six roadways surrounding the South March Highlands. Table 4 reports on the results of all three years. A total of 30 species of animals, including several birds were identified. Several of these species were not observed using the WGS.

**Table 4. Wildlife Road Mortalities around the South March Highlands 2011-2012-2013.**

<b>Species</b>	<b>TFD</b>	<b>HD</b>	<b>OCR</b>	<b>GFR</b>	<b>RSR</b>	<b>SLR</b>	<b>Total</b>
<b>AC</b>	0-0-1	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0	<b>1</b>
<b>BF</b>	1-0-0	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0	<b>1</b>
<b>BS</b>	0-0-3	0-0-4	0-0-0	0-0-2	0-0-0	0-0-0	<b>9</b>
<b>BT</b>	0-0-3	1-0-0	0-1-0	1-0-0	0-0-0	0-0-0	<b>6</b>
<b>CM</b>	1-1-1	0-1-1	0-2-0	0-0-0	0-0-0	0-0-0	<b>7</b>
<b>ES</b>	0-1-0	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0	<b>1</b>
<b>FG</b>	0-0-2	0-0-0	0-2-0	0-0-0	0-0-0	0-0-0	<b>4</b>
<b>GH</b>	0-0-0	0-1-0	0-0-0	0-0-0	0-0-0	0-1-0	<b>2</b>
<b>GR</b>	0-0-0	0-0-0	0-0-2	0-0-0	0-0-0	0-1-0	<b>3</b>
<b>GS</b>	2-0-0	0-0-2	0-0-0	0-0-0	0-0-0	0-0-0	<b>4</b>
<b>LF</b>	0-0-1	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0	<b>1</b>
<b>MK</b>	0-0-0	0-1-0	0-0-0	0-0-0	0-0-0	0-0-0	<b>1</b>
<b>ML</b>	0-1-0	1-0-0	0-0-0	0-0-0	0-0-1	0-1-0	<b>4</b>
<b>MR</b>	1-0-0	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0	<b>1</b>
<b>MS</b>	1-0-0	0-0-0	0-0-1	0-0-0	0-0-0	0-0-0	<b>2</b>
<b>PP</b>	1-3-0	2-3-4	0-0-2	0-0-0	0-0-0	0-0-0	<b>15</b>
<b>PT</b>	1-1-8	0-1-3	0-0-1	0-0-1	0-0-0	0-1-1	<b>18</b>
<b>RB</b>	0-0-0	0-1-0	0-0-0	0-0-0	0-0-0	0-0-0	<b>1</b>
<b>RC</b>	1-1-0	2-7-2	0-1-0	0-0-1	0-2-1	0-1-0	<b>19</b>

Species	TFD	HD	OCR	GFR	RSR	SLR	Total
<b>RQ</b>	0-0-0	0-0-2	0-0-2	0-0-1	0-0-0	0-0-0	<b>5</b>
<b>RS</b>	0-0-0	0-0-0	0-0-0	0-0-1	0-0-0	0-0-0	<b>1</b>
<b>RW</b>	0-0-0	0-0-1	0-0-0	0-0-0	0-0-0	0-0-0	<b>1</b>
<b>SK</b>	0-1-0	0-0-0	0-0-0	1-0-0	0-0-0	0-1-0	<b>3</b>
<b>SN</b>	21-0-1	1-0-0	1-2-0	0-1-0	0-0-0	0-0-0	<b>27</b>
<b>SP</b>	1-0-0	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0	<b>1</b>
<b>SQ</b>	0-0-1	0-1-2	1-1-0	0-0-1	0-0-0	0-0-1	<b>8</b>
<b>ST</b>	1-2-3	2-0-2	0-0-0	0-0-1	0-0-0	0-0-0	<b>11</b>
<b>VS</b>	0-0-1	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0	<b>1</b>
<b>WS</b>	1-0-0	0-0-0	0-2-0	0-0-0	0-0-0	0-1-0	<b>4</b>
<b>WT</b>	1-0-1	0-0-0	0-0-0	0-0-0	0-0-0	0-0-1	<b>3</b>
<b>Total</b>	<b>71</b>	<b>48</b>	<b>21</b>	<b>11</b>	<b>4</b>	<b>10</b>	<b>165</b>

Abbreviations: TFD = Terry Fox Drive, HD = Huntmar Drive, OCR = Old Carp Road, GFR = Goulbourn Forced Road, RSR = Richardson Side Road, SLR = Second Line Road. AC = American Crow (*Corvus brachyrhynchos*); BF= American Bullfrog (*Rana catesbeian*); BS = Bird species (*Aves spp*); BT = Blanding's Turtle (*Emydoidea blandingii*); CM = Eastern Chipmunk (*Tamias striatus*); ES= European Starling (*Sturnus vulgaris*); FG = Frog (*Rana spp*); GR = Groundhog (*Marmota monax*); GS = Common Garter Snake (*Thamnophis sirtalis*); LF = Northern Leopard Frog (*Rana pipiens*); MK= American Mink (*Neovison vison*); ML = Mallard (*Anas platyrhynchos*); MR = Muskrat (*Ondatra zibenthicus*); MS = Mouse (*Muridae spp*); PP = North American Porcupine (*Erethizon dorsatum*); PT = Painted Turtle (*Chrysemys picta*); RB = American Robin (*Turdus migratorius*); RC = Northern Raccoon (*Procyon lotor*); RQ = Red Squirrel (*Tamiasciurus hudsonicus*); RS = Rabbit Species (*Leporidae spp*); RW = Red-winged Blackbird (*Agelaius phoeniceus*); SK = Striped Skunk (*Mephitis mephitis*); SN = Snake (*Colubridae spp*); SQ = Eastern Gray Squirrel (*Sciurus carolinensis*); ST = Common Snapping Turtle (*Chelydra serpentina*); VS = Vole Species (*Arvicolinae sp*); WS = Northern Water Snake (*Nerodia sipedion*); WT = White-tailed Deer (*Odocoileus virginianus*)

The highest number of road mortalities occurred on Terry Fox Drive despite the integrity of the WGS. Of the 71 animals killed over the three year period, 21 were snakes basking along the railway tracks in the unprotected gap in the fence. Of the 50 remaining, 18 were midland painted turtles, many also found at the railway level crossing, as well as raccoons (19) and porcupine (15), both nocturnal, slow moving animals. Railway crossing structures are being developed for some species, mostly turtles, to allow them to escape the confinement of the dual rails and radiant heat of the ballast (Pelletier et al, 2005). This disparity may also be because the design road speed is higher on Terry Fox Drive, than elsewhere, and currently there are no traffic signals or other stopping zones to retard the flow of traffic, hence speeds often exceed the posted limit. Over time, this high number of road mortality is expected to reduce, as new intersections and traffic signals are added and the traffic slows down.

### Blanding's Turtle & Reptiles

Over the three year period of study, ten observations of Blanding's turtle moving through the culverts were made. There are many more observations of Common snapping turtle, Midland Painted turtle and snakes using the culverts, so it is clear that reptiles and turtles do not avoid using the crossing points provided by the City and will use them during their seasonal migrations. The three skylights per culvert may be effective at helping these cold-blooded species warm themselves, maintain homeostasis



through the otherwise cold subterranean culverts, but with the available data this theory is only an anthropomorphic-centric observation, that cannot be fully supported by this data set. Additional comparative studies will need to collect suitable data and provide analysis to conclusively address this question.

Road mortality patrols over the three year period demonstrated one Blanding's killed on each of Huntmar (2011), Goulbourn forced Road (2011) and Second Line Road (2011) and on Old Carp Road (2012). Three Blanding's (2 juvenile, one female) were killed on Terry Fox Drive in 2013. No Blanding's turtle were reported killed on the other five roads in 2013, so complete success at mitigating the effects of Terry Fox Drive on the Blanding's Turtle population cannot be claimed; however, the two Blanding's turtles killed at the railway level crossing in 2013 were at the point where mortalities of several other reptile species have been documented. By necessity, there is a 15 m wide gap at the railway crossing, and although the terminal ends of the fence wrap back on itself, there is a clear unprotected pathway of ballast stone and concrete that attracts reptiles to bask and warm themselves. As of this date, no practical solution to eliminating or reducing road mortalities at this location, have been proposed.

### **Wildlife**

It is clear from the passage results that the species richness and abundance observed suggests that the WGS and additional hydraulic culverts have been effective at creating the conditions that facilitate the movements of animals back and forth under the roadway. At a minimum, we know that over this time period, over 6,000 movements have occurred where animals were guided through the culverts and therefore not at risk of road kill. By comparison with these safe movements, over the same period, the number of animals actually killed on Terry Fox Drive (33 in 2011; 12 in 2012; 26 in 2013), suggesting that there were far fewer road mortalities than successful passages. The gap in the fencing system at the railway at-grade crossing seems to account for the majority of the road mortalities observed through the regular patrols, and of these kills the majority is caused by snakes laying in the track groove to bask.

It would be helpful in the understanding of this system if City roads-staff would record the species and location of each road mortality, logging the GPS coordinates with each pickup. When used over the extent of City roads, over several years, a relatively simple GIS Hot-Spot model could be developed to indicate the areas where animals are most likely to attempt crossing, and therefore where retrofitting culverts and a WGS may be most cost effective and most efficacious to the protection of vulnerable populations of wildlife.

### **Conclusions**

The results from the three year study suggest that the installation of the Wildlife Guide System has reduced the potential road mortalities that may have occurred if no system was in place and animals had to cross at grade. There are many different types of habitats along this stretch of TFD and therefore a diverse wildlife community exists that has the potential to be significantly affected by infrastructure development and urbanization. The WGS implemented on Terry Fox Drive was designed to reduce the negative issues associated with urban development in natural areas, while allowing the natural ecological functions to continue unabated.

The practice of Road Ecology is relatively new in the Canadian landscape, however the literature is rich in the practices and experiences of others in the United States and Europe. Within the local context of Canada's provincial and federal legislation however, there are lessons that we've learned that may benefit other practitioners faced with similar problems and looking for solutions.

### **Lessons Learned**

The following lessons learned and recommendations are drawn from the described work and are intended to provide leadership and instruction to other practitioners tasked with implementing a similar type of WGS in Canada or elsewhere. It's important to recognize that this system did not target large ungulate mammals and that the system has been completed within an urbanizing area along the border of the City of Ottawa, not within the larger landscapes of a National Park or wilderness area. Additional data, detail and guidance is provided in the 3<sup>rd</sup> year Wildlife Guide System summary report (Dillon, 2014) available from the authors.

#### Culvert Configuration:

We found many species of wildlife (24) using the culverts, even with the low openness factors (0.108 – 0.271), variable bottom substrates and limited headroom. Spacing between culverts was broadly set around an average of 250 m apart, but at locations that made sense rather than dictated by a literature reference or guideline. The target species (Blanding's turtle) and most wildlife groups expected in this region are represented in the sampling data. Large mammals, such as white tailed deer and black bear, although existing in this region of Ottawa were not the target species as we did not have the vertical grade height to accommodate their requirements.

The collected data demonstrates that the four locations selected for the terrestrial wildlife-only culverts were regularly used by many wildlife species. They functioned as designed and are generally effective. They did seem to be somewhat more effective at passing wildlife than the wetter hydraulic culverts, but some swimming species (beaver, muskrat, turtles, amphibians) may have been under represented in the dataset by our use of the camera traps. When dealing with multiple wildlife species in addition to a target species at risk, it is doubtful that extensive pre-design studies of population size, distribution, wildlife migration movements, winter tracking and /or behavioural studies would have determined culvert locations in places other than those used on the Terry Fox Drive extension. Good logic, observations of game trails, anecdotal evidence and sound field sense by a few experienced biologists was equally effective at establishing the wildlife culvert locations on a project of this size. Fenced culvert systems simply work because they give the animals no other choice to completing their migration movement. It's therefore more important to install them frequently and regularly, rather than agonizing over exactly where to install them.

#### Skylights:

Each skylight was a modified catch basin 600 X 600 mm square, mounted flush on a concrete riser of varying height. The top opening of each culvert was reinforced with additional structural steel to accept the riser-catch basin stresses, while maintaining structural integrity to carry the roadway. Each had an

expanded aluminum grate fixed overtop with two inch openings. Snow and ice from plowing operations and direct snow fall does accumulate underneath the skylights, but this does not inhibit movements by wildlife active during the winter. Air movement through the >50 m long culverts is increased due to the skylights, which helped keep them warmer in the winter and cool, but not cold, in the summer. Sequential images showed reptiles and turtles, including Blanding's turtle, basking on warmed stone beneath the skylights during the day and night periods. Snakes seem to circle underneath the skylights, presumably to stay warm as the sun tracks overhead. Overall, we feel the skylights were quite helpful to animals migrating through the WGS and make sense biologically. Considering the cost of skylight installation was just \$2,038 each, good value was received and we would recommend their installation on similar projects.

#### Substrates:

Either large cobblestone (100-150 mm rip rap), finer crushed gravel (20mm clear) or organic topsoil was placed in all 10 culverts to a depth of 30 cm. Fears of the topsoil washing out were unfounded and did not occur. The results show no difference between the types of substrate, however they do demonstrate clearly that both upland and lowland crossing points are important to wildlife. Culverts containing the larger cobblestone cause drier conditions and may be inhospitable to the animals requiring a higher moisture regime in the summer. Although frogs passed through all culverts equally well we did observe some seasonal differences.

Two wildlife-only culverts (TCV3 & TCV4) were also fitted with logs. Thirty logs, 2.4 m long, 20 - 25 cm diameter were placed in the culverts in a criss-cross pattern while the culverts were being assembled. The logs do diversify the habitat through which the animals are moving, retain moisture and provide cover from predators. In nature, a more complex, diverse habitat usually supports a higher diversity and abundance of species. We would recommend this approach from this aspect, but have little evidence to specifically comment on the efficacy of the logs. Logs of this size are cheap and plentiful during road construction, they make sense biologically and make a good use of an otherwise waste product.

#### Armourstone Guide Walls:

The guide walls on this project were specified as armour stone blocks, with an 800 mm exposed face height. The 600 mm wide and 200 mm thick cap stones provide a 250 mm overhanging lip. The gneiss blocks were very rough and did not fit tightly together with gap tolerances of 5 mm as specified. Filter fabric was used behind the blocks, to line the excavation and resist movement of fines out of the gravity structure. Flexible drainage pipe (100 mm Big-O) installed behind the walls minimizes lateral water pressure and ice expansion. Crushed gravel (Granular B) was backfilled behind the walls to assist drainage and enhance bedding of the armour stone. Similar guide wall systems elsewhere have used tightly fitting armour stone, formed concrete blocks, steel piling and poured concrete. In this location, several walls would need to be built through the wetlands, so stability, constructability and frost heave was a concern as well as cost; however, there are early signs that the walls may not be as sustainable as desired. Theft seems to be an issue, as new homeowners take the rock for their property landscape.

Where functionality alone is the deciding factor, we would recommend shorter lengths of poured concrete wall, with reinforcing steel and proper footings with a long service life.

#### Guide Fencing:

Although wood fence posts were specified, as a matter of cost savings, the contractor used 75 mm dia. steel posts throughout the 4.2 km length. These were set in augured holes with concrete footings so there are no issues with vertical stability. Diagonal cross bracing was done at each terminal end. Top bars were not specified as a matter of costs savings. Instead of top bars, a single 16 gauge tension wire along the top of the central panel was specified but was found to be insufficient to retain tautness. An additional tensioning wire was added during construction, along the top edge of the 40 cm overhang to maintain a taught topline and avoid sag. This was a good addition, however including a rigid top bar would have been a better choice and worth the additional cost.

The location of the fencing was intended to be outside of the municipal infrastructure, recreational path, boulevard and bike lanes, however the routing had to be adjusted in the field to contend with the storm drain outlets, sloped ditch lines and matching the fence to the end of the guide walls. Maintaining the integrity of the system so there were no gaps was quite challenging, requiring extensive supervision and inspection of the contractors work. The integrity of the fence-to-wall connection however, is of paramount importance as gaps at this interface is where two turtles were able to circumvent the WGS, resulting in one mortality and one serious injury.

#### Fence Fabric:

The fence fabric selected was a welded wire, galvanized product with 50 mm X 100 mm gaps on the vertical. Juvenile turtles begin to move away from the wetlands once they are about 100 mm in carapace diameter. A 50 mm maximum cross width was therefore selected to stop turtles, while a fabric with a larger gap would not provide a barrier for other species. The top edge of the panel was angled at 45° towards the habitat to create an overhang of 400 mm, which seems to have been effective at eliminating the threat of animals climbing over. The brackets used would normally include a top bar, which was not specified for this project as noted, so the configuration is weakest at the junction between the top edge and the overhang. We would recommend the use of a top bar in the future. The bottom flap was entrenched 400 mm and buried in crushed gravel, which seems to be very effective at stopping burrowing animals.

#### Maintenance:

Maintaining an area free of vegetation on the habitat side of the fence, was an objective of the mitigation plan, to help avoid animals from approaching the fence where they would be exposed to predators. Cutting grass on the outside of the fence is a problem however, as no gates or gaps were left for this and it has become impractical for City staff to implement. Therefore the vegetation grows tall beside the fence increasing the likelihood of animals climbing over. Deer jumping the fence have pierced the welded wire fabric, but the damages done are minimal and can be maintained easily with wire lacing.



### Monitoring with Camera Traps:

The mounts supplied by the manufacturer (UWAY) functioned very well for this purpose as did the cameras. We would not hesitate in recommending this product to others for this use. Inexpensive solar panels, hard wired to the cameras were considered to avoid replacing batteries so often, but felt they would be prone to vandalism, and because the SD cards had to be downloaded anyways, we stuck with batteries. More permanently mounted camera traps can be easily modified with a wiring harness for power, which is supplied by the distributor at low cost, however the wire runs must be protected to avoid being easily cut. Wireless downloads would be helpful. Spring flooding affected the ability to remount the cameras early in the spring, so much of the early movement activity was missed.

The cameras are unable to penetrate water, so animals using the wet hydraulic crossings may not be fully represented in the data set, however they were very effective at capturing images of wildlife under the less-than-ideal conditions of drought, darkness, winter and storms.

### **Acknowledgements**

The authors would like to recognize staff of the City of Ottawa and Dillon Consulting who have contributed to the construction of Terry Fox Drive and the results found in this paper: Councilor Marianne Wilkinson, Steven Stoddard, Steven Forestell, Tom Young, Jessica Wright, Mike Flainek, Shawn Doyle, Brandon Maynard and student field researchers 2011: Rebecca Rochman, Ryan Boudens, 2012: Sarah Larocque, Lindsay Bellingham; 2013: Mike Seabert, Kayley Fowler, Matteo Petti.

### **References**

Aresco, Matthew J. (2005). Mitigation Measures to Reduce Highway Mortality of Turtles and Other Herpetofauna at a North Florida Lake. *Journal of Wildlife Management* 69(2): 549-560.

Beckmann J.P., Clevenger A.P., Huijser M.P., Hilty J.A. 2010. Safe Passages – Highways, Wildlife and Habitat Connectivity. Island Press, 1718 Connecticut Avenue NW, Suite 300, Washington, DC.

Brudin, Carl O. III. (2003). Wildlife use of existing culverts and bridges in North Central Pennsylvania. UC Davis: Road Ecology Center. Retrieved from: <http://escholarhip.org/uc/item/67f406zv>

Brunton, D. 2004. Natural Environment Area boundary on South March Highlands Special Study Area, Final Report, June 2004.

Clavenger, A.P. and N. Waltho, 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. *Conservation Biology*, Pgs 47-56. Vol. 14, No. 1, Feb. 2000.

COSEWIC 2005. COSEWIC assessment and update status report on the Blanding's Turtle *Emydoidea blandingii* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 40 pp. ([www.sararegistry.gc.ca/status/status\\_e.cfm](http://www.sararegistry.gc.ca/status/status_e.cfm)).

Dillon Consulting Limited. 2003 Terry Fox Drive Environmental Assessment Addendum and Functional Design Brief Update; Unpublished report for the City of Ottawa.

Dillon Consulting Limited. 2010a Canadian Environmental Assessment – Part B; Terry Fox Drive – Detailed Design Richardson Side Road to March Road. Prepared for the City of Ottawa, Project #09 1518. April 10, 2010.

Dillon Consulting Limited. 2010b Blanding's Turtle Avoidance and Mitigation Plan, Terry Fox Drive – Detailed Design Richardson Side Road to March Road. Prepared for the City of Ottawa, Project #09 1518. April 14, 2010.

Dillon Consulting Limited. 2011. Terry Fox Drive Extension Project: Wildlife Guide System Monitoring Report, Year 1 of 3. Prepared for the City of Ottawa, Project# 10-3663.

Dillon Consulting Limited. 2012a. Terry Fox Drive Extension Project: Wildlife Guide System Monitoring Report, Year 2 of 3. Prepared for the City of Ottawa, Project# 12-6019, December 21, 2012.

Dillon Consulting Limited. 2012b Terry Fox Drive Extension Project: Blanding's turtle population estimate, distribution and range study, year 3 of 4. Prepared for the City of Ottawa, Project# 12-6019, December 20, 2012

Dillon Consulting Limited. 2013a. South March Highlands Blanding's Turtle Conservation Needs Assessment. Prepared for the City of Ottawa, Project# 12-6060, January 20, 2013.

Dillon Consulting Limited. 2014a. Terry Fox Drive Extension Project: Wildlife Guide System Monitoring Report, Year 3 of 3 and three year summary. Prepared for the City of Ottawa, Project# 12-6019, March 25, 2014

Dillon Consulting Limited. 2014b. Terry Fox Drive Extension Project: Blanding's turtle population estimate, distribution and range study, year 4 of 4. Prepared for the City of Ottawa, Project# 12-6019, January 31, 2014

Glenside, 2001. Winter mammal inventory and tracking study of the Terry Fox Drive preferred alignment, Glenside Ecological Services Ltd for the City of Ottawa.

Krikowski, L. 1989 The light and dark zones; two examples of tunnel and fence systems. Pgs 88-91 in Amphibians and Roads, T. Langton ed. ACO Polymer Products, Bedfordshire, UK.

Ministry of Transportation Ontario, 2005. Wildlife and Transportation Reference for the Oak Ridges Moraine, Provincial and Environment Planning Office, St Catharines, MTO, Ontario.

Ontario Superior Court of Justice, Divisional Court 2010. South March Highlands - Carp River Conservation Inc. and the Corporation of the City of Ottawa; Court File No. 296/10

Pelletier, S.K., L Carlson, N. David, R.D. Robert, 2005. Railroad crossing structures for spotted turtles: Massachusetts Bay Transportation Authority; Greenbush rail line wildlife crossing demonstration project. Road Ecology Centre, UC Davis. <http://escholarship.org/uc/item/6087h4st>

Smith, D. 2003. Monitoring wildlife use and determining standards for culvert design, Florida Department of Transport, Report No. BC354-34; University of Florida, Gainesville.

Van der Grift, Edgar A., R van der Ree, L. Fahrig, S. Findlay, J. Houlahan, J.A.G. Jaeger. N Klar, L.F. Madrinan and L. Olson 2012. Evaluating the effectiveness of road mitigation measures. Biodivers. Conserv. Open Access at Springerlink.com. Dec 19, 2012.

Woltz, Hara W., James P. Gibbs and Peter K. Ducey. 2008. Road crossing structures for amphibians and reptiles: Informing design through behavioural analysis. Biological Conservation 141: 2745-2750.