REPORT

Prince Edward County

County Road 49 Road Condition Assessment and Rehabilitation Options
Final Report

January 2019
Executive Summary

1 INTRODUCTION

Associated Engineering (Ont.) Ltd, (AE) was retained by the County of Prince Edward County (the County) in July 2017, to provide consulting engineering services pertaining to County Road 49 Road Condition Assessment and Rehabilitation Options. The purpose of this study is to assess the current condition of 17.3 kilometers of County Road 49 including drainage and roadside safety and provide rehabilitation or replacement options complete with cost estimates along County Road 49 from County Road 6 to County Road 15.

The following condition assessments were conducted to determine the overall condition of the road environment:

- Road Condition Assessment using MTO Condition Assessment Criteria,
- Geotechnical Investigation;
- Intersection Geometry Assessment,
- Roadside Drainage Assessment, and
- Roadside Safety Assessment including condition assessment of existing guide rail systems.

There are six road rehabilitation options that were considered for County Road 49, which include:

- Option 1: Rubblize concrete pavement and replace with hot mix asphaltic (HMA) pavement
- Option 2: Rubblize concrete pavement and replace with Portland Cement Concrete (PCC) pavement
- Option 3: Remove and haul away concrete pavement and replace with HMA pavement
- Option 4: Remove and haul away concrete pavement and replace with PCC pavement
- Option 5: Repair existing concrete and overlay PCC pavement
- Option 6: Repair existing concrete and overlay HMA pavement

2 RECOMMENDED ROAD REHABILITATION OPTION

The overall condition of the road was deemed to be poor and in need of replacement within the immediate future. It is recommended that the rehabilitation method chosen be applied to the entire 17.3km of roadway. When rehabilitation is being completed to County Road 49, it is recommended that improvements made to roadside safety including repairing or upgrading existing guide rails and installing guide rails in areas containing unprotected hazards. It is also recommended that culvert and drainage improvements be made.

A 30-year life cycle cost analysis was undertaken for the six options, considering the capital costs to rehabilitate the existing road and anticipated maintenance costs over a 30-year period.

The estimation of probable capital costs (Class D +/- 30%) for the various options are as follows:
Option 1: Rubblize concrete pavement and replace with hot mix asphaltic (HMA) pavement = $18.3 million
Option 2: Rubblize concrete pavement and replace with PCC pavement = $23.0 million
Option 3: Remove and haul away concrete pavement and replace with HMA pavement = $21.7 million
Option 4: Remove and haul away concrete pavement and replace with PCC pavement = $26.2 million
Option 5: Repair existing concrete and overlay PCC pavement = $47.2 million
Option 6: Repair existing concrete and overlay HMA pavement = $42.0 million

Option 1 has the lowest capital cost. However, Option 2, has the lowest net present value (NPV) for discount rates in the range of 0% to 4% for the 30-year life cycle. At discount rates higher than this, Option 1 becomes the more cost-effective option over the 30-year life cycle. It is also noted that these NPVs are based on a number of assumptions over the 30 years, and so neither Option 1 or 2 should be ruled out one way or the other based on this analysis alone. Figure E-1 shows the net present value of the options over a 30-year life cycle period and over a range of combined discount rates.

Figure E-1: Sensitivity Analysis to Combined Discount Rate for 30 Year Life Cycle

The graph shows that when the combined discount rates increase beyond 8%, Option 1 will still have the lowest net present value over the 30-year life cycle.

Given this, it is recommended that Option 1 and 2 be carried forward into the preliminary and detailed design stage, for further evaluation.

Option 1 involves rubblizing the existing concrete pavement and levelling with a layer of HMA to serve as the base for the rehabilitated road. A layer of Heavy Duty Binder Course (HDBC) HMA would then be
overlaid on the base followed by the HMA road surface. The recommended pavement structure design and associated layer thicknesses are as follows:

- 550 mm – existing granular material
- 225 mm – rubblized concrete
- 50 mm – HL3(HS) HMA
- 60 mm – HDBC HMA
- 40 mm – HL1 HMA

Option 2 involves rubblizing the existing concrete pavement and levelling with a layer of hot mix asphalt (HMA) to serve as the base for the rehabilitated road. The road surface recommended by Englobe would be composed of PCC (CSA Cat-2, 32 MPa, AE, 40 mm aggregate size). The pavement structure design and associated layer thicknesses recommended by Englobe are as follows:

- 550 mm – existing granular material
- 225 mm – rubblized concrete
- 100 mm – Granular A crusher run limestone
- 200 mm – PCC
3 CAPITAL COST SUMMARY

Tables E-1 and E-2 present high level estimated costs for the full project including road reconstruction, roadside safety improvements and culvert rehabilitation for Options 1 and 2. Estimates are construction costs with a contingency of 20%.

Table E-1: Full Estimated Construction Costs (Option 1)

<table>
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<tr>
<td>Road Reconstruction</td>
<td>$13,833,916</td>
</tr>
<tr>
<td>Roadside Safety Improvements</td>
<td>$300,000</td>
</tr>
<tr>
<td>Drainage Improvements</td>
<td>$200,000</td>
</tr>
<tr>
<td>Contingency (20%)</td>
<td>$2,635,032</td>
</tr>
<tr>
<td>Engineering Fees (10%)</td>
<td>$1,317,516</td>
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<tr>
<td><strong>Total Fees</strong></td>
<td><strong>$18,286,464</strong></td>
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1 Introduction

Associated Engineering (Ont.) Ltd, (AE) was retained by Prince Edward County (the County) in July 2017, to provide consulting engineering services pertaining to County Road 49 Road Condition Assessment and Rehabilitation Options.

1.1 STUDY BACKGROUND

County Road 49 was originally constructed in the 1950’s by the Ontario Ministry of Transportation as a rigid concrete cement two-lane roadway with gravel shoulders. In 1998, County Road 49 was turned over to the County. It has undergone numerous patch and spot repairs; and although these measures have prolonged the life of the road, County Road 49 can no longer be repaired by these measures. The surface is littered with severe joint failures, severe longitudinal and meandering cracking, severe transverse cracking and severe polishing of surface. In 2013 and 2016 staff conducted a basic condition evaluation and determined the road is at the end of its useful life. The road is an arterial roadway that currently services commercial traffic, facilitates municipality’s tourism and hospitality sector and supports many County resident’s everyday travels. County Road 49 has a posted speed of 80 km/h and sees traffic in the range of 3,500 to 4,800 AADT with approximately 5% heavy truck traffic.

1.2 STUDY PURPOSE & METHODOLOGY

The purpose of this study is to assess the current condition of 17.3 kilometers of Country Road 49 including drainage and roadside safety and provide rehabilitation or replacement options complete with cost estimates along County Road 49 from County Road 6 to County Road 15. Figure 1-1 shows the study area.

The following condition assessments were conducted to determine the overall condition of the road environment:

- Road Condition Assessment using MTO Condition Assessment Criteria,
- Geotechnical Investigation;
- Intersection Geometry Assessment,
- Roadside Drainage Assessment, and

Figure 1-1: Study Area
Roadside Safety Assessment including condition assessment of existing guide rail systems.

After determining the overall condition of the road, suitable rehabilitation or replacement options will be generated and evaluated based on traffic impacts and costs. The best option will be carried forward into a preliminary design, complete with estimated capital costs. The report generated as the overall deliverable of this study will be the basis of the County’s application for funding from the provincial government.

In the future, the County will move forward with a detail design and construction of this road. Since this study will only produce a conceptual design, a survey was not completed. When beginning the preliminary and detailed design, a full survey should be completed to obtain an accurate inventory of all guide rail systems, unprotected hazards, and culverts.
2 Existing Condition Assessments

2.1 DATA INVENTORY AND GAP ANALYSIS

The County provided AE with the following background information to complete the analysis:

- County Road 49 As-Constructed drawings from Spencer Street to Folkard Lane (Contract 2008-PW-008)
- County Road 49 As-Constructed drawings from at County Road 15 (Contract 2010-PW-002)
- County Road 49 Traffic Counts at three locations:
  - 75m north of Folkard Lane;
  - 500m north of County Road 6; and
  - 350m south of County Road 15
- Traffic Survey at two intersections:
  - County Road 49 and County Road 15; and
  - County Road 49 and White Chapel Road
- GIS Shapefile containing 50cm contours for study area
- Orthographic Imagery of entire area
- 2013 Road Condition Assessment
- 2016 Road Condition Assessment
- Deficiency pictures

2.2 ROAD CONDITION ASSESSMENT

To assess the road condition along Country Road 49, AE following the Ministry of Transportation (MTO) SP-026: Manual for Condition Rating of Rigid Pavements (Concrete Surface and Composite Distress Manifestations), September 1995. Trained field staff conducted the road condition assessment in August 2017. To conduct the assessment, the road was broken into one (1) kilometer sections, starting from the north.

The first part of the assessment involved driving the road at the posted speed to determine the ride condition rating (RCR). This is a qualitative assessment to determine how smooth the ride is, with ratings ranging from 1 (very poor condition, dangerous to drive at posted speed) to 10 (excellent condition, very smooth and pleasant drive at posted speed). Figure A1 in Appendix A shows the RCR for each segment. On the day of the assessment, the average RCR along the road was 4.

The second part of the assessment involved determining the distress manifestation index (DMI), which is a measure of the pavement distresses based on the severity and density of various types of distresses. Field staff looked at what types of distresses were present within each segment of road (defined in Table 2.1 below), how severe these distresses were (on a scale of 1 – very slight to 5 – very severe) and to what extent (the frequency) these distresses covered the road segment (<10% - few, 10-20% - intermittent, 20-50% - frequent, 50-80% - extensive, 80-100% - throughout).
### Table 2-1: Pavement Distress Types

<table>
<thead>
<tr>
<th>Pavement Distress</th>
<th>Definition</th>
</tr>
</thead>
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<tr>
<td><strong>Surface Defects</strong></td>
<td></td>
</tr>
<tr>
<td>Ravelling &amp; Coarse Aggregate Loss</td>
<td>Coarse aggregate particles have been removed from the pavement surface or fine aggregate has been lost from the pavement surface matrix</td>
</tr>
<tr>
<td>Polishing</td>
<td>Polished appearance of pavement surface due to glazing of coarse aggregate particles in mix</td>
</tr>
<tr>
<td>Scaling</td>
<td>Peeling away of the concrete surface</td>
</tr>
<tr>
<td>Potholing</td>
<td>Bowl-shaped depressions or holes in the pavement surface, unrelated to cracking or other surface defects.</td>
</tr>
<tr>
<td><strong>Joint &amp; Crack</strong></td>
<td></td>
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<tr>
<td>Spalling</td>
<td>The breaking or chipping of the pavement at joints and cracks, usually resulting in fragments with feathered edges or potholes.</td>
</tr>
<tr>
<td>Faulting (stepping)</td>
<td>Differential vertical displacement of abutting slabs at joints or cracks, creating a “step” deformation in the pavement surface.</td>
</tr>
<tr>
<td>Distortion (sagging &amp; slab warping)</td>
<td>A longitudinal deviation of the pavement surface from its original profile. Permanent slab distortion either bends downwards or upwards.</td>
</tr>
<tr>
<td><strong>Joint Deficiencies</strong></td>
<td></td>
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<tr>
<td>Joint Sealant Loss</td>
<td>Transverse or longitudinal joint sealant is squeezed out or pulled out of the joint.</td>
</tr>
<tr>
<td>Transverse Joint Creep</td>
<td>One lane’s transverse joint moves ahead or behind the one in the adjacent lane.</td>
</tr>
<tr>
<td>Longitudinal Joint Separation</td>
<td>Separation of two adjacent lanes along the longitudinal joint.</td>
</tr>
<tr>
<td><strong>Cracking</strong></td>
<td></td>
</tr>
<tr>
<td>Joint Failures (blow-ups)</td>
<td>Excessive breakdown or localized upward movement of slab adjacent to joint.</td>
</tr>
<tr>
<td>Longitudinal &amp; Meandering</td>
<td>Cracks which follow a course approximately parallel to the centreline of the pavement and are generally quite straight; or cracks which wander serpent-like across the traffic lane.</td>
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<tr>
<td>Diagonal Corner &amp; Edge Crescent</td>
<td>Diagonal and corner cracks form a triangle between a longitudinal edge or joint and a transverse joint or crack. Edge crescent cracks form an arc from the edge of pavement, with the centre located at a transverse joint of crack.</td>
</tr>
<tr>
<td>“D”</td>
<td>Closely spaced, fine, crescent-shaped cracks in the concrete surface, usually parallel to a joint or major crack, and usually curving across slab corners.</td>
</tr>
<tr>
<td>Transverse</td>
<td>Generally a single crack which follows a course approximately at right angles to the pavement centreline. Usually a single crack.</td>
</tr>
</tbody>
</table>
Some of the more prevalent distresses found on County Road 49 include: raveling and coarse aggregate loss, polishing, joint and crack sealing, transverse joint creep, joint failures (blow ups), longitudinal and meandering cracking, and transverse cracking. Figure 2-1 below shows various defects found on County Road 49 during the road condition assessment.

Figure 2-1: County Road 49 Defects

To determine the DMI, weightings are assigned to each distress, and the following calculation is applied based on MTO standards:

$$DMI = 10 \times (196 - \text{summation of } W \times (D+S))/196$$

Where $W$ is the weighting of each distress, $D$ is the density of each distress, and $S$ is the severity of each distress. DMI’s for County Road 49 ranged from 2.2 to 5.4, with the average being 3.64.

The RCR and DMI is used to calculate the pavement condition index (PCI), which is determined as follows and based on MTO standards:

$$PCI = 35.5 + (7 \times DMI) - (11 \times \exp((10.37-RCR)/4.77))$$

PCI results range from 0 to 100, and the higher the PCI, the better the condition of the road. PCI’s ranged from 0 to 45.5, with the average PCI being 19.5. The PCI for each segment can be found in Figure A2 of Appendix A.

The complete Rigid Pavement Condition Evaluation Forms used by AE's field staff for each road segment can also be found Appendix A.
The results of this road condition assessment are similar to the results found by the assessment completed by County staff.

2.3 GEOTECHNICAL ASSESSMENT

A geotechnical investigation was conducted along the 17.3 km of County Road 49 in October 2017 by Englobe Corporation (Englobe). The full geotechnical report is provided under a separate cover. A Ground Penetrating Radar Investigation was also undertaken by Englobe and the results are provided in a report under a separate over as well. A description of ground penetrating radar technology for pavement thickness estimation is provided in Section 2.3.3.

2.3.1 Existing Pavement Structure

County Road 49 is a Portland Cement Concrete (PCC) paved road that runs in a north-south direction in Prince Edward County, Ontario. The geotechnical investigation that was completed for County Road 49 included 36 boreholes. Results from the testing showed that there is a consistent concrete layer with a thick granular base along the entire segment; however, in some areas there is shallow bedrock. Table 2-2 below shows the existing pavement structure.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Average Thickness/ Depth (mm)</th>
<th>Thickness Range/ Depth (mm)</th>
<th>$F'_c$ (MPa)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforcement</td>
<td>105</td>
<td>60 – 140</td>
<td>NA</td>
<td>cover</td>
</tr>
<tr>
<td>PCC</td>
<td>227</td>
<td>190 – 255</td>
<td>44 (33.6 – 52.3)</td>
<td></td>
</tr>
<tr>
<td>Granular Base/Subbase</td>
<td>1218</td>
<td>385* – 1970</td>
<td>-</td>
<td>* shallow bedrock</td>
</tr>
</tbody>
</table>

The existing pavement is composed of a granular base/subbase, followed by a surface layer of reinforced Portland Cement Concrete (PCC). The average depth of reinforcement (measured from the road surface) is 105 mm, with measured depths ranging from 65 mm to 140 mm for the borehole samples collected. The average thickness of PCC is 227 mm, with thicknesses ranging from 190 mm to 255 mm. The average compressive strength for the existing PCC is 44 MPa, with samples ranging from 33.6 MPa to 52.3 MPa. The granular base and subbase has an average thickness of 1218 mm, with thicknesses ranging from 385 mm (in locations comprised of shallow bedrock) to 1970 mm.

For the full results of the geotechnical investigation, see Englobe’s Geotechnical Investigation for County Road 49 report, provided under a separate cover.
2.3.2 Existing Pavement Conditions

The existing pavement condition was visually assessed by Englobe to evaluate options for road reconstruction or rehabilitation. The pavement condition was rated from fair to poor and all joints were in poor condition. There is a lane shoulder drop-off and a lack of crossfall. Both transverse cracking and longitudinal cracking and subsequent repairs were seen throughout the entire length of the study area. This indicates poor load transfer from slab to slab. Load transfer dowels were used in the construction of the original road in 1968; however, they do not seem to be performing as required to keep the deflection in the road to a minimum. Figure 2-2 below shows the typical road conditions including the longitudinal cracking and subsequent repairs that are also failing.

Surface cracking was also observed in the form of Alkali Silica Reactivity (ASR). ASR is a swelling reaction that occurs over time in concrete between the highly alkaline cement paste and the reactive non-crystalline silica found in many common aggregates, if give sufficient moisture conditions. This swelling will cause spalling in the concrete and will eventually lead to the concrete’s failure. Once this ASR cracking is observed, it will continue to crack until the concrete fails. Figure 2-3 below provides an example of ASR cracking on County Road 49.
It is recommended that whichever remedial action be taken, it be applied to the entire 17.3 km length of County Road 49. The viable options for the proposed rehabilitation of the pavement structure will be discussed in Section 3.

An in-depth analysis of the existing pavement condition is included in the Englobe Geotechnical Investigation provided under a separate cover.

2.3.3 Ground Penetrating Radar (GPR) Investigation

Englobe was retained to conduct a Ground Penetrating Radar (GPR) survey with the intent of identifying the thickness of the pavement structure along County Road 49 for the length of the project site. GPR technology uses changes in radar frequency to determine pavement structure thicknesses. GPR data is processed by identifying reflections caused by changes in the electrical properties of materials. The reflections are digitized and converted into layer thickness using a digital software. The GPR data collected was calibrated using the borehole data collected.

An in-depth analysis of the pavement structure in included in the Englobe Ground Penetrating Radar Investigation Report provided under a separate cover.

2.4 ROAD AND INTERSECTION GEOMETRY ASSESSMENT

Currently, County Road 49 is a two-lane rigid concrete cement road with gravel shoulders. It is an arterial roadway with a posted speed of 80 km/h. The current AADT is between 3,500 to 4,800 AADT with approximately 5% heavy truck traffic. The shoulders are not paved and do not have consistent levels of
gravel, which does not make it user friendly for non-motorized vehicles. The existing cross section of County Road 49 is shown below in Figure 2-4.

Figure 2-4: Existing Cross Section of County Road 49

2.4.1 County Road 49 and County Road 15

County Road 15 is a two-lane hard-top rural road that approaches County Road 49 at approximately a 90-degree angle. It is stop-controlled with a stop bar. Travelling along County Road 49 southbound, there is a southbound right-turn lane for traffic turning onto westbound County Road 15. Travelling northbound on County Road 49, a left-lane warrant was conducted (found in Appendix B) and found that movement counts for the left-turn are too low to warrant a left-turn lane. Sight lines appear to be adequate. Traffic counts were conducted at this intersection during the morning (7am-10am), midday (11am-1pm), and afternoon peaks (3pm-6pm), which can be found in Appendix B. Figure 2-5 below provides a plan view of the intersection.

Figure 2-5: Plan View of County Road 49 and County Road 15 Intersection
2.4.2 County Road 49 and Fish Lake Road/Mount Carmel Road

Fish Lake Road and Mount Carmel Road are both two-lane hard-top rural roads that approach County Road 49 at highly skewed angles. Fish Lake Road approaches County Road 49 at an angle of 64 degrees and Mount Carmel Road approaches County Road 49 at an angle of 117 degrees. Intersection angles less than 70° and greater than 110° are typically not desirable due to poor driver visibility, increased intersection crossing distance, and driver tendency to take narrow turns. The two minor roads are also offset from each other, which can be seen in Figure 2-6 below. Both are stop-controlled with a stop bar. There are no right- or left-turn lanes along County Road 49 approaching this intersection. Although traffic volumes were not collected at this intersection, based on the condition of the road and observations made during various site visits, it is anticipated that turning volumes onto either Fish Lake Road or Mount Carmel Road are low, and therefore a right- or left-turn lane is not warranted. At the intersection of Fish Lake Road and County Road 49, there is a gravel area that may have been intended as an area to pull off of County Road 49.

![Image: Travelling westbound on Mount Carmel Road approaching County Road 49](image1)

![Image: Travelling eastbound on Fish Lake Road approaching County Road 49](image2)

Figure 2-6: County Road 49 and Fish Lake Road/ Mount Carmel Road
2.4.3 County Road 49 and County Road 35

County Road 35 is a two-lane hard-top rural road with a posted speed of 70 km/h. It approaches County Road 49 on a skew at approximately 63-degrees. Intersection angles less than 70 degrees are typically not desirable due to poor driver visibility and driver tendency to make narrow turns. County Road 35 is stop controlled with a stop bar. There are no right- or left-turn lanes on County Road 49 approaching County Road 35. Although traffic volumes were not collected at this intersection, based on observations made during several site visits, it is anticipated that there are low turning volumes on County Road 35, and therefore a right- or left-turn lane is not warranted. Figure 2-8 below provides a plan view of the intersection of County Road 49 and County Road 35.

Figure 2-8: Plan View of County Road 49 and County Road 35 Intersection
2.4.4 County Road 49 and County Road 6

County Road 6 is a two-lane hard-top rural road with a posted speed of 80 km/h. It approaches County Road 49 on a slightly skewed angle and is stop controlled with a stop bar. On County Road 49, there is a southbound right-turn lane and northbound left-turn lane approaching the intersection. Pictures of the intersection approaches are shown below in Figure 2-9. A plan view of the intersection is shown below in Figure 2-10. The County requested that AE review truck movements at this intersection, in the context of a proposed deep-water port that may be developed off White Chapel Road and would increase truck traffic at this intersection (eastbound right and northbound left turn movements).

Figure 2-9: County Road 49 and County Road 6

Figure 2-10: Plan View of County Road 49 and County Road 6 Intersection
An AutoTurn analysis was completed on this intersection to determine if transport trucks (WB-20) can adequately make an eastbound right turn and northbound left turn. An eastbound truck turning right would be required to encroach into the northbound left turn lane, therefore, it is recommended that widening be undertaken on the inside of the turn (southwest quadrant of the intersection). For the northbound left turn, minor encroachment would occur into the westbound lane, requiring that the truck only make this turn when there are no eastbound vehicles stopped at the stop bar. Given that the northbound left turns are made from their own dedicated lane and would not impact northbound through movements, no other widening was warranted at this intersection. The swept path of the trucks and the proposed widening along the southwest quadrant of the intersection is shown below in Figure 2-11.

![Figure 2-11: AutoTurn Analysis on County Road 49 and County Road 6](image)
2.4.5 County Road 49 and White Chapel Road

White Chapel Road is a two-lane hard-top rural road that approaches County Road 49 at almost a 90-degree angle. Intersection approaches are shown below in Figure 2-12. The geometry at this intersection is adequate. A plan view of this intersection is shown below in Figure 2-13.

Travelling northbound on County Road 49 approaching White Chapel Road

Travelling westbound on White Chapel Road approaching County Road 49

Figure 2-12: County Road 49 and White Chapel Road

Travelling northbound or southbound on County Road 49, no right- or left-turn lanes are present. Traffic counts were collected at this intersection during the morning (7am-10am), midday (11am-1pm), and afternoon peaks (3pm-6pm), which can be found in Appendix B. Using these counts, a left-turn lane warrant was conducted; however, the traffic volumes for left-turn movements are not high enough to warrant a left-turn lane. This warrant can also be found in Appendix B.
As noted earlier, a deep-water port is being developed off White Chapel Road and it is believed that this will result in an increase of truck traffic making the westbound right-turn movement onto County Road 49. The existing traffic volume along County Road 49 may not allow for a large number of westbound right turn movements made by transport trucks and may pose safety concerns. As such, the County asked AE to review the need for an acceleration lane along County Road 49.

In addition, the County forwarded a copy of a traffic impact assessment for the deep-water port development which also concluded that there was no need for a southbound left-turn lane under future traffic conditions (with full build out of the deep-water port).\(^1\)

### 2.5 ROADSIDE SAFETY ASSESSMENT

#### 2.5.1 Roadside Safety Assessment Methodology

The primary purpose of the roadside safety assessment is to confirm the location, type, and condition of the existing guide rails (in terms of type, end treatments, length, condition, etc.) and the existing unprotected hazards. For each guide rail and unprotected hazard, a set of recommended remediation measures has been identified to address any noted deficiencies.

Prior to collecting the condition and risk assessment data, a detailed data dictionary was developed identifying the guide rail and unprotected hazard attributes required to adequately assess the condition of any existing guide rails or lack thereof. Within the data dictionary provided in Appendix C, the various attributes required for assessing the condition and associated risk of a guide rail or unprotected hazard were identified, defined, and described in terms of the attribute’s optionality, data type, potential values, and data sources where applicable.

In the case of an existing guide rail, each individual guide rail may act as part of a compound guide rail system or act as a standalone guide rail system. For a compound guide rail system, each guide rail component (differentiated by the classification and type of guide rail) is associated with the compound guide rail system identifier; one system may have multiple components while one component must have one system. Within these compound guide rail systems, the first guide rail component in the system is denoted as the system approach component and the last guide rail component in the system was denoted as the system departure component. By relating each guide rail component by the compound guide rail system identifier, the overall length of the compound guide rail system can be compared to that of the length of need in relation to the hazard in which the guide rail system is protecting. For each guide rail, the approach and departure have a form of end treatment applied. In the event of a lack of end treatment, the values were “Not Applicable”. As presented, there is an option to indicate that an end treatment can be installed at an entrance or intersecting roadway. In some instances, a guide rail may be limited in length due to a conflict with an upstream or downstream entrance or intersecting roadway. Should a conflict exist and the length of need is not met, alternative treatments will need to be recommended. Lastly, the post material and block-out material (where applicable) were documented for information purposes only.

Whether assessing an existing guide rail or an unprotected hazard, several aspects are required to identify the presence, type, and geometry of a hazard. Similar to guide rails and end treatments, hazards were classified based on the general type of hazard. It is noted that a hazard is not necessarily present should there be a guide rail; this could represent a guide rail that should be removed or a compound guide rail system whereby the hazard is directly protected via another guide rail component within the system. When there is a guide rail and a hazard present, the hazard is indirectly defined through comparison of the approach and departure points of the guide rail in relation to the approach and departure points of the hazard.

The guide rail system was evaluated in terms of its potential to operate as intended, providing the desired level of safety in the event of a collision in addition to conforming to applicable standards. Guide rails were assessed in terms of hazard markers, snow plow markers, delineation strips, mounting height, plumb angle, cable tension, system transitions, rail-lapping, deflection area, run-out area, shoulder design, and shoulder stability. The condition of the rail, posts, and block-outs were also assessed based on a five-point scale.

2.5.2 Roadside Safety Assessment Findings

The assessment includes the identification and review of unprotected hazards along the 17.3 km of County Road 49. In total, 17 guide rails were inventoried, which consisted of 15 standalone guide rails and two (2) system guide rails. Only two (2) types of guide rails exist along County Road 49 – steel-beam and three-cable. Examples of these guide rails can be found below in Figure 2-14. The most frequent type of guide rail inventoried was steel beam, which accounted for approximately 59% of all guide rails inventoried. Approximately 1,930 m of guide rails were inventoried and of that, 1,060 m were steel-beam and 870 m were three-cable.
In total, 22 roadside hazards, including both those protected and unprotected were inventoried. Most of the hazards had roadside protection (17) and only a small number (5) had no form of roadside protection. Only two (2) types of hazards were observed – fixed objects and embankments. Examples of these hazard types can be found below in Figure 2-15. A total of ten (10) fixed object hazards in the form of box culverts were identified and 12 embankments were identified. Of these hazards, five (5) fixed objects (box culverts) were unprotected.

None of the guide rails had hazard markers; however, the majority (94%) had snow plow markers. Of the 17 guide rails, only ten (10) have delineation strips. All guide rails were installed at the correct mounting height. Most guide rails (88%) had the correct plumb angle. In terms of design conformance, none of the guide rails had adequate design conformance, meaning none of the guide rails have met the requirements for having adequate system transitions, rail lapping, deflection area, run-out area, shoulder design, shoulder stability, and approach/ departure length. All guide rails reviewed had a condition rating three (3) or less for the rail condition rating, with the average rail condition rating being 2.2, which indicates the need for replacement. All posts reviewed had a condition rating of two (2) or three (3), with the majority (76%) having a rating of two (2), indicating the need for replacement. All block-outs reviewed (applicable to steel-beam only installations and not three-cable guide rails) had a condition rating of two (2) or three (3) with the majority (90%) having a rating of two (2), indicating the need for replacement. Just over half of the guide rails reviewed were determined to have adequate approach (53%) or departure (59%) length for protecting motorists from a roadside hazard.

The complete table of findings from the roadside safety assessment, along with guide rail pictures and a guide rail and unprotected hazards location map, can be found in Appendix C.
2.6 CULVERT CONDITION ASSESSMENT

Culvert condition assessment methodology is comprised of a pre-site visit desktop data collection, site visit data collection, and culvert condition desktop analysis. The culvert condition assessment ultimately provides a score from zero (0) to one-hundred (100) which identifies whether the culvert is in poor or excellent condition, respectively. The result of the culvert condition assessment is a recommended action (replace, repair, or monitor) for each culvert.

2.6.1 Condition Assessment: Desktop Data Collection

The following information was collected from aerial imagery (Google Earth) and Plan and Profile Drawings (original set), as provided by the county:

- Culvert identification / location
- Culvert length
- Culvert crossing type (stream, road, entrance)

Culverts were identified using aerial imagery; Figure D1 in Appendix D is a map identifying the location of culverts crossing County Road 49. Within the study area, there are 26 culverts crossing County Road 49. From aerial imagery, it was possible to estimate each culvert’s length, which is recorded in the culvert condition assessment spreadsheet, also found in Appendix D. Only culverts that crossed beneath the road were considered as part of the culvert condition assessment.

2.6.2 Condition Assessment: Site Visit Data Collection

As part of the culvert condition assessment, two (2) site visits were completed, the first on August 21 – 22, 2017 and the second on October 2, 2017. During these site visits, the following information was collected:

- Physical culvert properties (material, shape, dimensions, embedment, cover, headwall/wingwalls, skew, water depth);
- Physical culvert damage (deterioration, cracks, deflections); and
- Damages or inadequacies in the culvert environment (scour, upstream and downstream channel, waterway adequacy)

Where accessible, culvert inspection and photos were taken at the upstream and downstream ends of the culvert (Appendix D). This information is further used in the desktop culvert condition assessment.

2.6.3 Condition Assessment: Desktop Culvert Condition Assessment

A desktop (spreadsheet) culvert condition assessment was completed using the data collected in the desktop data collection and site visits. In this spreadsheet analysis, physical culvert properties were recorded from the data collection tasks. Further, damage was assessed and a condition rating score value was assigned to the physical characteristics of the culvert and its environment.
The damage assessment considered the following types of culverts as identified in the study area:

1. Concrete box (open footing),
2. Metal circular,
3. Metal elliptical, and

Examples of these different types along County Road 49 are shown below in Figure 2-16. Of these 26 culverts, 14 were concrete box culverts, 11 were corrugated steel pipe (CSP) circular or elliptical pipes, and one (1) was a HDPE plastic circular pipe.

![Box Culvert](image1)
![Metal Circular](image2)
![Metal Elliptical](image3)
![Plastic Circular](image4)

**Figure 2-16: Culvert Types along County Road 49**
The three main types of physical damage to culverts covered in this assessment include:

1. Deterioration of material (scaling, disintegration, corrosion, rusting of surface, bolts, edges),
2. Deflection (vertical, horizontal, and misalignment), and
3. Cracks (longitudinal, spalling, slabbing).

Examples of these three types of physical damage on culverts along County Road 49 are shown below in Figure 2-17.

Due to accessibility issues at many of the sites, culvert joints were not explicitly included as part of this condition assessment.

Other types of damages or inadequacies within the culvert environment were also assessed including:
1. Waterway adequacy,
2. Upstream and downstream channel quality,
3. Scour, and
4. Embankment conditions.

A culvert condition assessment was completed for all crossing culverts. To maintain a level of consistency in assigning condition rating values, the MTO’s Identification of Culvert Damage Guide and MTO Culvert Assessment and Rating Field Guide were used to rate the observed degree of damage to each culvert and environmental component in the assessment. The rating guide used in this assessment can be found in Appendix D.

Rating modifiers were used to weight the relative importance of each culvert based on roadway class, culvert purpose, and culvert size, as shown in Table D-5 of Appendix D. The modifier increases with the importance of the culvert. Since all culverts in the assessment are located under County Road 49, they all have the same rating modifier for Roadway Class (Rural Principal Arterial; importance modifier value of 1.1). Since each of the culverts in the assessment are the same drain type, they all have the same rating modifier for Culvert Purpose (Main, under roadway; importance modifier of 1.1). However, since the culverts are different sizes, the rating modifiers for culvert size differ between culverts (culvert size modifiers from 0.9 – 1.1).

These ratings and modifiers were then converted to a Condition Rating Index (CRI) between [0-100] which reflects very poor (failure conditions; CRI<25) to excellent (no deficiencies; CRI>85) conditions. A CRI is calculated for each culvert in the assessment. This total condition rating can then be used as a relative means of identifying culverts which are in very poor [CRI 0-25] to excellent [CRI 85-100] condition. These condition ratings can then be used to help identify and prioritize infrastructure rehabilitation and replacement options.

The CRI for culverts along County Road 49 fell within the range of 32 to 79, with the average CRI being 64.

2.7 DRAINAGE ASSESSMENT

A drainage assessment (i.e. culvert capacity assessment) was completed for each culvert in the study area. This assessment was performed to determine the hydraulic adequacy of each culvert.

2.7.1 Drainage Assessment: Data Collection

Vector contours and DEM data was required to delineate catchment areas in GIS. Data collected in the field including culvert shape, material, and diameter were required for hydraulic modeling to estimate culvert performance.
2.7.2 Drainage Assessment: Desktop Drainage Assessment Methodology

The drainage assessment methodology consisted of the following steps for each culvert:

- Delineating the catchment area;
- Estimating the time of concentration;
- Calculating the estimated flow using the Modified Rational Method;
- HY8 hydraulic modelling to estimate the flow conveyance; and
- Based on hydraulic performance, provide a recommend course of action.

Catchments were delineated one of two ways: using the Ontario Flow Assessment Tool (OFAT) or using manual digitization in GIS. The OFAT tool was used to delineate larger catchment areas whereas smaller catchment areas were manually delineated based on 50cm contour lines provided by the County. In total, 26 catchment areas were delineated (one for each culvert). These catchment areas were then used to estimate flows using the Modified Rational Method.

The Federal Aviation Administration (FAA) method considers catchment characteristics such as hydraulic length, slope, and runoff coefficient, to estimate the time of concentration. Time of concentration is subsequently used to estimate flows using the Modified Rational Method.

Flows at the culvert location were estimated using the Modified Rational Method. This method uses the catchment area, time of concentration, and runoff characteristics to estimate flow at the culvert location. These flows are then used as input into HY8 hydraulic modeling program to determine culvert conveyance. The assumption is that all culverts are free of blockages and are part of the existing culvert system (i.e. that no other culverts are removed). Calculations for the complete drainage assessment including modified Rational Method calculations and HY8 analysis can be found in Appendix E.

Of the twenty-six (26) culverts in the analysis, seventeen (17) were considered hydraulically adequate, and nine (9) were potentially hydraulically inadequate; based on conveyance of the 5-year (design) and 100-year (regulatory) storms. The recommended actions for the nine (9) culverts is that an additional, more detailed hydraulic analysis be completed at these locations. The follow-up analyses may require more detailed terrain surfacing, additional flow estimates (more sophisticated estimation methods), and high-resolution and accurate field data. This additional data would help confirm existing level of service provided by these structures.

A summary table for both culvert condition and drainage recommendations can be found in Appendix E.
3 Evaluation of Road Rehabilitation Options

3.1 EXISTING CONCRETE PAVEMENT CONSIDERATIONS

The existing road surface is Portland Cement Concrete (PCC) pavement. The viable road rehabilitation options presented in the following section involve either rubblizing, removing and disposing of the existing concrete pavement or repairing the existing concrete pavement and overlaying it with either hot mix asphaltic concrete (HMA) pavement or PCC pavement. The following sections describe the advantages and disadvantages of each option for the existing pavement.

3.1.1 Rubblization

Rubblization is a slab fracturing technique that involves breaking the existing concrete surface down to a specified maximum particle size using highly specialized equipment. The fractured concrete is then left in place, serving as the base for the rehabilitated road. The purpose of rubblizing is to mitigate the reflective cracking that occurs when a new surface pavement is placed on top of an existing concrete road surface. The reflective cracking occurs at the existing pavement's joints, and propagates upwards, deteriorating the new road surface. A more detailed explanation of the rubblizing process is available in the Geotechnical Report which is provided under a separate cover.

3.1.2 Removing the Existing Concrete

Removing the existing concrete pavement has the clear benefit of removing the compromised concrete and disposing of it at an approved facility. Cement plants along County Road 49 make this a viable option, despite the long length of road rehabilitation. The cement plants in the area are likely to accept the concrete for reuse in other concrete applications. The wire mesh reinforcement and dowels will not likely be recyclable and will end up going to landfill.

If removing the concrete were to show to be the preferred option, the Ministry of the Environment and Climate Change (MOECC) may have certain requirements for a cement plant to accept this material for reuse.

3.1.3 Repairing the Existing Concrete

The existing concrete pavement has deteriorated significantly over the course of its extended life span. The original concrete could provide the base for an overlay in either concrete or asphalt if extensive repairs are made to the existing concrete road. This would involve the elimination of deflection and cracking between concrete slabs, replacing entire slabs, and generally creating as smooth a surface as possible before placing the levelling course and overlay.

Sealing the cracks is a costly task, with the likelihood of the underlying cracking reflecting through to the surface of the new pavement within five (5) to seven (7) years, whether the overlay is concrete or asphalt. Annual maintenance to inhibit the spread of the cracking will be significant. These costs associated with
keeping the original pavement in place will increase overall life cycle costs and decrease the life span of the new pavement.

### 3.2 ROAD REHABILITATION OPTIONS

There are six road rehabilitation options being considered for County Road 49. The options are as follows:

- Option 1: Rubblize concrete pavement and replace with hot mix asphaltic (HMA) pavement
- Option 2: Rubblize concrete pavement and replace with Portland Cement Concrete (PCC) pavement
- Option 3: Remove and haul away concrete pavement and replace with HMA pavement
- Option 4: Remove and haul away concrete pavement and replace with PCC pavement
- Option 5: Repair existing concrete and overlay PCC pavement
- Option 6: Repair existing concrete and overlay HMA pavement

#### 3.2.1 Option 1: Rubblize concrete pavement and replace with hot mix asphaltic (HMA) pavement

Option 1 involves rubblizing the existing concrete pavement and levelling with a layer of HMA to serve as the base for the rehabilitated road. A layer of Heavy Duty Binder Course (HDBC) HMA would then be placed followed by the asphaltic concrete road surface. The pavement structure design and associated layer thicknesses recommended by Englobe are as follows:

- 550 mm – existing granular material
- 225 mm – rubblized concrete
- 50 mm – HL3(HS) HMA
- 60 mm – HDBC HMA
- 40 mm – HL1 HMA

Details on its design life and pros and cons associated with this option are as follows:

**Design Life:**
- Milling and repaving top course likely at 15 years

**Pros:**
- Same equipment used for paving roads, familiar product
- Less expensive capital cost compared to concrete replacement
- Traffic can use pavement once it has cooled

**Cons:**
- Asphalt pavement wears faster than concrete pavement and requires sealing patching as required, typically every 5 to 7 years
- Design life may be shorter than concrete pavement
3.2.2 Option 2: Rubblize concrete pavement and replace with PCC pavement

Option 2 involves rubblizing the existing concrete pavement and levelling with a layer of hot mix asphalt (HMA) to serve as the base for the rehabilitated road. The road surface recommended by Englobe would be composed of PCC (CSA Cat-2, 32 MPa, AE, 40 mm aggregate size). The pavement structure design and associated layer thicknesses recommended by Englobe are as follows:

- 550 mm – existing granular material
- 225 mm – rubblized concrete
- 100 mm – Granular A crusher run limestone
- 200 mm – PCC

Details on its design life and pros and cons associated with this option are as follows:

**Design Life:**
- 30 years or more
- Joints need to be maintained for long service life

**Pros:**
- Durability, especially on hot days
- Lower annual maintenance costs
- Normally lower long-term life cycle costs

**Cons:**
- Higher initial capital cost
- Requires economies of scale to bring in concrete paving machines
- Requires specialized concrete paving machine and concrete batch plant for best results
- Requires curing time before traffic loading for regular concrete

For large areas of concrete, a concrete paving machine will give consistent uniform results and faster construction.

3.2.3 Option 3: Remove and haul away concrete pavement and replace with HMA pavement

Option 3 involves removing and hauling the existing concrete pavement off-site, thereby exposing the existing granular material below. Lower lift and top lift binder layers would then be placed, followed by the asphaltic concrete road surface. The pavement structure design and associated layer thicknesses recommended by Englobe are as follows:

- 550 mm – existing granular material
- 250 mm – Granular B crusher-run limestone
- 120 mm – HDBC HMA
- 45 mm – HL1 HMA
Details on its design life and pros and cons associated with this option are as follows:

**Design Life:**
- Milling and repaving top course likely at 15 years

**Pros:**
- Same equipment used for paving roads, familiar product.
- Less expensive capital cost compared to concrete.
- Traffic can use pavement once it has cooled.

**Cons:**
- Asphalt pavement wears faster than concrete pavement and requires sealing patching as required, typically every 5 to 7 years.
- Design life may be shorter than concrete pavement

### 3.2.4 Option 4: Remove and dispose of concrete pavement and replace with PCC pavement

Option 4 involves removing and hauling the existing concrete pavement off-site (thereby exposing the existing granular material below), then levelling with a layer of HMA to serve as the base for the rehabilitated road. The road surface would be composed of PCC (CSA Cat-2, 32 MPa, AE, 40 mm aggregate size) as recommended by Englobe. The pavement structure design and associated layer thicknesses as recommended by Englobe are as follows:

- 550 mm – existing granular material
- 35 mm – HL3(HS) HMA Levelling Course
- 220 mm – PCC

Details on its design life and pros and cons associated with this option are as follows:

**Design Life:**
- 30 years or more for concrete.

**Pros:**
- Less annual maintenance compared to all asphalt pavement.
- Durability, especially on hot days.
- Lower annual maintenance costs.
- Normally lower long-term life cycle costs

**Cons:**
- Higher initial capital cost.
- Requires economies of scale to bring in concrete paving machines.
3 - Evaluation of Road Rehabilitation Options

- Requires specialized concrete paving machine and concrete batch plant for best results.
- Requires curing time before traffic loading for regular concrete.

3.2.5 Option 5: Repair concrete pavement and overlay with PCC pavement

Option 5 involves making repairs to the existing concrete pavement, then applying a levelling course of with a layer of HMA to serve as the base for the rehabilitated road. The road surface would be composed of PCC (CSA Cat-2, 32 MPa, AE, 40 mm aggregate size) as recommended by Englobe. The pavement structure design and associated layer thicknesses as recommended by Englobe are as follows:

- 550 mm – repairs to existing granular material
- 40 mm – HL3(HS) HMA Levelling Course
- 175 mm – PCC

Details on its design life and pros and cons associated with this option are as follows:

Design Life:
- 30 years or more for concrete

Pros:
- Lower annual maintenance costs.
- Normally lower long-term life cycle costs

Cons:
- Higher initial capital cost due to repairs to existing concrete
- Higher annual maintenance costs due to likelihood of reflective cracking to the surface
- Requires economies of scale to bring in concrete paving machines
- Requires specialized concrete paving machine and concrete batch plant for best results
- Requires curing time before traffic loading for regular concrete

3.2.6 Option 6: Repair existing concrete pavement and replace with HMA pavement

Option 3 involves removing and hauling the existing concrete pavement off-site, thereby exposing the existing granular material below. Lower lift and top lift binder layers would then be placed, followed by the asphaltic concrete road surface. The pavement structure design and associated layer thicknesses recommended by Englobe are as follows:

- 550 mm – existing granular material
- 250 mm – Granular B crusher-run limestone
- 120 mm – HDBC HMA
- 45 mm – HL1 HMA

Details on its design life and pros and cons associated with this option are as follows:
Design Life:
- Milling and repaving top course likely at 15 years

Pros:
- No need to remove the existing concrete
- Same equipment used for paving roads, familiar product
- Less expensive capital cost compared to concrete
- Traffic can use pavement once it has cooled

Cons:
- Significant base repairs to existing concrete are required
- Reflective cracking to the surface is likely
- Asphalt pavement wears faster than concrete pavement and requires sealing patching as required, typically every 5 to 7 years
- Design life may be shorter than concrete pavement

### 3.3 UNIT COSTS AND MAINTENANCE ASSUMPTIONS

The unit costs used for developing the conceptual cost estimate were obtained from previous contractor tender prices in Southern Ontario and the MTO HICO database, where average tender bid prices are used for estimating purposes for MTO projects. The Eastern region was chosen when selecting unit price for the items below.

The costs below are conceptual and considered Class D (+/- 30%) and to be used for road rehabilitation option selection only.

The capital costs for the six options are based on the following unit rates:

- **Granular A**: $23/tonne
- **Granular B**: $18/tonne
- **Hot Mix Asphalt HL-3**: $131/tonne
- **Hot Mix Asphalt HL-8**: $100/tonne
- **Hot Mix Asphalt HL-1**: $167/tonne
- **Concrete Pavement**: $300/m³
- **Cold Planing of Concrete**: $20/m²
- **Cold Planing of Asphalt**: $20/m²
- **Rubblizing Concrete**: $5/m²

The maintenance costs are based on the following assumptions:

**Option 1**: Rubblize concrete pavement and replace with HMA pavement
- Capital Cost $18.3 million
- Annual maintenance $1.50/m² except for years where overlays were done
- Every ten years, mill and overlay 50 mm thick patchwork for 10% of the total road surface
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- Every fifteen years, for entire area, mill and overlay 100 mm thick for asphalt replacement
- Maintenance costs include 30% for contingency and engineering

Option 2: Rubblize concrete pavement and replace with PCC pavement
- Capital Cost $23.0 million
- Annual maintenance $0.75/m² over entire area
- Every ten years, 30% of joint seals are replaced, and 10% of total panels are replaced
- Maintenance costs include 30% for contingency and engineering

Option 3: Remove and dispose of concrete pavement and replace with HMA pavement
- Capital Cost $21.7 million
- Annual maintenance $1.50/m² except for years where overlays were done
- Every ten years, mill and overlay 50 mm thick patchwork for 10% of the total road surface
- Every fifteen years, for entire area, mill and overlay 100 mm thick for asphalt replacement
- Maintenance costs include 30% for contingency and engineering

Option 4: Remove and haul away concrete pavement and replace with PCC pavement
- Capital Cost $26.2 million
- Annual maintenance $0.75/m² for concrete
- Every ten years, 30% of concrete seals are repaired, and 10% total panels are replaced
- Maintenance costs include 30% for contingency and engineering

Option 5: Repair Concrete and Overlay PCC pavement
- Capital Cost $47.2 million
- Annual maintenance $2.00/m² for concrete
- Every five years, 15% of concrete seals are repaired and 5% of total panels are replaced
- Maintenance costs include 30% for contingency and engineering

Option 6: Repair Concrete and Overlay HMA pavement
- Capital Cost $41.9 million
- Annual maintenance $2.00/m² for concrete
- Every five years, mill and overlay 50 mm HL1 for 15% of the total road surface
- Every fifteen years, for entire area, mill and overlay 100 mm thick for asphalt replacement
- Maintenance costs include 30% for contingency and engineering

3.3.1 Concrete Unit Pricing

A discussion over the uncertainty in concrete pricing prompted Prince Edward County to request that AE confirm the unit price costing used as a basis for the options involving using a concrete overlay. This was done by means of contacting a neighbouring County which has a similar concrete road, area contractors, the Cement Association and Lehigh Cement Company, who operates a local quarry adjacent to County Road 49. Based on discussions with these parties as well as weighing sources of the range of concrete costs obtained, AE recommended that the unit cost for concrete be $300/m³. This unit cost is reflective of the various estimates identified in our analysis. A tech memo describing assumptions and recommendations was written and is provided in Appendix F.
3.4 LIFE CYCLE COST ANALYSIS

Appendix G gives the results of the life cycle cost analysis for all the options. The life cycle cost analysis was done over a period of 30 years. Rather than inflating costs over time and then discounting to present value, a combined discount rate was used which combines inflation and discounting into one rate. The combined rate is expressed as:

\[
\text{Combined Discount Rate} = \frac{(1+\text{discount})}{(1+\text{inflation})} - 1.
\]

For a sensitivity analysis, the combined discount rate ranged from 0% to 8%. Salvage value was not considered because the 30-year life cycle assumes that all options will have depleted their life cycle by the end of the 30 years, and so the salvage value will be zero. At the end of the 30 years, each option is assumed to need a full replacement. To ensure a fair comparison of different options, life cycle costs are typically evaluated in terms of their Net Present Worth (NPW). The present worth represents the cost of a future activity in terms of today's dollars. The initial costs and on-going costs are then combined to evaluate the total project present worth. The future costs are discounted to adjust for inflation and interest rates. The discount rate used to adjust the future costs is typically set at an agency level. The current discount rate used by the Province of Ontario is 5.0%. When evaluating the life-cycle cost, it is typically understood that there is a margin of error due to possible differences in quantities, unit costs, and pavement performance over the service life. Comparisons with marginal differences in cost may require further investigation into other factors to determine the optimal pavement type.

A 0% combined discount rate is not realistic given the time value of money. The province of Ontario currently uses a discount rate of 5%.

Concrete pavement is comparable in life cycle cost to asphalt, the proposed thick structure and generally lower price of oil makes concrete paving a comparable option to asphalt in this current market. Higher asphalt pricing in the future may shift concrete paving to be more competitive in a 30-year life cycle.

Options 5 and 6 both involved repairing the existing concrete structure to a point where it is structurally sound to then place a levelling course over top and finally the top course overlay. These two options were determined to be the most expensive options over the 30-year life cycle, due to the high cost of repair the existing road as well as the anticipated operations and maintenance cost of the rehabilitated road.

3.4.1 Life Cost Analysis Summary

The estimation of probable capital costs (Class D +/- 30%) for the various options are as follows:

Option 1: Rubblize concrete pavement and replace with hot mix asphaltic (HMA) pavement = $18.3 million
Option 2: Rubblize concrete pavement and replace with PCC pavement = $23.0 million
Option 3: Remove and haul away concrete pavement and replace with HMA pavement = $21.7 million
Option 4: Remove and haul away concrete pavement and replace with PCC pavement = $26.2 million
Option 5: Repair existing concrete and overlay PCC pavement = $47.2 million
Option 6: Repair existing concrete and overlay HMA pavement = $42.0 million

Option 1 has the lowest capital cost. However, Option 2, has the lowest net present value for discount rates in the range of 0% to 4% for the 30-year life cycle. At discount rates higher than this, Option 1 becomes the more cost-effective option over the 30-year life cycle. It is also noted that these NPVs are based on several assumptions over the 30 years, and so neither Option 1 or 2 should be ruled out one way or the other based on this analysis alone. Figure 3-1 shows the net present value of the options over a 30-year life cycle period and over a range of combined discount rates.

![Figure 3-1: Sensitivity Analysis to Combined Discount Rate for 30 Year Life Cycle](image)

The graph shows that when the combined discount rates increase beyond 8%, Option 1 will still have the lowest net present value over the 30-year life cycle.

### 3.5 PREFERRED ROAD REHABILITATION OPTION

Overall, the preferred options for the rehabilitation of County Road 49 are Option 1: rubblize and replace with HMA pavement (with an estimated construction cost of $18.3 M) and Option 2: rubblize and replace with PCC pavement (with an estimated construction cost of $23.0 M). Given that the cost estimate for the construction is conceptual (+/- 30%) and it is not clear which option would be more cost-effective over the 30-year life cycle, it is recommended that both options be carried forward. The estimation of probable cost should be further refined at the preliminary and detailed design stage.
4 **Recommended Improvements**

It is recommended that the entire road, including intersections, guide rails, and culverts be rehabilitated or replaced. Drawings showing the proposed preliminary design are provided under a separate cover.

4.1 **ROAD CONDITION IMPROVEMENTS**

Based on the results from the Road Condition Assessment, it is recommended that the road be replaced in the immediate future, by means of either Option 1 or Option 2.

Option 1 involves rubblizing the existing concrete pavement and levelling with a layer of HMA to serve as the base for the rehabilitated road. A layer of Heavy Duty Binder Course (HDBC) HMA would then be placed followed by the asphaltic concrete road surface. The pavement structure design and associated layer thicknesses recommended by Englobe are as follows:

- 550 mm – existing granular material
- 225 mm – rubblized concrete
- 50 mm – HL3(HS) HMA
- 60 mm – HDBC HMA
- 40 mm – HL1 HMA

Option 2 involves rubblizing the existing concrete pavement and levelling with a layer of hot mix asphalt (HMA) to serve as the base for the rehabilitated road. The road surface recommended by Englobe would be composed of PCC (CSA Cat-2, 32 MPa, AE, 40 mm aggregate size). The pavement structure design and associated layer thicknesses recommended by Englobe are as follows:

- 550 mm – existing granular material
- 225 mm – rubblized concrete
- 100 mm – 19 mm Granular A crusher run limestone
- 200 mm – PCC
4.2 ROAD AND INTERSECTION GEOMETRY IMPROVEMENTS

The recommended or preferred cross sections are shown below in Figure 4-1 and Figure 4-2. AE recommends extra wide shoulders (2.0m) to accommodate non-motorized vehicles, such as bicycles. Perforated pipe located under the shoulder of the road on either side is recommended to extend the life cycle of the road. Since asphalt is somewhat permeable, the perforated pipe collects the water under the road to prevent it from pooling under the surface and causing damage during freeze-thaw. This allows the road profile to remain unaltered over the course of its useful life.
4.2.1 County Road 49 and County Road 15

Based on AE’s review of the intersection, no modifications are recommended to the intersection of County Road 49 and County Road 15, as a left-turn lane is not warranted.

4.2.2 County Road 49 and Fish Lake Road/Mount Carmel Road

Based on AE’s review of the intersection of County Road 49 and Fish Lake Road/ Mount Carmel Road, the intersection should ideally be realigned. The existing roads intersect County Road 49 at angles of 64 degrees and 117 degrees. Intersection angles less than $70^\circ$ and greater than $110^\circ$ are typically not desirable due to poor driver visibility, increased intersection crossing distance, and driver tendency to take narrow turns. AE has evaluated the best practice alternatives to realign the minor streets to meet at the recommended $90^\circ$ angle as depicted below in Figure 4-3.

![Figure 4-3: Proposed Realignment of County Road 49 and Fish Lake Road/ Mount Carmel Road](Source: TAC Geometric Guidelines For Canadian Roads- Figure 9.7.2)

However, it was determined that this configuration at this specific location would not be feasible unless the County would consider acquiring significant property. Therefore, no modifications are recommended to this intersection at this time. However, if development were to occur along County Road 49 and traffic volumes were to increase, this intersection should be realigned as shown above.
4.2.3 County Road 49 and County Road 35

Based on AE’s review of the intersection of County Road 49 and County Road 35, ideally the intersection should be realigned. The existing intersection angle is 63 degrees and intersection angles less than 70 degrees are typically not desirable due to poor driver visibility and driver tendency to take narrow turns. AE evaluated best practice alternatives to realign the minor street to meet County Road at the recommended 90-degree angle, as shown below in Figure 4-4.

However, it was determined that this configuration at this specific location would not be feasible unless the County would consider acquiring significant property. Therefore, no modifications are recommended to this intersection at this time. However, if development were to occur along County Road 49 and traffic volumes were to increase, this intersection should be realigned as shown in Figure 4-4.
4.2.4 County Road 49 and County Road 6

Based on AE’s review of the intersection of County Road 49 and County Road 6, and the proposed development of the deep-water port on White Chapel Road, the geometry at the intersection should be widened to better accommodate truck traffic. The southwest corner of the intersection should be widened by approximately 80 square metres as shown below in Figure 4-5. A paved shoulder is also recommended along County Road 49.

4.2.5 County Road 49 and White Chapel Road

Based on AE’s review of the intersection of County Road 49 and White Chapel Road, the geometry at this intersection is adequate; and therefore, no modifications are being recommended to the intersection of County Road 49 and White Chapel Road. However, an acceleration lane is being recommended for the westbound right-turn onto County Road 49. The acceleration lane on County Road 49 is recommended to be 160 m, with a taper length of 65 m, as shown below in Figure 4-6.
Figure 4-6: Proposed Acceleration Lane on County Road 49 north of White Chapel Road
4.3 ROADSIDE SAFETY IMPROVEMENTS

Based upon the condition of the guide rail or lack thereof, remediation measures were recommended during the assessment and have been divided into five (5) types of remediation: minor treatments, install, extend, replace, or remove. It has been assumed that if a system should be repaired, it will be more cost-effective to remove the damaged section and install a new guide rail. In situations where guide rails are installed as a compound system leading up to a concrete bridge or structure, the length of the guide rail was assessed based on its system identifier and the overall length of the compound guide rails through post-processing of the data. Overall, the remediation costs were based on individual guide rails or unprotected hazards and can be summarized by system. Remediation measures and suggested associated unit costs obtained from the Ministry of Transportation Ontario’s Highway Costing (HICO) System.

The proposed roadside safety improvements for each of the guide rails and hazards (protected and unprotected) are shown below in Table 4-1. The facility ID represents the guide rail or hazard ID, which can be found on the map in Appendix C.

<table>
<thead>
<tr>
<th>Facility ID</th>
<th>Guide Rail Type</th>
<th>Hazard Type</th>
<th>Remedia-</th>
<th>Remediation Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Steel-Beam</td>
<td>Embankment</td>
<td>Replace</td>
<td>Replace Guide Rail</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Install 2 Hazard Marker(s). Install 2 Snow Plow Marker(s). Install Delineation Strips. Install Entrance or Intersection Roadway Treatment on Approach. Install Energy Attenuating Terminal on Departure. Replace 55 metres of Steel-Beam with 45 metres of Steel-Beam.</td>
</tr>
<tr>
<td>2</td>
<td>Steel-Beam</td>
<td>Box-Culvert</td>
<td>Replace</td>
<td>Replace Guide Rail</td>
</tr>
<tr>
<td>3</td>
<td>Steel-Beam</td>
<td>Box-Culvert</td>
<td>Replace</td>
<td>Replace Guide Rail</td>
</tr>
<tr>
<td>4</td>
<td>Steel-Beam</td>
<td>Embankment</td>
<td>Replace</td>
<td>Replace Guide Rail</td>
</tr>
<tr>
<td>5</td>
<td>Steel-Beam</td>
<td>Embankment</td>
<td>Replace</td>
<td>Replace Guide Rail</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Install 2 Hazard Marker(s). Install 2 Snow Plow Marker(s). Install Delineation Strips. Install Energy Attenuating Terminal on Approach. Install Energy Attenuating Terminal on Departure. Replace 100 metres of Steel-Beam with 85 metres of Steel-Beam.</td>
</tr>
<tr>
<td>Facility ID</td>
<td>Guide Rail Type</td>
<td>Hazard Type</td>
<td>Remediation Classification</td>
<td>Remediation Measure</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------</td>
<td>-------------</td>
<td>----------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>7</td>
<td>Steel-Beam</td>
<td>Box-Culvert</td>
<td>Remove Guide Rail</td>
<td>Remove 35 metres of Steel-Beam. Make Hazard Traversable.</td>
</tr>
<tr>
<td>8</td>
<td>Steel-Beam</td>
<td>Embankment</td>
<td>Remove Guide Rail</td>
<td>Remove 125 metres of Steel-Beam.</td>
</tr>
<tr>
<td>9</td>
<td>Steel-Beam</td>
<td>Box-Culvert</td>
<td>Remove Guide Rail</td>
<td>Remove 45 metres of Steel-Beam. Make Hazard Traversable.</td>
</tr>
<tr>
<td>13</td>
<td>Three-Cable</td>
<td>Embankment</td>
<td>Remove Guide Rail</td>
<td>Remove 45 metres of Three-Cable.</td>
</tr>
<tr>
<td>14</td>
<td>Steel-Beam</td>
<td>Embankment</td>
<td>Replace Guide Rail</td>
<td>Install 1 Hazard Marker(s). Install 1 Snow Plow Marker(s). Install Delineation Strips. Install Energy Attenuating Terminal on Approach. Address 1 System Transition(s). Replace 55 metres of Steel-Beam with 60 metres of Steel-Beam.</td>
</tr>
<tr>
<td>15</td>
<td>Three-Cable</td>
<td>Embankment</td>
<td>Remove Guide Rail</td>
<td>Remove 100 metres of Three-Cable.</td>
</tr>
<tr>
<td>16</td>
<td>Not Applicable</td>
<td>Box-Culvert</td>
<td>Minor Treatments</td>
<td>Make Hazard Traversable.</td>
</tr>
<tr>
<td>Facility ID</td>
<td>Guide Rail Type</td>
<td>Hazard Type</td>
<td>Remediation Classification</td>
<td>Remediation Measure</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------</td>
<td>-------------</td>
<td>----------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>17</td>
<td>Not Applicable</td>
<td>Box-Culvert</td>
<td>Minor Treatments</td>
<td>Make Hazard Traversable.</td>
</tr>
<tr>
<td>18</td>
<td>Not Applicable</td>
<td>Box-Culvert</td>
<td>Minor Treatments</td>
<td>Make Hazard Traversable.</td>
</tr>
<tr>
<td>21</td>
<td>Not Applicable</td>
<td>Box-Culvert</td>
<td>Install Guide Rail</td>
<td>Install 2 Hazard Marker(s). Install 2 Snow Plow Marker(s). Install Delineation Strips. Install Entrance or Intersecting Roadway Treatment on Approach. Install Entrance or Intersecting Roadway Treatment on Departure. Install 20 metres of Steel-Beam.</td>
</tr>
<tr>
<td>22</td>
<td>Not Applicable</td>
<td>Box-Culvert</td>
<td>Install Guide Rail</td>
<td>Install 2 Hazard Marker(s). Install 2 Snow Plow Marker(s). Install Delineation Strips. Install Entrance or Intersecting Roadway Treatment on Approach. Install Energy Attenuating Terminal on Departure. Install 30 metres of Steel-Beam.</td>
</tr>
</tbody>
</table>

### 4.4 CULVERT & DRAINAGE IMPROVEMENTS

Based on hydraulic performance, a recommended course of action is provided for each culvert. These actions include: maintain culvert; or upsize culvert. Maintain culvert recommendation suggests the existing culvert has adequate hydraulic capacity to convey existing 5-Year design flows. Upsize culvert recommendation suggests existing culvert does not have adequate capacity to convey existing 5-Year design flows.
Table 4-2 provides a summary of the recommended actions for each culvert based on the culvert condition and drainage assessments. These actions should ultimately be considered within the context of the detailed culvert condition assessment and detailed hydraulic capacity assessments in Appendix D and E, respectively.

<table>
<thead>
<tr>
<th>Culvert ID</th>
<th>Culvert Description (interior dimensions as measured in the field)</th>
<th>Culvert Condition Assessment Recommended Action</th>
<th>Culvert Drainage Assessment Recommended Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Concrete box (1500x1800)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>2</td>
<td>Concrete box (750x1200)</td>
<td>Monitor or minor repair</td>
<td>Further investigation</td>
</tr>
<tr>
<td>3</td>
<td>CSP (1050x1200)</td>
<td>Repair, reline, or replace</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>4</td>
<td>Concrete box (900x850)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>5</td>
<td>Concrete box (1250x1800)</td>
<td>Repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>6</td>
<td>Concrete box (1850x1400)</td>
<td>Repair, reline, or replace</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>7</td>
<td>Concrete box (1250x1600)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>8</td>
<td>Concrete box (1550x1600)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>9</td>
<td>Concrete box (1250x1600)</td>
<td>Repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>10</td>
<td>Concrete box (2100x2500)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>11</td>
<td>Concrete box (1500x1650)</td>
<td>Repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>12</td>
<td>CSP (700x550)</td>
<td>Repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>12B</td>
<td>Concrete box (TBD)</td>
<td>To be assessed</td>
<td>Further investigation</td>
</tr>
<tr>
<td>13</td>
<td>HDPE (1300)</td>
<td>Monitor or minor repair</td>
<td>Further investigation</td>
</tr>
<tr>
<td>14</td>
<td>CSP (750)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>15</td>
<td>Concrete box (1250x1600)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>16</td>
<td>CSP (1250x850)</td>
<td>Repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>17</td>
<td>CSP (900x600)</td>
<td>Repair</td>
<td>Further investigation</td>
</tr>
<tr>
<td>17B</td>
<td>CSP (TBD)</td>
<td>To be assessed</td>
<td>Further investigation</td>
</tr>
<tr>
<td>Culvert ID</td>
<td>Culvert Description (interior dimensions as measured in the field)</td>
<td>Culvert Condition Assessment Recommended Action</td>
<td>Culvert Drainage Assessment Recommended Action</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>18</td>
<td>CSP (1100)</td>
<td>Monitor or minor repair</td>
<td>Further investigation</td>
</tr>
<tr>
<td>19</td>
<td>CSP (950)</td>
<td>Monitor or minor repair</td>
<td>Further investigation</td>
</tr>
<tr>
<td>20</td>
<td>CSP (1250x750)</td>
<td>Repair, reline, or replace</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>21</td>
<td>CSP (900x650)</td>
<td>Repair</td>
<td>Further investigation</td>
</tr>
<tr>
<td>22</td>
<td>Concrete box (1250x1850)</td>
<td>Repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>23</td>
<td>CSP (950)</td>
<td>Monitor or minor repair</td>
<td>Further investigation</td>
</tr>
<tr>
<td>24</td>
<td>Concrete box (3000x1750)</td>
<td>Repair</td>
<td>Further investigation</td>
</tr>
<tr>
<td>25</td>
<td>Concrete box (2400x1400)</td>
<td>Repair</td>
<td>Further investigation</td>
</tr>
<tr>
<td>26</td>
<td>CSP (750)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>
5 Estimated Capital Costs

5.1 ROADS

The preferred road rehabilitation options are to either rubblize and apply HMA pavement (Option 1) or rubblize and apply PCC pavement (Option 2). Table 5-1 and Table 5-2 below provides the capital construction costs for these two options.

Table 5-1: Road Rehabilitation Estimated Capital Construction Costs – Option 1

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobilization and Demobilization</td>
<td>LS</td>
<td></td>
<td></td>
<td>$ 658,758</td>
</tr>
<tr>
<td>Traffic Accommodation</td>
<td>LS</td>
<td></td>
<td></td>
<td>$ 500,000</td>
</tr>
<tr>
<td>Rubblize Existing Concrete Pavement</td>
<td>m3</td>
<td>142,725</td>
<td>$ 5.00</td>
<td>$ 713,625</td>
</tr>
<tr>
<td>Levelling 50mm HL 3 HS Asphalt</td>
<td>m3</td>
<td>8,434</td>
<td>$ 314.40</td>
<td>$ 2,651,571</td>
</tr>
<tr>
<td>Binder Course HL-8 and Tack Coat (60mm)</td>
<td>m3</td>
<td>9,342</td>
<td>$ 240.00</td>
<td>$ 2,242,080</td>
</tr>
<tr>
<td>Asphaltic Concrete HL1 (40mm)</td>
<td>m3</td>
<td>6,228</td>
<td>$ 400.00</td>
<td>$ 2,491,200</td>
</tr>
<tr>
<td>Granular B</td>
<td>m3</td>
<td>11,418</td>
<td>$ 43.20</td>
<td>$ 493,258</td>
</tr>
<tr>
<td>Perforated Pipe 100 mm</td>
<td>m</td>
<td>39,582</td>
<td>$ 20.00</td>
<td>$ 791,648</td>
</tr>
<tr>
<td>Bike Lane Addition</td>
<td>LS</td>
<td></td>
<td></td>
<td>$ 3,191,504</td>
</tr>
<tr>
<td>Intersection Improvements</td>
<td>LS</td>
<td></td>
<td></td>
<td>$ 48,951</td>
</tr>
<tr>
<td>Guiderail Improvements</td>
<td>LS</td>
<td></td>
<td></td>
<td>$ 300,000</td>
</tr>
<tr>
<td>Drainage Improvements</td>
<td></td>
<td></td>
<td></td>
<td>$ 200,000</td>
</tr>
<tr>
<td>Shoudering / Access Management Improvements</td>
<td></td>
<td></td>
<td></td>
<td>$ 51,322</td>
</tr>
<tr>
<td>Contingency (20%)</td>
<td></td>
<td></td>
<td></td>
<td>$ 2,635,032</td>
</tr>
<tr>
<td>Engineering Service Fees (10%)</td>
<td></td>
<td></td>
<td></td>
<td>$ 1,317,516</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>$ 18,286,464</td>
</tr>
</tbody>
</table>
Table 5-2: Road Rehabilitation Estimated Capital Construction Costs – Option 2

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobilization and Demobilization</td>
<td>LS</td>
<td></td>
<td></td>
<td>$ 831,738</td>
</tr>
<tr>
<td>Traffic Accommodation</td>
<td>LS</td>
<td></td>
<td></td>
<td>$ 500,000</td>
</tr>
<tr>
<td>Rubblize Existing Concrete Pavement</td>
<td>m3</td>
<td>142,725</td>
<td>$ 5.00</td>
<td>$ 713,625</td>
</tr>
<tr>
<td>Granular A</td>
<td>m3</td>
<td>3,205</td>
<td>$ 55.20</td>
<td>$ 931,086</td>
</tr>
<tr>
<td>PCC Pavement</td>
<td>m3</td>
<td>28,545</td>
<td>$ 300.00</td>
<td>$ 8,563,500</td>
</tr>
<tr>
<td>Granular B</td>
<td>m3</td>
<td>11,418</td>
<td>$ 43.20</td>
<td>$ 493,258</td>
</tr>
<tr>
<td>Perforated Pipe 100 mm</td>
<td>m</td>
<td>39,582</td>
<td>$ 20.00</td>
<td>$ 791,648</td>
</tr>
<tr>
<td>Bike Lane Addition</td>
<td>LS</td>
<td></td>
<td></td>
<td>$ 4,533,984</td>
</tr>
<tr>
<td>Intersection Improvements</td>
<td>LS</td>
<td></td>
<td></td>
<td>$ 52,502</td>
</tr>
<tr>
<td>Guiderail Improvements</td>
<td>LS</td>
<td></td>
<td></td>
<td>$ 300,000</td>
</tr>
<tr>
<td>Drainage Improvements</td>
<td>LS</td>
<td></td>
<td></td>
<td>$ 200,000</td>
</tr>
<tr>
<td>Shoudering / Access Management Improvements</td>
<td></td>
<td></td>
<td></td>
<td>$ 51,322</td>
</tr>
<tr>
<td>Contingency (20%)</td>
<td></td>
<td></td>
<td></td>
<td>$ 3,326,954</td>
</tr>
<tr>
<td>Engineering Service Fees (10%)</td>
<td></td>
<td></td>
<td></td>
<td>$ 1,663,477</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>$ 22,956,939</td>
</tr>
</tbody>
</table>

5.2 ROADSIDE SAFETY

Remediation measures and suggested associated unit costs for roadside safety improvements were obtained from the Ministry of Transportation Ontario’s Highway Costing (HICO) System and are presented in Table 5-3.
Table 5-3: Roadside Safety Remediation Measures and HICO System Unit Costs

<table>
<thead>
<tr>
<th>No.</th>
<th>Installation Cost</th>
<th>Cost/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Install Hazard Markers</td>
<td>$200.00/each</td>
</tr>
<tr>
<td>2</td>
<td>Install Snow Plow Markers</td>
<td>$200.00/each</td>
</tr>
<tr>
<td>3</td>
<td>Install Delineation Strips</td>
<td>$200.00/each</td>
</tr>
<tr>
<td>4</td>
<td>Install Approach End Treatment</td>
<td>$5,100.00/each</td>
</tr>
<tr>
<td>5</td>
<td>Install Departure End Treatment</td>
<td>$5,100.00/each</td>
</tr>
<tr>
<td>6</td>
<td>Install System Transitions</td>
<td>$5,100.00/each</td>
</tr>
<tr>
<td>7</td>
<td>Install Guide-Post</td>
<td>$20.00/m</td>
</tr>
<tr>
<td>8</td>
<td>Install Three-Cable</td>
<td>$34.00/m</td>
</tr>
<tr>
<td>9</td>
<td>Install Entrance or Intersecting Roadway</td>
<td>$82.00/m</td>
</tr>
<tr>
<td>10</td>
<td>Install High-Tension Cable</td>
<td>$51.00/m</td>
</tr>
<tr>
<td>11</td>
<td>Install Steel-Beam</td>
<td>$82.00/m</td>
</tr>
<tr>
<td>12</td>
<td>Install Steel-Beam with Channel</td>
<td>$96.00/m</td>
</tr>
<tr>
<td>13</td>
<td>Install Concrete</td>
<td>$190.00/m</td>
</tr>
<tr>
<td>14</td>
<td>Extend Guide-Post</td>
<td>$20.00/m</td>
</tr>
<tr>
<td>15</td>
<td>Extend Three-Cable</td>
<td>$34.00/m</td>
</tr>
<tr>
<td>16</td>
<td>Extend Entrance or Intersecting Roadway</td>
<td>$82.00/m</td>
</tr>
<tr>
<td>17</td>
<td>Extend High-Tension Cable</td>
<td>$51.00/m</td>
</tr>
<tr>
<td>18</td>
<td>Extend Steel-Beam</td>
<td>$82.00/m</td>
</tr>
<tr>
<td>19</td>
<td>Extend Concrete</td>
<td>$190.00/m</td>
</tr>
<tr>
<td>20</td>
<td>Remove Guide-Post</td>
<td>$3.00/m</td>
</tr>
<tr>
<td>21</td>
<td>Remove Three-Cable</td>
<td>$5.75/m</td>
</tr>
<tr>
<td>22</td>
<td>Remove Entrance or Intersecting Roadway</td>
<td>$9.00/m</td>
</tr>
<tr>
<td>23</td>
<td>Remove High-Tension Cable</td>
<td>$8.65/m</td>
</tr>
<tr>
<td>24</td>
<td>Remove Steel-Beam</td>
<td>$9.25/m</td>
</tr>
<tr>
<td>25</td>
<td>Remove Concrete</td>
<td>$88.00/m</td>
</tr>
</tbody>
</table>
Table 5-4 below shows the estimated construction cost per guide rail and hazard and is approximately $300,000.

Table 5-4: Roadside Safety Estimated Capital Construction Costs

<table>
<thead>
<tr>
<th>Facility ID</th>
<th>Remediation Measure Classification</th>
<th>Total Remediation Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Replace Guide Rail</td>
<td>$15,385.00</td>
</tr>
<tr>
<td>2</td>
<td>Replace Guide Rail</td>
<td>$21,304.00</td>
</tr>
<tr>
<td>3</td>
<td>Replace Guide Rail</td>
<td>$15,896.33</td>
</tr>
<tr>
<td>4</td>
<td>Replace Guide Rail</td>
<td>$43,235.00</td>
</tr>
<tr>
<td>5</td>
<td>Replace Guide Rail</td>
<td>$19,070.00</td>
</tr>
<tr>
<td>6</td>
<td>Replace Guide Rail</td>
<td>$19,820.00</td>
</tr>
<tr>
<td>7</td>
<td>Remove Guide Rail</td>
<td>$315.00</td>
</tr>
<tr>
<td>8</td>
<td>Remove Guide Rail</td>
<td>$1,125.00</td>
</tr>
<tr>
<td>9</td>
<td>Remove Guide Rail</td>
<td>$405.00</td>
</tr>
<tr>
<td>10</td>
<td>Replace Guide Rail</td>
<td>$17,816.22</td>
</tr>
<tr>
<td>11</td>
<td>Replace Guide Rail</td>
<td>$14,250.00</td>
</tr>
<tr>
<td>12</td>
<td>Replace Guide Rail</td>
<td>$15,480.00</td>
</tr>
<tr>
<td>13</td>
<td>Remove Guide Rail</td>
<td>$180.00</td>
</tr>
<tr>
<td>14</td>
<td>Replace Guide Rail</td>
<td>$16,215.00</td>
</tr>
<tr>
<td>15</td>
<td>Remove Guide Rail</td>
<td>$400.00</td>
</tr>
<tr>
<td>16</td>
<td>Minor Treatments</td>
<td>$-</td>
</tr>
<tr>
<td>17</td>
<td>Minor Treatments</td>
<td>$-</td>
</tr>
<tr>
<td>18</td>
<td>Minor Treatments</td>
<td>$-</td>
</tr>
<tr>
<td>19</td>
<td>Replace Guide Rail</td>
<td>$36,550.00</td>
</tr>
<tr>
<td>20</td>
<td>Replace Guide Rail</td>
<td>$32,660.00</td>
</tr>
<tr>
<td>21</td>
<td>Install Guide Rail</td>
<td>$12,840.00</td>
</tr>
<tr>
<td>22</td>
<td>Install Guide Rail</td>
<td>$13,660.00</td>
</tr>
</tbody>
</table>
5.3 TOTAL OVERALL COST ESTIMATE

Table 5-5 and Table 5-6 are high level estimated costs for the full project including road reconstruction, roadside safety improvements and culvert rehabilitation for Options 1 and 2. Estimates are construction costs with a contingency of 20%.

Table 5-5: Full Estimated Construction Costs (Option 1)

<table>
<thead>
<tr>
<th></th>
<th>Fees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Reconstruction</td>
<td>$13,833,916</td>
</tr>
<tr>
<td>Roadside Safety Improvements</td>
<td>$300,000</td>
</tr>
<tr>
<td>Drainage Improvements</td>
<td>$200,000</td>
</tr>
<tr>
<td>Contingency (20%)</td>
<td>$2,635,032</td>
</tr>
<tr>
<td>Engineering Fees (10%)</td>
<td>$1,317,516</td>
</tr>
<tr>
<td><strong>Total Fees</strong></td>
<td><strong>$18,286,464</strong></td>
</tr>
</tbody>
</table>

Table 5-6: Full Estimated Construction Costs (Option 2)

<table>
<thead>
<tr>
<th></th>
<th>Fees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Reconstruction</td>
<td>$17,411,341</td>
</tr>
<tr>
<td>Roadside Safety Improvements</td>
<td>$300,000</td>
</tr>
<tr>
<td>Drainage Improvements</td>
<td>$200,000</td>
</tr>
<tr>
<td>Contingency (20%)</td>
<td>$3,326,954</td>
</tr>
<tr>
<td>Engineering Fees (10%)</td>
<td>$1,663,477</td>
</tr>
<tr>
<td><strong>Total Fees</strong></td>
<td><strong>$22,956,939</strong></td>
</tr>
</tbody>
</table>
6  Next Steps for Design and Construction

The next steps for the County Road 49 road reconstruction are detailed below. Comments from MTO Provincial Highways Management have been included here, and are also appended to this report. When moving forward into preliminary and detailed design and construction, these tasks should be to be addressed:

1. A proper survey is required to determine the existing road and landscape profile, as well as to document the exact location of the existing culverts, guide rails, and hazards.
2. The MOECC requirements for concrete disposal need to be confirmed.
3. Traffic control during construction should be decided upon. There are many options for how to control traffic during construction, including constructing one lane at a time or creating a temporary lane so the entire width of the roadway can be rubblized at the same time. It is important to remember that during construction, after rubblizing the concrete, two (2) lifts of asphalt are required prior to vehicular traffic being able to use the lane.
4. Preliminary and detailed design should be scheduled for one year. Construction will most likely take two construction seasons to complete. Construction staging should be determined during detail design and will be dependent upon funding allocation over the two years.
5. Further analysis will be required at the detailed design stage to determine whether Option 1 or 2 is the most cost-effective option.
6. Improved drainage could be achieved if Granular O is used instead of Granular A. This option could lead to limiting the use of subdrains along the road and cost saving could be achieved. This should be analysed further in preliminary design.
7. The need for subdrains all along the road in both shoulders should be analyzed further. Cost savings could be achieved by noting locations where subdrains are warranted, for instance in locations of dips the road profile versus high points in the road.
8. Additional analysis may be warranted with regards to resonant vs. multi-head hammer rubblizing equipment (i.e. costs vs. capabilities vs. production rates). OPSS hard-specifies the use of resonant equipment based on better fracturing results and less damage to subgrade surface, however many jurisdictions allow hammer-based rubblization recognizing benefits of the relatively high production rate and resultant lower cost and reduced lane closure periods.
9. The use of rubblization should be discussed with a specialized rubblization contractor. The use of this technology for concrete slabs with dowels, wire mesh and slabs spacers should be confirmed at the preliminary design stage.
10. Additional correlation work between the GPR data and available cores may be warranted.
11. Ditching work and cross sections of ditches should be revisited during preliminary design after a full topographical survey has been completed on the road and existing ditches.
12. The percent crossfall (1.5% versus 2%) used for the new road should be further investigation at the preliminary design stage.
This report presents our findings regarding the Prince Edward County - County Road 49 Road Condition Assessment and Rehabilitation Options Final Report

Prepared By:

Simone Bourke, M.Sc., P.Eng.
Civil Engineer

Jeff Suggett, M.Sc.
Acting Manager, Transportation
Appendix A – Road Condition Assessment
Supporting Documents
Legend
*Number on road represents Section ID

Riding Condition Rating (RCR)

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10

Figure A1
County Road 49
Road Condition Assessment
Riding Condition Rating

SCALE 1:100,000
**Rigid Pavement Condition Evaluation Form**

**Section ID:** Section 1  
**From (km):** 0 km (at County Road 15)  
**To (km):** 1 km

**LHRS**  
**Section Length:** 1 km

**Survey Date:** 17 08  
**PCR:**  
**RCR:** 4  
**Traffic Direction:** B  
**Highway:** 49

**Contract No.**  
**WP No.**  
**Class**

**Evaluation by:** A. Connell & B. Bradt

**Roadside Environment:** Rural

**Ride Comfort Rating (RCR), 0 to 10:** 4

**Distress Manifestation Index (DMI), 0 to 10:** 2.3

**Pavement Condition Index (PCI), 0 to 100:** 10

---

### Sev. of Distress

<table>
<thead>
<tr>
<th>Severity</th>
<th>Very Bad</th>
<th>Slight</th>
<th>Moderate</th>
<th>Severe</th>
<th>Very Severe</th>
<th>Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Good</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fair</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Poor</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Few</td>
</tr>
</tbody>
</table>

---

### Density of Distress

<table>
<thead>
<tr>
<th>Density</th>
<th>Very Bad</th>
<th>Slight</th>
<th>Moderate</th>
<th>Severe</th>
<th>Very Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Fair</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Good</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

---

### Pavement Defects

#### Surface Defects

- **Patching & C. App. Loss**
- **Polishing**
- ** Scaling**
- **Potholing**
- **Joint & Crack Spalling**

#### Surface Deformations

- **Patching (Staggering)**
- **Distress (Slagging of Slab Warping)**

#### Joint Deficiencies

- **Joint Sealant Loss**
- **Transverse Joint creep**
- **Longitudinal Joint Separation**
- **Joint Failure (Shoe up)**
- **Longitudinal and Meandering**

#### Cracking

- **Diagonal, Corner, and Edge Crescent**
- **Transverse**

---

**Distress Comments:**  
- Almost alligator cracking / surface exhaustion throughout
- Edge drop off northbound

**Other Comments:**
### Rigid Pavement Condition Evaluation Form

**Section ID:** Section 2  
**From (km):** 1 km  
**To (km):** 2 km

**LHRS:** Begins  
**Section Length:** 1 km

**Survey Date:** 17 08  
**PCR:**  
**RCR:** 3  
**Traffic Direction:** B  
**Highway:** 49

**Contract No.:**  
**WP No.:**

**Facility:**  
**Class:**

---

**Ride Condition Rating (at 80 km/h):**

- **Excellent:** Smooth and pavement
- **Good:** Conformable
- **Fair:** Usable
- **Poor:** Rough and bumpy
- **Very Poor:** Dangerous at 80 km/h

**Roadside Environment:** Rural

**Ride Comfort Rating (RCR), 0 to 10:** 3

**Distress Manifestation Index (DMI), 0 to 10:** 2.2

**Pavement Condition Index (PCI), 0 to 100:** 0

---

#### Pavement

<table>
<thead>
<tr>
<th>Surface Defects</th>
<th>Severity</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaveling &amp; C. App. Loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polishing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scaling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polishing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joint &amp; Crack Spalling</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surface Deformations</th>
<th>Severity</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distortion (Peeling or Splitting)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Joint Deficiencies</th>
<th>Severity</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse Joint Creep</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitudinal Joint Separation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joint Failure (Blow up)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cracking</th>
<th>Severity</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal and Meandering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagonal, Corner, and Edge Crescent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transverse</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Distress Comments:** Loss of crown in middle of southbound lane, large crack likely from inadequate drainage

**Other Comments:** (e.g., subsections, additional comments)

---

Evaluated by A. Connell & B. Bradt
## Rigid Pavement Condition Evaluation Form

### Section Information
- **Section ID:**
- **From (km):** 2 km
- **To (km):** 3 km
- **LHRS:**
  - Begins
  - Offset
- **Section Length:** 1 km

### Survey Information
- **Survey Date:**
  - Year: 17
  - Month: 08
- **PCR:**
- **RCR:** 3
- **Traffic Direction:** B
- **Highway:** 49
- **Contract No.:**
- **WP No.:**

### Pavement Condition

#### Distress Manifestation Index (DMI), 0 to 10:
- **Joint Deficiencies:**
  - **Distress:**
    - Fading (Drying): 7
    - Joint Sealant Loss: 5
    - Transverse Joint Creep: 9
    - Joint Failure: 9
    - Longitudinal Joint Separation: 9
    - Joint Failure ( Blow gap): 11
  - **Density of Distress:**
    - Very slight
    - Slight
    - Moderate
    - Severe
    - Very Severe
    - Few
    - Intermittent
    - Frequent
    - Extensive
    - Throughout

#### Ride Comfort Rating (RCR), 0 to 10:
- **Rural:**

#### Pavement Condition Index (PCI), 0 to 100:
- **3.9**

### Distress Comments
- (Items not covered above)

### Other Comments
- (e.g. subsections, additional contracts)
## Rigid Pavement Condition Evaluation Form

### Section 4

- **From (km):** 3 km
- **To (km):** 4 km
- **LHRS Begins:** km
- **District:**
- **Section Length:** 1 km
- **Survey Date:** 17 08
- **PCR:**
- **RCR:** 3.5
- **Traffic Direction:** B
- **Highway:** 49
- **Contract No.:**
- **WP No.:**

### Pavement

#### Surface Defects

<table>
<thead>
<tr>
<th>Description</th>
<th>Severity of Distress</th>
<th>Density of Distress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raveling &amp; C. App. Loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polishing</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Sealing</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Polishing</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Joint &amp; Crack Spalling</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

#### Surface Deformations

<table>
<thead>
<tr>
<th>Description</th>
<th>Severity of Distress</th>
<th>Density of Distress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distortion (Slight &amp; Stiff)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Joint Displacement</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

#### Joint Deficiencies

<table>
<thead>
<tr>
<th>Description</th>
<th>Severity of Distress</th>
<th>Density of Distress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse Joint Creep</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Longitudinal Joint Separation</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Joint Failure (Blow up)</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

#### Cracking

<table>
<thead>
<tr>
<th>Description</th>
<th>Severity of Distress</th>
<th>Density of Distress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal and Meandering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hairline, Corner, and Edge Crescent 'Y'</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Transverse</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

### Ride Comfort Rating (RCR)

- **Ride Comfort Rating:** 3.5

### Distress Manifestation Index (DMI)

- **Distress Manifestation Index:** 2.3

### Pavement Condition Index (PCI)

- **Pavement Condition Index:** 5

### Other Comments

- (e.g. subsections, additional contracts)

---

---
**RIGID PAVEMENT CONDITION EVALUATION FORM**

Section ID: **Section 5**  
From (km): **4 km**  
To (km): **5 km**

**LHRS**  
BEGIN: [ ]  
OFFSET: [ ]  
Section Length: **1 km**

**Survey Date**  
YEAR: **17**  
MONTH: **08**  
PCR: [ ]  
RCR: **4**  
Traffic Direction: **B**  
Highway: **49**

**Contract No.**  
[ ]  
WP No.  
[ ]  
[ ]

**Facility**  
[ ]  
Class  
[ ]

EVALUATED BY: A. Connell & B. Bradt

---

**Roadside Environment:** Rural

**Ride Comfort Rating (RCR), 0 to 10:**  
4

**Distress Manifestation Index (DMI), 0 to 10:**  
3.3

**Pavement Condition Index (PCI), 0 to 100:**  
16.7

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**Pavement**

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**Surface Defects**

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**Cracking**

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</tr>
<tr>
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<td>Joint &amp; Crack Spalling</td>
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**Distress Comments**  
(items not covered above)

**Other Comments**  
(e.g. subsections, additional contracts)
## Rigid Pavement Condition Evaluation Form

**Section ID:** Section 8  
**From (km):** 7 km  
**To (km):** 8 km

**LHRS** begins at km 0 and ends at km 1.  
Section Length: 1 km

**Survey Date:** 17 08  
**PCR:**  
**RCR:** 5  
**Traffic Direction:** B  
**Highway:** 49

**Contract No.** -  
**WP No.** -  
**Facility** -  
**Class** -

### Pavement

#### Surface Defects
- Reaveling & C. App. Loss: 1  
- Polishing: 2
- Scaling: 3
- Potholing: 4
- Joint & Crack Spalling: 5

#### Surface Deformations
- Distress (Sinking or Slab Warping): 1
- Joint S卫健委 Loss: 2
- Transverse Joint Creep: 3
- Longitudinal Joint Separation: 4
- Joint Failure (Blow up): 5

#### Joint Deficiencies
- Longitudinal and Meandering: 6
- Diagonal, Corner, and Edge Lienvescent: 7

#### Cracking
- Transverse: 8

### Distress Comments
(Items not covered above)

### Other Comments
(e.g. subsections, additional contracts)

### Ride Comfort Rating (RCR), 0 to 10:

5

### Distress Manifestation Index (DMI), 0 to 10:

4.3

### Pavement Condition Index (PCI), 0 to 100:

32

### Roadside Environment:

Rural

### Evaluated by:

A. Connell & B. Bradt
**RIGID PAVEMENT CONDITION EVALUATION FORM**

Section ID: Section 7  
From (km): 6 km  
To (km): 7 km  

**LHRS**  
BEGIN  
OFFSET  

**Section Length**  
1 km  

**Survey Date**  
17 08  

**PCR**  
rcr  

**RCR**  
6  

**Traffic Direction**  
B  

**Highway**  
49  

**Contract No.**  
-  

**WP No.**  
-  

**Evaluative by**  
A. Connell & B. Bradt

---

**Ride Comfort Rating (RCR), 0 to 10:** 6  
**Distress Manifestation Index (DMI), 0 to 10:** 4.6  
**Pavement Condition Index (PCI), 0 to 100:** 40

---

**Roadside Environment:** Rural  

---

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<tr>
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<th>Severity of Distress</th>
<th>Density of Distress</th>
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<td>Surface Defects</td>
<td>Very Slight</td>
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<td>Scaling</td>
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<tr>
<td>Joint &amp; Crack Spalling</td>
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**Distress Comments**  
(e.g. subsections, additional contracts)

---

**Other Comments**  
(e.g. subsections, additional contracts)
RIGID PAVEMENT CONDITION EVALUATION FORM

Section ID: Section 8  From (km): 7 km  To (km): 8 km

LHRS  km  Section Length  1 km

Survey Date  17  8  PCR  RCR  6

Traffic Direction  B  Highway  49

Contract No.  -  WP No.  -  -

Facility  -  Class  -

Evaluated by  A. Connell & B. Bradt

Roadside Environment:  Rural

Ride Comfort Rating (RCR), 0 to 10:  6

Distress Manifestation Index (DMI), 0 to 10:  5.1

Pavement Condition Index (PCI), 0 to 100:  44

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<th>SEVERITY OF DISTRESS</th>
<th>DENSITY OF DISTRESS</th>
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<td>(e.g. subsections, additional contracts)</td>
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Pavement Condition Index (PCI), 0 to 100:  44

Ride Comfort Rating (RCR), 0 to 10:  6

Distress Manifestation Index (DMI), 0 to 10:  5.1
## Rigid Pavement Condition Evaluation Form

**Section ID:** Section 9  
**From (km):** 8 km  
**To (km):** 9 km  
**LHRS** Begins:  
**Section Length:** 1 km  
**Survey Date:** 17 08  
**PCR:**  
**RCR:** 6  
**Traffic Direction:** B  
**Highway:** 49  
**Contract No.:**  
**WP No.:**  
**Facility:**  
**Class:**  
**District:**  
**Roadside Environment:** Rural  
**Ride Comfort Rating (RCR):** 6  
**Distress Manifestation Index (DMI):** 5.4  
**Pavement Condition Index (PCI):** 46  

### Pavement

#### Distress Comments

**Other Comments**

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<td>Potholing</td>
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<tr>
<td>Distress Cracking or Wiping</td>
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<tr>
<td>Joint Failure (Blow up)</td>
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<tr>
<td>Transverse Joint Crack</td>
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### Survey Date

**YEAR:** 17  
**MONTH:** 08  
**PCR:**  
**RCR:** 6  
**Traffic Direction:** B  
**Highway:** 49  
**Contract No.:**  
**WP No.:**  
**Facility:**  
**Class:**  
**District:**  
**Roadside Environment:** Rural  
**Ride Comfort Rating (RCR):** 6  
**Distress Manifestation Index (DMI):** 5.4  
**Pavement Condition Index (PCI):** 46  

### Severity of Distress

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### Density of Distress

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<th>Intermittent</th>
<th>Frequent</th>
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Evaluated by: A. Connell & B. Bradt

---

**Section ID:** Section 9  
**From (km):** 8 km  
**To (km):** 9 km  
**LHRS** Begins:  
**Section Length:** 1 km  
**Survey Date:** 17 08  
**PCR:**  
**RCR:** 6  
**Traffic Direction:** B  
**Highway:** 49  
**Contract No.:**  
**WP No.:**  
**Facility:**  
**Class:**  
**District:**  
**Roadside Environment:** Rural  
**Ride Comfort Rating (RCR):** 6  
**Distress Manifestation Index (DMI):** 5.4  
**Pavement Condition Index (PCI):** 46  

### Pavement

#### Distress Comments

**Other Comments**

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<td>Transverse Joint Crack</td>
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### Survey Date

**YEAR:** 17  
**MONTH:** 08  
**PCR:**  
**RCR:** 6  
**Traffic Direction:** B  
**Highway:** 49  
**Contract No.:**  
**WP No.:**  
**Facility:**  
**Class:**  
**District:**  
**Roadside Environment:** Rural  
**Ride Comfort Rating (RCR):** 6  
**Distress Manifestation Index (DMI):** 5.4  
**Pavement Condition Index (PCI):** 46  

### Severity of Distress

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### Density of Distress

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Evaluated by: A. Connell & B. Bradt

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2017.5144 County Rd 49 Assessment
## Rigid Pavement Condition Evaluation Form

### Section Information
- **Section ID:** Section 10
- **From (km):** 9 km
- **To (km):** 10 km
- **LHRS:** BEGINS 1 km OFFSET
- **Section Length:** 1 km
- **District:**
- **Survey Date:** 17 08
- **PCR:**
- **RCR:** 6
- **Traffic Direction:** B
- **Highway:** 49
- **Contract No.:**
- **WP No.:**
- **Facility:**
- **Class:**

### Pavement Condition

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### Roadside Environment
- **Roadside Environment:** Rural

### Ride Comfort Rating (RCR)
- **0 to 10:** 6

### Distress Manifestation Index (DMI)
- **0 to 10:** 4.9

### Pavement Condition Index (PCI)
- **0 to 100:** 42

### Other Comments
- (e.g., subsections, additional contracts)
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Distress Comments: (Items not covered above)

Other Comments: (eg. subsections, additional contracts)

Pavement Condition Index (PCI), 0 to 100: 39

Roadside Environment: Rural

Pavement Condition Index (PCI), 0 to 100: 39

Ride Comfort Rating (RCR), 0 to 10: 5

Distress Manifestation Index (DMI), 0 to 10: 5.4
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<td>Very Poor</td>
<td>Dangerous at 60 km/h</td>
</tr>
</tbody>
</table>

- **Pavement**
  - **SURFACE DEFECTS**
    - Reaveling & C. App. Loss
    - Polishing
    - Scaling
    - Potholing
    - Joint & Crack Spalling
  - **SURFACE DEFORMATIONS**
    - Distortion (Sagging or Slab Warping)
  - **JOINT DEFCIENCIES**
    - Transverse Joint Creep
    - Longitudinal Joint Separation
    - Joint Failure (Blow up)
  - **CRACKING**
    - Longitudinal and Meandering
    - Diagonal, Corner, and Edge Crescents
    - Transverse

- **Roadside Environment:** Rural
- **Ride Comfort Rating (RCR), 0 to 10:** 4
- **Distress Manifestation Index (DMI), 0 to 10:** 3.1
- **Pavement Condition Index (PCI), 0 to 100:** 15

**Other Comments** (e.g. subsections, additional contracts)

**Evaluators:** A. Connell & B. Bradt
RIGID PAVEMENT CONDITION EVALUATION FORM

Section ID: Section 13  
From (km): 12 km  
To (km): 13 km  

District

Survey Date: 17/08  
PCR: 3  
RCR: 3  
Traffic Direction: B  
Highway: 49

Contract No. - WP No.

Facility - Class

Evaluated by: A. Connell & B. Bradt

Roadside Environment: Rural

Ride Comfort Rating (RCR), 0 to 10: 3

Distress Manifestation Index (DMI), 0 to 10: 2.4

Pavement Condition Index (PCI), 0 to 100: 1

SEVERITY OF DISTRESS

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<tr>
<th>Pavement</th>
<th>Very Slight</th>
<th>Slight</th>
<th>Moderate</th>
<th>Severe</th>
<th>Very Severe</th>
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<td>3</td>
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<tr>
<td>Joint &amp; Crack Spalling</td>
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DENSITY OF DISTRESS

<table>
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<tr>
<th>Pavement</th>
<th>Few</th>
<th>Intermittent</th>
<th>Frequent</th>
<th>Extensive</th>
<th>Throughout</th>
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<td>4</td>
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<td>4</td>
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<td>Joint &amp; Crack Spalling</td>
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Distress Comments: (Items not covered above)

Other Comments: (e.g. subsections, additional contracts)
### RIGID PAVEMENT CONDITION EVALUATION FORM

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<th><strong>Pavement</strong></th>
<th><strong>Severity of Distress</strong></th>
<th><strong>Density of Distress</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Surface Defects</strong></td>
<td>Good, Med, &amp; Bad</td>
<td>Few, Intermittent, Frequent, Throughout</td>
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<tr>
<td></td>
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<td>Slight</td>
</tr>
<tr>
<td></td>
<td>Few</td>
<td>Intermittent</td>
</tr>
<tr>
<td><strong>Surface Deformations</strong></td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Very Rough &amp; Uneven</td>
<td>Rough</td>
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<tr>
<td><strong>Joint Deficiencies</strong></td>
<td>Excellent</td>
<td>Good</td>
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<tr>
<td></td>
<td>Very Good</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Cracking</strong></td>
<td>Excellent</td>
<td>Good</td>
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<tr>
<td></td>
<td>Excellent</td>
<td>Good</td>
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</table>

- **Joins & Crack Spalling**: 3
- **Faulting (Stepping)**: 1
- **Distortion (Sagging or Slab Warping)**: 3
- **Joint Sealant Loss**: 3
- **Transverse Joint Creep**: 3
- **Longitudinal Joint Separation**: 2
- **Joint Failure (Blow ups)**: 4
- **Longitudinal and Meandering**: 3
- **Dia, Corner, and Edge Crevice**: 3
- **Transverse**: 4

**Roadside Environment**: Rural

**Ride Comfort Rating (RCR)**: 2.5

**Distress Manifestation Index (DMI)**: 3.0

**Pavement Condition Index (PCI)**: 0

**Other Comments**: (e.g., subsections, additional contracts)
# Rigid Pavement Condition Evaluation Form

**Section ID:** Section 15  
**From (km):** 14 km  
**To (km):** 15 km  
**LHRS:**  
**Section Length:** 1 km  
**Survey Date:** 17 08  
**PCR:**  
**RCR:** 3  
**Traffic Direction:** B  
**Highway:** 49  
**Contract No.:**  
**WP No.:**  
**Facility:**  
**Class:**  

**EVALUATED BY:** A. Connell & B. Bradt

## Pavement

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<tr>
<th>Defect Type</th>
<th>Severity</th>
<th>Density</th>
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<td>Raveling &amp; C. App. Loss</td>
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<td>Polishing</td>
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<td>3</td>
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<tr>
<td>Scaling</td>
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<tr>
<td>Polishing</td>
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<td>3</td>
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<tr>
<td>Joint &amp; Crack Spalling</td>
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<tr>
<td>Distress (Sloping or Stiff Wasting)</td>
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<tr>
<td>Faulting (Stepping)</td>
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<td>Joint Seaward Loss</td>
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<td>Transverse Joint Creep</td>
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<td>Longitudinal Joint Separation</td>
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<tr>
<td>Joint Failure (Blow up)</td>
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<td>Longitudinal and Meandering</td>
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<td>Diagonal, Corner, and Edge Crescent 'D'</td>
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<td>Transverse</td>
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**Roadside Environment:** Rural

**Ride Comfort Rating (RCR), 0 to 10:** 3

**Distress Manifestation Index (DMI), 0 to 10:** 3.1

**Pavement Condition Index (PCI), 0 to 100:** 6

**Other Comments**

(e.g. subsections, additional contracts)
RIGID PAVEMENT CONDITION EVALUATION FORM

Section ID: Section 16
From (km): 15 km
To (km): 16 km

LHRS

Section Length 1 km

Survey Date 17 08

PCR

RCR 3.5

Traffic Direction B

Highway 49

Contract No. - WP No. -

Facility - Class -

Roadside Environment: Rural

Ride Comfort Rating (RCR), 0 to 10: 3.5

Distress Manifestation Index (DMI), 0 to 10: 3.8

Pavement Condition Index (PCI), 0 to 100: 15

Evaluating

A. Connell & B. Bradt

Pavement Condition Index (PCI), 0 to 100: 15

SEVERITY OF DISTRESS

DENSITY OF DISTRESS

EXCELLENT

GOOD

FAIR

POOR

VARY POOR

0

1

2

3

4

5

6

7

8

9

10

Ride Comfort Rating (at 80 km/h)

EXCELLENT

GOOD

FAIR

POOR

VARY POOR

Very rough and bumpy

Rough

Bumpy

Poor

Very poor

Emergency

Slight

Moderate

Severe

Very severe

Ripped

Intermittent

Frequent

Extensive

Throughout

Facility

Class

Severities of Distress

Density of Distress

Exceeds

Significant

Moderate

Slight

Very slight

None

Facility

Traffic Direction

Survey Date

PCR

RCR

Traffic Direction

Highway

Contract No.

WP No.

Ride Comfort Rating (RCR)

Distress Manifestation Index (DMI)

Pavement Condition Index (PCI)

Roadside Environment

Rural

3.5

3.8

15

A. Connell & B. Bradt

2017-5144 County Rd 49 Assessment

Other Comments (e.g. subsections, additional contracts)
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<tr>
<th>Item</th>
<th>Severity</th>
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**Distress Comments**

This section includes the extra 0.3 km to complete the study area at 667 County Rd 49.
Appendix B – Road and Intersection Geometry Supporting Documents
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Date: Thurs. Sept. 7, 2017
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**Date:** Thurs. Sept. 7, 2017  
**Location:** County Road 49 and County Road 15  
**Location:** County Road 49 and County Road 15
LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALLIZED

% LEFT TURNS IN $V_A = 5%$
S = STORAGE LENGTH
DESIGN SPEED = 90 km/h

Worst case:
Time: 16:30 - 17:30
Advancing Volume: 198 vehicles
Opposing Volume: 239 vehicles
Turning Vehicles: 8 vehicles

Left Turn Lane NOT warranted.

TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL
AREAS OR URBAN AREAS WITH RESTRICTED FLOW

TRAFFIC SIGNALS MAY BE WARRANTED IN
"FREE FLOW" URBAN AREAS

LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALLIZED

% LEFT TURNS IN $V_A = 10%$
S = STORAGE LENGTH
DESIGN SPEED = 90 km/h

Figure EA-18
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Date: Friday Sept. 8, 2017
Location: County Road 49 and White Chapel Road

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Date: _Friday Sept. 8, 2017_

Location: County Road 49 and White Chapel Road

Location: County Road 49 and White Chapel Road

Time: North Approach, East Approach, South Approach, West Approach

Location: County Road 49 and White Chapel Road
LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALED

% LEFT TURNS IN $v_a = 5\%$

$S =$ STORAGE LENGTH

DESIGN SPEED = 90 km/h

Worst Case:
Time: 16:15 - 17:15
Advancing Volume: 258 vehicles
Opposing Volume: 219 vehicles
Turning Vehicles: 1 vehicle

Left Turn Lane NOT warranted.

TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW

TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS

Figure EA-18
ROADSIDE OBJECTS LAYER DATA DICTIONARY

TABLE OF CONTENTS

Table of Contents 1
1. General Information 2
2. Guide Rail Information 7
3. Hazard Information 11
4. Condition Assessment Information 13
5. Risk Assessment Information 16
6. Remediation Information 24
1 GENERAL INFORMATION

facilityID

facilityID uniquely identifies each guide rail/unprotected hazard in the roadside objects layer and was automatically assigned at the time of the assessment.

previousFacilityID

previousFacilityID uniquely identifies each guide rail/unprotected hazard in the roadside objects layer and was previously assigned by the County of Prince Edward.

roadSegmentFacilityID

roadSegmentFacilityID corresponds with the objectID in the single line road network (SLRN) layer provided by the County of Prince Edward and denotes the unique identifier of the roadway adjacent to the corresponding guide rail/unprotected hazard and was automatically appended at the time of the assessment.

fullName

fullName corresponds with the street_name in the single line road network (SLRN) layer provided by the County of Prince Edward and denotes the full name of the roadway adjacent to the corresponding guide rail/unprotected hazard and was automatically appended at the time of the assessment.

fromStreet

fromStreet corresponds with the limit1 in the single line road network (SLRN) layer provided by the County of Prince Edward and is a non-directional attribute denoting the intersecting street at the approaching end of the roadway adjacent to the corresponding guide rail/unprotected hazard and was automatically appended at the time of the assessment.

toStreet

toStreet corresponds with the limit2 in the single line road network (SLRN) layer provided by the County of Prince Edward and is a non-directional attribute denoting the intersecting street at the departing end of the roadway adjacent to the corresponding guide rail/unprotected hazard and was automatically appended at the time of the assessment.

currentAADT

currentAADT corresponds with the currentAADT derived from various data sources appended to the single line road network layer (SLRN) provided by the County of Prince Edward and denotes the non-directional average annual daily traffic (AADT) volume of the roadway adjacent to the guide rail/unprotected hazard and was automatically appended at the time of the assessment.
postedSpeed

postedSpeed is a integer data type representing the posted speed limit (in kilometres per hour) of the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

*note:* where posted speed limits were not present, a statutory speed limit of 80 kilometres per hour was assumed

designSpeed

designSpeed is a integer data type representing the design speed limit (in kilometres per hour) of the roadway adjacent to the guide rail/unprotected hazard and was calculated at the time of the assessment using \( \text{designSpeed} = \text{postedSpeed} + 10 \)

horizontalAlignment

horizontalAlignment is a “yes” or “no” indicator of whether or not a horizontal curve is present on the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

dividedRoadway

dividedRoadway is a “yes” or “no” indicator of whether or not a physical median is present on the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

adjacentLanes

adjacentLanes is a integer data type representing the number of adjacent lanes of the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

leftTurnLane

leftTurnLane is a “yes” or “no” indicator of whether or not a two-way/continuous left-turn lane is present on the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

barrierCurb

barrierCurb is a “yes” or “no” indicator of whether or not a barrier curb is present on the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

concreteSidewalk

concreteSidewalk is a “yes” or “no” indicator of whether or not a concrete sidewalk is present on the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment
clearZone

clearZone is a floating-point double data type representing the clear zone of the roadway adjacent to the guide rail/unprotected hazard and was determined at the time of the assessment using currentAADT, designSpeed, horizontalAlignment, and barrierCurb, and with the Roadside Safety Manual.¹

IF horizontalAlignment = Yes THEN horizontalCurveCorrelationFactor = 1.50

IF horizontalAlignment = No THEN horizontalCurveCorrelationFactor = 1.00

clearZone = clearZone × horizontalCurveCorrelationFactor

Table 1-1
Clear Zone Widths

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<th>B</th>
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### Table 1-2
**Horizontal Curve Correlation Factors**

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<th>Horizontal Curve Correlation Factor</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Design Speed (kilometres per hour)</td>
</tr>
<tr>
<td></td>
<td>≤ 60</td>
</tr>
<tr>
<td>1000</td>
<td>1.00</td>
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</tr>
<tr>
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<td>1.08</td>
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<tr>
<td>700</td>
<td>1.09</td>
</tr>
<tr>
<td>600</td>
<td>1.10</td>
</tr>
<tr>
<td>500</td>
<td>1.11</td>
</tr>
<tr>
<td>400</td>
<td>1.14</td>
</tr>
<tr>
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</tr>
<tr>
<td>300</td>
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<tr>
<td>250</td>
<td>1.22</td>
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<tr>
<td>220</td>
<td>1.25</td>
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<tr>
<td>120</td>
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</tr>
<tr>
<td>100</td>
<td>1.50</td>
</tr>
<tr>
<td>50</td>
<td>1.75</td>
</tr>
</tbody>
</table>

**ownership**

*ownership* is a string data type representing the jurisdictional ownership and responsibility to manage the guide rail/unprotected hazard and was entered at the time of the assessment:

**values**: municipality, province, private
direction

direction is a string data type representing the direction of the guide rail/unprotected hazard in relation to the direction of travel of the nearest lane of the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment.

values: north, northeast, east, southeast, south, southwest, west, northwest

position

position is a string data type representing the position of the guide rail/unprotected hazard in relation to the nearest lane of the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment.

values: left, right

guideRailPhotograph

guideRailPhotograph is a string data type representing the filename of the photograph of the guide rail and was entered at the time of the assessment.

dateEntered

dateEntered is a date data type representing the date in which the guide rail/unprotected hazard was first entered in the roadside objects layer and was automatically entered at the time of the assessment.

dateEntered = today()

dateUpdated

dateUpdated is a date data type representing the date in which the guide rail/unprotected hazard was last updated in the roadside objects layer and was automatically entered at the time of the assessment using a default date.

dateUpdated = 01/01/1900

inspectedBy

inspectedBy is a string data type representing those responsible for the inventory, condition assessment, and/or risk assessment of the guide rail/unprotected hazard and was automatically entered at the time of the assessment.

generalComments

generalComments is a string data type representing additional comments pertaining to the guide rail/unprotected hazard and was entered at the time of the assessment.
2 GUIDE RAIL INFORMATION

systemID

systemID uniquely identifies each guide rail/unprotected hazard system in the roadside objects layer and was automatically assigned at the time of the assessment.

guideRailClassification

guideRailClassification is a string data type representing the classification of the guide rail and was entered at the time of the assessment.

values: flexible, semi-rigid, rigid, not applicable

guideRailType

guideRailType is a string data type representing the type of the guide rail and was entered at the time of the assessment.

values: guide-post, three-cable, box-beam, entrance or intersecting roadway, high-tension cable, steel-beam, steel-beam with channel, thrie-beam, concrete, not applicable

approachEndTreatmentClassification

approachEndTreatmentClassification is a string data type representing the classification of the guide rail approach end treatment and was entered at the time of the assessment.

values: tapered-down, stand-up non-energy absorbing, stand-up energy absorbing, system transition, not applicable

approachEndTreatmentType

approachEndTreatmentType is a string data type representing the type of the guide rail approach end treatment and was entered at the time of the assessment.

values: three-cable turned-down, steel-beam turned-down, concrete turned-down, breakaway cable terminal, crash attenuator, eccentric loader, entrance or intersecting roadway, extruder, softstop or equivalent, proper transition, improper transition, not applicable

approachDistanceEntranceIntersectingRoadway

approachDistanceEntranceIntersectingRoadway is an integer data type representing the approximate distance to the nearest upstream entrance or intersecting roadway which may limit the available space required for installation or extension of the guide rail and was entered at the time of the assessment.
note: if the upstream conflict is outside the bounds for installation or extension, a default value of 999 metres is used

**approachTransitionFacilityID**

*approachTransitionFacilityID* corresponds with the *facilityID* in the roadside objects layer and denotes the unique identifier or the guide rail which occurs sequentially before the current guide rail within respective guide rail system and was automatically entered at the time of the assessment.

**departureEndTreatmentClassification**

*departureEndTreatmentClassification* is a string data type representing the classification of the guide rail departure end treatment and was entered at the time of the assessment.

*values*: tapered-down, stand-up non-energy absorbing, stand-up energy absorbing, system transition, not applicable

**departureEndTreatmentType**

*departureEndTreatmentType* is a string data type representing the type of the guide rail departure end treatment and was entered at the time of the assessment.

*values*: three-cable turned-down, steel-beam turned-down, concrete turned-down, breakaway cable terminal, crash attenuator, eccentric loader, entrance or intersecting roadway, extruder, softstop or equivalent, proper transition, improper transition, not applicable

**departureDistanceEntranceIntersectingRoadway**

*departureDistanceEntranceIntersectingRoadway* is an integer data type representing the approximate distance to the nearest downstream entrance or intersecting roadway which may limit the available space required for installation or extension of the guide rail and was entered at the time of the assessment.

note: if the downstream conflict is outside the bounds for installation or extension, a default value of 999 metres is used.

**departureTransitionFacilityID**

*departureTransitionFacilityID* corresponds with the *facilityID* in the roadside objects layer and denotes the unique identifier or the guide rail which occurs sequentially after the current guide rail within respective guide rail system and was automatically entered at the time of the assessment.

**postMaterial**

*postMaterial* is a string data type representing the guide rail post material and was entered at the time of the assessment.

*values*: wood, steel, not applicable
**blockOutMaterial**

*blockOutMaterial* is a string data type representing the guide rail block-out material and was entered at the time of the assessment.

**values:** wood, steel, plastic, not applicable

**guideRailLength**

*guideRailLength* is a floating-point double data type representing the length of the guide rail and was previously determined during the prior guide rail inventory and for those newly identified guide rails was measured at the time of the assessment using aerial/orthographic photography or field measurements.

**notes:** *guideRailLength* includes the approach and departure end treatments; however, since these do not assist in providing protection from roadside hazards but assist in providing protection from the blunt ends of the guide rail will be subtracted from any length of need calculations.

**guideRailAdjacentOffset**

*guideRailAdjacentOffset* is a floating-point double data type representing the horizontal offset (in half-metre increments) of the guide rail from the nearest adjacent lane of the roadway adjacent to the guide rail and was entered at the time of assessment.

**guideRailOpposingOffset**

*guideRailOpposingOffset* is a floating-point double data type representing the horizontal offset (in half-metre increments) of the guide rail from the nearest opposing lane of the roadway adjacent to the guide rail and was calculated at the time of the assessment using *adjacentLanes*, *dividedRoadway*, *leftTurnLane*, and *guideRailAdjacentOffset*.

\[
guideRailOpposingOffset = (guideRailAdjacentOffset + 3.5 \times adjacentLanes + 3.5 \times leftTurnLane) \times dividedRoadway
\]

**guideRailValue**

*guideRailValue* is a currency data type representing the total cost to replace the existing guide rail with the same type and quantity of materials and was calculated at the time of the assessment using costs adapted from the Ministry of Transportation Ontario’s Highway Costing (HiCo) System.
Table 2-1
Guide Rail Value and HiCo System Unit Costs

<table>
<thead>
<tr>
<th>No.</th>
<th>Installation Cost</th>
<th>Cost/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Install Hazard Markers</td>
<td>$200.00</td>
</tr>
<tr>
<td>2</td>
<td>Install Snow Plow Markers</td>
<td>$200.00</td>
</tr>
<tr>
<td>3</td>
<td>Install Delineation Strips</td>
<td>$200.00</td>
</tr>
<tr>
<td>4</td>
<td>Install Approach End Treatment</td>
<td>$5,100.00</td>
</tr>
<tr>
<td>5</td>
<td>Install Departure End Treatment</td>
<td>$5,100.00</td>
</tr>
<tr>
<td>6</td>
<td>Install System Transitions</td>
<td>$5,100.00</td>
</tr>
<tr>
<td>7</td>
<td>Install Guide-Post</td>
<td>$20.00</td>
</tr>
<tr>
<td>8</td>
<td>Install Three-Cable</td>
<td>$34.00</td>
</tr>
<tr>
<td>9</td>
<td>Install Box-Beam</td>
<td>$305.00</td>
</tr>
<tr>
<td>10</td>
<td>Install Entrance or Intersecting Roadway</td>
<td>$82.00</td>
</tr>
<tr>
<td>11</td>
<td>Install High-Tension Cable</td>
<td>$51.00</td>
</tr>
<tr>
<td>12</td>
<td>Install Steel-Beam</td>
<td>$82.00</td>
</tr>
<tr>
<td>13</td>
<td>Install Steel-Beam with Channel</td>
<td>$96.00</td>
</tr>
<tr>
<td>14</td>
<td>Install Thrie-Beam</td>
<td>$510.00</td>
</tr>
<tr>
<td>15</td>
<td>Install Concrete</td>
<td>$190.00</td>
</tr>
</tbody>
</table>
3 HAZARD INFORMATION

**hazardClassification**

*hazardClassification* is a string data type representing the classification of the hazard and was entered at the time of the assessment

*values*: embankment, fixed object, not applicable

**hazardType**

*hazardType* is a string data type representing the type of the hazard and was entered at the time of the assessment

*values*: embankment, watercourse, other (embankment), box-culvert, bridge abutment, bridge rail or wall, other (fixed object), not applicable

**hazardLength**

*hazardLength* is a floating-point double data type representing the length of the hazard and was calculated at the time of the assessment using *guideRailLength*, *approachDistanceHazard*, and *departureDistanceHazard*

\[
hazardLength = guideRailLength \pm approachDistanceHazard \pm departureDistanceHazard
\]

**hazardAdjacentOffset**

*hazardAdjacentOffset* is a floating-point double data type representing the horizontal offset (in half-metre increments) of the hazard from the nearest adjacent lane of the roadway adjacent to the hazard and was entered at the time of assessment

**hazardOpposingOffset**

*hazardOpposingOffset* is a floating-point double data type representing the horizontal offset (in half-metre increments) of the hazard from the nearest opposing lane of the roadway adjacent to the hazard and was calculated at the time of the assessment using *adjacentLanes*, *dividedRoadway*, *leftTurnLane*, and *hazardAdjacentOffset*

\[
hazardOpposingOffset = (hazardAdjacentOffset + 3.5 \times adjacentLanes + 3.5 \times leftTurnLane) \times dividedRoadway
\]

**guideRailApproachBeforeHazard**

*guideRailApproachBeforeHazard* is a “yes” or “no” indicator of whether or not the approach point of the guide rail begins prior to the approach point of the hazard and was entered at the time of the assessment
**approachDistanceHazard**

*approachDistanceHazard* is an integer type representing the absolute distance from the approach point of the guide rail to the approach point of the hazard and was entered at the time of the assessment.

*note*: if a guide rail is not present (i.e. an unprotected hazard), then the *approachDistanceHazard* will be equal to half of the length of the hazard.

**guideRailDepartureAfterHazard**

*guideRailDepartureAfterHazard* is a “yes” or “no” indicator of whether or not the departure point of the guide rail ends after the departure point of the hazard and was entered at the time of the assessment.

**departureDistanceHazard**

*departureDistanceHazard* is an integer data type representing the absolute distance from the departure point of the guide rail to the departure point of the hazard and was entered at the time of the assessment.

*note*: if a guide rail is not present (i.e. an unprotected hazard), then the *departureDistanceHazard* will be equal to half of the length of the hazard.

**makeTraversable**

*makeTraversable* is a “yes” or “no” indicator of whether or not a hazard can be made traversable to remove it from the clear zone without the installation of other roadside protection measures and was entered at the time of assessment.
4 CONDITION ASSESSMENT INFORMATION

hazardMarkers

*hazardMarkers* is a string data type representing the adequacy of the current state of the hazard markers and was entered at the time of the assessment.

*values:* yes, no, not applicable

snowPlowMarkers

*snowPlowMarkers* is a string data type representing the adequacy of the current state of the snow plow markers and was entered at the time of the assessment.

*values:* yes, no, not applicable

delineationStrips

*delineationStrips* is a string data type representing the adequacy of the current state of the delineation strips and was entered at the time of the assessment.

*values:* yes, no, not applicable

mountingHeight

*mountingHeight* is a string data type representing the adequacy of the current state of the mounting height with respect to the guide rail type, applicable mounting height design standards, and applicable mounting height tolerances and was entered at the time of the assessment.

*values:* yes, no, not applicable

plumbAngle

*plumbAngle* is a string data type representing the adequacy of the current state of the plumb angle and was entered at the time of the assessment.

*values:* yes, no, not applicable

cableTension

*cableTension* is a string data type representing the adequacy of the current state of the cable tension with respect to three-cable and high-tension cable guide rails and was entered at the time of the assessment.
values: yes, no, not applicable

**systemTransitions**

*systemTransitions* is a string data type representing the adequacy of the current state of the system transitions with respect to post spacing, changes in rigidity, and overlap and was entered at the time of the assessment

values: yes, no, not applicable

**railLapping**

*railLapping* is a string data type representing the adequacy of the current state of the rail lapping with respecting to steel-beam, steel-beam with channel, and thrie-beam guide rails and was entered at the time of the assessment

values: yes, no, not applicable

**deflectionArea**

*deflectionArea* is a string data type representing the adequacy of the current state of the deflection area with respect to embankments or fixed objects within the deflection area behind a guide rail and was entered at the time of the assessment

values: yes, no, not applicable

**runOutArea**

*runOutArea* is a string data type representing the adequacy of the current state of the run-out area with respect to embankments or fixed objects within the run-out area behind a gating end treatment and was entered at the time of the assessment

values: yes, no, not applicable

**shoulderDesign**

*shoulderDesign* is a string data type representing the adequacy of the current state of the shoulder design with respect to the presence and horizontal offset of barrier curbs in relation to the face of a guide rail and was entered at the time of the assessment

values: yes, no, not applicable
shoulderStability

shoulderStability is a string data type representing the adequacy of the current state of the shoulder stability with respect to erosion, slope, and stabilization and was entered at the time of the assessment.

values: yes, no, not applicable

railConditionRating

railConditionRating is an integer data type representing the condition rating of the current state of the rail component of a guide rail and was entered at the time of the assessment. A railConditionRating of 1 represents a completely failing rail which is between 0% and 20% condition while a railConditionRating of 5 represents a completely adequate rail which is between 80% and 100%.

values: 1, 2, 3, 4, 5

postConditionRating

postConditionRating is an integer data type representing the condition rating of the current state of the post component of a guide rail and was entered at the time of the assessment. A postConditionRating of 1 represents completely failing posts which are between 0% and 20% condition while a postConditionRating of 5 represents completely adequate posts which are between 80% and 100% condition.

values: 1, 2, 3, 4, 5

blockOutConditionRating

blockOutConditionRating is an integer data type representing the condition rating of the current state of the block-out component of a guide rail and was entered at the time of the assessment. A blockOutConditionRating of 1 represents completely failing block-outs which are between 0% and 20% condition while a blockOutConditionRating of 5 represents completely adequate block-outs which are between 80% and 100% condition.

values: 1, 2, 3, 4, 5
5 RISK ASSESSMENT INFORMATION

**designConformance**

designConformance is a string data type representing the overall conformance to the applicable design standards and the overall condition rating of the guide rail’s components and its ability to serve its intended function to protect against roadside hazards in the event of a collision and was determined at the time of the assessment using mountingHeight, plumbAngle, cableTension, railLapping, deflectionArea, shoulderDesign, shoulderStability, railConditionRating, postConditionRating, and blockOutConditionRating

\[
\text{IF} \text{ mountingHeight OR plumbAngle OR cableTension OR railLapping OR deflectionArea OR shoulderDesign OR shoulderStability = No} \\
\text{THEN designConformance = No}
\]

\[
\text{IF} \text{ railConditionRating } \leq 3 \text{ OR postConditionRating } \leq 3 \text{ OR blockOutConditionRating } \leq 3 \\
\text{THEN designConformance = No}
\]

values: yes, no, not applicable

**approachLengthNeed**

approachLengthNeed is a floating-point doubled data type representing the length of need required on the approach end of the guide rail and was determined at the time of the assessment using designSpeed with the Geometric Design Guide\(^2\)

**approachLengthConformance**

approachLengthConformance is a string data type representing the adequacy of the length of the approach of the guide rail in order to protect against the hazard and was determined at the time of the assessment using approachDistanceHazard and approachLengthNeed

\[
\text{IF} \text{ approachDistanceHazard } > \text{ approachLengthNeed} \text{ THEN approachLengthConformance = Yes}
\]

values: yes, no, not applicable

notes: if the guide rail is bounded by a nearby entrance or intersecting roadway or is part of a system, then the approachLengthConformance is insignificant as the guide rail cannot be recommended for extension but instead an entrance or intersecting roadway end treatment would be recommended

**approachLengthExtension**

approachLengthExtension is a floating-point double data type representing the length of extension (in metres) recommended for the approach end of the guide rail if the guide rail is too short to adequately protect against the hazard

and was calculated at the time of the assessment using approachDistanceHazard and approachLengthNeed and is only calculated if the hazardAdjacentOffset is within the clear zone

notes: approachLengthExtension is 0 if the end treatment is a system transition

departureLengthNeed

departureLengthNeed is a floating-point doubled data type representing the length of need required on the departure end of the guide rail and was determined at the time of the assessment using designSpeed with the Geometric Design Guide

departureLengthConformance

departureLengthConformance is a string data type representing the adequacy of the length of the departure of the guide rail in order to protect against the hazard and was determined at the time of the assessment using departureDistanceHazard and departureLengthNeed

IF departureDistanceHazard > departureLengthNeed THEN departureLengthConformance = Yes

values: yes, no, not applicable

notes: if the guide rail is bounded by a nearby entrance or intersecting roadway or is part of a system, then the departureLengthConformance is insignificant as the guide rail cannot be recommended for extension but instead an entrance or intersecting roadway end treatment would be recommended

departureLengthExtension

departureLengthExtension is a floating-point double data type representing the length of extension (in metres) recommended for the departure end of the guide rail if the guide rail is too short to adequately protect against the hazard and was calculated at the time of the assessment using departureDistanceHazard and departureLengthNeed and is only calculated if the hazardOpposingOffset is within the clear zone

notes: departureLengthExtension is 0 if the departure end treatment is a system transition
Table 5-1
Length of Need

<table>
<thead>
<tr>
<th>Design Speed (kilometres per hour)</th>
<th>Encroachment Distance (E) Given Traffic Volume (ADT) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Over 10,000 veh/day</td>
</tr>
<tr>
<td>130</td>
<td>143</td>
</tr>
<tr>
<td>110</td>
<td>110</td>
</tr>
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<td>91</td>
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<td>80</td>
<td>70</td>
</tr>
<tr>
<td>60</td>
<td>49</td>
</tr>
<tr>
<td>50</td>
<td>34</td>
</tr>
</tbody>
</table>

**guideRailAdjacentProbability**

**guideRailAdjacentProbability** is a floating-point double data type representing the probability, that in the event of roadway departure, an errant vehicle will collide with the guide rail from the adjacent lane and was determined at the time of the assessment using **designSpeed** and **guideRailAdjacentOffset** and with the **Roadside Design Guide**

*IF* **guideRailAdjacentOffset** > clearZone *THEN* **guideRailAdjacentProbability** = 0.00

**guideRailOpposingProbability**

**guideRailOpposingProbability** is a floating-point double data type representing the probability, that in the event of roadway departure, an errant vehicle will collide with the guide rail from the opposing lane and was determined at the time of the assessment using **designSpeed** and **guideRailOpposingOffset** and with the **Roadside Design Guide**

*IF* **guideRailOpposingOffset** > clearZone *THEN* **guideRailOpposingProbability** = 0.00

**hazardAdjacentProbability**

**hazardAdjacentProbability** is a floating-point double data type representing the probability, that in the event of roadway departure, an errant vehicle will collide with the hazard from the adjacent lane and was determined at the time of the assessment using **designSpeed** and **hazardAdjacentOffset** and with the **Roadside Design Guide**

---

hazardOpposingProbability

hazardOpposingProbability is a floating-point double data type representing the probability, that in the event of roadway departure, an errant vehicle will collide with the hazard from the opposing lane and was determined at the time of the assessment using designSpeed and hazardOpposingOffset and with the Roadside Design Guide

IF hazardOpposingOffset > clearZone THEN hazardOpposingProbability = 0.00

Table 5-2
Horizontal Offsets and Encroachment Rates

<table>
<thead>
<tr>
<th>Horizontal Offset (metres)</th>
<th>Encroachment Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design Speed (kilometres per hour)</td>
</tr>
<tr>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>0.50</td>
<td>0.68</td>
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</tr>
<tr>
<td>1.50</td>
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<td>0.27</td>
</tr>
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</tr>
<tr>
<td>7.50</td>
<td>0.04</td>
</tr>
<tr>
<td>8.00</td>
<td>0.03</td>
</tr>
<tr>
<td>8.50</td>
<td>0.03</td>
</tr>
</tbody>
</table>
guideRailSeverityIndex

guideRailSeverityIndex is an integer data type representing the severity index of the guide rail and was determined at the time of the assessment using designSpeed, guideRailType, and designConformance and with the Roadside Design Guide3

hazardSeverityIndex

hazardSeverityIndex is an integer data type representing the severity index of the hazard and was determined at the time of the assessment using designSpeed and hazardClassification and with the Roadside Design Guide3

Table 5-3
Severity Indices by Guide Rail Type or Hazard Type (Part 1)

<table>
<thead>
<tr>
<th>Design Speed (kilometres per hour)</th>
<th>Severity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Guide-Post</td>
</tr>
<tr>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>70</td>
<td>3</td>
</tr>
<tr>
<td>80</td>
<td>4</td>
</tr>
<tr>
<td>90</td>
<td>4</td>
</tr>
<tr>
<td>100</td>
<td>4</td>
</tr>
</tbody>
</table>
Table 5-4
Severity Indices by Guide Rail Type (Part 2)

<table>
<thead>
<tr>
<th>Design Speed (kilometers per hour)</th>
<th>Severity Index</th>
<th>Box-Beam</th>
<th>Entrance or Intersecting Roadway</th>
<th>High-Tension Cable</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td></td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
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<td>3</td>
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</tr>
<tr>
<td>70</td>
<td></td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
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<td>4</td>
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<td>3</td>
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<tr>
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<td>5</td>
</tr>
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<td>3</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 5-5
Severity Indices by Hazard Classification

<table>
<thead>
<tr>
<th>Design Speed (kilometres per hour)</th>
<th>Severity Index</th>
<th>Embankment</th>
<th>Fixed Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
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<td>4</td>
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<td>4</td>
<td>4</td>
</tr>
<tr>
<td>80</td>
<td></td>
<td>5</td>
<td>5</td>
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<tr>
<td>90</td>
<td></td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

guideRailRiskScore

guideRailRiskScore is a floating-point double date type representing the risk score of the guide rail and was calculated at the time of the assessment using currentAADT, guideRailLength, guideRailAdjacentProbability, guideRailOpposingProbability, and guideRailSeverityIndex with the Roadside Design Guide:\(^3\)

\[
\text{exposure} = 0.0003 \times \text{currentAADT} / 2 \times \text{guideRailLength} / 1000
\]

\[
\text{probability} = \text{guideRailAdjacentProbability} + \text{guideRailOpposingProbability}
\]

\[
\text{consequence} = (1 \times \text{prob\{property damage only\}}) + (10 \times \text{prob\{non-fatal injury\}}) + (1967 \times \text{prob\{fatality\}})
\]

\[
\text{guideRailRiskScore} = \text{exposure} \times \text{probability} \times \text{consequence}
\]
**hazardRiskScore**

*hazardRiskScore* is a floating-point double date type representing the risk score of the hazard if it were fully-unprotected and was calculated at the time of the assessment using *currentAADT*, *hazardLength*, *hazardAdjacentProbability*, *hazardOpposingProbability*, and *hazardSeverityIndex* with the *Roadside Design Guide*.

\[
\text{exposure} = 0.0003 \times \frac{\text{currentAADT}}{2 \times \text{hazardLength}} / 1000 \\
\text{probability} = \text{hazardAdjacentProbability} + \text{hazardOpposingProbability} \\
\text{consequence} = (1 \times \text{prob}^{\text{property damage only}}) + (10 \times \text{prob}^{\text{non-fatal injury}}) + (1967 \times \text{prob}^{\text{fatality}}) \\
\text{hazardRiskScore} = \text{exposure} \times \text{probability} \times \text{consequence}
\]

**Table 5-6**

*Severity Indices and Probability of Collision Severity*

<table>
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<tr>
<th>Collision Type</th>
<th>Probability of Collision Severity</th>
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</thead>
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<td>0.0</td>
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<tr>
<td>Property Damage Only</td>
<td>0</td>
</tr>
<tr>
<td>Non-Fatal Injury</td>
<td>0</td>
</tr>
<tr>
<td>Fatality</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>0</td>
</tr>
</tbody>
</table>

**combinedRiskScore**

*combinedRiskScore* is a floating-point double data type representing the summation of the risk associated with the guide rail and proportioned risk of the hazard and was calculated at the time of the assessment using *guideRailLength*, *hazardLength*, *designConformance*, *approachLengthConformance*, *departureLengthConformance*, *approachLengthExtension*, *departureLengthExtension*, *guideRailRiskScore*, and *hazardRiskScore*.

\[
\text{IF designConformance} = \text{Yes AND approachLengthConformance} = \text{Yes AND departureLengthConformance} = \text{Yes} \\
\text{THEN combinedRiskScore} = \text{guideRailRiskScore} \\
\text{IF designConformance} = \text{No} \\
\text{THEN combinedRiskScore} = \text{guideRailRiskScore} + \text{hazardRiskScore} \\
\text{IF designConformance} = \text{Yes AND approachLengthConformance} = \text{No} \\
\text{THEN combinedRiskScore} = \text{guideRailRiskScore} + \text{hazardRiskScore} \times \text{approachLengthExtension} / \text{guideRailLength} \\
\text{IF designConformance} = \text{Yes AND departureLengthConformance} = \text{No}
\]
$\text{THEN } \text{combinedRiskScore} = \text{guideRailRiskScore} + \text{hazardRiskScore} \times \text{departureLengthExtension} / \text{guideRailLength}$

**systemRiskScore**

systemRiskScore is a floating-point double data type representing the summation of the risk associated with all guide rails within a system and was calculated at the time of the assessment using systemID and combinedRiskScore.
6 REMEDIATION INFORMATION

installHazardMarkers

installHazardMarkers is a integer data type representing the recommended number of hazard markers to be installed as part of the remediation measures

values: 0, 1, 2

installSnowPlowMarkers

installSnowPlowMarkers is a integer data type representing the recommended number of snow plow markers to be installed as part of the remediation measures

values: 0, 1, 2

installDelineationStrips

installDelineationStrips is a integer data type representing the recommended number of delineation strips to be installed as part of the remediation measures

values: 0, 1

installApproachEndTreatment

installApproachEndTreatment is a integer data type representing the recommended number of approach end treatments to be installed as part of the remediation measures

values: 0, 1

installDepartureEndTreatment

installDepartureEndTreatment is a integer data type representing the recommended number of departure end treatments to be installed as part of the remediation measures

values: 0, 1

addressSystemTransitions

addressSystemTransitions is a integer data type representing the recommended number of system transitions to be addressed as part of the remediation measures

values: 0, 1, 2
installGuideRail

installGuideRail is a floating-point double data type representing the length of guide rail to be installed at a location whereby an unprotected hazard is situated within the clear zone.

extendGuideRail

extendGuideRail is a floating-point double data type representing the length of guide rail to be extended at a location whereby a guide rail of insufficient length is in front of a partially protected hazard situated within the clear zone.

replaceGuideRail

replaceGuideRail is a floating-point double data type representing the length of guide rail to be installed at a location whereby a guide rail of inadequate condition is in front of a partially protected hazard situated within the clear zone.

Note: the length of guide rail to be removed is not explicitly recorded but is accounted for in remediationMeasures and reflected upon in totalRemediationCost.

removeGuideRail

removeGuideRail is a floating-point double data type representing the length of guide rail to be removed at a location whereby no hazard exists or is situated outside of the clear zone.

remediationMeasures

remediationMeasures is a string data type representing the recommended remediation measures to address deficiencies relating to guide rails and unprotected hazards inventoried and was determined at the time of the assessment.

Values: install hazard markers, install snow plow markers, install delineation strips, install approach end treatment, install departure end treatment, address system transitions, install guide rail, extend guide rail, replace guide rail, remove guide rail

remediationMeasuresClassification

remediationMeasuresClassification is a string data type representing the classification of the remediation measures and was determined at the time of the assessment.

Values: minor treatments, install guide rail, extend guide rail, replace guide rail, remove guide rail
**totalRemediationCost**

totalRemediationCost is a currency data type representing the total cost to implement the remediation measures and was calculated at the time of the assessment using costs adapted from the Ministry of Transportation Ontario’s Highway Costing (HiCo) System.

<table>
<thead>
<tr>
<th>No.</th>
<th>Installation Cost</th>
<th>Cost/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Install Hazard Markers</td>
<td>$200.00</td>
</tr>
<tr>
<td>2</td>
<td>Install Snow Plow Markers</td>
<td>$200.00</td>
</tr>
<tr>
<td>3</td>
<td>Install Delineation Strips</td>
<td>$200.00</td>
</tr>
<tr>
<td>4</td>
<td>Install Approach End Treatment</td>
<td>$5,100.00</td>
</tr>
<tr>
<td>5</td>
<td>Install Departure End Treatment</td>
<td>$5,100.00</td>
</tr>
<tr>
<td>6</td>
<td>Install System Transitions</td>
<td>$5,100.00</td>
</tr>
<tr>
<td>7</td>
<td>Install Guide-Post</td>
<td>$20.00</td>
</tr>
<tr>
<td>8</td>
<td>Install Three-Cable</td>
<td>$34.00</td>
</tr>
<tr>
<td>9</td>
<td>Install Box-Beam</td>
<td>$305.00</td>
</tr>
<tr>
<td>10</td>
<td>Install Entrance or Intersecting Roadway</td>
<td>$82.00</td>
</tr>
<tr>
<td>11</td>
<td>Install High-Tension Cable</td>
<td>$51.00</td>
</tr>
<tr>
<td>12</td>
<td>Install Steel-Beam</td>
<td>$82.00</td>
</tr>
<tr>
<td>13</td>
<td>Install Steel-Beam with Channel</td>
<td>$96.00</td>
</tr>
<tr>
<td>14</td>
<td>Install Thrie-Beam</td>
<td>$510.00</td>
</tr>
<tr>
<td>15</td>
<td>Install Concrete</td>
<td>$190.00</td>
</tr>
<tr>
<td>16</td>
<td>Extend Guide-Post</td>
<td>$20.00</td>
</tr>
<tr>
<td>17</td>
<td>Extend Three-Cable</td>
<td>$34.00</td>
</tr>
<tr>
<td>18</td>
<td>Extend Box-Beam</td>
<td>$305.00</td>
</tr>
<tr>
<td>19</td>
<td>Extend Entrance or Intersecting Roadway</td>
<td>$82.00</td>
</tr>
<tr>
<td>20</td>
<td>Extend High-Tension Cable</td>
<td>$51.00</td>
</tr>
<tr>
<td>21</td>
<td>Extend Steel-Beam</td>
<td>$82.00</td>
</tr>
<tr>
<td>22</td>
<td>Extend Steel-Beam with Channel</td>
<td>$96.00</td>
</tr>
<tr>
<td>No.</td>
<td>Installation Cost</td>
<td>Cost/Unit</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>23</td>
<td>Extend Thrie-Beam</td>
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</tr>
<tr>
<td>24</td>
<td>Extend Concrete</td>
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</tr>
<tr>
<td>25</td>
<td>Remove Guide-Post</td>
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</tr>
<tr>
<td>26</td>
<td>Remove Three-Cable</td>
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</tr>
<tr>
<td>27</td>
<td>Remove Box-Beam</td>
<td>$17.00</td>
</tr>
<tr>
<td>28</td>
<td>Remove Entrance or Intersecting Roadway</td>
<td>$9.00</td>
</tr>
<tr>
<td>29</td>
<td>Remove High-Tension Cable</td>
<td>$8.65</td>
</tr>
<tr>
<td>30</td>
<td>Remove Steel-Beam</td>
<td>$9.25</td>
</tr>
<tr>
<td>31</td>
<td>Remove Steel-Beam with Channel</td>
<td>$12.00</td>
</tr>
<tr>
<td>32</td>
<td>Remove Thrie-Beam</td>
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</tr>
<tr>
<td>33</td>
<td>Remove Concrete</td>
<td>$88.00</td>
</tr>
</tbody>
</table>

**remediationPriority**

*remediationPriority* is a string data type representing the priority for the implementation of remediation measures and was not entered at the time of the assessment.

*values*: high, medium, low, not applicable

---

**Prepared by:**
Jordan Frost, P.Eng.
Signature/Seal

**Reviewed by:**
Jeff Suggett, M.Sc.
Signature

**Initials**
JF
<table>
<thead>
<tr>
<th>Facility</th>
<th>Full Name</th>
<th>Street 1</th>
<th>Street 2</th>
<th>County</th>
<th>Road</th>
<th>Side</th>
<th>Distance</th>
<th>Type</th>
<th>Direction</th>
<th>Length</th>
<th>Speed</th>
<th>51</th>
<th>90</th>
<th>80</th>
<th>100</th>
<th>60</th>
<th>North</th>
<th>Right</th>
<th>IMG</th>
<th>21/08/2017</th>
<th>Cost</th>
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<td>60</td>
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<td>4,624</td>
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<td>Embankment</td>
<td>Steel-B</td>
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<td>40</td>
<td>10</td>
<td>3</td>
<td>18.20</td>
<td>218.00</td>
<td>21.00</td>
<td>315,000.00</td>
</tr>
<tr>
<td>County 2 Road 49</td>
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<td>White Chapel Road</td>
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<td>60</td>
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<td>4,624</td>
<td>21/08/2017</td>
<td>15</td>
<td>Embankment</td>
<td>Steel-B</td>
<td>45</td>
<td>40</td>
<td>10</td>
<td>3</td>
<td>18.20</td>
<td>218.00</td>
<td>21.00</td>
<td>315,000.00</td>
</tr>
<tr>
<td>County 3 Road 49</td>
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<td>Iredale Lane</td>
<td>3,855</td>
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<td>21/08/2017</td>
<td>15</td>
<td>Embankment</td>
<td>Steel-B</td>
<td>45</td>
<td>40</td>
<td>10</td>
<td>3</td>
<td>18.20</td>
<td>218.00</td>
<td>21.00</td>
<td>315,000.00</td>
</tr>
<tr>
<td>County 4 Road 49</td>
<td>Lower Highmore Road</td>
<td>Bethesda Road</td>
<td>3,855</td>
<td>60</td>
<td>60</td>
<td>40</td>
<td>North</td>
<td>3</td>
<td>4,624</td>
<td>21/08/2017</td>
<td>15</td>
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<td>Steel-B</td>
<td>45</td>
<td>40</td>
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<td>18.20</td>
<td>218.00</td>
<td>21.00</td>
<td>315,000.00</td>
</tr>
<tr>
<td>County 5 Road 49</td>
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<td>60</td>
<td>40</td>
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<td>3</td>
<td>4,624</td>
<td>21/08/2017</td>
<td>15</td>
<td>Embankment</td>
<td>Steel-B</td>
<td>45</td>
<td>40</td>
<td>10</td>
<td>3</td>
<td>18.20</td>
<td>218.00</td>
<td>21.00</td>
<td>315,000.00</td>
</tr>
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<td>County 6 Road 49</td>
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<td>4,624</td>
<td>21/08/2017</td>
<td>15</td>
<td>Embankment</td>
<td>Steel-B</td>
<td>45</td>
<td>40</td>
<td>10</td>
<td>3</td>
<td>18.20</td>
<td>218.00</td>
<td>21.00</td>
<td>315,000.00</td>
</tr>
<tr>
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<td>60</td>
<td>60</td>
<td>40</td>
<td>North</td>
<td>3</td>
<td>4,624</td>
<td>21/08/2017</td>
<td>15</td>
<td>Embankment</td>
<td>Steel-B</td>
<td>45</td>
<td>40</td>
<td>10</td>
<td>3</td>
<td>18.20</td>
<td>218.00</td>
<td>21.00</td>
<td>315,000.00</td>
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<td>County 8 Road 49</td>
<td>Lower Highmore Road</td>
<td>Bethesda Road</td>
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<td>60</td>
<td>60</td>
<td>40</td>
<td>North</td>
<td>3</td>
<td>4,624</td>
<td>21/08/2017</td>
<td>15</td>
<td>Embankment</td>
<td>Steel-B</td>
<td>45</td>
<td>40</td>
<td>10</td>
<td>3</td>
<td>18.20</td>
<td>218.00</td>
<td>21.00</td>
<td>315,000.00</td>
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<td>County 9 Road 49</td>
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<td>60</td>
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<td>North</td>
<td>3</td>
<td>4,624</td>
<td>21/08/2017</td>
<td>15</td>
<td>Embankment</td>
<td>Steel-B</td>
<td>45</td>
<td>40</td>
<td>10</td>
<td>3</td>
<td>18.20</td>
<td>218.00</td>
<td>21.00</td>
<td>315,000.00</td>
</tr>
</tbody>
</table>

Total Cost: $15,385.00
| County Road 49 | Lyons Road (North) | County Road 35 | 3,541 | 80 | 100 | 6.0 | North | IMG_2638 | 21/08/2017 | 1.4 | Flexible | Three-Cable | Embankment | Beam | 45 | Embankment | Beam | 65 | No | 3 | 6 | 9 | 4.12 | 0.00 | 4.12 | 4.12 | Remove 45 metres of Three-Cable. | $180.00 |
| County Road 49 | Lyons Road (North) | County Road 35 | 3,541 | 80 | 100 | 6.0 | North | IMG_2648 | 21/08/2017 | 1.4 | Semi-Rigid | Steel-Beam | Embankment | Beam | 60 | Embankment | Beam | 80 | No | 1 | 6 | 9 | 5.26 | 14.13 | 10.61 | 20.77 | Install 1 Semi-Rigid Beam, Install Steel-Beam, Install Declaration Signs, Install Energy Attenuating Terminal on Approach, Address 1 System Transition(s), Replace 45 metres of Steel-Beam with 45 metres of Steel-Beam. | $14,215.00 |
| County Road 35 | County Road 69 | Roblins Hill Road | 508 | 80 | 100 | 4.0 | East | IMG_2643 | 21/08/2017 | 1.4 | Flexible | Three-Cable | Embankment | Beam | 100 | Embankment | Beam | 100 | No | 5 | 0 | 0 | 1.36 | 0.00 | 1.36 | 1.36 | Remove 100 metres of Three-Cable. | $400.00 |
| County Road 49 | County Road 35 | Fish Lake Road/Mount Carmel Road | 3,541 | 80 | 100 | 6.0 | North | IMG_2643 | 21/08/2017 | 1.4 | Semi-Rigid | Steel-Beam | Fixed Object | Box-Culvert | 10 | Fixed Object | Box-Culvert | 10 | 5 | 0 | 0 | 0.00 | 1.68 | 1.68 | 1.68 | Install 0 metres of Not Applicable, Make Hazard Traversable. | $0.00 |
| County Road 49 | County Road 35 | Fish Lake Road/Mount Carmel Road | 3,541 | 80 | 100 | 6.0 | North | IMG_2644 | 21/08/2017 | 1.5 | Semi-Rigid | Steel-Beam | Fixed Object | Box-Culvert | 15 | Fixed Object | Box-Culvert | 15 | 5 | 0 | 0 | 0.00 | 1.68 | 1.68 | 1.68 | Remove 0 metres of Not Applicable, Make Hazard Traversable. | $10.00 |
| County Road 49 | County Road 35 | Fish Lake Road/Mount Carmel Road | 3,541 | 80 | 100 | 6.0 | North | IMG_2645 | 21/08/2017 | 1.6 | Flexible | Three-Cable | Embankment | Beam | 250 | Embankment | Beam | 250 | No | 5 | 10 | 0 | 27.85 | 98.90 | 126.75 | 126.75 | Install 200 metres of Steel-Beam, Install 200 metres of Steel-Beam. | $135,550.00 |
| County Road 49 | County Road 35 | Fish Lake Road/Mount Carmel Road | 3,541 | 80 | 100 | 6.0 | South | IMG_2646 | 21/08/2017 | 1.7 | Semi-Rigid | Steel-Beam | Fixed Object | Box-Culvert | 15 | Fixed Object | Box-Culvert | 15 | 10 | 0 | 0 | 23.05 | 84.06 | 107.11 | 107.11 | Install 150 metres of Steel-Beam, Install 150 metres of Steel-Beam. | $12,660.00 |
| County Road 49 | Lyons Road (North) | County Road 35 | 3,541 | 80 | 100 | 6.0 | North | IMG_2647 | 02/10/2017 | 2.0 | Not Applicable | Not Applicable | Fixed Object | Box-Culvert | 15 | Fixed Object | Box-Culvert | 15 | 5 | 0 | 0 | 0.00 | 2.21 | 2.21 | 2.21 | Install Entrance or Intersecting Roadway Treatment on Approach, Install Energy Attenuating Terminal on Departure, Install Entrance or Intersecting Roadway Treatment on Approach, Install Energy Attenuating Terminal on Departure. | $12,840.00 |
| County Road 49 | Lyons Road (North) | County Road 35 | 3,541 | 80 | 100 | 6.0 | South | IMG_2647 | 02/10/2017 | 2.0 | Not Applicable | Not Applicable | Fixed Object | Box-Culvert | 15 | Fixed Object | Box-Culvert | 15 | 5 | 0 | 0 | 0.00 | 1.84 | 1.84 | 1.84 | Install Entrance or Intersecting Roadway Treatment on Approach, Install Energy Attenuating Terminal on Departure. | $133,680.00 |
Appendix D – Culvert Condition Assessment Supporting Documents
Appendix E – Drainage Assessment Supporting Documents
**Existing Site Peak Runoff - Catchment 1**

**Rational Method Calculations**

<table>
<thead>
<tr>
<th>DESIGN STORM:</th>
<th>5 yr</th>
<th>100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>500</td>
<td>835</td>
</tr>
<tr>
<td>b</td>
<td>0.764</td>
<td>0.776</td>
</tr>
<tr>
<td>c</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>IDF I = A / (Tc+b) ^ c</td>
<td></td>
<td>IDF I = A / (Tc+c) ^ b</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Catchment Area</th>
<th>835,075 m²</th>
<th>(Found by delineating in GIS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff Coefficient, C</td>
<td>0.4</td>
<td>(unimproved land)</td>
</tr>
<tr>
<td>time of concentration</td>
<td>93.91 minutes</td>
<td>(Calculated using FAA Method)</td>
</tr>
</tbody>
</table>

**Rainfall Intensity Calculation**

\[
I = \frac{A}{(Tc+b)^c} \\
I = \frac{500}{(0.764)^{(0.005)}} \\
I = 15.55 \text{ mm/hr} \\
\]

**5 year Runoff Peak Flow Rate (Rational Method)**

\[
Q = CIA \\
Q = (0.40) \times (15.55 \text{ mm/hr}) \times (835,075 \text{ m}^2) \times (1 \text{ m/1000 mm}) \times (1 \text{ hr/3600 s}) \\
Q = 1.44 \text{ m}^3/\text{s} \\
Q = 1443 \text{ lps} \\
\]

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Date: 07-Nov-17

**100 year Runoff Peak Flow Rate (Rational Method)**

\[
Q = CIA \\
Q = (0.40) \times (24.60 \text{ mm/hr}) \times (835,075 \text{ m}^2) \times (1 \text{ m/1000 mm}) \times (1 \text{ hr/3600 s}) \\
Q = 2.28 \text{ m}^3/\text{s} \\
Q = 2282 \text{ lps} \\
\]
Existing Site Peak Runoff - Catchment 2
Rational Method Calculations

<table>
<thead>
<tr>
<th></th>
<th>5 yr</th>
<th>100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>DESIGN STORM:</td>
<td>5 yr</td>
<td>100 yr</td>
</tr>
<tr>
<td>A</td>
<td>500 (from MTO grid: 44° 6' 15&quot; N, 77° 6' 44&quot; W )</td>
<td>835 (from MTO grid: 44° 6' 15&quot; N, 77° 6' 44&quot; W )</td>
</tr>
<tr>
<td>b</td>
<td>0.764</td>
<td>0.776</td>
</tr>
<tr>
<td>c</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>IDF  I = A / (Tc+b) ^ c</td>
<td></td>
<td>I = A / (Tc+c) ^ b</td>
</tr>
</tbody>
</table>

| Total Catchment Area        | 514,016 m$^2$ (Found by delineating in GIS)                | 514,016 m$^2$ (Found by delineating in GIS)             |
| time of concentration       | 48.06 minutes (Calculated using FAA Method)                | 48.06 minutes (Calculated using FAA Method)             |
| Runoff Coefficient, C       | 0.4 (unimproved land)                                      | 0.4 (unimproved land)                                   |

Rainfall Intensity Calculation

\[
I = \frac{A}{(Tc+b)^c}
\]

\[
I = \frac{(500)}{(Tc+0.764)^0.005}
\]

Rainfall Intensity

\[
I = \frac{A}{(Tc+c)^b}
\]

\[
I = \frac{(835)}{(Tc+0.776)^0.005}
\]

5 year Runoff Peak Flow Rate (Rational Method)

\[
Q = CIA
\]

\[
Q = (0.40) \times (25.95 \text{ mm/hr}) \times (514,016 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s})
\]

\[
Q = 1.48 \text{ m}^3/\text{s}
\]

\[
Q = 1482 \text{ lps}
\]

100 year Runoff Peak Flow Rate (Rational Method)

\[
Q = CIA
\]

\[
Q = (0.40) \times (41.36 \text{ mm/hr}) \times (514,016 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s})
\]

\[
Q = 2.36 \text{ m}^3/\text{s}
\]

\[
Q = 2362 \text{ lps}
\]

Design by: A. Peck
Date: 07-Nov-17
### Existing Site Peak Runoff - Catchment 3

Rational Method Calculations

<table>
<thead>
<tr>
<th>Design Storm:</th>
<th>5 yr</th>
<th>100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>500</td>
<td>835</td>
</tr>
<tr>
<td>b</td>
<td>0.764</td>
<td>0.776</td>
</tr>
<tr>
<td>c</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>IDF = A / (Tc+b)^c</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(from MTO grid: 44° 6' 15&quot; N, 77° 6' 44&quot; W)</td>
<td>(from MTO grid: 44° 6' 15&quot; N, 77° 6' 44&quot; W)</td>
</tr>
</tbody>
</table>

#### Total Catchment Area
- 65,571 m$^2$ (Found by delineating in GIS)

#### Runoff Coefficient, C
- 0.4 (unimproved land)

#### Time of Concentration
- 21.10 minutes (Calculated using FAA Method)

#### Rainfall Intensity Calculation
I = A / (Tc+b)^c

#### 5 year Runoff Peak Flow Rate (Rational Method)
Q = CIA
Q = (0.40) * (48.66 mm/hr) * (65,571 m$^2$) * (1 m / 1000 mm) * (1 hr / 3600 s)
Q = 0.35 m$^3$/s
Q = 355 lps

#### 100 year Runoff Peak Flow Rate (Rational Method)
Q = CIA
Q = (0.40) * (78.35 mm/hr) * (65,571 m$^2$) * (1 m / 1000 mm) * (1 hr / 3600 s)
Q = 0.57 m$^3$/s
Q = 571 lps

---

**Design by:** A. Peck
**Date:** 07-Nov-17
## Existing Site Peak Runoff - Catchment 4
### Rational Method Calculations

**PROJECT:** County Rd 49  
**PROJECT NUMBER:** 2017-5144  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**

<table>
<thead>
<tr>
<th>Design Storm</th>
<th>( A )</th>
<th>( b )</th>
<th>( c )</th>
<th>IDF ( I )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 yr</td>
<td>500</td>
<td>0.764</td>
<td>0.005</td>
<td>( A / (T_c+b)^c )</td>
</tr>
<tr>
<td>100 yr</td>
<td>835</td>
<td>0.776</td>
<td>0.005</td>
<td>( A / (T_c+c)^b )</td>
</tr>
</tbody>
</table>

- **Total Catchment Area**: 203,922 m²  
  (Found by delineating in GIS)
- **Runoff Coefficient, C**: 0.4  
  (unimproved land)
- **Time of Concentration**: 50.31 minutes  
  (Calculated using FAA Method)

### Rainfall Intensity Calculation

- **5 year Rainfall Intensity**
  \[ I = \frac{A}{(T_c+b)^c} \]
  \[ I = \frac{500}{(0.764)^{0.005}} \]
  \[ I = 25.06 \text{ mm/hr} \]

- **100 year Rainfall Intensity**
  \[ I = \frac{A}{(T_c+c)^b} \]
  \[ I = \frac{835}{(0.776)^{0.005}} \]
  \[ I = 39.92 \text{ mm/hr} \]

### 5 Year Runoff Peak Flow Rate (Rational Method)

\[ Q = CIA \]
\[ Q = (0.40) \times (25.06 \text{ mm/hr}) \times (203,922 \text{ m}^2) \times (1 \text{ m}/1000 \text{ mm}) \times (1 \text{ hr}/3600 \text{ s}) \]
\[ Q = 0.57 \text{ m}^3/\text{s} \]

\[ Q = 568 \text{ lps} \]

### 100 Year Runoff Peak Flow Rate (Rational Method)

\[ Q = CIA \]
\[ Q = (0.40) \times (39.92 \text{ mm/hr}) \times (203,922 \text{ m}^2) \times (1 \text{ m}/1000 \text{ mm}) \times (1 \text{ hr}/3600 \text{ s}) \]
\[ Q = 0.90 \text{ m}^3/\text{s} \]

\[ Q = 905 \text{ lps} \]

**Design by:** A. Peck  
**Date:** 07-Nov-17
## Existing Site Peak Runoff - Catchment 5

### Rational Method Calculations

<table>
<thead>
<tr>
<th>DESIGN STORM:</th>
<th>5 yr</th>
<th>100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>500</td>
<td>835</td>
</tr>
<tr>
<td>b</td>
<td>0.764</td>
<td>0.776</td>
</tr>
<tr>
<td>c</td>
<td>0.005</td>
<td>0.005</td>
</tr>
</tbody>
</table>

\[
\text{IDF I} = \frac{A}{(Tc+b)^c}
\]

- **Total Catchment Area**: 312,719 m² (Found by delineating in GIS)
- **Runoff Coefficient, C**: 0.4 (unimproved land)
- **time of concentration**: 56.54 minutes (Calculated using FAA Method)

#### Rainfall Intensity Calculation

\[
I = \frac{A}{(Tc+b)^c}
\]

\[
I = \frac{500}{(Tc+0.764)^{0.005}}
\]

\[
I = \frac{835}{(Tc+0.776)^{0.005}}
\]

- **5 year Runoff Peak Flow Rate (Rational Method)**
  \[
  Q = CIA
  
  Q = (0.40) \times (22.92 \text{ mm/hr}) \times (312,719 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s})
  
  Q = 0.80 \text{ m}^3/\text{s} \quad 796 \text{ lps}
  
- **100 year Runoff Peak Flow Rate (Rational Method)**
  \[
  Q = CIA
  
  Q = (0.40) \times (36.46 \text{ mm/hr}) \times (312,719 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s})
  
  Q = 1.27 \text{ m}^3/\text{s} \quad 1267 \text{ lps}

Design by: A. Peck  
Date: 07-Nov-17
## Existing Site Peak Runoff - Catchment 6

### Rational Method Calculations

**PROJECT:** County Rd 49  
**CLIENT:** Prince Edward County

### DESIGN STORM: 5 yr

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>500</td>
</tr>
<tr>
<td>b</td>
<td>0.764</td>
</tr>
<tr>
<td>c</td>
<td>0.005</td>
</tr>
</tbody>
</table>

\[
\text{IDF} = \frac{A}{(Tc+b)^c}
\]

**Total Catchment Area:** 589,779 m²  
**Runoff Coefficient, C:** 0.4  
**time of concentration:** 61.66 minutes

### Rainfall Intensity Calculation

\[
I = \frac{A}{(Tc+b)^c}
\]

\[
I = \frac{500}{(0.764)^0.005}
\]

\[
I = 21.45 \text{ mm/hr}
\]

### 5 year Runoff Peak Flow Rate (Rational Method)

\[
Q = C \times I 
\]

\[
Q = (0.40) \times (21.45 \text{ mm/hr}) \times (589,779 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s})
\]

\[
Q = 1.41 \text{ m}^3/\text{s}
\]

\[
1405 \text{ lps}
\]

### DESIGN STORM: 100 yr

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>835</td>
</tr>
<tr>
<td>b</td>
<td>0.776</td>
</tr>
<tr>
<td>c</td>
<td>0.005</td>
</tr>
</tbody>
</table>

\[
\text{IDF} = \frac{A}{(Tc+c)^b}
\]

**Total Catchment Area:** 589,779 m²  
**Runoff Coefficient, C:** 0.4  
**time of concentration:** 61.66 minutes

### Rainfall Intensity Calculation

\[
I = \frac{A}{(Tc+c)^b}
\]

\[
I = \frac{835}{(0.776)^0.005}
\]

\[
I = 34.09 \text{ mm/hr}
\]

### 100 year Runoff Peak Flow Rate (Rational Method)

\[
Q = C \times I 
\]

\[
Q = (0.40) \times (34.09 \text{ mm/hr}) \times (589,779 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s})
\]

\[
Q = 2.23 \text{ m}^3/\text{s}
\]

\[
2234 \text{ lps}
\]

Design by: A. Peck  
**Date:** 07-Nov-17
### Existing Site Peak Runoff - Catchment 7

#### Rational Method Calculations

**PROJECT:** County Rd 49  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**

<table>
<thead>
<tr>
<th>Design Storm</th>
<th>A</th>
<th>b</th>
<th>c</th>
<th>IDF ( I = \frac{A}{(Tc+b)^c} )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5 yr</strong></td>
<td>500</td>
<td>0.764</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td><strong>100 yr</strong></td>
<td>835</td>
<td>0.776</td>
<td>0.005</td>
<td></td>
</tr>
</tbody>
</table>

**Total Catchment Area**  
- **41,628 m²**  
  (Found by delineating in GIS)
- **23.54 minutes**  
  (Calculated using FAA Method)

**Runoff Coefficient, C**  
- **0.4**  
  (unimproved land)

**Rainfall Intensity Calculation**

\[
I = \frac{A}{(Tc+b)^c}
\]

- \( I = \frac{500}{(Tc+0.764)^{0.005}} \)  
  \( I = 44.76 \text{ mm/hr} \)
- \( I = \frac{835}{(Tc+0.776)^{0.005}} \)  
  \( I = 71.97 \text{ mm/hr} \)

**5 year Runoff Peak Flow Rate (Rational Method)**

\[
Q = CIA
\]

- \( Q = (0.40) \times (44.76 \text{ mm/hr}) \times (41,628 \text{ m}^2) \times (1 \text{ m/1000 mm}) \times (1 \text{ hr/3600 s}) \)  
  \( Q = 0.21 \text{ m}^3/\text{s} \)  
  \( 207 \text{ lps} \)

**100 year Runoff Peak Flow Rate (Rational Method)**

\[
Q = CIA
\]

- \( Q = (0.40) \times (71.97 \text{ mm/hr}) \times (41,628 \text{ m}^2) \times (1 \text{ m/1000 mm}) \times (1 \text{ hr/3600 s}) \)  
  \( Q = 0.33 \text{ m}^3/\text{s} \)  
  \( 333 \text{ lps} \)

Design by: A. Peck  
Date: 07-Nov-17
### Rational Method Calculations

**PROJECT:** County Rd 49  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**

<table>
<thead>
<tr>
<th><strong>DESIGN STORM:</strong></th>
<th>5 yr</th>
<th>(from MTO grid: 44° 6' 15&quot; N, 77° 6' 44&quot; W)</th>
<th><strong>DESIGN STORM:</strong></th>
<th>100 yr</th>
<th>(from MTO grid: 44° 6' 15&quot; N, 77° 6' 44&quot; W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A=</td>
<td>500</td>
<td></td>
<td>A=</td>
<td>835</td>
<td></td>
</tr>
<tr>
<td>b=</td>
<td>0.764</td>
<td></td>
<td>b=</td>
<td>0.776</td>
<td></td>
</tr>
<tr>
<td>c=</td>
<td>0.005</td>
<td></td>
<td>c=</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>IDF I = A / (Tc+b) ^ c</td>
<td></td>
<td></td>
<td>IDF I = A / (Tc+c) ^ b</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Total Catchment Area</strong></th>
<th>302,222 m²</th>
<th>(Found by delineating in GIS)</th>
<th><strong>Total Catchment Area</strong></th>
<th>302,222 m²</th>
<th>(Found by delineating in GIS)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Runoff Coefficient, C</strong></td>
<td>0.4</td>
<td>(unimproved land)</td>
<td><strong>Runoff Coefficient, C</strong></td>
<td>0.4</td>
<td>(unimproved land)</td>
</tr>
<tr>
<td><strong>time of concentration</strong></td>
<td>36.61 min</td>
<td>(Calculated using FAA Method)</td>
<td><strong>time of concentration</strong></td>
<td>36.61 min</td>
<td>(Calculated using FAA Method)</td>
</tr>
</tbody>
</table>

**Rainfall Intensity Calculation**

\[
I = \frac{A}{(Tc+b)^c} \\
I = \frac{500}{(Tc+0.764)^{0.005}} \\
I = 31.94 \text{ mm/hr}
\]

**5 year Runoff Peak Flow Rate (Rational Method)**

\[
Q = CIA \\
Q = (0.40) \cdot (31.94 \text{ mm/hr}) \cdot (302,222 \text{ m}^2) \cdot (1 \text{ m} / 1000 \text{ mm}) \cdot (1 \text{ hr} / 3600 \text{ s}) \\
Q = 1.07 \text{ m}^3/\text{s} \\
1072 \text{ lps}
\]

**100 year Runoff Peak Flow Rate (Rational Method)**

\[
Q = CIA \\
Q = (0.40) \cdot (36.61 \text{ mm/hr}) \cdot (302,222 \text{ m}^2) \cdot (1 \text{ m} / 1000 \text{ mm}) \cdot (1 \text{ hr} / 3600 \text{ s}) \\
Q = 1.72 \text{ m}^3/\text{s} \\
1715 \text{ lps}
\]

Design by: A. Peck  
Date: 07-Nov-17
## Rational Method Calculations

**PROJECT:** County Rd 49  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**

<table>
<thead>
<tr>
<th>Design Storm</th>
<th>5 yr</th>
<th>100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td>500</td>
<td>835</td>
</tr>
<tr>
<td><strong>b</strong></td>
<td>0.764</td>
<td>0.776</td>
</tr>
<tr>
<td><strong>c</strong></td>
<td>0.005</td>
<td>0.005</td>
</tr>
</tbody>
</table>

**IDF Calculation:**

\[
I = \frac{A}{(Tc+b)^c}
\]

**Total Catchment Area:**

- 5 yr: 93,425 m² (Found by delineating in GIS)
- 100 yr: 93,425 m² (Found by delineating in GIS)

**Runoff Coefficient, C:**

- 5 yr: 0.4 (unimproved land)
- 100 yr: 0.4 (unimproved land)

**Time of Concentration:**

- 5 yr: 38.23 minutes (Calculated using FAA Method)
- 100 yr: 38.23 minutes (Calculated using FAA Method)

**Rainfall Intensity Calculation:**

\[
I = \frac{A}{(Tc+b)^c}
\]

- 5 yr: \(30.90 \text{ mm/hr}\)
- 100 yr: \(49.40 \text{ mm/hr}\)

**5 year Runoff Peak Flow Rate (Rational Method):**

\[
Q = CIA
\]

- 5 yr: \(0.32 \text{ m}^3/\text{s}

\(321 \text{ lps}\)

**100 year Runoff Peak Flow Rate (Rational Method):**

\[
Q = CIA
\]

- 100 yr: \(0.51 \text{ m}^3/\text{s}

\(513 \text{ lps}\)

Design by: A. Peck  
Date: 07-Nov-17
**Existing Site Peak Runoff - Catchment 10**

**Rational Method Calculations**

**PROJECT:** County Rd 49  
**PROJECT NUMBER:** 2017-5144  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**

<table>
<thead>
<tr>
<th>DESIGN STORM:</th>
<th>5 yr</th>
<th>100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>A=</td>
<td>500</td>
<td>835</td>
</tr>
<tr>
<td>b=</td>
<td>0.764</td>
<td>0.776</td>
</tr>
<tr>
<td>c=</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>IDF I = A / (Tc+b) ^ c</td>
<td>IDF I = A / (Tc+c) ^ b</td>
<td></td>
</tr>
</tbody>
</table>

- Total Catchment Area: **4,799,445 m²** (Found by delineating in GIS)
- Runoff Coefficient, C: 0.4 (unimproved land)
- time of concentration: **131.63 minutes** (Calculated using FAA Method)

**Rainfall Intensity Calculation**

\[
I = \frac{A}{(Tc+b)^c} = \frac{(500)}{(0.764+0.005)} = 12.02 \text{ mm/hr}
\]

- **5 year Runoff Peak Flow Rate (Rational Method)**
  \[
  Q = CIA = (0.40) \times (12.02 \text{ mm/hr}) \times (4,799,445 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s}) = 6.41 \text{ m}^3/\text{s} = 6408 \text{ lps}
  \]

- **100 year Runoff Peak Flow Rate (Rational Method)**
  \[
  Q = CIA = (0.40) \times (18.93 \text{ mm/hr}) \times (4,799,445 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s}) = 10.09 \text{ m}^3/\text{s} = 10093 \text{ lps}
  \]

Design by: A. Peck  
Date: 07-Nov-17
## Existing Site Peak Runoff - Catchment 11

### Rational Method Calculations

**PROJECT:** County Rd 49  
**PROJECT NUMBER:** 2017-5144  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**  

<table>
<thead>
<tr>
<th>DESIGN STORM</th>
<th>A (mm/hr)</th>
<th>b</th>
<th>c</th>
<th>IDF I = A / (Tc+b) ^ c</th>
<th>Total Catchment Area</th>
<th>Runoff Coefficient</th>
<th>time of concentration</th>
<th>Rainfall Intensity</th>
<th>5 year Runoff Peak Flow Rate (Rational Method)</th>
<th>100 year Runoff Peak Flow Rate (Rational Method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 yr</td>
<td>500</td>
<td>0.764</td>
<td>0.005</td>
<td>( I = \frac{A}{(Tc+b)^c} )</td>
<td>89,145 m²</td>
<td>0.4</td>
<td>24.72 minutes</td>
<td>( I = \frac{A}{(Tc+b)^c} )</td>
<td>43.12 mm/hr</td>
<td>69.29 mm/hr</td>
</tr>
<tr>
<td>100 yr</td>
<td>835</td>
<td>0.776</td>
<td>0.005</td>
<td>( I = \frac{A}{(Tc+b)^c} )</td>
<td>89,145 m²</td>
<td>0.4</td>
<td>24.72 minutes</td>
<td>( I = \frac{A}{(Tc+b)^c} )</td>
<td>69.29 mm/hr</td>
<td>686 lps</td>
</tr>
</tbody>
</table>

**Runoff Coefficient, C:** 0.4  
**time of concentration:** 24.72 minutes  
**Rainfall Intensity Calculation:**  
\[
I = \frac{A}{(Tc+b)^c}
\]

\[
I = \frac{500}{(Tc+0.764)^{0.005}} = 43.12 \text{ mm/hr}
\]

**5 year Runoff Peak Flow Rate (Rational Method):**  
\[
Q = CIA = 0.40 \times (43.12 \text{ mm/hr}) \times (89,145 \text{ m}^2) \times (1 \text{ hr} / 3600 \text{ s})
\]

\[
Q = 0.43 \text{ m}^3/\text{s}
\]

427 lps

**100 year Runoff Peak Flow Rate (Rational Method):**  
\[
Q = CIA = 0.40 \times (69.29 \text{ mm/hr}) \times (89,145 \text{ m}^2) \times (1 \text{ hr} / 3600 \text{ s})
\]

\[
Q = 0.69 \text{ m}^3/\text{s}
\]

686 lps

Design by: A. Peck  
Date: 07-Nov-17
### Existing Site Peak Runoff - Catchment 12

#### Rational Method Calculations

**PROJECT:** County Rd 49  
**PROJECT NUMBER:** 2017-5144  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**

#### DESIGN STORM:

- **5 yr**
  - A = 500  
  - b = 0.764  
  - c = 0.005  
  - IDF I = \( \frac{A}{(T_c+b)^c} \)
- **100 yr**
  - A = 835  
  - b = 0.776  
  - c = 0.005  
  - IDF I = \( \frac{A}{(T_c+c)^b} \)

#### Total Catchment Area

- **97,946 m²**  
  (Found by delineating in GIS)

#### Runoff Coefficient, C

- **0.4**  
  (unimproved land)

#### Time of Concentration

- **23.45 minutes**  
  (Calculated using FAA Method)

#### Rainfall Intensity Calculation

- **I = \( \frac{A}{(T_c+b)^c} \)**  
  I = \( \frac{(500)}{(0.764)^{0.005}} \)  
  I = 44.88 mm/hr

#### 5 year Runoff Peak Flow Rate (Rational Method)

- \( Q = CAI \)
  - \( Q = (0.40) \times (44.88 \text{ mm/hr}) \times (97,946 \text{ m}^2) \times (1 \text{ m/1000 mm}) \times (1 \text{ hr/3600 s}) \)
  - \( Q = 0.49 \text{ m}^3/\text{s} \)
  - 488 lps

#### Design by:

- A. Peck  
**Date:** 07-Nov-17

#### Runoff Coefficient, C

- **0.4**  
  (unimproved land)

#### Time of Concentration

- **23.45 minutes**  
  (Calculated using FAA Method)

#### Rainfall Intensity Calculation

- **I = \( \frac{A}{(T_c+b)^c} \)**  
  I = \( \frac{(835)}{(0.776)^{0.005}} \)  
  I = 72.17 mm/hr

#### 100 year Runoff Peak Flow Rate (Rational Method)

- \( Q = CAI \)
  - \( Q = (0.40) \times (72.17 \text{ mm/hr}) \times (97,946 \text{ m}^2) \times (1 \text{ m/1000 mm}) \times (1 \text{ hr/3600 s}) \)
  - \( Q = 0.79 \text{ m}^3/\text{s} \)
  - 785 lps
# Rational Method Calculations

**PROJECT:** County Rd 49  
**PROJECT NUMBER:** 2017-5144  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**

<table>
<thead>
<tr>
<th>DESIGN STORM :</th>
<th>5 yr</th>
<th>100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>A=</td>
<td>500</td>
<td>835</td>
</tr>
<tr>
<td>b=</td>
<td>0.764</td>
<td>0.776</td>
</tr>
<tr>
<td>c=</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>IDF  ( I = \frac{A}{(Tc+b)^c} )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Catchment Area**: 259,107 m² (Found by delineating in GIS)  
**Runoff Coefficient, C**: 0.4 (unimproved land)  
**Time of Concentration**: 39.72 minutes (Calculated using FAA Method)

### Rainfall Intensity Calculation

\[
I = \frac{A}{(Tc+b)^c} 
\]

\[
I = \frac{500}{(0.40 + 0.005)} = 30.01 \text{ mm/hr} 
\]

### 5 year Runoff Peak Flow Rate (Rational Method)

\[
Q = CIA 
\]

\[
Q = 0.40 \times (44.88 \text{ mm/hr}) \times (97,946 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s}) 
\]

\[
Q = 0.86 \text{ m}^3/\text{s} \approx 864 \text{ lps} 
\]

### 100 year Runoff Peak Flow Rate (Rational Method)

\[
Q = CIA 
\]

\[
Q = 0.40 \times (72.17 \text{ mm/hr}) \times (97,946 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s}) 
\]

\[
Q = 1.38 \text{ m}^3/\text{s} \approx 1381 \text{ lps} 
\]

---

**Design by:** S. Bourke  
**Date:** 05-Feb-18
# Existing Site Peak Runoff - Catchment 13
## Rational Method Calculations

**PROJECT:** County Rd 49  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**  
**PROJECT NUMBER:** 2017-5144  
**CLIENT:** Prince Edward County

### Design Storms

<table>
<thead>
<tr>
<th>Design Storm</th>
<th>A</th>
<th>b</th>
<th>c</th>
<th>IDF: ( I = \frac{A}{(Tc+b)^c} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 yr</td>
<td>500</td>
<td>0.764</td>
<td>0.005</td>
<td>( \frac{500}{(Tc+0.764)^{0.005}} )</td>
</tr>
<tr>
<td>100 yr</td>
<td>835</td>
<td>0.776</td>
<td>0.005</td>
<td>( \frac{835}{(Tc+0.776)^{0.005}} )</td>
</tr>
</tbody>
</table>

### Total Catchment Area

- **5 yr:** 2,229,686 m² (Found by delineating in GIS)
- **100 yr:** 2,229,686 m² (Found by delineating in GIS)

### Runoff Coefficient

- **5 yr:** 0.4 (unimproved land)
- **100 yr:** 0.4 (unimproved land)

### Time of Concentration

- **5 yr:** 82.06 minutes (Calculated using FAA Method)
- **100 yr:** 82.06 minutes (Calculated using FAA Method)

### Rainfall Intensity Calculation

\[ I = \frac{A}{(Tc+b)^c} \]

- **5 yr:** \( I = \frac{17.24}{(Tc+0.764)^{0.005}} \) mm/hr
- **100 yr:** \( I = \frac{27.31}{(Tc+0.776)^{0.005}} \) mm/hr

### 5 year Runoff Peak Flow Rate (Rational Method)

\[ Q = CIA \]

- **5 yr:** \( Q = 4.27 \text{ m}^3/\text{s} \)
- **5 yr:** \( Q = 4271 \text{ lps} \)

### 100 year Runoff Peak Flow Rate (Rational Method)

\[ Q = CIA \]

- **100 yr:** \( Q = 6.77 \text{ m}^3/\text{s} \)
- **100 yr:** \( Q = 6766 \text{ lps} \)

---

Design by: A. Peck  
Date: 07-Nov-17
# Existing Site Peak Runoff - Catchment 14

## Rational Method Calculations

**PROJECT:** County Rd 49  
**PROJECT NUMBER:** 2017-5144  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**

### DESIGN STORM: 5 yr
- **A:** 500 (from MTO grid: 44° 6' 15" N, 77° 6' 44" W )
- **b:** 0.764
- **c:** 0.005

\[
\text{IDF } I = \frac{A}{(Tc+b)^c}
\]

### DESIGN STORM: 100 yr
- **A:** 835 (from MTO grid: 44° 6' 15" N, 77° 6' 44" W )
- **b:** 0.776
- **c:** 0.005

\[
\text{IDF } I = \frac{A}{(Tc+c)^b}
\]

### Total Catchment Area
- **18,123 m²** (Found by delineating in GIS)

### Runoff Coefficient, C
- **0.4** (unimproved land)

### Time of Concentration
- **18.62 minutes** (Calculated using FAA Method)

### Rainfall Intensity Calculation
\[
I = \frac{A}{(Tc+b)^c} = \frac{(500)}{(Tc+0.764)^0.005}
\]

\[
I = 53.53 \text{ mm/hr}
\]

### 5 year Runoff Peak Flow Rate (Rational Method)
\[
Q = CIA = (0.40) \times (53.53 \text{ mm/hr}) \times (18,123 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s})
\]

\[
Q = 0.11 \text{ m}^3/\text{s}
\]

\[
108 \text{ lps}
\]

### 100 year Runoff Peak Flow Rate (Rational Method)
\[
Q = CIA = (0.40) \times (86.31 \text{ mm/hr}) \times (18,123 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s})
\]

\[
Q = 0.17 \text{ m}^3/\text{s}
\]

\[
174 \text{ lps}
\]

---

Design by: A. Peck  
Date: 07-Nov-17
### Existing Site Peak Runoff - Catchment 15

#### Rational Method Calculations

**PROJECT:** County Rd 49  
**PROJECT NUMBER:** 2017-5144  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**

<table>
<thead>
<tr>
<th>DESIGN STORM</th>
<th>5 yr</th>
<th>100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>500</td>
<td>835</td>
</tr>
<tr>
<td>b</td>
<td>0.764</td>
<td>0.776</td>
</tr>
<tr>
<td>c</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>IDF I</td>
<td>( \frac{A}{(Tc+b)^c} )</td>
<td>( \frac{A}{(Tc+c)^b} )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Catchment Area</th>
<th>151,050 m²</th>
<th>(Found by delineating in GIS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff Coefficient, C</td>
<td>0.4</td>
<td>(unimproved land)</td>
</tr>
<tr>
<td>time of concentration</td>
<td>32.43 minutes</td>
<td>(Calculated using FAA Method)</td>
</tr>
</tbody>
</table>

**Rainfall Intensity Calculation**

\[
I = \frac{A}{(Tc+b)^c} \\
I = \frac{(500)}{(Tc+0.764)^{0.005}} \\
I = 35.04 \text{ mm/hr} \\
I = \frac{A}{(Tc+c)^b} \\
I = \frac{(835)}{(Tc+0.776)^{0.005}} \\
I = 56.12 \text{ mm/hr}
\]

<table>
<thead>
<tr>
<th>5 year Runoff Peak Flow Rate (Rational Method)</th>
<th>100 year Runoff Peak Flow Rate (Rational Method)</th>
</tr>
</thead>
</table>
| \[
Q = CIA \times \left( \frac{35.04 \text{ mm/hr}}{1 \text{ m} / 1000 \text{ mm}} \right) \times \left( \frac{1 \text{ hr}}{3600 \text{ s}} \right) \\
Q = 0.59 \text{ m}^3/\text{s} \\
Q = 588 \text{ lps}
\] | \[
Q = CIA \times \left( \frac{56.12 \text{ mm/hr}}{1 \text{ m} / 1000 \text{ mm}} \right) \times \left( \frac{1 \text{ hr}}{3600 \text{ s}} \right) \\
Q = 0.94 \text{ m}^3/\text{s} \\
Q = 942 \text{ lps}
\] |

**Design by:** A. Peck  
**Date:** 07-Nov-17
## Existing Site Peak Runoff - Catchment 16
### Rational Method Calculations

**PROJECT:** County Rd 49  
**MUNICIPALITY:**  
**CLIENT:** Prince Edward County  
**PROJECT NUMBER:** 2017-5144

### Design Storm:
- **5 yr**
  - \( A = 500 \) (from MTO grid: 44° 6' 15" N, 77° 6' 44" W)
  - \( b = 0.764 \)
  - \( c = 0.005 \)
  - South Fork of the Quay (IMTA grid: 44° 6' 15" N, 77° 6' 44" W)

### 5 year Runoff Peak Flow Rate (Rational Method)

\[
Q = (0.40) \times (41.30 \text{ mm/hr}) \times (262,500 \text{ m}^2) \times \left( \frac{1 \text{ m}}{1000 \text{ mm}} \right) \times \left( \frac{1 \text{ hr}}{3600 \text{ s}} \right)
\]

\[
Q = 1.20 \text{ m}^3/s \quad 1205 \text{ lps}
\]

### 100 year Runoff Peak Flow Rate (Rational Method)

\[
Q = (0.40) \times (66.32 \text{ mm/hr}) \times (262,500 \text{ m}^2) \times \left( \frac{1 \text{ m}}{1000 \text{ mm}} \right) \times \left( \frac{1 \text{ hr}}{3600 \text{ s}} \right)
\]

\[
Q = 1.93 \text{ m}^3/s \quad 1934 \text{ lps}
\]

### Design by: A. Peck  
**Date:** 07-Nov-17
## Existing Site Peak Runoff - Catchment 17

### Rational Method Calculations

**PROJECT:** County Rd 49  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**

- **DESIGN STORM:** 5 yr  
  - A= 500  
  - b= 0.764  
  - c= 0.005

- **100 yr**  
  - A= 835  
  - b= 0.776  
  - c= 0.005

### Rainfall Intensity Calculation

- **I = A / (Tc+b)^c**
  - I = 26.40 mm/hr
  - I = 42.10 mm/hr

### Total Catchment Area

- **593,029 m²** (Found by delineating in GIS)

### Runoff Coefficient, C

- **0.4** (unimproved land)

### Time of concentration

- **46.97 minutes** (Calculated using FAA Method)

### 5 year Runoff Peak Flow Rate (Rational Method)

\[
Q = C*IA
\]

\[
Q = (0.40) * (26.40 \text{ mm/hr}) * (593,029 \text{ m}^2) * (1 \text{ m} / 1000 \text{ mm}) * (1 \text{ hr} / 3600 \text{ s})
\]

\[
Q = 1.74 \text{ m}^3/\text{s}
\]

\[
Q = 1740 \text{ lps}
\]

### 100 year Runoff Peak Flow Rate (Rational Method)

\[
Q = C*IA
\]

\[
Q = (0.40) * (42.10 \text{ mm/hr}) * (593,029 \text{ m}^2) * (1 \text{ m} / 1000 \text{ mm}) * (1 \text{ hr} / 3600 \text{ s})
\]

\[
Q = 2.77 \text{ m}^3/\text{s}
\]

\[
Q = 2774 \text{ lps}
\]
## Existing Site Peak Runoff - Catchment 17b
### Rational Method Calculations

**PROJECT:** County Rd 49  
**CLIENT:** Prince Edward County  
**PROJECT NUMBER:** 2017-5144  
**MUNICIPALITY:**  

### DESIGN STORM: 5 yr
- **A:** 500  
- **b:** 0.764  
- **c:** 0.005  
- **IDF:** \( I = \frac{A}{(T_c+b)^c} \)

### DESIGN STORM: 100 yr
- **A:** 835  
- **b:** 0.776  
- **c:** 0.005  
- **IDF:** \( I = \frac{A}{(T_c+b)^c} \)

### Total Catchment Area
- **387,608 m\(^2\)**  
  (Found by delineating in GIS)

### Runoff Coefficient, C
- **0.4**  
  (unimproved land)

### Time of Concentration
- **41.82 minutes**  
  (Calculated using FAA Method)

### Rainfall Intensity Calculation
\[
I = \frac{A}{(T_c+b)^c} \\
I = \frac{500}{(T_c+0.764)^{(0.005)}} \\
I = 28.85 \text{ mm/hr} \\
I = \frac{835}{(T_c+0.776)^{(0.005)}} \\
I = 46.07 \text{ mm/hr}
\]

### 5 year Runoff Peak Flow Rate (Rational Method)
\[
Q = CIA \\
Q = (0.40) \times (26.40 \text{ mm/hr}) \times (593,029 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s}) \\
Q = 1.24 \text{ m}^3/\text{s} \\
Q = 1243 \text{ lps}
\]

### 100 year Runoff Peak Flow Rate (Rational Method)
\[
Q = CIA \\
Q = (0.40) \times (42.10 \text{ mm/hr}) \times (593,029 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s}) \\
Q = 1.98 \text{ m}^3/\text{s} \\
Q = 1984 \text{ lps}
\]

---

Design by: S.Bourke  
Date: 05-Feb-18
## Existing Site Peak Runoff - Catchment 18

### Rational Method Calculations

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>County Rd 49</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROJECT NUMBER</td>
<td>2017-5144</td>
</tr>
<tr>
<td>CLIENT</td>
<td>Prince Edward County</td>
</tr>
<tr>
<td>MUNICIPALITY</td>
<td></td>
</tr>
</tbody>
</table>

### DESIGN STORM:

- **5 yr**
  - \( A = 500 \) (from MTO grid: 44° 6' 15" N, 77° 6' 44" W)
  - \( b = 0.764 \)
  - \( c = 0.005 \)
  - \( \text{IDF} \ I = \frac{A}{(Tc+b)^c} \)

- **100 yr**
  - \( A = 835 \) (from MTO grid: 44° 6' 15" N, 77° 6' 44" W)
  - \( b = 0.776 \)
  - \( c = 0.005 \)
  - \( \text{IDF} \ I = \frac{A}{(Tc+c)^b} \)

### Total Catchment Area

- **801,628 m²** (Found by delineating in GIS)

### Runoff Coefficient, C

- **0.4** (unimproved land)

### Time of Concentration

- **45.90 minutes** (Calculated using FAA Method)

### Rainfall Intensity Calculation

- **5 year Runoff Peak Flow Rate (Rational Method)**
  
  \[ Q = CIA \]
  
  \[ Q = (0.40) \times (26.87 \text{ mm/hr}) \times (801,628 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s}) \]
  
  \[ Q = 2.39 \text{ m}^3/\text{s} \]
  
  \[ 2393 \text{ lps} \]

### Design by: A. Peck

Date: **07-Nov-17**
## Existing Site Peak Runoff - Catchment 19

### Rational Method Calculations

**PROJECT:** County Rd 49  
**PROJECT NUMBER:** 2017-5144  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**  
**DESIGN STORM:**  
- 5 yr  
  - $A = 500$ (from MTO grid: 44° 6' 15" N, 77° 6' 44" W)  
  - $b = 0.764$  
  - $c = 0.005$  
  - $IDF = \frac{A}{(Tc+b)^c}$  
- 100 yr  
  - $A = 835$ (from MTO grid: 44° 6' 15" N, 77° 6' 44" W)  
  - $b = 0.776$  
  - $c = 0.005$  
  - $IDF = \frac{A}{(Tc+c)^b}$

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Catchment Area</td>
<td>955,716 m$^2$</td>
<td>(Found by delineating in GIS)</td>
</tr>
<tr>
<td>Runoff Coefficient, C</td>
<td>0.4</td>
<td>(unimproved land)</td>
</tr>
<tr>
<td>Time of concentration</td>
<td>44.43 minutes</td>
<td>(Calculated using FAA Method)</td>
</tr>
</tbody>
</table>

### Rainfall Intensity Calculation

- **5 year Runoff Peak Flow Rate (Rational Method)**
  
  $Q = CIA$
  
  $Q = (0.40) \times (27.55 \text{ mm/hr}) \times (955,716 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s})$
  
  $Q = 2.93 \text{ m}^3/\text{s}$  
  
  2926 lps

- **100 year Runoff Peak Flow Rate (Rational Method)**
  
  $Q = CIA$
  
  $Q = (0.40) \times (43.96 \text{ mm/hr}) \times (955,716 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s})$
  
  $Q = 4.67 \text{ m}^3/\text{s}$  
  
  4668 lps

Design by: A. Peck  
Date: 07-Nov-17
Existing Site Peak Runoff - Catchment 20

Rational Method Calculations

**PROJECT: County Rd 49**
**PROJECT NUMBER: 2017-5144**
**CLIENT: Prince Edward County**
**MUNICIPALITY: **

**DESIGN STORM :** 5 yr

| A= | 500 | (from MTO grid: 44° 6' 15" N, 77° 6' 44" W ) |
| b= | 0.764 |
| c= | 0.005 |
| IDF I = A / (Tc+b) ^ c |

**DESIGN STORM :** 100 yr

| A= | 835 | (from MTO grid: 44° 6' 15" N, 77° 6' 44" W ) |
| b= | 0.776 |
| c= | 0.005 |
| IDF I = A / (Tc+c) ^ b |

**Total Catchment Area** 260,517 m² (Found by delineating in GIS)

**Runoff Coefficient, C** 0.4 (unimproved land)

**time of concentration** 29.91 minutes (Calculated using FAA Method)

**Rainfall Intensity Calculation**

\[
I = \frac{A}{(Tc+b)^c} \\
I = \frac{(500)}{(0.005)} \\
I = \frac{37.27 \text{ mm/hr}}{(Tc+0.764)^{0.005}} \\
I = 37.27 \text{ mm/hr} \\
I = \frac{835}{(0.005)} \\
I = \frac{59.75 \text{ mm/hr}}{(Tc+0.776)^{0.005}} \\
I = 59.75 \text{ mm/hr} \\
\]

**5 year Runoff Peak Flow Rate (Rational Method)**

\[
Q = CIA \\
Q = (0.40) * (37.27 \text{ mm/hr}) * (260,517 \text{ m}^2) * (1 \text{ m} / 1000 \text{ mm}) * (1 \text{ hr} / 3600 \text{ s}) \\
Q = 1.08 \text{ m}^3/\text{s} \\
Q = 1079 \text{ lps} \\
\]

**100 year Runoff Peak Flow Rate (Rational Method)**

\[
Q = CIA \\
Q = (0.40) * (59.75 \text{ mm/hr}) * (260,517 \text{ m}^2) * (1 \text{ m} / 1000 \text{ mm}) * (1 \text{ hr} / 3600 \text{ s}) \\
Q = 1.73 \text{ m}^3/\text{s} \\
Q = 1730 \text{ lps} \\
\]

Design by: A. Peck
Date: 07-Nov-17
## Existing Site Peak Runoff - Catchment 21

### Rational Method Calculations

<table>
<thead>
<tr>
<th>Design Storm</th>
<th>5 yr</th>
<th>100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>500</td>
<td>835</td>
</tr>
<tr>
<td>b</td>
<td>0.764</td>
<td>0.776</td>
</tr>
<tr>
<td>c</td>
<td>0.005</td>
<td>0.005</td>
</tr>
</tbody>
</table>

\[
\text{IDF } I = \frac{A}{(Tc+b)^c} \\
\text{IDF } I = \frac{A}{(Tc+c)^b}
\]

<table>
<thead>
<tr>
<th>Total Catchment Area</th>
<th>1,119,229 m²</th>
<th>(Found by delineating in GIS)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Runoff Coefficient, C</th>
<th>0.4</th>
<th>(unimproved land)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Time of Concentration</th>
<th>39.80 minutes</th>
<th>(Calculated using FAA Method)</th>
</tr>
</thead>
</table>

### Rainfall Intensity Calculation

\[
I = \frac{A}{(Tc+b)^c} \\
I = \frac{(500)}{(Tc+0.764)^{0.005}} \\
I = 29.96 \text{ mm/hr}
\]

\[
I = \frac{A}{(Tc+c)^b} \\
I = \frac{(835)}{(Tc+0.776)^{0.005}} \\
I = 47.88 \text{ mm/hr}
\]

### 5 year Runoff Peak Flow Rate (Rational Method)

\[
Q = CIA \\
Q = (0.40) \times (29.96 \text{ mm/hr}) \times (1,119,229 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} \times 3600 \text{ s}) \\
Q = 3.73 \text{ m}^3/\text{s} \\
Q = 3726 \text{ lps}
\]

Design by: A. Peck
Date: 07-Nov-17

### 100 year Runoff Peak Flow Rate (Rational Method)

\[
Q = CIA \\
Q = (0.40) \times (47.88 \text{ mm/hr}) \times (1,119,229 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} \times 3600 \text{ s}) \\
Q = 5.95 \text{ m}^3/\text{s} \\
Q = 5954 \text{ lps}
\]
## Existing Site Peak Runoff - Catchment 22

### Rational Method Calculations

**PROJECT:** County Rd 49  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**  
**PROJECT NUMBER:** 2017-5144  
**ADDRESS:** Suite 201, 110A Hannover Drive, St. Catharines, ON, L2W 1A4

### DESIGN STORM: 5 yr

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>A=</td>
<td>500</td>
<td>(from MTO grid: 44° 6' 15&quot; N, 77° 6' 44&quot; W )</td>
</tr>
<tr>
<td>b=</td>
<td>0.764</td>
<td></td>
</tr>
<tr>
<td>c=</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>IDF = A / (Tc+b) ^ c</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### DESIGN STORM: 100 yr

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>A=</td>
<td>835</td>
<td>(from MTO grid: 44° 6' 15&quot; N, 77° 6' 44&quot; W )</td>
</tr>
<tr>
<td>b=</td>
<td>0.776</td>
<td></td>
</tr>
<tr>
<td>c=</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>IDF = A / (Tc+c) ^ b</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Total Catchment Area

<table>
<thead>
<tr>
<th>Total Catchment Area</th>
<th>151,016 m²</th>
<th>(Found by delineating in GIS)</th>
</tr>
</thead>
</table>

### Runoff Coefficient, C

| Runoff Coefficient, C | 0.4         | (unimproved land)    |

### Time of Concentration

| Time of Concentration | 40.65 minutes | (Calculated using FAA Method) |

### Rainfall Intensity Calculation

\[ I = \frac{A}{(Tc+b)^c} \]

<table>
<thead>
<tr>
<th>Rainfall Intensity Calculation</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I = A / (Tc+b) ^ c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I = (500) / (Tc+0.764) ^ (0.005)</td>
<td>29.49 mm/hr</td>
<td></td>
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</tbody>
</table>

### 5 year Runoff Peak Flow Rate (Rational Method)

\[ Q = CIA \]

<table>
<thead>
<tr>
<th>5 year Runoff Peak Flow Rate (Rational Method)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Q = (0.40) * (29.49 mm/hr) * (151,016 m²) * (1 m / 1000 mm) * (1 hr / 3600 s)</td>
<td>0.49 m³/s</td>
<td>495 lps</td>
</tr>
</tbody>
</table>

### Design by: A. Peck  
**Date:** 07-Nov-17
### Existing Site Peak Runoff - Catchment 23

#### Rational Method Calculations

**PROJECT:** County Rd 49  
**MUNICIPALITY:**  
**CLIENT:** Prince Edward County  
**PROJECT NUMBER:** 2017-5144

<table>
<thead>
<tr>
<th>DESIGN STORM :</th>
<th>5 yr</th>
<th>100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td>500</td>
<td>835</td>
</tr>
<tr>
<td><strong>b</strong></td>
<td>0.764</td>
<td>0.776</td>
</tr>
<tr>
<td><strong>c</strong></td>
<td>0.005</td>
<td>0.005</td>
</tr>
</tbody>
</table>

**IDF I = A / (Tc+b) ^ c**  
**IDF I = A / (Tc+c) ^ b**

<table>
<thead>
<tr>
<th>Total Catchment Area</th>
<th>418,830 m²</th>
<th>418,830 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Found by delineating in GIS)</td>
<td>(Found by delineating in GIS)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Runoff Coefficient, C</th>
<th>0.4</th>
<th>0.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(unimproved land)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>time of concentration</th>
<th>46.58 minutes</th>
<th>46.58 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Calculated using FAA Method)</td>
<td>(Calculated using FAA Method)</td>
<td></td>
</tr>
</tbody>
</table>

**Rainfall Intensity Calculation**

\[
I = \frac{A}{(Tc+b)^c} \\
I = \frac{(500)}{(Tc+0.764)^{(0.005)}} \\
I = \frac{26.57 \text{ mm/hr}}{} \\
I = \frac{42.38 \text{ mm/hr}}{} \\
\]

**5 year Runoff Peak Flow Rate (Rational Method)**

\[
Q = CIA \\
Q = (0.40) \times (26.57 \text{ mm/hr}) \times (418,830 \text{ m}^2) \times \left(\frac{1 \text{ m}}{1000 \text{ mm}}\right) \times \left(\frac{1 \text{ hr}}{3600 \text{ s}}\right) \\
Q = 1.24 \text{ m}^3/\text{s} \\
Q = 1237 \text{ lps} \\
\]

**Design by:** A. Peck  
**Date:** 07-Nov-17

- **5 year Runoff Peak Flow Rate (Rational Method)**
  \[Q = CIA\]
  \[Q = (0.40) \times (26.57 \text{ mm/hr}) \times (418,830 \text{ m}^2) \times \left(\frac{1 \text{ m}}{1000 \text{ mm}}\right) \times \left(\frac{1 \text{ hr}}{3600 \text{ s}}\right)\]
  \[Q = 1.24 \text{ m}^3/\text{s}\]
  \[Q = 1237 \text{ lps}\]

- **100 year Runoff Peak Flow Rate (Rational Method)**
  \[Q = CIA\]
  \[Q = (0.40) \times (42.38 \text{ mm/hr}) \times (418,830 \text{ m}^2) \times \left(\frac{1 \text{ m}}{1000 \text{ mm}}\right) \times \left(\frac{1 \text{ hr}}{3600 \text{ s}}\right)\]
  \[Q = 1.97 \text{ m}^3/\text{s}\]
  \[Q = 1972 \text{ lps}\]
# Existing Site Peak Runoff - Catchment 24

## Rational Method Calculations

<table>
<thead>
<tr>
<th>Design Storm:</th>
<th>5 yr</th>
<th>100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>A=</td>
<td>500</td>
<td>835</td>
</tr>
<tr>
<td>b=</td>
<td>0.764</td>
<td>0.776</td>
</tr>
<tr>
<td>c=</td>
<td>0.005</td>
<td>0.005</td>
</tr>
</tbody>
</table>

\[ \text{IDF} = \frac{A}{(Tc+b)^c} \]

### Total Catchment Area
- 6,091,632 m² (Found by delineating in GIS)

### Runoff Coefficient, C
- 0.4 (unimproved land)

### Time of Concentration
- 81.08 minutes (Calculated using FAA Method)

### Rainfall Intensity Calculation

\[ I = \frac{500}{(Tc+0.764)^{0.005}} \]

\[ I = \frac{835}{(Tc+0.776)^{0.005}} \]

\[ I = 17.40 \text{ mm/hr} \]

\[ I = 27.56 \text{ mm/hr} \]

### 5 year Runoff Peak Flow Rate (Rational Method)

\[ Q = CIA \]

\[ Q = (0.40) \times (17.40 \text{ mm/hr}) \times (6,091,632 \text{ m}^2) \times \left( \frac{1 \text{ m}}{1000 \text{ mm}} \right) \times \left( \frac{1 \text{ hr}}{3600 \text{ s}} \right) \]

\[ Q = 11.78 \text{ m}^3/\text{s} \]

\[ Q = 11777 \text{ lps} \]

### 100 year Runoff Peak Flow Rate (Rational Method)

\[ Q = CIA \]

\[ Q = (0.40) \times (27.56 \text{ mm/hr}) \times (6,091,632 \text{ m}^2) \times \left( \frac{1 \text{ m}}{1000 \text{ mm}} \right) \times \left( \frac{1 \text{ hr}}{3600 \text{ s}} \right) \]

\[ Q = 18.66 \text{ m}^3/\text{s} \]

\[ Q = 18656 \text{ lps} \]

Design by: A. Peck

Date: 07-Nov-17
### Existing Site Peak Runoff - Catchment 25

#### Rational Method Calculations

**PROJECT:** County Rd 49  
**PROJECT NUMBER:** 2017-5144  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**

#### DESIGN STORM:
- **5 yr**  
  - $A_5 = 500$  
  - $b_5 = 0.764$  
  - $c_5 = 0.005$  
  - $I_5 = A_5 / (Tc+b)^c$  
  - **Total Catchment Area:** 6,500,962 m²  
  - **Runoff Coefficient, $C$:** 0.4  
  - **time of concentration:** 74.43 minutes  
  - **Rainfall Intensity Calculation:** 
    \[ I = A / (Tc+b)^c \]  
  - **5 year Runoff Peak Flow Rate (Rational Method):** 
    \[ Q = CIA \]  
    \[ Q = (0.40) \times (18.57 \text{ mm/hr}) \times (6,500,962 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s}) \]  
    \[ Q = 13.42 \text{ m}^3/\text{s} \]  
    \[ 13417 \text{ lps} \]

**Design by:** A. Peck  
**Date:** 07-Nov-17

#### 100 yr  
- $A_{100} = 835$  
- $b_{100} = 0.776$  
- $c_{100} = 0.005$  
- $I_{100} = A_{100} / (Tc+b)^c$  
- **Total Catchment Area:** 6,500,962 m²  
- **Runoff Coefficient, $C$:** 0.4  
- **time of concentration:** 74.43 minutes  
- **Rainfall Intensity Calculation:** 
  \[ I = A / (Tc+b)^c \]  
- **100 year Runoff Peak Flow Rate (Rational Method):** 
  \[ Q = CIA \]  
  \[ Q = (0.40) \times (29.46 \text{ mm/hr}) \times (6,500,962 \text{ m}^2) \times (1 \text{ m} / 1000 \text{ mm}) \times (1 \text{ hr} / 3600 \text{ s}) \]  
  \[ Q = 21.28 \text{ m}^3/\text{s} \]  
  \[ 21277 \text{ lps} \]
## Existing Site Peak Runoff - Catchment 26
### Rational Method Calculations

**PROJECT:** County Rd 49  
**PROJECT NUMBER:** 2017-5144  
**CLIENT:** Prince Edward County  
**MUNICIPALITY:**  

<table>
<thead>
<tr>
<th>DESIGN STORM :</th>
<th>5 yr</th>
<th>DESIGN STORM :</th>
<th>100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>A=</td>
<td>500</td>
<td>A=</td>
<td>835</td>
</tr>
<tr>
<td>b=</td>
<td>0.764</td>
<td>b=</td>
<td>0.776</td>
</tr>
<tr>
<td>c=</td>
<td>0.005</td>
<td>c=</td>
<td>0.005</td>
</tr>
<tr>
<td>IDF I = A / (Tc+b) ^ c</td>
<td></td>
<td>IDF I = A / (Tc+c) ^ b</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Catchment Area</th>
<th>13,276 m²</th>
<th>Runoff Coefficient, C</th>
<th>0.4</th>
<th>time of concentration</th>
<th>26.10 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Found by delineating in GIS)</td>
<td></td>
<td>(unimproved land)</td>
<td></td>
<td>(Calculated using FAA Method)</td>
<td></td>
</tr>
<tr>
<td>Rainfall Intensity Calculation</td>
<td></td>
<td>I = A / (Tc+b) ^ c</td>
<td></td>
<td>I = (500) / (Tc+0.764) ^ (0.005)</td>
<td></td>
</tr>
<tr>
<td>I = (500) / (Tc+0.764) ^ (0.005)</td>
<td></td>
<td>I = 41.37 mm/hr</td>
<td></td>
<td>I = 66.43 mm/hr</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5 year Runoff Peak Flow Rate (Rational Method)</th>
<th>100 year Runoff Peak Flow Rate (Rational Method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q = CIA * (41.37 mm/hr) * (13,276 m²) * (1 m / 1000 mm) * (1 hr / 3600 s)</td>
<td>Q = CIA * (66.43 mm/hr) * (13,276 m²) * (1 m / 1000 mm) * (1 hr / 3600 s)</td>
</tr>
<tr>
<td>Q = 0.06 m³/s</td>
<td>Q = 0.10 m³/s</td>
</tr>
<tr>
<td>61 lps</td>
<td>98 lps</td>
</tr>
</tbody>
</table>

Design by: A. Peck  
Date: 07-Nov-17
### Culvert 1
- **Hydraulic Length:** 2215 m
- **Slope:** 0.022 m/m

<table>
<thead>
<tr>
<th>Method</th>
<th>Adjust. Factor</th>
<th>Hydraulic Length</th>
<th>Slope</th>
<th>Runoff coeff.</th>
<th>Retardance</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kirsip</td>
<td>K</td>
<td>2</td>
<td>0.4</td>
<td>0.1</td>
<td>0.4</td>
<td>0.8268</td>
</tr>
</tbody>
</table>

### Culvert 2
- **Hydraulic Length:** 2076 m
- **Slope:** 0.007 m/m

<table>
<thead>
<tr>
<th>Method</th>
<th>Adjust. Factor</th>
<th>Hydraulic Length</th>
<th>Slope</th>
<th>Runoff coeff.</th>
<th>Retardance</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kirsip</td>
<td>K</td>
<td>2</td>
<td>0.4</td>
<td>0.1</td>
<td>0.4</td>
<td>0.8268</td>
</tr>
</tbody>
</table>

### Culvert 3
- **Hydraulic Length:** 888 m
- **Slope:** 0.025 m/m

<table>
<thead>
<tr>
<th>Method</th>
<th>Adjust. Factor</th>
<th>Hydraulic Length</th>
<th>Slope</th>
<th>Runoff coeff.</th>
<th>Retardance</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kirsip</td>
<td>K</td>
<td>2</td>
<td>0.4</td>
<td>0.1</td>
<td>0.4</td>
<td>0.8268</td>
</tr>
</tbody>
</table>

**Kirsip method** is for channeled flow, not overland flow.

**Kerby Method** can be used for small watersheds where overland flow is an important component of overall travel time.

**FAA (US Federal Aviation Administration) equation** is the most commonly used method because it uses the widely recognized Rational Coefficient to describe the watershed ground cover.
Hydraulic Length, L = 605 m
Slope, S = 0.023 m
Kerby
Adjust. Factor, K = 2
r = 0.4 m
G = 869

Hydraulic Length, L = 425 m
Slope, S = 0.014 m
Kerby
Adjust. Factor, K = 2
r = 0.4 m
G = 11.18

Hydraulic Length, L = 865 m
Slope, S = 0.009 m
Kerby
Adjust. Factor, K = 2
r = 0.4 m
G = 1.8

Hydraulic Length, L = 230 m
Slope, S = 0.011 m
Kerby
Adjust. Factor, K = 2
r = 0.4 m
G = 0.8268

Hydraulic Length, L = 615 m
Slope, S = 0.009 m
Kerby
Adjust. Factor, K = 2
r = 0.4 m
G = 1.8

Hydraulic Length, L = 1590 m
Slope, S = 0.012 m
Kerby
Adjust. Factor, K = 2
r = 0.4 m
G = 1.8

Hydraulic Length, L = 1273 m
Slope, S = 0.012 m
Kerby
Adjust. Factor, K = 2
r = 0.4 m
G = 1.8

Hydraulic Length, L = 1350 m
Slope, S = 0.013 m
Kerby
Adjust. Factor, K = 2
r = 0.4 m
G = 1.8

Hydraulic Length, L = 2150 m
Slope, S = 0.013 m
Kerby
Adjust. Factor, K = 2
r = 0.4 m
G = 1.8
\[ G = G \times (L \times r / S^{0.5})^{0.467} \]

\[ 1585 = G \times (L \times r / S^{0.5})^{0.467} \]

\[ c_{0.0} \]

\[ 2 \]

\[ K \]

\[ 1740 \]

\[ 47.35 \]

\[ 5300 \]

\[ 0.0 \]

\[ r \]

\[ 26.10 \]

\[ 2150 \]

\[ 0.0 \]

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Water Surface Profile Plot for Culvert: c1

Crossing - Crossing 1, Design Discharge - 2.36 cms

Culvert - c1, Culvert Discharge - 2.36 cms
Water Surface Profile Plot for Culvert: c3

Crossing - Crossing 3, Design Discharge - 0.57 cms

Culvert - c3, Culvert Discharge - 0.57 cms

Elevation (m) vs Station (m)
Water Surface Profile Plot for Culvert: c5

Crossing - Crossing 5, Design Discharge - 1.27 cms
Culvert - c5, Culvert Discharge - 1.27 cms
Water Surface Profile Plot for Culvert: c6

Crossing - Crossing 6, Design Discharge - 2.23 cms

Culvert - c6, Culvert Discharge - 2.23 cms
Water Surface Profile Plot for Culvert: c7

Crossing - Crossing 7, Design Discharge - 0.33 cms

Culvert - c7, Culvert Discharge - 0.33 cms
Water Surface Profile Plot for Culvert: c8

Crossing - Crossing 8, Design Discharge - 1.72 cms

Culvert - c8, Culvert Discharge - 1.72 cms
Water Surface Profile Plot for Culvert: c9

Crossing - Crossing 9, Design Discharge - 0.51 cms

Culvert - c9, Culvert Discharge - 0.51 cms
Water Surface Profile Plot for Culvert: c10

Crossing - Crossing 10, Design Discharge - 10.09 cms

Culvert - c10, Culvert Discharge - 10.09 cms

Elevation (m)

Station (m)
Water Surface Profile Plot for Culvert: c11

Crossing - Crossing 11, Design Discharge - 0.69 cms
Culvert - c11, Culvert Discharge - 0.69 cms
Water Surface Profile Plot for Culvert: c12

Crossing - Crossing 12, Design Discharge - 0.79 cms
Culvert - c12, Culvert Discharge - 0.79 cms
Water Surface Profile Plot for Culvert: c13

Crossing - Crossing 13, Design Discharge - 6.77 cms

Culvert - c13, Culvert Discharge - 0.29 cms
Water Surface Profile Plot for Culvert: c14

Crossing - Crossing 14, Design Discharge - 0.17 cms

Culvert - c14, Culvert Discharge - 0.17 cms
Water Surface Profile Plot for Culvert: c17

Crossing - Crossing 17, Design Discharge - 2.77 cms
Culvert - c17, Culvert Discharge - 0.06 cms
Water Surface Profile Plot for Culvert: c18

Crossing - Crossing 18, Design Discharge - 3.82 cms
Culvert - c18, Culvert Discharge - 1.81 cms
Water Surface Profile Plot for Culvert: c19

Crossing - Crossing 19, Design Discharge - 4.67 cms
Culvert - c19, Culvert Discharge - 0.81 cms
Water Surface Profile Plot for Culvert: c20

Crossing - Crossing 20, Design Discharge - 1.73 cms

Culvert - c20, Culvert Discharge - 1.73 cms
Water Surface Profile Plot for Culvert: c21

Crossing - Crossing 21, Design Discharge - 5.95 cms
Culvert - c21, Culvert Discharge - 0.09 cms
Water Surface Profile Plot for Culvert: c22

Crossing - Crossing 22, Design Discharge - 0.79 cms

Culvert - c22, Culvert Discharge - 0.79 cms
Water Surface Profile Plot for Culvert: c24

Crossing - Crossing 24, Design Discharge - 18.66 cms
Culvert - c24, Culvert Discharge - 13.73 cms
Water Surface Profile Plot for Culvert: c25

Crossing - Crossing 25, Design Discharge - 21.28 cms

Culvert - c25, Culvert Discharge - 8.33 cms
Water Surface Profile Plot for Culvert: c26

Crossing - Crossing 26, Design Discharge - 0.10 cms

Culvert - c26, Culvert Discharge - 0.10 cms
Table E-1: Summary of culvert recommendations based on culvert condition assessment and culvert drainage (conveyance) assessment.

<table>
<thead>
<tr>
<th>Culvert ID</th>
<th>Culvert Description (interior dimensions as measured in the field)</th>
<th>Culvert Condition Assessment Recommended Action</th>
<th>Culvert Drainage Assessment Recommended Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Concrete box (1500x1800)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>2</td>
<td>Concrete box (750x1200)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>3</td>
<td>CSP (1050x1200)</td>
<td>Repair, reline, or replace</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>4</td>
<td>Concrete box (900x850)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>5</td>
<td>Concrete box (1250x1800)</td>
<td>Repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>6</td>
<td>Concrete box (1850x1400)</td>
<td>Repair, reline, or replace</td>
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</tr>
<tr>
<td>7</td>
<td>Concrete box (1250x1600)</td>
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<tr>
<td>8</td>
<td>Concrete box (1550x1600)</td>
<td>Monitor or minor repair</td>
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</tr>
<tr>
<td>9</td>
<td>Concrete box (1250x1600)</td>
<td>Repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>10</td>
<td>Concrete box (2100x2500)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>11</td>
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<td>12</td>
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<td>12B</td>
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<td>Further investigation</td>
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<td>Further investigation</td>
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<tr>
<td>14</td>
<td>CSP (750)</td>
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<td>15</td>
<td>Concrete box (1250x1600)</td>
<td>Monitor or minor repair</td>
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<tr>
<td>16</td>
<td>CSP (1250x850)</td>
<td>Repair</td>
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<tr>
<td>17</td>
<td>CSP (900x600)</td>
<td>Repair</td>
<td>Further investigation</td>
</tr>
<tr>
<td>Culvert ID</td>
<td>Culvert Description (interior dimensions as measured in the field)</td>
<td>Culvert Condition Assessment Recommended Action</td>
<td>Culvert Drainage Assessment Recommended Action</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------------------------------------------</td>
<td>------------------------------------------------</td>
<td>---------------------------------------------</td>
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<tr>
<td>17B</td>
<td>CSP (TBD)</td>
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<td>Further investigation</td>
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<td>CSP (1100)</td>
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<td>Further investigation</td>
</tr>
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<td>Further investigation</td>
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<td>21</td>
<td>CSP (900x650)</td>
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<td>Further investigation</td>
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<td>22</td>
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<td>23</td>
<td>CSP (950)</td>
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<td>Further investigation</td>
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<td>24</td>
<td>Concrete box (3000x1750)</td>
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<td>Further investigation</td>
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<td>25</td>
<td>Concrete box (2400x1400)</td>
<td>Repair</td>
<td>Further investigation</td>
</tr>
<tr>
<td>26</td>
<td>CSP (750)</td>
<td>Monitor or minor repair</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>
Appendix F – Concrete Pricing Memo
1 BACKGROUND

Associated Engineering (Ont.) Ltd. (AE) has been retained by Prince Edward County to complete a Road Condition Study for 17.3 km of County Road 49. The existing Portland Cement Concrete (PCC) road has surpassed its design service life and major defects have been observed and documented. AE performed a road condition assessment which included assessment of pavement conditions based on MTO methodology, an engineering assessment of intersection geometry, a roadside hazard assessment, a drainage assessment and a life cycle cost analysis, while Englobe Corporation was retained to provide road structure condition assessment, geotechnical investigation and recommendations for road rehabilitation.

AE identified six options for the rehabilitation of the roadway, each of which were reviewed over a 30-year life cycle to determine which option was the most cost effective. On the basis of this analysis, it had been determined that the option determined to be the most cost effective was rubblization of the concrete with asphalt replacement (Option 1). The County of Prince Edward then directed AE to confirm the unit price costing used as a basis for the options involving using a concrete overlay. This was done by means of contacting a neighbouring County which has a similar concrete road, area contractors, the Cement Association and Lehigh Cement Company, who operates a local quarry adjacent to County Road 49.

The unit price used in the draft Interim Road Condition Report submitted in November 2017 was $400 per metre cubed of concrete. The basis for using this cost was to provide a conservative estimate at this preliminary phase. This technical memorandum documents the results of the investigation into concrete unit cost pricing.

2 STAKEHOLDERS CONTACTED

The following stakeholders provided information on their experience with concrete roadways:

- County of Lennox and Addington
- Cement Association of Canada/Lehigh Cement Company
- Rankin Construction
2.1 County of Lennox and Addington

The County of Lennox and Addington County provided background information on County Road 4, a 9.4 km concrete road, which is also nearing the end of its service life. A report by AECOM was provided for review and consideration. In the report, AECOM identified three repair strategies:

- Option 1: Continue the County’s program of joint repair;
- Option 2: Apply a strategy of repairing the worst joint failures first; and
- Option 3: Full depth road reconstruction.

AECOM evaluated these options from a cost, needs and longevity standpoint and selected Option 2 as the preferred option for County Road 4. It is noted that County Road 4 is not in the same state of disrepair as County Road 49 in Prince Edward County. AECOM’s evaluation team for County Road 4 felt that the service life for County Road 4 could be extended a number of years by improving the strategy of their road repair program. Conversely, the approach taken for County Road 49 is that the road is in a further deteriorated state, and that a patch repair strategy is no longer seen as a viable option.

2.2 Cement Association of Canada (CAC)/Lehigh Cement Company

The County also provided contacts with the Cement Association and the Lehigh Cement Company, who have a cement plant along County Road 49. AE held a teleconference with both agencies in early December 2017 in order to share the findings of the life cycle cost analysis and obtain their feedback. Given that the Lehigh Cement Company is located directly adjacent to the project site, it was hoped that they would be able to provide additional insight into the cost implications of rehabilitating the roadway by means of concrete replacement. The CAC subsequently provided an estimated unit cost price for concrete based on the project’s size and location both for standard concrete paving in addition to concrete paving using a Roller Compacted Concrete (RCC) technique.

2.3 Englobe Corporation

Englobe Corporation, the geotechnical consultant for County Road 49, provided an estimate of the unit cost for a concrete pavement road construction project based on their knowledge of contractor unit cost pricing in Ontario.

2.4 Rankin Construction

Finally, a contractor estimator from Rankin Construction was contacted and asked to provide their unit cost estimate for a concrete pavement road construction project in Eastern Ontario with a length of 17.3 kilometres.

3 ANALYSIS OF FINDINGS

Due to the varying estimates for concrete pricing, the following sections aim to document the different concrete unit prices quoted and which price Associated Engineering is recommending be used in the life cycle cost analysis and the Final Report.
The previous sources of information gained through the consultation conducted by AE in addition to information already gathered by AE was used to assess the range of values provided for estimating unit cost pricing for concrete paving. Table 1 summarizes the various sources of information.

<table>
<thead>
<tr>
<th>Source</th>
<th>Concrete Unit Price</th>
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</thead>
<tbody>
<tr>
<td>Ministry of Transportation – HiCO Database</td>
<td>~$800/m³</td>
</tr>
<tr>
<td>Engineering Estimate used in Interim Report</td>
<td>$400/m³</td>
</tr>
<tr>
<td>CAC</td>
<td>$230-285/m³</td>
</tr>
<tr>
<td>Rankin Construction</td>
<td>$375/m³</td>
</tr>
<tr>
<td>Englobe Corporation</td>
<td>$200/m³</td>
</tr>
<tr>
<td>CAC – Roller Compacted Concrete (See Discussion Below)</td>
<td>$230-$270/m³</td>
</tr>
</tbody>
</table>

The widely varying unit price for concrete suggests that many factors are evaluated when selecting a price for concrete paving in construction projects. These factors include:

- Mobilization/demobilization cost
- Traffic control – single lane closure
- Haul distance
- Plant production rate
- Trucking cost
- Handwork, if any
- Adjustment of manholes
- Concrete testing
- Installation cost

4 ROLLER COMPACTED CONCRETE

Roller compacted concrete (RCC) was mentioned as an alternative option for County Road 49 by the CAC.

RCC is placed using conventional or high-density asphalt paving equipment, then compacted with rollers. Roller compacted concrete mix is a drier mix so that it is stiff enough to be compacted by vibratory rollers. RCC is usually constructed without joints or dowels, and requires very little finishing or handwork. RCC is commonly used for industrial and commercial applications, due to the strength and performance of concrete.

Due to the high operating speeds on County Road 49, it was felt that RCC may lead to issues with vehicle traction at high speeds/in wet pavement conditions. In many highway applications, a thin layer of asphalt is often overlaid on top to increase vehicle traction.

5 DISCUSSION AND RECOMMENDATION

Assumptions regarding each factor described above can have a significant affect on the unit price that is used. Based on the widely varying concrete costs estimated by several sources, the question remains which is the best price to move forward with the preliminary analysis of the road rehabilitation options. The following are points for further consideration:

- While the MTO HiCo Database is generally a good indicator of unit cost pricing as it represents an aggregate of all past projects that involve that particular type of work, it was clearly much higher than the average unit costs
provided through other sources. Information on the specific conditions/issues the contractors considered when bidding on the work are unknown. This concrete price was therefore used for informational purposes only;

- The unit cost estimate provided by the CAC may be more aggressive than reality given their interest in being cost competitive to asphalt pricing.

- Contractors who bid on this contract will likely have widely varying prices for concrete as well, given that concrete construction work is considerably less common than asphalt construction work. Asphalt prices, on the other hand are expected to be somewhat consistent between contractor bids, based on asphalt being widely used for the majority of road works in the province of Ontario.

- A sensitivity analysis was done on the life cycle analysis, and it was determined that a unit cost of $300/m$^3$ for concrete paving was the “break even” point, where the Option 2 (replace with concrete) life cycle costing was comparable to Option 1 (replace with asphalt).

Given the uncertainty with the unit cost pricing of concrete, it is our opinion that Option 2 (replace with concrete) cannot be ruled out as a option going forward for the rehabilitation of County Road 49. It is therefore recommended that the unit cost for concrete be lowered to $300/m^3$. This unit cost is more reflective of the various estimates identified in our analysis.

Reviewed by: Jeff Suggett

Signature/Seal

Initials
Appendix G – Life Cycle Costing
## PAVEMENT OPTIONS COST BREAKDOWN SUMMARY

**Project No.:** 2017-5144  
**Owner:** Prince Edward County  
**File No.:** 01.A00  
**Project:** County Road 49 Road Condition Assessment  
**Date: December-18**  

<table>
<thead>
<tr>
<th>Option 1: Rubblize and HMA Pavement</th>
<th>Area</th>
<th>129,750 m²</th>
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<tbody>
<tr>
<td>Item</td>
<td>Units</td>
<td></td>
<td>Depth</td>
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<tr>
<td>Mobilization and Demobilization</td>
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<td></td>
</tr>
<tr>
<td>Traffic Accommodation</td>
<td>LS</td>
<td></td>
<td></td>
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<tr>
<td>Rubblize Existing Concrete Pavement</td>
<td>m³</td>
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<td>Leveling 50mm HL 3 HS Asphalt</td>
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<td>Binder Course HL-8 and Tack Coat (60mm)</td>
<td>m³</td>
<td>129,750</td>
<td>0.06</td>
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<tr>
<td>Asphatic Concrete HL1 (40mm)</td>
<td>m³</td>
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<tr>
<td>Granular B</td>
<td>m³</td>
<td>10380</td>
<td>1.00</td>
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<tr>
<td>Perforated Pipe 100 mm</td>
<td>m</td>
<td>35984</td>
<td>1.00</td>
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<tr>
<td>Bike Lane Addition</td>
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</tr>
<tr>
<td>Intersection Improvements</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guiderail Improvements</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage Improvements</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shouldering / Access Management Improvements</td>
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<tr>
<td>Contingency (20%)</td>
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<tr>
<td>Engineering Service Fees(10%)</td>
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<tr>
<td>Mobilization and Demobilization</td>
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<td>Traffic Accommodation</td>
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<td>Rubblize Existing Concrete Pavement</td>
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<td>Gruneral A</td>
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<td>Perforated Pipe 100 mm</td>
<td>m</td>
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<tr>
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<td>Item</td>
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<td>Remove Concrete Pavement</td>
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# Pavement Options Cost Breakdown Summary

**Project No.**: 2017-5144  
**Owner**: Prince Edward County  
**File No.**: 01.A00  
**Project**: County Road 49 Road Condition Assessment  
**Date**: December-18

**Total Pavement Area**: 129,750 m²

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| 5      | Repair Concrete and Overlay With Concrete |      |       | 129,750 m²  |       |               |        |                   | $1,731,205 |             |
|        | Mobilization and Demobilization   | LS   |       |             |       |               |        |                   | $500,000   |             |
|        | Traffic Accommodation             | LS   |       |             |       |               |        |                   |            |             |
|        | Repair Concrete                   | m³   | 129,750 | 0.25  | 12,975   | 10% | 14,273 | $250.00 | 3,566,125 |
|        | Repair joints                     | m    | 129,750 | 0.25  | 45,845   | 10% | 50,430 | $250.00 | 12,607,375 |
|        | Levelling 35 HL3                   | m³   | 129,750 | 0.04  | 5,190    | 30% | 6,747 | $314.40 | 2,121,257 |
|        | Concrete Overlay (220mm)          | m³   | 129,750 | 0.175 | 22,706   | 10% | 24,977 | $400.00 | 9,990,750 |
|        | Bike Lane Addition                | LS   |       |             |       |               |        |                   | $5,714,259 |             |
|        | Intersection Improvements         | LS   |       |             |       |               |        |                   | $71,015    |             |
|        | Guiderail Improvements            | LS   |       |             |       |               |        |                   | $300,000   |             |
|        | Drainage Improvements             | LS   |       |             |       |               |        |                   | $200,000   |             |
|        | Shouldering / Access Management Improvements | LS |       |       |       |               |        |                   | $51,322    |             |
|        | Contingency (20%)                 |      |       |             |       |               |        |                   | $6,924,821 |             |
|        | Engineering Service Fees(10%)     |      |       |             |       |               |        |                   | $3,462,410 |             |
|        | TOTAL                             |      |       |             |       |               |        |                   | $47,242,539 |

| 6      | Repair Concrete and Overlay HMA Pavement |      |       | 129,750 m²  |       |               |        |                   | $1,535,106 |             |
|        | Mobilization and Demobilization   | LS   |       |             |       |               |        |                   | $500,000   |             |
|        | Traffic Accommodation             | LS   |       |             |       |               |        |                   |            |             |
|        | Repair Concrete                   | m³   | 129,750 | 0.25  | 12,975   | 10% | 14,273 | $250.00 | 3,566,125 |
|        | Binder Course HL-8 and tack Coat (120mm) | m³ | 129,750 | 0.12 | 15,570 | 15% | 17,906 | $240.00 | 4,297,320 |
|        | Asphatic Concrete HL1 (45mm)      | m³   | 129,750 | 0.09  | 11,678   | 10% | 12,845 | $400.00 | 5,138,100 |
|        | Bike Lane Addition                | LS   |       |             |       |               |        |                   | $4,484,160 |             |
|        | Intersection Improvements         | LS   |       |             |       |               |        |                   | $55,728    |             |
|        | Guiderail Improvements            | LS   |       |             |       |               |        |                   | $300,000   |             |
|        | Drainage Improvements             | LS   |       |             |       |               |        |                   | $200,000   |             |
|        | Shouldering / Access Management Improvements | LS |       |       |       |               |        |                   | $51,322    |             |
|        | Contingency (20%)                 |      |       |             |       |               |        |                   | $6,140,426 |             |
|        | Engineering Service Fees(10%)     |      |       |             |       |               |        |                   | $3,070,313 |             |
|        | TOTAL                             |      |       |             |       |               |        |                   | $41,947,875 |

Note:  
1. Costs are based on the data provided in the attached Excel file: \s-nia-fs-01\projects\20175144\00_Road_CA\Advisory\01.00_Advice\Life Cycle Analysis\[dnt_CtyRd49 - Pavement Life Cycle Cost Analysis_FINAL_20181212.xlsx]Capital Cos.
# OPTION 1: OPERATIONS AND MAINTENANCE COST ESTIMATE

**Project: County Road 49 Road Condition Assessment**

**File No.: 01.A00**

**Date: 12/12/18**

## HMAC Annual Maintenance Cost

### Including local pavement repairs

<table>
<thead>
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<th>Year</th>
<th>$ per sq.m</th>
<th>Adjustments</th>
<th>Notes</th>
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*Note: escalation rate during 5 yrs of life span: 0%*

## Asphalt Concrete Maintenance Cost - 50mm Mill and Overlay every 10 yrs patchwork

**$5.20 per sq.m including contingency and engineering fees**

### Example for Maintenance Cost Calculation

<table>
<thead>
<tr>
<th>Year</th>
<th>Unit Rate</th>
<th>Area</th>
<th>Inflation Factor</th>
</tr>
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<tr>
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<td>$674,700 factored for inflation</td>
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<td>5</td>
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<td>129,750</td>
<td>$674,700</td>
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**Total: $674,700**

**Repair & Maintenance Cost for Asphalt Concrete Only**

- **Milling Existing Asphalt Concrete**: $20.00 per sq.m, 10% Assumed 10% of total area
- **Asphalt Concrete Cost**: $166.67 per tonne, 10% Assumed 10% of total area
- **Unit Weight**: $2.40 tonnes/cu.m
- **Repair Area of road**: 12,975 sq.m
- **Thickness**: 0.05 meter
- **Volume**: 649 cu.m
- **Weight**: 1,557 tonnes
- **Total Costs**: $519,000 net construction costs
- **Total Capital Costs**: $674,700 contingency and engineering fee (30% included)

### Option 1: Every 15 yrs Capital Costs

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## OPTION 2: OPERATIONS AND MAINTENANCE COST ESTIMATE

### Project: County Road 49 Road Condition Assessment

**File No.: 01.A00**

**Unit: Thousand $**

**Date:** 12/12/18

### PCC Annual Maintenance Cost

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### PCC Panel Maintenance Cost - Repairs every 10 yrs

- **$32.54 per sq.m** including contingency and engineering fees

### Example for Maintenance Cost Calculation

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### Construction Joint Repairs

- **$10.50 per lin.m** 30% Assumed 30% of total lengths

### Panel Crack Repairs

- **$250.00 per sq.m** 10% Assumed 10% of total panels

### Volume

- Weight: 4,541 tonnes
- **4,541 cu.m**

### Repair Area of Roads

- **12,975 sq.m**

### Weight

- **0.35 meter**

### Total Costs

- $3,247,919 Net Construction Costs
- **$4,222,295** contingency and engineering fee (30% included)

### Total Capital Costs

- $7,785,000 PCC Pavement
- $2,076,000 Contingency
- **$1,038,000** Engineering Service Fees
- **$13,494,000** Total

### Option 2: Every 30 yrs Capital Costs

- **$2,595,000** Milling Costs
- **$2,076,000** Contingency
- **$1,038,000** Engineering Service Fees
- **$13,494,000** Total

---

*Note: escalation rate during 5 yrs of life span: 0%*
### Option 3: Operations and Maintenance Cost Estimate

**Project: County Road 49 Road Condition Assessment**

**File No.: 01.A00**

**Date: 12/12/18**

#### HMAC Road Maintenance Cost
Including local pavement repairs

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**Total** 31,996.3 1,349.4 5,255.2 38,600.8

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* Note: escalation rate during 5 yrs of life span: 0%

#### Asphalt Concrete Maintenance Cost - 50mm Mill and Overlay every 10 yrs

**$5.20 per sq.m including contingency and engineering fees**

**Example for Maintenance Cost Calculation**

<table>
<thead>
<tr>
<th>Year</th>
<th>Unit Rate</th>
<th>Area</th>
<th>Inflation Factor</th>
<th>$674,700 factored for inflation</th>
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</thead>
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**Total $519,000 net construction costs**

**Total Capital Costs $674,700 contingency and engineering fee (30% included)**

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<td>Engineering Service Fees</td>
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<td><strong>Total</strong></td>
<td><strong>$10,276,200</strong></td>
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### Option 4: Operations and Maintenance Cost Estimate

**Project:** County Road 49 Road Condition Assessment  
**File No.:** 01.A00  
**Date:** 12/12/18

**PCC Annual Maintenance Cost**  
Including local repairs, construction joint repairs, crack sealants

<table>
<thead>
<tr>
<th>Year</th>
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</table>

**PCC Annual Maintenance Cost - Repairs every 10 yrs**  
$32.54 per sq.m including contingency and engineering fees

**Example for Maintenance Cost Calculation**

<table>
<thead>
<tr>
<th>Year</th>
<th>Unit Rate</th>
<th>Area</th>
<th>Inflation Factor</th>
</tr>
</thead>
<tbody>
<tr>
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<td>(1+0)^0</td>
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<tr>
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<tr>
<td>10</td>
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<td>129,750</td>
<td>(1+0)^6</td>
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</table>

**$4,222,295** Repair & Maintenance Cost for PCC Only

- Construction Joint Repairs: $10.50 per lin.m  
  30% Assumed 30% of total lengths
- Panel Crack Repairs: $250.00 per sq.m  
  10% Assumed 10% of total panels

**Option 4: Every 30 yrs Capital Costs**

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>Milling Costs</td>
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<td>PCC Pavement</td>
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<tr>
<td>Contingency</td>
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<tr>
<td>Engineering Service Fees</td>
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</tr>
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<td><strong>$11,975,925</strong></td>
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</table>
### OPTION 5: OPERATIONS AND MAINTENANCE COST ESTIMATE

**Project:** County Road 49 Road Condition Assessment  
**File No.:** 01.A00  
**Date:** 12/12/18

#### Concrete Annual Maintenance Cost

<table>
<thead>
<tr>
<th>Year</th>
<th>$ per sq.m</th>
<th>Adjustment</th>
<th>Notes</th>
</tr>
</thead>
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<tr>
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<tr>
<td>4</td>
<td>$2.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: escalation rate during 5 yrs of life span: 0%*

#### PCC Panel Maintenance Cost - Repairs every 5 yrs

$16.27 per sq.m including contingency and engineering fees

#### Example for Maintenance Cost Calculation

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<th>Year</th>
<th>$ per sq.m</th>
<th>Area</th>
<th>Inflation Factor</th>
</tr>
</thead>
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<td>15</td>
<td>$16.27</td>
<td>129,750</td>
<td>$(1+0)^6</td>
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</tbody>
</table>

#### Repair & Maintenance Cost for Concrete Overlay

- **Construction Joint Repairs:** $10.50 per lin.m  
  - 15% Assumed 15% of total lengths
- **Panel Crack Repairs:** $250.00 per sq.m  
  - 5% Assumed 5% of total panels
- **Unit Weight:** $2.42 tonnes/cu.m
- **Repair Area of roads:** 6,488 sq.m
- **Thickness:** 0.35 meter
- **Volume:** 2,271 cu.m
- **Weight:** tonnes

**Total Costs:** $1,623,960

**Net Construction Costs:** $2,111,147 (contingency and engineering fee (30% included))

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<th>Option 5: Every 30 yrs Capital Costs</th>
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<td>Milling Costs</td>
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<td>PCC Pavement</td>
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</tr>
<tr>
<td>Engineering Service Fees</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Concrete Repairs</th>
<th><strong>129,750</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>10% of concrete needs removal/replace</td>
<td>0.1</td>
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<tr>
<td>80% of longitudinal joints for repair</td>
<td>0.8</td>
</tr>
<tr>
<td>50% transverse joints for repair</td>
<td>0.5</td>
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</table>

**Total length of joint repair:** 45845
### Option 6: Operations and Maintenance Cost Estimate

**Project No.:** 2017-5144  
**File No.:** 01.A00  
**Date:** 12/12/18

**Project:** County Road 49 Road Condition Assessment  
**Unit:** Thousand $

#### HMAC Road Maintenance Cost  
Including local pavement repairs

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**Total**  
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4,048.2  
7,006.8  
63,279

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* Note: escalation rate during 5 yrs of life span: 0%

### Asphalt Concrete Maintenance Cost - 50mm Mill and Overlay every 5 yrs  
$7.80 per sq.m including contingency and engineering fees

#### Example for Maintenance Cost Calculation

- **Unit Rate:** $7.80  
- **Area:** 129,750  
- **Inflation Factor:** $(1+0)^{0/5}$  
- **Total:** $1,012,050 factored for inflation

**Option 6:** Every 15 yrs Capital Costs
- **Milling Costs:** $2,595,000  
- **Asphalt Concrete Pavement:** $5,190,000  
- **Contingency:** $1,557,000  
- **Engineering Service Fees:** $934,200  
- **Total:** $10,276,200

**Concrete Repairs**  
10% of concrete needs removal/replacement  
80% of longitudinal joints for repair  
50% transverse joints for repair  
Total length of joint repair

---

8 of 15
## Comparision of Alternative NPVs ($1,000) to Discount Rate for 30 Year Life Cycle

**Client:** Prince Edward County  
**Project:** County Road 49 Road Assessment  
**Unit:** $ 1,000  
**Date:** December 12, 2018

### Table: Sensitivity Analysis to Combined Discount Rate For 30 Year Life Cycle

<table>
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<tr>
<th>Alternatives</th>
<th>Combined Discount Rate (%)</th>
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<th>4%</th>
<th>6%</th>
<th>8%</th>
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</thead>
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<td>Total NPV</td>
<td>Rank</td>
<td>$ above Lowest</td>
<td>Total NPV</td>
<td>Rank</td>
<td>$ above Lowest</td>
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<td>29,055</td>
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<td>27,075</td>
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### Diagram: Sensitivity Analysis to Combined Discount Rate For 30 Year Life Cycle

**County Road 49 - Prince Edward County**

- Option 1: Rubblize and Replace HMA Pavement
- Option 2: Rubblize and Replace with PCC Pavement
- Option 3: Remove and Replace with HMA Pavement
- Option 4: Remove and Replace with PCC Pavement
- Option 5: Repair and Overlay PCC Pavement
- Option 6: Repair and Overlay HMA Pavement
Appendix H - Comments from MTO Transportation
Hello Peter and Robert.

As requested a high-level review of the AE and EnGlobe reports for County Road 49 has been completed by our office.

We would offer the following comments on the technical aspects of the reports:

- A sound business case has been made for rubblization.
- Regarding the asphalt cement, Ministry guidelines applied to this project would result in a PGAC grade of 58-28. 64-28 would not be considered to be warranted.
- The rehabilitation options show the addition of 100 mm of new Granular ‘A’ base under new PCC pavement but not under new HMA pavement. It would seem that this layer would afford an opportunity for fine grading and crossfall correction much more readily than trying to reshape the rubblized material for either option. It also could be an opportunity to provide improved base drainage by specifying Granular ‘O’ instead of Granular ‘A’. (Note: The Associated Engineering report shows this layer as 19 mm in depth for Option 2 but reference back to the Englobe report characterizes this layer as 100 mm of 19 mm stone.)
- The proposed method of providing improved subdrainage (i.e. trenched subdrains) will be expensive and time consuming. It may be worthwhile to take a detailed look at whether, or where, additional drainage appears to be warranted as it may be that simply re-instating the original ditches will be satisfactory for a large portion of the project. Also, achieving positive outlet to subdrains may be challenging in areas since the historical contract documents show intermittent rock excavation for construction of the original ditches.
- Additional analysis may be warranted with regards to resonant vs. multi-head hammer rubblizing equipment (i.e. costs vs. capabilities vs. production rates). OPSS hard-specifies the use of resonant equipment based on better fracturing results and less damage to subgrade surface however many jurisdictions allow hammer-based rubblization recognizing benefits of the relatively high production rate and resultant lower cost and reduced lane closure periods.
- In the Typical Drawings for Contact 68-16, 6 inch spacer plates are shown running below the dowelled joints at the base of the concrete. It is not clear whether this presents a challenge for rubblizing.
- Historical records and cores show roughly 230mm of PCC pavement however GPR shows 186 to 187 on average. Additional correlation work between the GPR data and available cores may be warranted.
• Section 5.1, recommendation to ditch to 600 mm below subgrade is not very clear. Perhaps it would be clearer to specify a depth or use the subgrade depth assumed for the pavement design options.

• The hot mix paving recommendation is to place the new surface at 2% crossfall and use HL3 levelling course to make corrections. It should be noted the original design for the concrete is 1.5% crossfall, which may support the suggestion to consider a new layer of granular base for both of the rubblizing options.

• The cost analysis looking at sensitivity to discount rate assumptions was particularly well done.

If further discussion on any of these comments is in order, please contact Bruce, Mike or myself at your convenience.

Les Shepherd P.Eng.
Head Geotechnical Eastern Region
MTO Provincial Highways Management
1355 John Counter Blvd, Kingston ON K7L 5A3
(o) (613) 545-4656
(c) (613) 449-8844