CULVERT INSTALLMENT AND REMOVALS, HOW THEY AFFECT SURROUNDING HABITAT AND HOW WE CAN IMPROVE OUR METHODS OF MAINTENANCE

by

Alysia Ewaskiw

FACULTY OF NATURAL RESOURCES MANAGEMENT
LAKEHEAD UNIVERSITY
THUNDER BAY, ONTARIO

April 2018

CULVERT INSTALLMENT AND REMOVALS, HOW THEY AFFECT SURROUNDING HABITAT AND HOW WE CAN IMPROVE OUR METHODS OF MAINTENANCE

by

Alysia Ewaskiw

An Undergraduate Thesis Submitted in
Partial Fulfillment of the Requirements for the
Degree of Honours Bachelor of Environmental Management

Faculty of Natural Resources Management

Lakehead University

April 2018

Dr. Jian Wang	Ryan Wilkie
Major advisor	Second Reader

LIBRARY RIGHTS STATEMENT

A CAUTION TO THE READER

This HBEM thesis has been through a semi-formal process of review and comment by at least two faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific forestry.

The reader should be aware that opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of the thesis supervisor, the faculty or Lakehead University.

ABSTRACT

Culvert maintenance has been a problem for watersheds and roadways. The purpose for culvert installation is to increase the water carrying capacity away from road structures and buildings within the environment. Small mammals rely on culverts as habitat corridors for reproduction, food availability, and to escape predation. There are various management strategies developed for culverts so that they do not impact the surrounding habitat in a negative way, these include beaver deceivers, intake guards, and other management barriers. There are also several factors that influence types of management strategies for wildlife protection when it comes to culvert management. This study brings together results conducted from three plots in northwestern Ontario, where vegetation comeback and animal use were analyzed from culvert extractions along deactivated roads. This study also analyzes the process of extracting and installation of a concrete box culvert within a highly populated area. The study site in southern Ontario is used for recreation and tourism, it experiences frequent flooding from spring runoff and beaver damming. Management strategies have been suggested towards flood control and beaver damage within the watershed.

CONTENTS

FIGURES

Figures

ACKNOWLEDGEMENTS

A special thank you goes to Ryan Wilkie for providing critical feedback. Without his help, conducting the plot analysis in the English River Forest Management Unit would be impossible. During the process of data collection, I collaborated with colleagues in the Faculty of Natural Recourses Management, I would like to extend my gratitude for their assistance and support within the English River Forest Managements Unit. Another acknowledgement goes towards the thesis supervisor, Dr. Jain Wang, for providing articles and giving support towards the structure of this thesis. Acknowledgements goes to Lakehead University for providing the tools that assisted in conducting the soils analysis for both site locations. I would also like to thank the dean of the Natural Resources Management Program at Lakehead University, Ulf Runesson, for adding detail and knowledge towards the literature review. Lastly, warm regards go towards Albion Hills Conservation Area in southern Ontario for inspiring this thesis, as well as allowing wildlife and soils analysis to be conducted on the property.

INTRODUCTION

The methods of sustaining habitat quality around culverts, regarding the installation, removal, and maintenance has been an ongoing issue in areas where people often frequent, such as watersheds and roadways. This thesis focuses on watersheds and roadways as they are abundant for flooding and habitat degradation. Maintaining watersheds and roadway drainage is critical for habitat life and human safety. Improper drainage along roadways can cause severe damage to the pavement structure, causing detrimental effects such as hydroplaning, erosion, and flooding. Other issues regarding culvert installation and removal include the abundance of vegetation within and around the culvert area. Maintaining edge habitat when extracting or installing culverts is important for wildlife that use the area as part of their home range. Preform the proper maintenance required to preserve habitat for terrestrial and aquatic wildlife is critical for animals such as beavers, moose, fish species and other wildlife that use culverts as resources for foraging and shelter. Preservation of infrastructure and habitat in culvert management can be done in several methods including beaver management and long-term flood management methods.

This thesis reviews present maintenance strategies, the process of culvert extraction and installation, and examines the wildlife and vegetation comeback after a certain amount of time has passed. The first area of observation was in the Resolute harvesting licence land, located just north of Upsala in northwestern Ontario in the English River Forest Management Unit. The second area of observation was Albion Hills Conservation Area, located in southern Ontario, north of Toronto. The analysis within the management unit consisted of three areas where culverts were extracted. These sites were left alone as part of the reclamation process for a period of 5-7 years. Within the sites, one plot acted as the control because there was old aged vegetation and no water running through the site. The second plot contained more land disruption as well as the presents of standing water. The third plot consisted of a high abundance of vegetation and the presence of running water. All three of these areas host different soil types, from gravel to sand and clay. The management unit hosts a variety of animal life and vegetation, such as native and non-native plant species shown in the appendix. Evidence of scat and foot prints were found within and around the culvert plots including moose scat, moose and wolf prints, and visual sightings of squirrels and songbirds.

The analysis at Albion Hills started during the summer of 2017. The purpose for the culvert removal was due to road degradation and exposure of the culvert. The three corrugated steel culverts that were replaced had begun to bend (see figure 5), the average serviceability of a steel culvert is approximately 50 years, depending on the roadway and environmental conditions (OCPA 2010) yet it is unknown as to when the steel culverts were originally installed. Contractors hired by the TRCA began at the water crossing site and extracted the three culverts. The extraction happened to be in the most highly populated areas of the land for public recreation. The observation of the process of extraction was examined, as well as the longevity of the extraction, and the impact it had on the surrounding environment. Albion Hills is an area of recreation, as well as the host to many events pertaining to family and community usage. The area that the culvert was extracted and replaced was the main connection between one of the most desirable areas for picnics and large events. Due to this, there were cries of outrage from the public, resulting in loss of revenue to the park, as well as a longer period of operation. Other factors hindered the process of installing the new culvert, such as heavy rains and beaver dams.

OBJECTIVES

Culvert installations, removal, and maintenance, when not executed properly can cause serious damage to the surrounding habitat. The purpose of analyzing the different sites in north and southern Ontario was to examine management strategies and how they can be improved, as well as to analyze degradation when extraction has taken place over time. As well, beaver impacts and vegetation comeback has also been examined for analyzing soil degradation and wildlife usage after culverts were extracted. The purpose of including beavers into this thesis is due to their behaviour around culverts, particularly their damaging impacts to the structure, watershed, and roadways. The literature review provides information on beaver management strategies that could have been useful towards the watershed area examined in this thesis. The objective of this paper was to assess whether we can develop and improve the ways of maintaining culverts so that they do not cause extensive damage to the surrounding habitat for plant species, animals, and humans.

LITERATURE REVIEW

CULVERT REPLACEMENT AND HABITAT RESTORATION

By reconnecting reproductive habitats, as well as foraging habitats in fragmented watersheds, large-scale culvert replacement programs could benefit migratory fish population. Restoration is the process of returning disrupted habitat to is former condition, in habitat restoration the primary objective for stream habitat is to restore ecological function (Poplar-Jeffers et al. 2008). The most significant factor constituting fish population declining worldwide is dispersal barriers. Habitat patchiness, fish movement, and life stage-dependent shifts in critical habitat requires dynamic landscapes that will influence fish populations (Poplar-Jeffers et al. 2008). By isolating reproductive habitat from preferred foraging habitats, movements of barriers have the potential to reduce the productivity of the overall fish species in the area. The full recovery of ecological functions and the requirement of stream restoration programs will address stream network connectivity and the removal of dispersal of barriers (Poplar-Jeffers et al. 2008).

There are a variety of reasons why fish pass through culverts including migration, feeding, and spawning. Culvert outlets perched above the stream bottom, high flow velocities, and shallow water depths within culver barrels allow for fish passage though culverts. Because road crossings are common in mountainous regions due to steep topography, which forces road construction to occur near streams, culverts are the more cost-effective option as opposed to bridges (Poplar-Jeffers et al. 2008). There is a need to develop cost-effective culvert designs. Though better road designs and culvert instillation, a considerable amount of ecological function could be recovered to stream ecosystems.

HANGING CULVERTS

Over time erosion on the downstream side of the culvert will create a freefall condition, this is called a hanging or perched culvert. Hanging culverts are the cause for fragmentation in fish populations, particularly in streams. This results in creating upstream movement barriers. Habitat fragmentation is the subdivision of once-continuous disconnected patches, fragmentation is a threat to ecosystem integrity and species persistence globally (Park et al. 2008). Traditional management approach to build and regulate agencies has failed to prevent the development of hanging culverts and fragmentation of small boreal streams. Culverts are commonly used to provide crossings of low-order streams and can be a serious hindrance to up-stream movement of aquatic organisms (Park et al. 2008).

When a hanging culvert is established, it is usually caused by erosion of the stream bed below the stature of improperly installed culverts. Resource management agencies have regulations in place for proper culvert installation, work has been made to develop culvert design and installation protocols for minimizing negative effects on the surrounding area (Park et al. 2008). Monitoring of culverts and understanding the state of various culvert installation as well as after is limited, cumulative effects of stream habitat fragmentation causes hanging culvers and landscape scale damage (Park et al. 2008).

HABITAT STRUCTURE AND HIGHWAY CULVERTS

Within North America, beavers have cause substantial damage to roads though constructing dams around roadways and causing flooding. Since 1995, culvert blockage and road flooding were the two most reported types of beaver damage between Canada and the United States (Jensen et al 2001). Damages to roads tend to occur whenever a beaver plugs a culvert or constructs a dam near a roadside area, resulting in the impoundment of water that leaks onto a roadway. Damages to the road includes saturation, settling and the formation of potholes, which compromises the stability of the road (Jensen et al 2001). Economic and human safety play an important role in beaver damage, flooding and road washout cause serious concern – thousands of dollars are spent in the effort to repair beaver-obstructed culverts annually.

Temporary measure to deter beavers include wire-mesh culverts, T – culverts, Pitchfork guards, and water-level control devices. Other devises often used are intel guards which keeps sediment out, deep-water fencing to exclude beavers from plugging the intakes of culverts, and electric breach guards – an energized fence to keep beavers away form the culvert (Jensen et al 2001). Trapping has also been used to assist in elevating the issue, it is only necessary annually due to dispersing juvenile beavers. All these tactics are short-term methods, long-term well-developed beaver deterrents are needed for successful culvert management and operation. Studies have suggested that in terms of highway culverts, the instalments of larger culverts may be used to help deter beavers from colonizing the area. The source material suggests that the culverts can be expanded to at least $2.1m^2$ (of the inlet opening) for a 0% gradient stream and at least $0.8m^2$ for stream with gradients up to 3% to reduces plugging (up to at least 50%)

(Jensen et al 2001). This technique is also useful with other tactic being used, such as water level control devices downstream of the culvert. (Jenson et al 2001).

BEAVER CONTROL SCREEN FOR CULVERT PIPE

As an added deterrent to beavers in culvert monitoring and assessment, the beaver control screen was developed to attach to a steel culvert pipe during time of rising waster due to heavy rain or melting snow. Maintenance of roadway personnel's will often usually try to dismantle a beaver dam during its early stages of construction. When this happens, the beavers are often relocated to another area, as already stated, this tactic is often a short – term method as they tend to return to the original culvert site or move downstream and plug up the waterway (Fleury 2002). As a long-term deterrent, permanent screens have been developed to the mouths of culverts as a prevention method, this enables the beaver to plug the inlet out the culvert.

There have been many variations of screens for culverts, all depending on the culvert size, stream, or brook size, and water output. For one such screen, a cone-shaped screen attachment with a base and an apex and horizontal axis can be used to assist in deterring beavers from the culvert area. See appendix seven for diagram. (Fleury 2002). There are two sets of rods in this design, the first set are spaced apart and extend from the base of the apex, then disposed in a first conical layer. The second layer of rods are dispersed a conical layer inside the first set of rods. The second set extend towards the aspects of the screens, but only reach about one-half the distance of the first conical layer (Fleury 2002). The purpose of this invention is to protect the entire culvert against damages caused by water, prevent beavers from building dams on the end of the culvert or inside, and to preserve the natural habitat of aquatic animal life (predominantly fish).

CONTROL OF PROBLEM BEAVER

An older method used during the 1960's were beaver pipes, used most frequently in New Hampshire. The beaver pipe was designed with the use of fiber or wooden tube plugged at one end. About one-fourth of the pipe's circumference is perforated to allow water to flow. The pipes are placed though a beaver dam and the pipes height outlet will determine the thickness that will fit roughly into one end of the pipe (Henry et al 1963). The pipes are around 12 inches squared and approximately 24 feet long, for preparation the combined area of the openings in the pipe bottom should be at least double the cross-section are of the pipe. The procedure upon installing the pipe usual involve using a contour map of the area and determining the drainage of the problem area and the location.

The number of pipes required are determined by the width of the stream. The pipes are placed through the dam where the depth of the upstream water is the greatest (Henry et al 1963). Iron fencing stakes are driven into the bottom of the pond at both ends of each pipe and at couplings. In New Hampshire, beaver pipes are only used on small watersheds, from 4 to 10 square miles in area (Henry et al 1963). On a larger land base, culverts are used. Beaver pipe installations need regular maintenance for proper function, and maintenance requirements can vary with the season (Henry et al 1963). After installation, pipes should be checked a few days after for movements, after which, monthly inspections are necessary. Maintenance is usually done by the landowner, conservations officers, or other interested local people (volunteer environments groups (Henry et al 1963).

HABITAT INFLUENCING BEAVER DAMN ESTABLISHMENT

Beavers predominantly rely on plant composition and vegetation abundance in an upstream watershed when determining where to build their dam. Impounded water (like an enclosure) is the most important ecological factor that limits beaver habitat use (Barnes et al 1997). Beavers tend to build their dams in areas with high shoreline densities of woody vegetation. The diameters at which these vegetation densities are chosen are usually 1.5-2.4 cm, 2.5-3.4 cm, and 3.4-4.4 cm (Barnes et al 1997). Beavers tend to typically choose these stem sizes for dam construction because they ensure rapid construction of the dam, as well as optimal foraging while minimizing the risk of timber wolf predation (Barnes et al 1997).

Contrary to the popular opinion, food availability is not the main determining factor for choosing an optimal habitat dam site. The most significant habitat determinant for the location of a beaver dam is predominantly determined by upstream watershed area. Although food is a major determining factor for a dam site, woody vegetation in active dam sites and abandoned dam sites have been found more frequently than other determining facts, such as alders, other shrubs, conifers, and food sources (Barnes et al 1997). Beaver dams have been recorded to reach lengths of up to 652 meters, resulting in higher abundance of food availability. The longest beaver dam in the world has been recorded to reach around 850 meters and has existed for over 25 years in Alberta's Wood Buffalo National Park in the Athabasca Delta (Parks Canada 2017). The extending length of the beaver dam has allowed for a wide foraging range, but conclusively, is not the determining factor for a beaver dam site (Barnes et al 1997).

FLOW DEVICES WITH BEAVERS ALONG ROADWAYS

There has been ongoing conflict with the re-colonization of the massive historical range of beaver habitat and the widely inhabited area that has been claimed by humans. Actions that cause stress towards humans are felling of trees and shrubs, as well as impounded water that floods agricultural lands, timber structure, buildings, and roads, as well as causes erosion issues resulting in hanging culverts (Boyles et al 2009). As water freely flows though narrow channels and culverts (particularly steel culverts – resonating the sound of flowing water) beavers will tend to respond to this by constructing dams and impound water against the roadbeds, resulting in flooding and washouts (Boyles et al 2009). If culverts are left untreated after being plugged, the result could be as detrimental as the road being washed out altogether, resulting in an expensive, time-consuming road repair.

There are three ways to assist in beaver relief and the reduction of culvert pugging and flooding. Beaver Deceivers are designed to not only deny beaver access to culverts, but reduce the “feel” of running water, this is successful by spreading stream flow over a long perimeter (Boyles et al 2009). They are shaped to discourage damming behavior as well. The Castor Mater is a pipe system that is used with a filter called a Round Fence, which helps control water flow through an existing dam. The Round Fences help prevent beavers and debris from plugging the pipe that is directing water thought the dam. These flow devices can be efficient and cost-beneficial for resolving conflicts between humans and beavers. The Virginia Department of Transportation conducted a series of studies that aimed in determining potential benefits of using flow devices at chronic beaver damage sites. The department saved $8.37 for every $1 spent, totaling at $372,508 of resources saved per year. Prior to installation, maintenance of beaver damager revealed that for every $1 that the department spent, $0.39 were saved in resources, totaling at $116,165 (Boyles et al 2009).

DRAINAGE CULVERTS AS HABITAT

Small mammals such as weasels, martin, red squirrel, and deer mice tend to use culverts for passage during winter time. The use of culverts as corridors holds many variables, such as seasonality, openness and clearance, and noise. Study's have found that predators such as coyote will tend to avoid culverts due to high traffic noise from highways. Marten tends to be attracted to culverts with low clearance and high openness ratios, they prefer areas with dense canopy cover and a complex understory. However, high through culvert visibility is important for snowshoe hares. Weasels, as well as snowshoed hares prefers a high amount of vegetation around the culvert. Weasels rely on a hunting strategy that required traveling though burrows and runway systems where escape is easy (Clevenger et al 2002). Major highways, such as the Trans-Canada highway act as conduits, barriers, or filters for many animal populations in North America (Clevenger et al 2002).

For small and medium size mammals, drainage culverts can assist in mitigating the potential harmful effects of busy transportation corridors by providing linkages towards vital habitat (Clevenger et al 2002). Forest-associated mammal species tend to avoid open areas without overstory or shrub cover, culverts used by small species may act as a response to fragmentation of their habitat, thus mimicking the learned behaviour passed on by the surviving individuals who selected the appropriate culvert type for cross-highway travel (Clevenger et al 2002).

BARRIERS FOR FISH PASSAGE

Barriers such as culverts and dams can impose negative affects in habitat connectivity for fish species. Mitigation efforts are available, such as fishways, yet the process is typically expensive, and the budget constraints restrict the amount of restoration that could occur. Studying and modeling physical characteristics of barriers is challenging due to fish physiology and how it varies by species, hydrological conditions, as well as fish size. Physical barriers are also varied due to stream flow (Bourne et al 2001). In more recent studies, landscape ecology, much life fragmentation and patch dynamics have been used for aquatic systems in investing the impacts of barriers on various stream networks and catchments.

From a restoration stance for fish species, connectivity is based on the extent of the watershed and what is available once the barrier is removed. This approach to fish passage promotes a cost-benefit analysis: the next-to-optimal culvert is cheaper to restore than the most optimal, this is the most pragmatic solution. Caution is recommended when determining whether culverts are backwatered – some may appear to be passable at low flows yet act as barriers at high flow (Bourn et al 2001). Limiting factors of restoration in culvers include drop height and slope, resulting in the deterrents for juvenilia fish. When modifying culverts, for restoration, velocity, depth and/or jumps can vary based on the discharge rate. If fish dispersal or migration period coincide with period of high or low flow, then culvert modification should be a priority to accommodate the need of the aquatic life (Bourn et al 2001). Flow baffles may assist with brook trout and salmon during high flow rates, conversely – periods of low stream flow coincide with salmon migration; thus, modification must be conceded to increase water depth within the culvert (Bourn et al 2001).

MATERIALS AND METHODS

Upon visiting Albion Hills Conservation Area, removal of three steel culverts had begun. The purpose for the removal of the steel culvert was due to infrastructural frailer, predominantly exposure of the culverts, as well as soft foundation problems – causing the culverts to bend or "banana". Beavers are active around the conservation area, yet there was no use of barriers or other tactics mentioned within the literature review to mitigate the annual flooding that occurs within this lowland area.

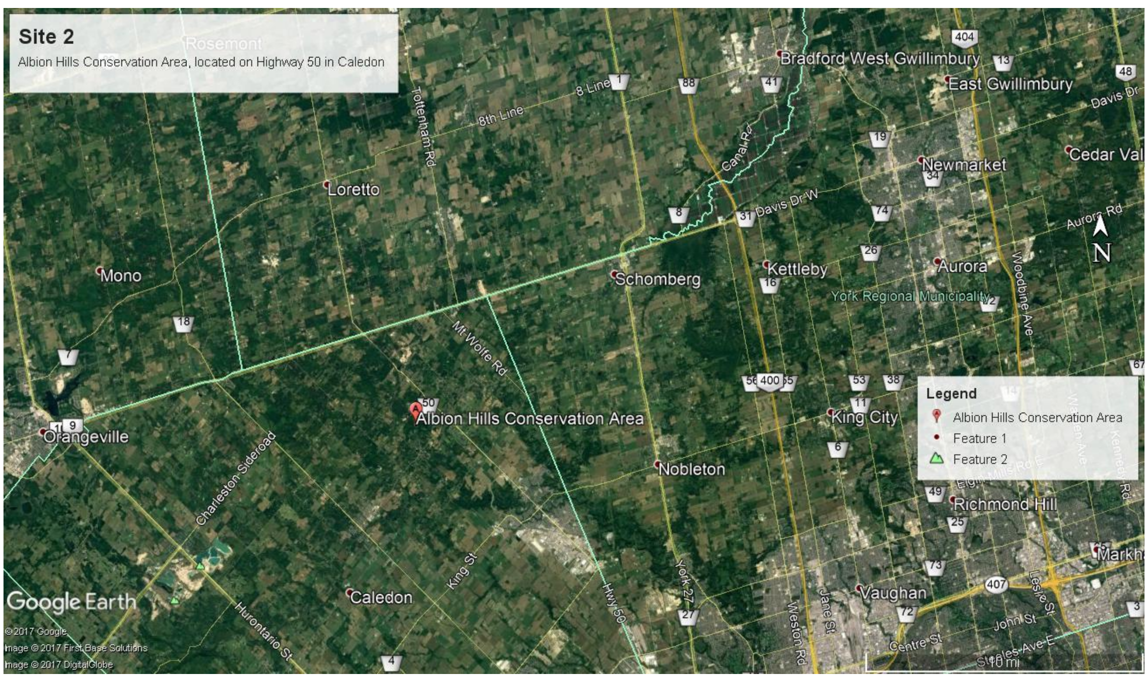

Figure 1. Map of first study site (Ewaskiw 2018)

As shown above, Albion Hills is located on the Etobicoke Creek watershed, home to 286,361 people and expands to about 59km long, draining an area of 211km^2 though the cities of Brampton, Mississauga, the City of Toronto, and the Town of Caledon. The Etobicoke Creek watershed currently consist of three major land uses:

27% rural, 68% urban, and 5% urbanized (TRCA 2018). The watershed houses 503 plant and animal species, river valleys and stream corridor represent 13.8% of the watershed.

Figure 2. Water pump from culvert extraction site at Albion Hills (Ewaskiw 2017)

The Toronto and Regions Conservation Authority provides a series of checklists for contractors when intending to preform a culvert removal. Criteria listed within the checklist for *culvert replacement and extension*s includes: identifying any dewatering/unwatering requirements, and how to mitigate opportunities, identifying the exact location of all watercourses and wetlands, dewatering and unwatering plans, showing groundwater and surface water from the work are will be treated prior to release to the natural environment (as shown in figure 2), engineering requirements, fish removal plan for any section of the water course, as well as a copy of the hydrology report and any recommendations (TRCA 2010).

Figure 3. View of metal culverts as prepping for extraction begins (Ewaskiw 2017)

Within the *culvert replacement and extension* document, the checklist requires that the contactor abided by the TRCAs standers, as mentioned above. Within the checklist, it states that the contractor must make confirmation on the scope of the work, as well as include site accesses, standing and storage, and proposed erosion and sediment control (TRCA 2010). Other requirements that are include is erosion and sediment control plans for the study area, which is states in the *Erosion and Sediment Control Guidelines of Urban Construction* (TRCA 2010). Under the *Water Crossings Inventory Instruction Manuel,* erosion of the three culverts were moderate, resulting in some erosion in the form of rills and gullies, as well as the loss of material form the fill slope and roadbed (MNR 2014).

Figure 4. View of roadway water crossing prior to culvert extraction (Ewaskiw 2017)

The TRCA's checklist requires a map showing the location, drawing numbers, and water courses crossing of the culvert removal area. Four copies of detailed design plans are require and must be signed and stamped by the MNR (Ministry of Natural Resources) showing: location of the watercourses/wetlands, size of the structure, construction access route (Shown in figure 4), isolation of the work are, phases and staging of construction, dewatering and unwatering plans – how groundwater and surface water from the work will be treated prior to the release to the natural environment (TRCA 2010). A culvert analysis must also be conducted thought the MTO, which considers the shape, size, material, in and outlet velocity, headwater elevation, tailwater elevation, and slope (MTO 2016). MTO approvals require a hydrology report, ensuring that the requirements for corridor, route and detail planning are met (MTO 2016).

Figure 5. view of metal culverts (Ewaskiw 2017)

Requirements for on-site storage are also indicated in the checklist, including the confirmation of the scope, site access, staging and storage, and the proposed erosion and sediment control (TRCA 2010). The TRCA provides another checklist, pertaining to debris removal for culvert maintenance, part of the criteria required is whether debris will be removed from the site (figure 5) and not reposition on the flood plain, and properly disposed off-site (TRCA 2014).

Figure 6. View of concrete culvers prior to installation (Ewaskiw 2017)

While the process of extraction was taking place, the concrete culvert arrived on site as the extraction progressed during the summertime. The durability and stability of the concrete foundation will provide excellent support for the water crossing as it will support multiple vehicles during the summertime. This water crossing acts as a linkage to one of the most used picnic areas of the park, as well as an area were large events typically take place. A concrete box culvert was desired for the low-fill stream. The soil compaction for this site was around 4.5kg/cm^2 and the soil was predominantly silty around the water.

Figure 7. Riparian preservation with silt fences (Ewaskie 2018)

Silt fencing was used to protect wildlife areas around the culvert extraction site. Figure 7 shows just one area where this barrier was used. Silt fencing was used to protect stream flow on both the inlet and the outlet portion of the culvert to not disrupt the flow even further.

Figure 8. View of setting the concreate culvert (Ewaskiw 2018)

On the second visit to Albion Hills during October, data was collected on the installation of the new concrete culvert. Upon re-evaluation of the vegetation abundance, site disturbance and soil compaction, other information was also gathered on the new culvert such as: upon laying down the concrete, it will take up to 28 days before the culvert can be driven on.

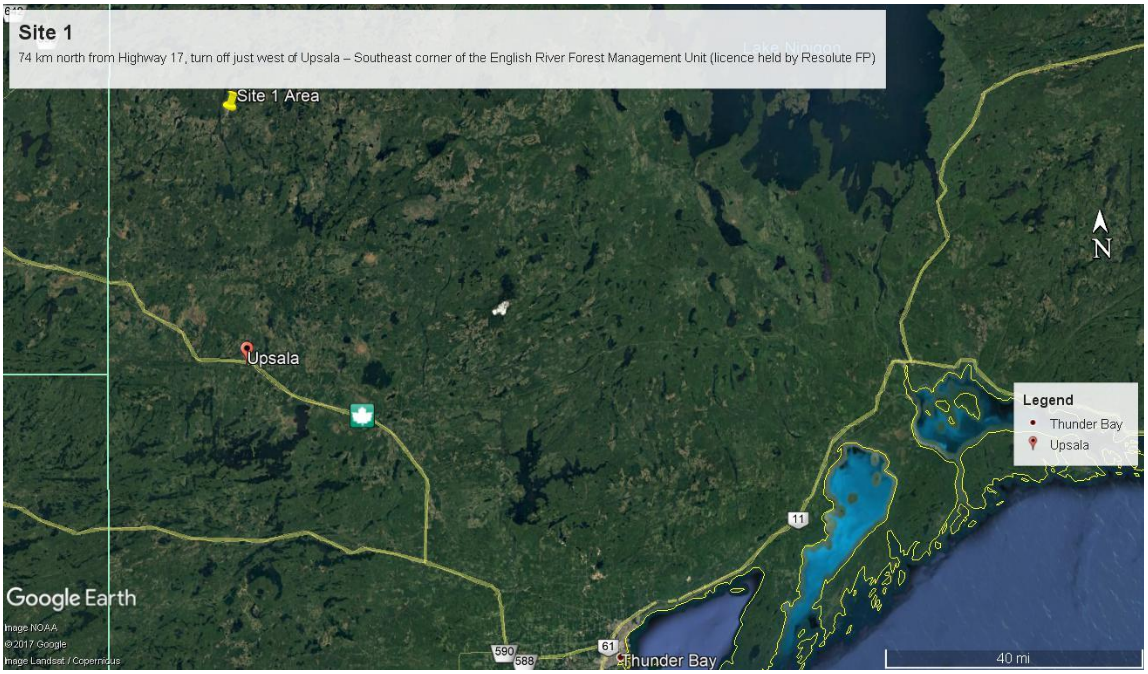

Figure 9. Map of second study site (Ewaskw 2018)

The second study site was located 74 km north from Highway 17, turn off just west of Upsala – Southeast corner of the English River Forest Management Unit (license held by Resolute FP). Culvert extraction was approximately 5-7 years ago – locations of each culvert are along deactivated roads. Three culvert extraction sites were analyzed: the third (control) had no water, first had standing water in a marsh area, and the second plot was in a running stream. There were three 15m^2 plots in the extracted culvert sites, plots were established using survey tape and rods. The plot analysis involved vegetation within and around the culvert, type of soil, compaction using a handheld soil compactor, vegetations abundance, and if animals use the area (scat, footprints). The methodology behind conducing this analysis was to survey the three plots and evaluate the abundance of plant species present, native, or non-native, live or dead, and possible height. Evaluations of other factors such as the type of road, stream analysis (presents of vegetation and aquatic life) and site description helped determine the characteristics that may be like that of site 1.

Figure 10. First culvert extraction site (Ewaskiw 2017)

The first plot that was examined was on an active road, leading to a deactivated road on the other side of the culvert extraction area. The soil type was primary cobble, organic mater and gravel surrounded by marshland. There was a standing stream present and it was about 0.5ft deep with high amount of vegetation in and around the area. Soil compaction was around 1.5kg/cm$^{2.}$ There was deep trenching on this site, no ground evidence of animal life, only the calls of songbirds were present, as shown in appendix 6.

Figure 11. Second culvert extraction site (Ewaskiw 2017)

The second plot that was evaluated was on a running stream on a one-sided active road, upon reaching the site, vegetation begins to overtake the road about 25 meters before entering the stream. There is low trenching with a soil type of loamy sand. Soil compaction was around 3.0-2.5kg.cm^2. The road leading up to the culvert was about 6m across. The stream is intermitted and contains algae, sand, and rocks with no aquatic life as shown in appendix 3. This location had a high amount of song bird activity, as well as evidence of squirrels and moose tracks (both older moose and caff). This sight also had the most amount of vegetation out of all three of the sites examined.

Figure 12. Third culvert extraction site – CONTROL (Ewaskiw 2017)

The third culvert site acted as a control for examining the landscape after a culvert removal. It sits in a lowland area on a fully deactivated road with very little regeneration as shown in appendix 2. There is no running water in the area, as well as a high amount of living native vegetation. The soil type is sandy, gravel, and clay with a compaction of 2.5-3.5kg/cm^2. The stream was dry and aliened with rocks. There is high evidence of animal life around the culvert area, such as song birds, moose scat, moose tracks and wolf tracks. Hidden camera footage provided by the second reader - Ryan Wilkie, provided evidence of black bears using this area for foraging and habitat linkage.

RESULTS

The result from the analysis conducted at Albion Hills concluded that the process for extraction of a highly populated area (such as the conservation area) caused issues towards the public, as well as the installation period was longer than anticipated. Complaints from park users were more prevalent this year than in previous years due to the abundance of construction equipment in the park, resulting in areas being blocked off for safety. Results also showed the process of extraction and the methods used to preserve habitat quality around the site. The results for the second site was to see how well the vegetation comeback was after a culvert removal on different soil sites, as well as to assess wildlife activity in the disturbed site. Wildlife that occupied all three areas were wolf, moose, small mammals, birds, and bears.

For the second site, the first plot analyzed was on cobble, organic and gravel soil, with a compaction of around 1.5 kg/cm. This site was located along a deactivated road. There was a presence of standing water within the culvert extraction site, with marshland around the boarder of the area. There was no evidence of large animals near the areas, only the presence of song birds. For calculation of the present of the assessment area (15m^2) covered by vegetation (living or dead) was around 7.2%. this was calculated by the sum of present vegetation (16 species found in the plot), multiplied by 100 and then divided by the total number of samples in the plot (220). The calculated percentage of the live vegetation that is living native groundcover was calculated using the total living native ground cover, multiplied by 100 and then divided by the total living ground cover, plus the total living non-native ground cover.

Conclusively, plot 1 had 92.3% presence of living native ground cover in the plot area. For more information see appendix five and six.

Plot 2 was located on a sand soil type, along a deactivated road with a soil compaction of 3.0-3.5kg/cm^2. There was an active running stream with a depth of 1.5ft. The stream was intermittent and contained alga, sand, and rocks. There was a high amount of song bird activity around the area, as well as evidence of moose *(Alce alces)* tracks (both young and old). Calculating the percent of the assessment (15m^2) covered by vegetation, the presence of any vegetation (19 samples) was multiplied by 100 and divided by the number of total samples in the plot (217). This resulted in 9% of the area studied being covered by vegetation. The calculated percentage of vegetation that is native groundcovers was calculated by the total presence of living native ground cover (15 samples), multiplied by 100, then divided by the total presence of living native ground cover (15 samples), pulse the total presence of living non-native ground cover (1 sample). Conclusively there are 93.75% living native ground cover in plot 2. For more information see appendix three and four.

Plot 3 acted as the control area due to the lack of water present at the site. This plot was located on a sandy, gravel, and clay area along a deactivated road. The compaction of the soil was around 2.5-3.5kg/cm^2. The stream bed of the culvert extraction site was dry, with rotten log and rocks present. There were song birds present, as well as moose *(Alce alces)* scat. There was also the presence of moose *(Alce alces)* and wolf *(Canis lupus)* footprints. There was video footage of black bears (*Ursus americanus)* occupying the area. For calculating the percent of the assessment area (15m^2) covered by vegetation, the presence of any vegetation (5 samples) was multiplied by 100 and divided by the number of total samples in the plot (103). This resulted in 5% of the area being covered by vegetation. The calculated percentage of vegetation that is native groundcovers was calculated by the total presence of living native ground cover (5 samples), multiplied by 100, then divided by the total presence of living native ground cover (5 samples), pulse the total presence of living non-native ground cover (none). Conclusively there was 100% living native ground cover in plot 3. For more information see appendix one and two.

DISCUSSION

It was not surprising to find that out of all three plots, plot 2 of site 2 had the most abundance of vegetation around the removal site, as there was a running stream present. Plot 3 of site 2 was the control site, and out of all three plots, it contains the most living native vegetation, as well as the most abundance of wildlife sightings and usage. The main purpose of this assessment was to see how well the vegetation comeback was after a culvert removal on different soil sites, as well as to assess wildlife activity in the disturbed site. Wildlife that occupied plot 2 and three the most were wolf (*canis lupus),* moose *(alces alces),* small mammals, birds *(Aves),* and black bears *(ursus americanus)*. One possibility for why wildlife used plot 3 the most is the amount of forest cover that is present within the English River Forest Management area. Prey wildlife such as moose would use the dense vegetation for foraging and cover against predators such as wolves (*canis lupus)*. As stated in the literature review, prey wildlife will typically use culverts as habitat corridors. Although no evidence of marten or weasels were shown in the culvert areas or on wildlife video footage, it can be assumed that small mammals such as these would use this culvert extraction sites as a corridor. It is unknown if beavers occupied the English River Management Unit area as there was no evidence when conducting the analysis.

The construction of the concrete box culvert at Albion Hills Conservation Area was able to follow the rules and regulation of Toronto and Regions Conservation Authority, as well as the Ontario governments standers for an environmental assessment. Although the process of extraction caused a substantial amount of aggravations towards the public, this upgrade was mandatory not only for the health of the stream, but it is an addition towards Albion Hills' Master Plan. Since the fall of 2013, Albion Hills has been working with the Public Advisory committee and public consultations to come up with a draft for the Master Plan, as well as the summary of comments received which is currently not available yet. Road degradation was prevalent throughout the years, exposer of the culvert was a result of a soft foundation and exposure to harsh whether.

The fish species most affected in the culvert extraction was brook trout *(Salvelinuus fontinalis)* and redside dace *(Clinostomus elongatus)*, both found in the Humber River and Credit Valley River. Redside dace is endangered under both the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the Species at Risk Act (SARA). The Humber rivers acts as a channel for the redside dace, providing passage into the lake Simco drainage basin, where they and other populations accounts for less than 10% of their global range and populations The Humber river is important habitat for the redside dace as its is apart of the headwaters, one of their primary habitats. The Humber river has silt and gravel substrates as well as overhanging grasses and shrubs. Development such as the culvert extraction could pose serious damage to the habitat requirements of this species, changes in stream structure such as channel widening or decrees in pool depth could causes serious threats to this species. Brook trout have also been found in the Humber river, they require habits in clear, cool, well oxygenated creeks and stream systems with water temperatures at 14-16 degrees Celsius. They also require a plentiful amount of cover from overhanging branches and fast running water with quite pools in between. Managing for this species can becomes difficult due to the many other requirements they have.

The analysis conducted at site 2 provided information about the vegetation that regenerated after multiple culvert removals over time. Soil type, water, and size of the culvert determine the vegetation abundance and therefore, provided the necessary features for animal life within the extraction area. For restoration purposes, knowing how much vegetation comeback and animal usage on different soil types in important for wildlife niches and habitat quality. Site 1 analyzed the process of extraction from a steel culvert to a concrete box culvert. This site was located in a lowland area that is annually flooding with spring run-off and is subjected to beaver dams. Suggestion that could have been brought towards the conservation area was the use of barriers such as the beaver deceivers or screens for the previous steel culvert. The use of these devices would have assisted with flood control and continuous road washouts. The use of beaver pipes, as stated in the literature review, could have been useful for downstream blockage as well, this could have mitigated flooding issues that the conservation area frequently faced. For fish passage, flow baffles in the corrugated culvert would have also assist in fish passage for brook trout and salmon (Poplar-Jeffers et al. 2008). A disadvantage to the new concrete culvert is that it has a wide flat bottom, this is problematic for fish passage and could cause obstruction during periods of normal to low flow (DFO 2015). Culvert barriers can be expensive and complex due to the consideration of several factors throughout this thesis. Management for beaver blockage and wildlife usage is unavoidable, and proper precautionary measure for terrestrial and aquatic usage is critical for balance between habitat functionality and human activity.

CONCLUSION

Conclusively, we can agree with the hypothesized objective: Improvement in maintaining culverts so that they do not cause extensive stress towards the surrounding habitat is possible though careful planning, barriers, and continuous maintenance. Features that can be implement towards culvert maintenance includes guards, water poles, relocation of nuisance beavers, re-evaluations of the size of the culvert to allow for better fish passage, and other methods. Maintaining an active culvert is critical for both terrestrial and aquatic wildlife. It has been proven that small mammals use functioning culverts as linkage corridors for reproductive sites and foraging, especially in the winter time. It has also been proven that hanging culverts, as well as culverts that experience blockage pose issues for fish passage way and migration patterns. Ideally for fish passage in the new concrete box culvert, management practices will need to be put in place during normal and low flow. Through proper maintenances, issues such as blockages, bent culverts, and perched culverts, can be mitigated to avoid damages to wildlife usage.

The results presented from the Upsala site showed that wildlife was actively using the areas where the culverts were extracted. There were differences in vegetation abundance, age, and comeback, but overall the vegetation availability for species was not overly degraded to the point were there was no wildlife in the areas, or vegetation completely degraded and therefor unusable due to poor soil composition. It is important to note that these findings can be used for determining vegetation comeback around the installed concrete box culvert. Plot 2 of site 2 shares a similar soil type with site 1, therefor we can determine that in the same approximate amount of time, vegetation will become as abundant as that of plot 2. Obvious facts that differ between the two is the presents of a new culvert, but conclusively, vegetation around the edge and around the culvert will have similar comeback in the same amount of time. Culvert installation, removal, and maintenance are critical for wildlife and human use. The public depend on fully functioning water crossings for transportation and infrastructure security. Without proper maintenance, consequences such as vehical hydroplaning, road washouts, and loss of habitat will be the ending result. Thought careful planning, properly completed environmental assessments, long-term management solutions such as barriers, and foresight towards issues pertaining to beavers and watershed damming, we can manage human caused environmental disturbances more efficiently and therefore, develop and improve our ways of maintaining culverts so that they do not cause extensive damage to the surrounding habitat for plant species, animals, and humans.

LITERATURE CITED

Albion Hills conservations area master plan. Toronto and regions conservation authority. 2018. https://trca.ca/conservation/greenspace-management/conservation-land-care/albion-hills-master-plan/.

Barnes, D. M., and Mallik, A. U. Habitat factors influencing beaver dam establishment in a northern Ontario watershed. 1997. The journal of wildlife management. 61(4): 1371-1377.

Bourne, M. C., Kehler, G. D. Wiersma, F. Y. Cote, D. Barriers to fish passage and barriers to fish passage assessments: the impact of assessment methods and assumptions on barrier identification and qualification of watershed connectivity. Aquatic ecology. 2011. 45(3) 389-403.

Boyles, L. S., and Savizky, A. B. An analysis of the efficacy comparative cost of using floe devices to resolve conflict with north American beavers along roadways in the coastal plain of Virginia. University of California. 2009. 47-52. https://cloudfront.escholarship.org/dist/prd/content/qt3v67w722/qt3v67w722.pdf

Clevenger, P. A., Chruszcz, B. Gunson, K. Drainage culverts as habitat linkage and factors affecting passage by mammals. Journal of applied ecology. 2002. 38(6).

Culvert replacements and extensions. Toronto and regions conservation authority. 2010. https://trca.ca/app/uploads/2016/02/Culvert_Replacements_and_Extensions_-_Checklist.pdf

Debris removal for culvert maintnece. Toronto and regions conservation authority. 2014. https://trca.ca/app/uploads/2016/02/Debris_Removal_for_Culvert_Maintenance___Exemptions_-_Jan_27_2014.pdf

Etobicoke creek watershed. Toronto and regions conservation authority. 2018. https://trca.ca/conservation/watershed-management/etobicoke-mimico-creek/watershed-features/.

Fleury, M. Beaver control screen for culvert pipe. Faune-Experts Inc. 2002. https://patentimages.storage.googleapis.com/3e/f2/47/d604631a66e529/US6447206.pdf.

Guidelines for design of fish passage for culvert in Nova Scotia. Fisheries and oceans Canada. 2014. http://www.dfo-mpo.gc.ca/Library/353873.pdf

Henry, A. and Laramie, Jr. A device for control of problem beavers. 1963. The journal of wildlife management. 27(3): 472-276.

Jensen, P. G., P. D. Curtis, M. E. Lehnert, and D. L. Hamelin. Habitat and structure factures influencing beaver interference with highway culverts. 2001. Wildlife society bulletin. 29(2): 654-664.

Estimated material service life of drainage pipes. Ontario concrete pipe association. 2010.http://www.ocpa.com/getblob.php?table=technical_articles&field=pdf&_ID=17&file=Estimated_Material_Service_Life_of_Drainage_Pipes

Park, D., M. Sullivan, E. Bayne, and G. Scrimgeour. 2008. Landscape-level stream fragmentation caused by hanging culverts along roads in Alberta's boreal forest. NRC Canada. 1 (38): 566-575.

Preforming the hydraulic design. Ministry of transportation. 2016. http://www.mto.gov.on.ca/english/publications/drainage/hydrology/section7.shtml

Poplar-Jeffers, O.I., J. T. Petty, J. T. Anderson, S. J. Kite, M. P. Strager, R. H. Fortney. 2008. Culvert replacement and Stream habitat restoration: implications from brook trout management in an Appalachian watershed, U.S.A. Restoration ecology. 17(3): 404-413.

Redside dace. Fisheries and oceans Canada. 2017. http://www.dfo-mpo.gc.ca/species-especes/profiles-profils/redsidedace-menelong-eng.html.

Wood buffalo national park. Parks Canada. 2017. https://www.pc.gc.ca/en/pn-np/nt/woodbuffalo/decouvrir-discover/beaver_gallery

Water crossing inventory instruction manuel. Ministry of natural resource. 2004. http://files.ontario.ca/environment-and-energy/crown-land/mnr_e005022.pdf

APPENDIX I

plot 3 control

Vegetation and Soil analysis around culvert removal site sheet

October 3rd, 2017 Alysia Ewaskiw

Location: Resolute Forest licence, North of upsala

Plot size 12.5 m

Table 1. Species analyses

Species	Native	Non-native	Live	Dead	Height (cm)	Total
Pearly everlasting	X		X			
Hawkweed	X					
Alder	X					
Common green peatmoss	X					
Bog goldenrod						

Soil type: Sandy, gravelly, clay

Soil compaction around culvert: enterance side 3.5 kg/cm²
far side: 2.5 kg/cm²

Stream present: none.

Stream analysis: Dry, rotten logs and rocks

APPENDIX II

Site decryption (animal description, health, damage, debris):

- Plentiful grown veg.
- hardly no regeneration due to soil
- lowland area

Evidence of animal use (scat, Food, prints, fish...):

- Song birds present
- hardly any bugs
- moose scat
- moose prints, wolf prints

Road description (erosion, degradation, type…):

- Both sides completly deactivated, walk in access, over 25 m walk in

Calculations of vegetation

D = Presence of any vegetation (living or dead)

E = Presence of living native groundcover

F = Presence of living non-native groundcover

Calculated percent of the assessment area (m^2) coverd by vegetation (living or dead)

$$\frac{Sum\ of\ D \times 100}{Number\ of\ total\ samples\ in\ plot}$$

APPENDIX III

Plot 2

Vegetation and Soil analysis around culvert removal site sheet

October 3rd, 2017 Alysia Ewaskiw

Location: Resolute Forest licence

Plot size ~~25m²~~ ~~25m~~ x 6m
12.5m

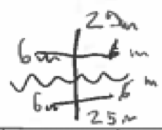

Table 1. Species analyses

Species	Native	Non-native	Live	Dead	Height (cm)	Total
Pearley Everlasting	X		X		40-60	13
〃	〃			X	40-60	10
Bog goldenrod	X			X	1m	+25
Black spruce			X		5cm-1.5m	16
Cedar	X		X		20-1.5	3
Alder	X		X		40-1m	+25
Rough Bedstraw ~~[illegible]~~	X		X		20	1
Bunch B.	X		X		5	+25-280
Scots pine		X	X		20	3
interrupted club moss	X		X		1	20%
Poor-Fen Peat moss	X		X		1	20%
Juniper moss	X		X		1	20%
Common green peat moss	X		X		1	20%
Rose-Twisted Stalk	X		X		2 dm	1
Creeping Snowberry	X		X		20-40	+25
leather leaf	X		X		10-40	+25
labrador tea	X		X		10-40	+20
Common Pinmoss	X		X		7 cm	+20
Cat tails	X			X	15	4

Soil type: Sand, active side compaction ≈ 3.0Kg/cm²
non-active side compaction ≈ 3.5Kg/cm²

Soil compaction around culvert: road lifted, high trenched along road, not able to get in, road 6m across

Stream present:

Stream analysis: active 1/2ft stream, intermittent
Stream contains alge, sand, and rocks both in and along stream

APPENDIX IV

Site decryption (animal description, health, damage, debris):

-low trenching, good condition, high Sedge, alder, ceder and spruce yeald

Evidence of animal use (scat, Food, prints, fish...):

-fish bird activity, high nut activity, moose tracks (calf and older)
->song birds (chichadees)
-squerrls

Road description (erosion, degradation, type…):

"active" on one side, non-active on the other, active portion is being taken over by nature, have to walk 25m to site, un-drivable

Calculations of vegetation

D = Presence of any vegetation (living or dead)

E = Presence of living native groundcover

F = Presence of living non-native groundcover

Calculated percent of the assessment area (m^2) coverd by vegetation (living or dead)

$$\frac{Sum\ of\ D \times 100}{Number\ of\ total\ samples\ in\ plot}$$

APPENDIX V

Culverts taken out 2012-2017

1st plot

· Resolute Forest licence

Vegetation and Soil analysis around culvert removal site sheet

October 3rd, 2017

Alysia Ewaskiw

Location: active road, to deactivated road, south of Bright sand conservation area, north of wagner Land

Plot size ~~25~~ m² 12.5

Table 1. Species analyses

Species	Native	Non-native	Live	Dead	Height (cm)	Total
Bog golden rod	X			X	1 m	+25
Cattail	X			X	5 cm	3
Sedge	X		X		25 cm	+25
Alder	X		X		1 m	18
Wulf's peat moss	X		X		1 cm	25 %
Black spruce	X		X		10-1 [illegible]	+25
Scots pine		X				
Pitch weed 1 Midway peat moss	X		X		1 cm	15%
Pearly everlasting	X				3 - 25 cm	+25
(grass) Redtop	X			X	1.5 m	+25
woolgrass	X		X		1.5 m	15
Dogwood	X		X		3 cm	+25
(fern) Interrupted	X		X		2 cm	~~7~~
clubmoss	X		X		1 cm	15%
Bunch Berry	X		X		1 cm	40%
Broom moss	X		X		1	100%

Soil type: Cobble, organic, gravel ~~[illegible]~~

Soil compaction around culvert: (abandoned road = 1.5 Kg/cm) (active road =

Stream present: standing water, marshy area

Stream analysis: 1/2 Ft deep, highly vegatated

APPENDIX VI

Site decryption (animal description, health, damage, debris):

- nats
- heavily vegatated abandond road
- marshy swamp

Evidence of animal use (scat. Food, prints, fish...):

- no prints
- no scat
- Birds "song birds"
-

Road description (erosion, degradation, type…):

- rock and cable
- eroded sediment into standing water
- moss and vegetation overtaking

Calculations of vegetation

D = Presence of any vegetation (living or dead)

E = Presence of living native groundcover

F = Presence of living non-native groundcover

Calculated percent of the assessment area (m^2) coverd by vegetation (living or dead)

$$\frac{Sum\ of\ D \times 100}{Number\ of\ total\ samples\ in\ plot}$$

APPENDIX VII