Effect of Utility Cuts on Serviceability of Pavement Assets – A Case Study from The City of Calgary

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ABSTRACT

The City of Calgary has a road network of nearly 16,000 lane-kilometres with an asset value of about $10.0B. With such an extensive roadway network, it can be very expensive and disruptive to carry out maintenance activities on sections affected by utility cuts. Pavement engineers generally agree that utility cuts negatively impact the integrity of pavement structure and reduce the serviceability of pavements. Therefore, a forensic investigation was conducted to determine the level of impact on the serviceability of pavements in Calgary due to the utility cuts. The impact was evaluated separately for arterial, collector, and local roads. Additionally, for each road class pavements in different age groups were evaluated. A total of 72 sections (24 for each road class) from different geographic locations in the city were selected to provide statistically significant data. Each of the 72 sections consisted of a sample unit with a utility cut and an adjacent sample unit without a utility cut.

In order to quantify the impact of the utility cuts on the pavement performance, a comprehensive field investigation plan was developed. Field investigation included the following testing being carried out for both sample units in each section:

- Visual distress evaluation;
- Falling Weight Deflectometer testing;
- Ground Penetrating Radar survey; and
- Roughness survey using SurPRO.

The results from the sample units with cuts were analyzed and compared with the results from sample units without cuts, to determine the loss in pavement service life due to the presence of a cut. Statistical analyses including ANOVA were carried out to confirm the research hypothesis. A fee structure was also developed for each of the three road classes and for the different age groups.

This paper discusses and summarizes all the above research activities. Results of the entire study are included and the conclusions presented at the end.

1. INTRODUCTION

Pavements, when constructed new, act as one uniform structure consisting of similar material through the length of the project. Such pavements move up or down evenly in the event of freeze and thaw. Introducing cuts and backfilling with different or even the same material, but compacted at different times, with different levels of effort and having different moisture content, makes that section of pavement react differently to the applied traffic and environmental loading. This divides the road into many different segments with a potential for uneven heaving or depressions. This can result in a rough surface, reduced serviceability, requirement for additional maintenance activities, and ultimately early major rehabilitation or reconstruction.

The City of Calgary (the City) owns and maintains a pavement network in access of 16,000 lane-kilometres with the asset value of about $10.0B. This makes it very expensive and disruptive to carry out maintenance activities on sections affected by utility cuts. Pavement engineers generally agree that utility cuts negatively impact the long term integrity of the pavement structure and reduce the serviceability of pavements.

The City retained Golder Associates Ltd. (Golder) to carry out a forensic investigation to determine the level of impact on the serviceability of pavements in the City due to the presence utility cuts. Developing a fee structure that may be implemented and charged for each utility cut to compensate the City for the reduction in the pavement service life was included in the scope of the work.

The impact was evaluated separately for arterial, collector, and local roads. Additionally, for each road class pavements in different age groups were evaluated. A total of 72 sections (24 for each road class) from different geographic locations in the city were selected to provide representative data set. Each of the 72 sections consisted of a sample unit with a utility cut and an adjacent sample unit without a utility cut.

2. BACKGROUND INFORMATION

The National Guide to Sustainable Municipal Infrastructure [1] states, "An inherent by-product of utility cuts is the reduced service life of pavements. No matter how well a utility cut is repaired, the nature of the excavation process and the disturbance of the sub-base have a significant effect on lessening the overall life of the pavement infrastructure. In general, road infrastructure is in poorer condition than the underground utilities and is usually the more difficult area for raising funds due to the lack of a dedicated funding source."

A study carried out in 1987 [2] reported a reduction in surfacing functional life of about 8 years due to utility cuts. The City of San Francisco commissioned a study in 1992 to study the effects of utility cuts on pavement service life [3]. This study concluded that streets with utility cuts experienced decreases as high as 50% in service life and reduced condition scores. The City of Seattle [4] concluded that pavements with utility cuts required 50 mm additional strengthening compared to the pavements without utility cuts. A study carried out recently by the City of Toronto [5] determined the pavement degradation fee based on the reduction in service life of the pavements due to utility cuts. Other cities across Canada and the United States including Vancouver, Ottawa, Surrey, St. Johns, District of Saanich, London, Seattle and San Francisco have conducted studies or implemented fees of their own. In some cases, utility companies have legally challenged the local municipalities' authority to charge a pavement degradation fee. One of the decisions that the courts have rendered says, "Municipalities have to demonstrate to the courts, using their own data, that the damage is attributable to the utility cuts."

The studied carried out for the City of Toronto [5] included only a visual condition assessment to determine the Pavement Quality Index (PQI). Ground Penetrating Radar (GPR) was carried out to confirm the existence of the utilities under the pavement surface.

The City needed a detailed investigation that would determine the impact on:

- The structural integrity of the pavement;
- The ride comfort to the travelling public;
- The additional surface distresses that may have been caused due to the intrusion of the cut; and
- The overall Pavement Quality Index (PQI).

The above investigation would also satisfy the decision rendered by courts to have the City's own data that can demonstrate the quantity of the reduction in service life.

3. PAVEMENT PERFORMANCE INDICATORS

The three indicators that the City used as sub-indices of an overall PQI for its pavement performance were:

- Pavement visual surface condition;
- Pavement ride quality or smoothness; and
- Pavement structural capacity.

3.1 Pavement Visual Surface Condition

The extent and severity of the following distresses were collected during the visual condition assessment:

- Raveling;
- Alligator cracking;
- Block cracking;
- Longitudinal cracking;
- Transverse cracking;
- Pavement edge cracking; and
- Rutting.

The density and severity of the distresses describe the frequency of the occurrence of a particular distress and the condition respectively. The distress data that was collected in the field was used to calculate the Visual Condition Index (VCI). The VCI can range between 0 and 10, with 10 being a pavement in excellent condition which has no visible distresses on the surface and 0 being a pavement in failed surface condition. For each distress type, the severity and density combination that is observed in the field is used to calculate a Deduct Value (DV).

3.2 Pavement Ride Quality and Smoothness

The smoothness of a pavement has an impact on pavement ride quality for the travelling public as well as the service life of the pavement. In terms of the travelling public, the smoothness of the pavement will affect their comfort, safety and their vehicle performance. The pavement service life is affected by the increased magnitude of dynamic loading that is applied to a rougher pavement which in turn reduces its fatigue life.

Due to the large number of different indices that can be used, equations have been developed by the industry to convert one index to another. The City uses inertial profilograph to collect International Roughness Index (IRI) data, which is then converted to Ride Comfort Index (RCI) using the following equation.

$$RCI = 22.5 - 3.3 \times \ln(63.36 \times IRI)$$

The RCI of a pavement can range between 0 and 10, with 0 indicating a very rough pavement and 10 indicating a very smooth pavement.

3.3 Pavement Structural Capacity

The structural capacity or load bearing capacity of a pavement is a critical performance indicator as it indicates the magnitude of the traffic loading that the pavement is able to accommodate. The City uses Falling Weight Deflectometer (FWD) in conjunction with Ground Penetrating Radar (GPR) and corehole/borehole investigation to determine the structural capacity of its pavements.

The raw data is analyzed to obtain different parameters for the pavement structure including normalized deflections, pavement surface modulus and layer moduli. The deflections that are obtained from the non-destructive testing equipment are used to calculate indices, such as the Structural Adequacy Index (SAI).

The following equation is used in our pavement management system to determine SAI for flexible pavements.

$$SAI = 10^{\left[1.22251 + 0.0032 \times (a+1.65)^{1.39} - 0.157 \times b \times (a+1.1)^{1.44} - 12.538 \times b\right]}$$

Where:
a = the Equivalent Single Axle Loads (ESALs) that the pavement has had to accommodate to date divided by 100,000; and
b = the normalized deflection (mm) for the pavement as measured using the Benkleman Beam.

Although the Benkleman Beam device is no longer typically used to evaluate the structural capacity of a pavement, at the time these equations were developed the device was routinely used.

Since the Benkleman Beam device is no longer commonly used in the industry an equation has been developed to convert deflections measured from the FWD to those measured by the Benkleman Beam. This method is the current state-of-the-practice in the industry. The Asphalt Institute Manual Series Number 17 (MS-17) [6] recommends multiplying an FWD measured deflection by a factor of 1.61 to obtain an equivalent Benkleman Beam static deflection.

3.4 Composite Performance Indices

The following equation is used to calculate the composite performance index, Pavement Quality Index (PQI), for the pavements having FWD data and was used in the analysis.

$$PQI = 0.5 \times VCI + 0.3 \times RCI + 0.2 \times SAI$$

PQI, as with the individual indices that comprise it, ranges from 0 to 10. A new pavement, if constructed in accordance with specifications, being smoother and having sufficient structural capacity would have a PQI of 10. As the pavement continues to age and deteriorate the PQI continually decreases until a critical PQI value is reached at which point the pavement would typically be rehabilitated.

4. FIELD INVESTIGATION

A field investigation program was developed which included the testing that would be undertaken for each pavement section and the recommendations for the number of pavement sections that would be evaluated. The impact of the utility cuts on the pavement was considered independently for arterial, collector and local roads. Further, different age groups for each of the road classes was also considered independently.

Based on a review of previous investigations and the size of the network included in this investigation it was decided that a total of 72 sections would be surveyed. The 72 sections were to consist of 24 arterials, collectors and locals each. Each of the road sections consisted of a 25 m sample unit that included a utility cut and another 25 m sample unit, adjacent to the first, without a utility cut. The testing carried out on each section included visual distress inspection, FWD testing, Ground Penetrating Radar (GPR) and a roughness survey.

The field data collection phase of this project was completed between July 19, 2013 and July 24, 2013. The location of each road section is shown in Figure 1. The sections were selected based on the locations of the utility cut within the lane and the size of the utility cut within the 25 m sample unit.

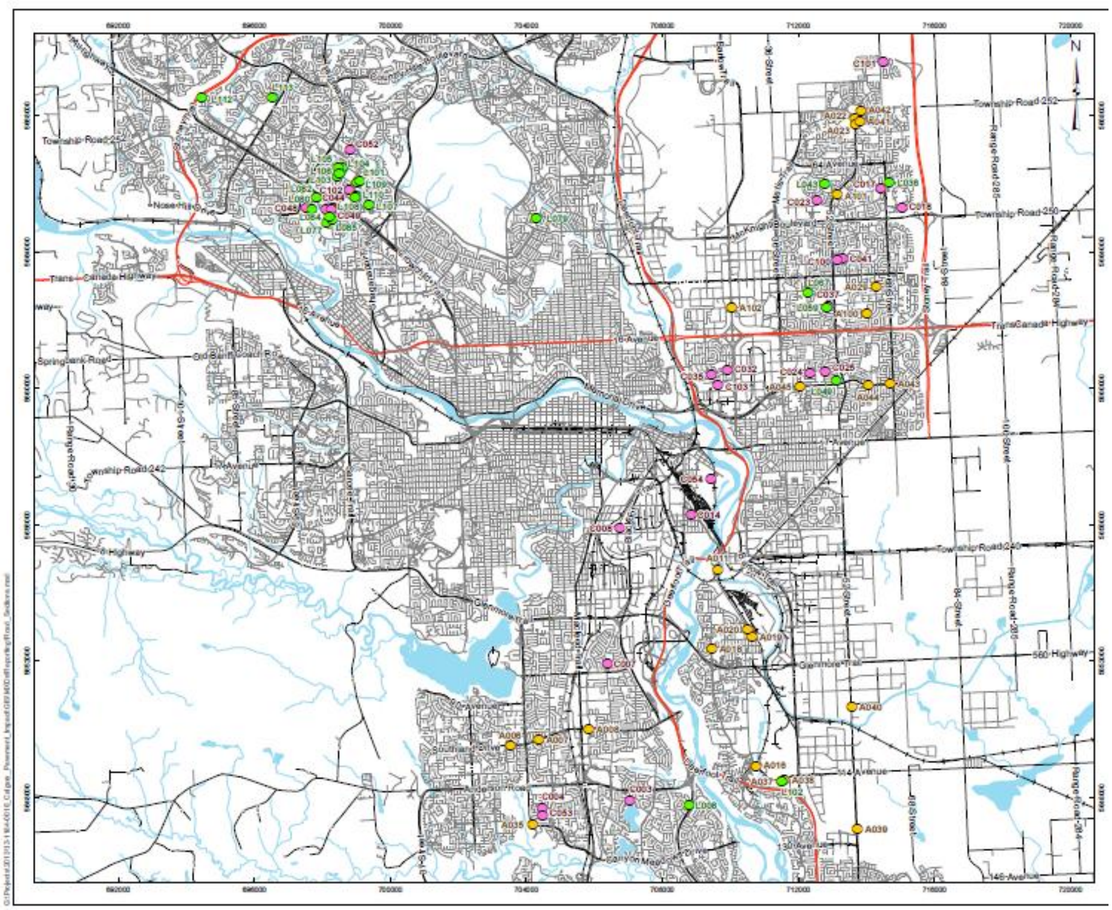

Figure 1: Location Map of Sample Units Throughout The City

4.1 Visual Distress Inspection

The types, severities and densities of the distresses were surveyed and documented. For each pavement section, the distresses were separately surveyed for the sample unit containing the cut and the sample unit without the cut. In addition to noting the present distresses, photographs were also taken of each section which showed the general condition of the section. The distress inspection findings for each section were input into a separate table. A sample of the visual condition inspection data is presented in Table 1.

Table 1: Sample Visual Condition Data for a Section

Distress	Density		
	Low Severity	Moderate Severity	High Severity
Raveling	80%	-	-
Bleeding	-	-	-
Block Cracking	-	-	-
Alligator Cracking	-	-	-
Edge Cracking	-	45%	-
Longitudinal Cracking	-	-	-
Transverse Cracking	5%	-	-
Rutting	-	-	-
Rippling and Shoving	-	-	-
Distortion	-	-	-
Potholes	-	-	-
Crown	-	-	-
Patching	-	-	-

4.2 Roughness Survey

The roughness survey for all the sections was carried out using a walking profiler, SurPRO, manufactured by International Cybernetics. The SurPRO meets the requirements for a Class I profiler as per ASTM E950 based on its sampling frequency, measurement resolution, precision and bias. For each section two 25 m lines were established, along which the true elevation profile of the road surface was measured using the SurPRO. Each of the 25 m lines were demarcated using a chalk line and a closed loop profile was measured. Figure 2 shows an example of one of the sections with a marked 25 m line being measured using the SurPRO.

The raw data from the SurPRO was analyzed to determine the International Roughness Index (IRI) for the 25 m line. An average IRI was calculated for the line.

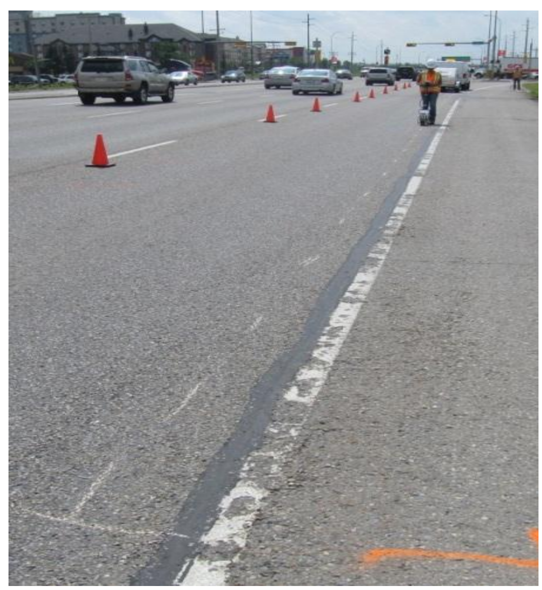

Figure 2: Example of 25 m Line Being Measured Using the SurPRO

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4.3 Falling Weight Deflectometer (FWD) Testing

The FWD load/deflection testing was carried out at select locations for each of the sections being surveyed. The testing for each section was carried out for both the sample unit containing the utility cut as well as the sample unit without the utility cut. A total of 18 points were tested for each section with an equal number in each 25 m sample unit. The locations of each of the test points were selected immediately prior to the testing with the spacing between the test points being approximately equal while ensuring that both the centre of the patch and the joints were tested. A typical layout of FWD test locations is given in Figure 3.

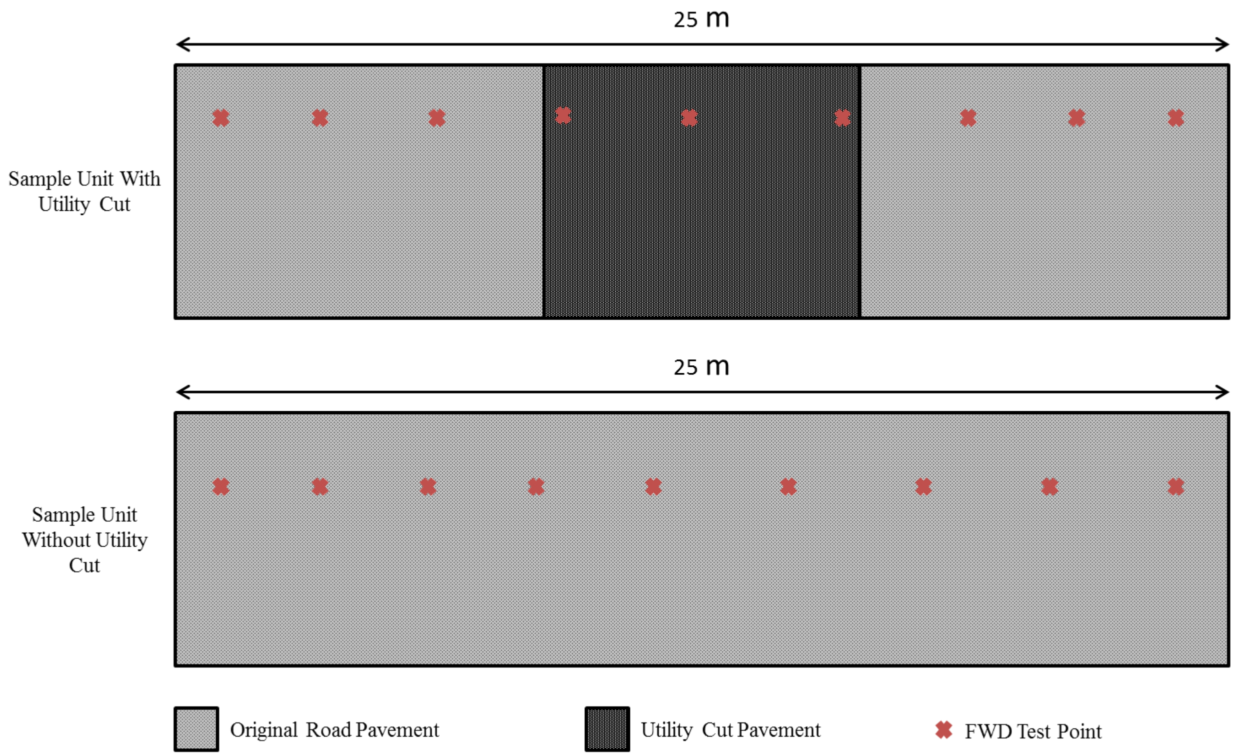

Figure 3: Layout of the FWD Test Locations on Sample Units With and Without Utility Cuts

4.4 Ground Penetrating Radar (GPR) Survey

The GPR was used to scan the two adjacent 25 m sample units to identify the asphalt thickness for the utility cut and the surrounding pavement. The purpose of the GPR testing was to identify the thickness of asphalt at the cut location as well as the section adjacent to it. The raw data obtained from the GPR testing was analyzed to identify which reflection signal was due to the asphalt interface with the underlying granular material.

5. <u>DATA ANALYSIS</u>

5.1 *Surface Distress* Data

The distress data that was recorded in the field was immediately reviewed on site and quality control checks were carried out on the data to ensure its accuracy. The quality control checks for the data included a comparison between the photographs for each section and the type, severities and densities of the distresses that were noted. Upon completion of the quality control checks, the data was input into a table for further analysis and calculation of VCI. Table 1 above shows an example of the distress table that was completed for each of the two sample units, with utility cut and without utility cut, for each pavement section included in the study. The first column in Table 1 lists the distress types that may be observed in an asphalt pavement. The body of the table shows the percentage of distresses area, density, for each distress type and severity combination.

These tables were developed and used for each of the sections to calculate the VCI.
Table 2 shows the VCI summary statistics for the 24 road sections in each of the three road classifications. The summary statistics have been separately computed for the sample unit with the utility cut and without the utility cut. It is important to note that when computing the VCI for each 25 m sample unit the impact of the utility cut itself i.e. the patch, was not included in the VCI calculation as this is the procedure used in the City's Pavement Management System. Typically, for other distress indices, such as Pavement Condition Index, the presence of a patch may significantly reduce the distress index for that section due to the high deduct value for a patch.

Table 2: VCI Summary Statistics for Arterial, Collector and Local Road Sections

Road Classification	VCI for Sample Unit With Utility Cut				VCI for Sample Unit Without Utility Cut			
	Minimum	Maximum	Average	Standard Deviation	Minimum	Maximum	Average	Standard Deviation
Arterial	0.42	10.00	7.33	2.92	0.26	10.00	7.35	2.91
Collector	1.57	10.00	6.32	2.59	1.61	10.00	6.98	2.65
Local	4.14	10.00	7.69	1.91	4.48	10.00	8.27	1.46

Some of the key observations that can be made from the data shown in Table 2 are listed below:

- The maximum VCI was observed to be 10 for sample units with and without a utility cut; however, it is important to note that this is only the case due to the fact that the presence of the utility cut was excluded for the VCI calculation.
- The minimum VCI was similar for the sample units with a utility cut and those without a utility cut, regardless of the road classification. However, the minimum VCI was higher for the locals as compared to the arterials, which would be expected due to the higher traffic volumes that is experienced on the arterials.
- No significant reduction in the average VCI was observed between the sample units with and without a utility cut regardless of the road classification. As noted previously, a reduction would likely only hold true if the utility cut patch itself is not included in the VCI calculation.
- The standard deviation for the VCI was similar for the sample units with the utility cut as compared to those without the utility cut. This trend was similar for road sections in all three classifications.

In addition to the summary statistics shown in Table 2, the percent change in VCI was calculated for each of the sections for the sample unit with the utility cut as compared to without the utility cut. This percent change in VCI for each section can be considered to be the proportional impact of the utility cut or patch on the increased development of visual distresses. Figure 4 shows a plot of the percent change VCI versus the age of the road for all the sections in each of the road classifications.

Figure 4 shows that there is a large spread in the percent change data with some of the values being negative, i.e. the VCI for the sample unit with the cut was greater than the one without the cut. This large variability in the percent change can generally be attributed to some of the distresses, particularly patching, not being considered in the calculation of the index. Additionally, from the above plot it can be observed that there is no discernible relationship between the age of a particular road section and the percent change in VCI. Similarly, there also appears to be no discernible impact of the road classification on the percent change in VCI as the arterial, collectors and locals of the same age generally have similar percent change value regardless.

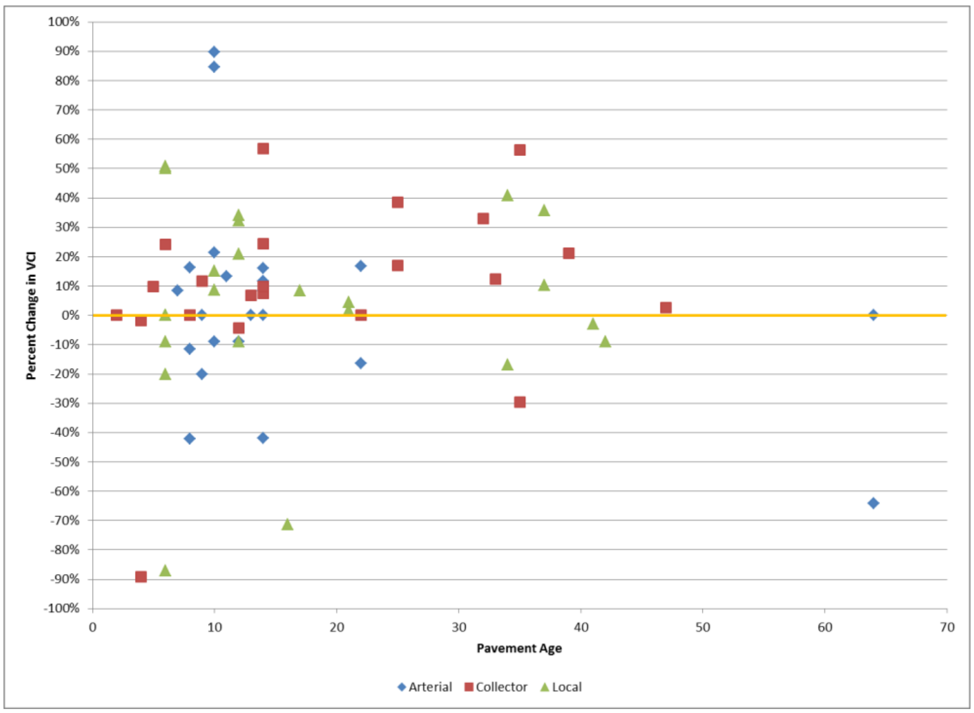

Figure 4: Percent Change in VCI for Surveyed Road Sections

5.2 Roughness Data

Upon completion of the field testing the roughness data was downloaded from the built-in SurPRO computer. For each sample unit the closed loop profiles were split into the forward and reverse run. The IRI was calculated from the true elevation profile for the forward and reverse runs as specified by ASTM E1926 [7]. The representative IRI for each sample unit was then calculated as the average of the forward and reverse IRI for that sample unit.

The RCI for each sample unit was calculated using the representative IRI and the equation described in Section 3.2. Table 3 shows a summary of the RCI for the different road classifications for both the sample units with the utility cut as well as those without a utility cut.

Table 3: RCI Summary Statistics for Arterial, Collector and Local Road Sections

Road Classification	RCI for Sample Unit With a Utility Cut				RCI for Sample Unit Without a Utility Cut			
	Minimum	Maximum	Average	Standard Deviation	Minimum	Maximum	Average	Standard Deviation
Arterial	1.64	5.14	3.11	1.11	2.50	8.43	6.42	1.64
Collector	0.00	4.70	2.58	1.18	1.69	8.26	5.61	1.44
Local	0.82	4.48	2.43	1.15	1.41	7.79	4.66	1.76

Following are some key observations that can be made from the summary statistics in Table 3.

- The maximum and average RCI for the sample units with a utility cut were significantly lower than the sample units without a utility cut, indicating that the presence of the utility cut has a quantifiable reduction in the ride quality or smoothness of a pavement.
- The standard deviation of the RCI for sample units with and without a utility cut was found to be comparable.

The percentage decrease in RCI for sample unit with a utility cut as compared to those without a utility cut was relatively consistent for all three road classifications.

For each section included in the study, the percentage difference between the RCI for the sample unit with a utility cut as compared to the sample units without a utility cut was calculated. Figure 5 shows the percentage difference in RCI for the different road classifications as a function of the age of the section. The majority of the sections in Figure 5 are above the yellow line (zero percent change) indicating that for most of the sections included in the study the RCI or the ride quality was negatively impacted by the introduction of the utility cut. The plot also shows that the percentage change in the RCI is not significantly impacted by the age of the road and that there is no significant difference in the percent change based on the road classification.

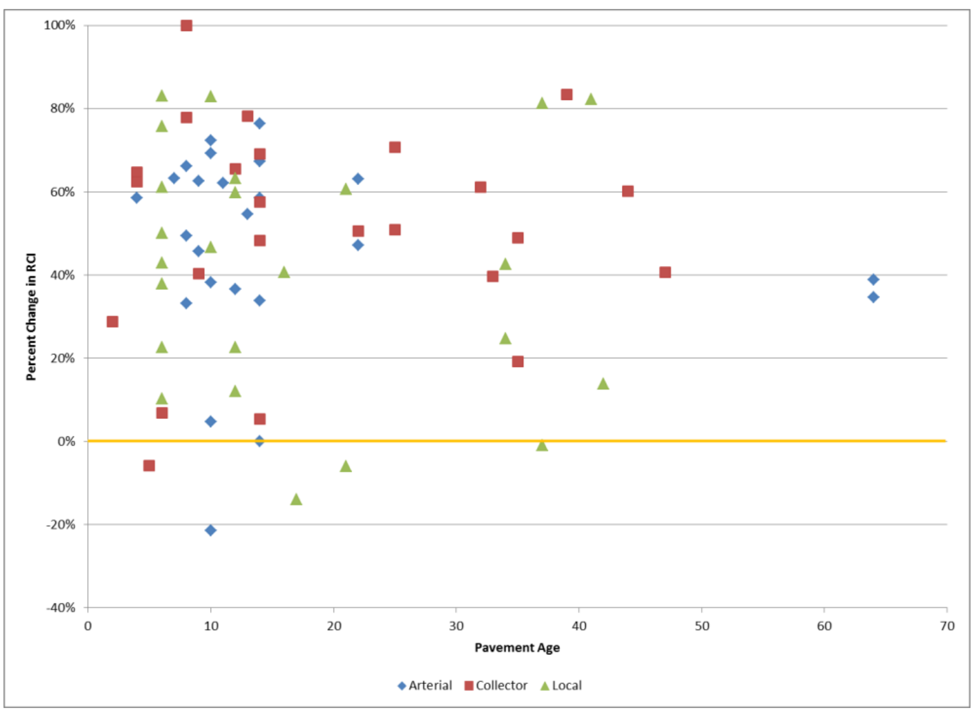

Figure 5: Percentage Change in RCI for Surveyed Road Sections

5.3 Deflection Data

The raw deflection data obtained from the FWD was reviewed immediately on-site to confirm the location of the test points in relation to the utility cut. The purpose of the initial review was to generally identify whether the test points located within the utility cut had higher deflections than the points located outside the utility cut. Following the initial review of the raw data, the deflections obtained from the central sensor were normalized to a standard temperature of 21°C and standard load of 40 kN. It is critical to convert the raw deflection data to a standard temperature and load to carry out comparisons.

In order to calculate the SAI for each sample unit of all the tested sections, the normalized deflection values were converted to an equivalent static deflection that may be obtained from a Benkleman Beam. The method used to convert the normalized dynamic deflection, as measured by the FWD, to a static deflection is detailed in the Asphalt Institute Manual Series No. 17 (MS-17) [6]. This method requires that the dynamic deflection value be multiplied by a factor of 1.61 to obtain a representative static deflection. Having measured deflection data, thickness of pavement layers, and traffic information, SAI was calculated for each sample unit (with and without a utility cut). Table 4 shows a summary of the SAI statistics for the different road classifications.

Table 4: SAI Summary Statistics for Arterial, Collector and Local Road Sections

Road Classification	SAI for Sample Unit With a Utility Cut				SAI for Sample Unit Without a Utility Cut			
	Minimum	Maximum	Average	Standard Deviation	Minimum	Maximum	Average	Standard Deviation
Arterial	0.00	10.00	3.67	3.00	0.03	10.00	6.27	3.39
Collector	0.06	9.52	3.63	2.43	0.94	10.00	5.22	2.70
Local	1.08	7.25	3.85	2.05	1.59	10.00	5.79	2.72

Listed below are key observations that can be made from the data shown in Table 4.

- The average SAI for the sample units with utility cuts was generally lower than the sample units without utility cuts for the sections in all road classifications; however, it was noted that the proportion reduction in the SAI due to the utility cut was not constant either for a particular road classification or road age group.
- In general, the maximum deflection for the sample units with the utility cut was lower than the sample units without the utility cut.
- From the section by section deflections it was observed that the mean deflection for the sample units with the utility cut as determined from the nine test locations was generally higher than the mean deflection for the sample units without the utility cut.

The SAI for each sample unit for each section was used to calculate the percent change in SAI due to the presence of a utility cut. Figure 6 shows a plot of the percent change in SAI as a function of the age of the section. The data was plotted separately for the different road classifications. From the plot it can be seen that there is no clear trend in the percent change in SAI as a function of the road age and there appears to be no significant impact on the percent change for the different road classification. However, the majority of the data points are above the yellow line (zero percent change in SAI) therefore clearly indicating that the SAI generally decreases due to the presence of a utility cut.

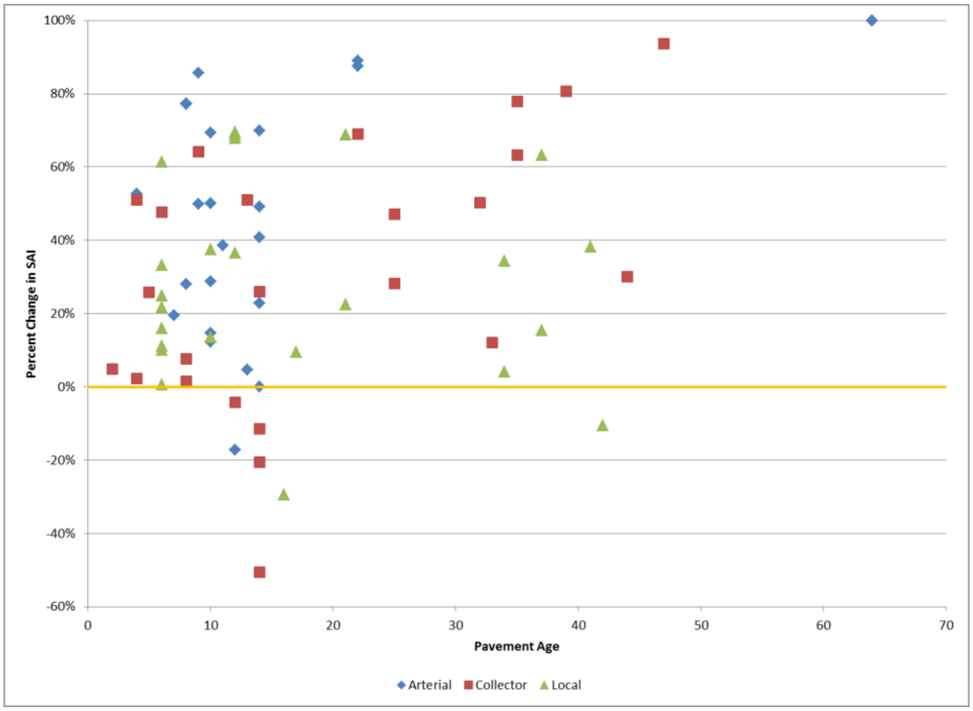

Figure 6: Percent Change in SAI for Surveyed Road Sections

5.4 Pavement Quality Index (PQI)

The Pavement Quality Index (PQI) for each sample unit was calculated using the VCI, SAI and RCI indices, as described in previous sections of this paper.

The summary statistics for PQI was calculated for the different road classifications, separately for the sample units with and without utility cuts. Table 5 presents these summary statistics.

Table 5: PQI Summary Statistics for Arterial, Collector and Local Road Sections

Road Classification	PQI for Sample Unit With a Utility Cut				PQI for Sample Unit Without a Utility Cut			
	Minimum	Maximum	Average	Standard Deviation	Minimum	Maximum	Average	Standard Deviation
Arterial	1.49	7.78	5.29	1.65	2.87	9.33	6.78	1.84
Collector	1.56	7.82	4.66	1.53	2.28	8.28	6.22	1.66
Local	2.73	7.51	5.34	1.26	3.36	9.13	6.69	1.28

Key observations from the data in Table 5 and from the section by section PQI analysis are listed below:

- The maximum and average PQI for the sample units with utility cuts is significantly lower than for those without a utility cut. This observation holds true regardless of the road classification in question. The reduction in the PQI due to the utility cut indicates that the introduction of a utility cut into a road section has a negative impact on the overall serviceability of the pavement.

- The standard deviation for the PQI was relatively unaffected by the road classification as well as by the presence of the utility cut.
- The percentage change in the PQI due to the presence of the utility cut was not significantly different for the different road classifications.

As with the other indices, the percent change in PQI due to the presence of the utility cut was computed for each section and the results are shown in Figure 7. The percent change for each section has been plotted as a function of the age of the section and different symbols have been used to identify the road classifications. The plot shows that the majority of the test points are above the yellow line (zero percent change), indicating that the utility cut generally results in a reduction in the PQI and serviceability of a road section. The magnitude of the reduction in PQI was found to be relatively unaffected by the age of the pavement section in question as well as its road classification.

Based on the above observations, the average percent change in PQI was calculated using sections of all ages and in all the road classifications was found to be approximately 22 percent. This implies that for any road section, regardless of the age of the road or its classification, the introduction of a utility cut into the road pavement will reduce the PQI of that road by approximately 22 percent at that point in time.

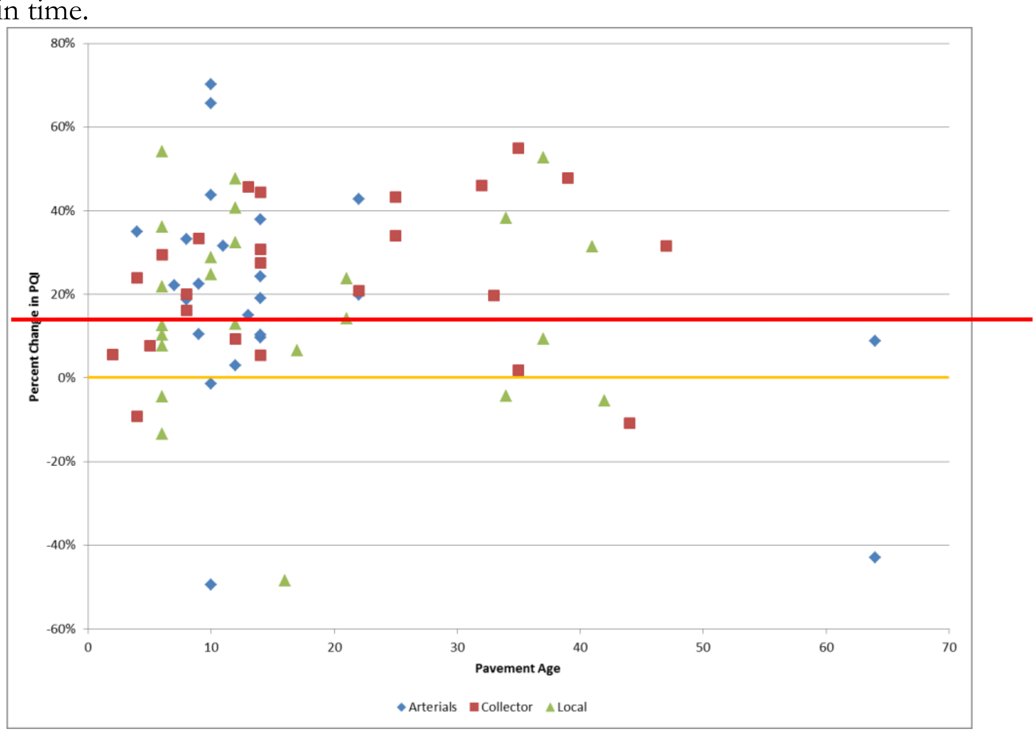

Figure 7: Percentage Change in PQI for Surveyed Road Sections

6. <u>STATISTICAL ANALYSIS</u>

A statistical analysis was carried out on the PQI data to confirm the following hypotheses:

- For the arterial road sections, the percent change in PQI is not different for the different age groups;

- For the collector road sections, the percent change in PQI is not different for the different age groups;
- For the local road sections, the percent change in PQI is not different for the different age groups;
- The percent change in PQI is not different for the different road classifications (i.e. arterial, collector and local); and
- There is a difference between the PQI for the sample units with a utility cut as compared to the sample units without a utility cut.

For the first four hypotheses listed above an Analysis of Variance was carried out. The critical F value were calculated for a 95 percent confidence level and the degrees of freedom associated with the between and within sources of variation. The analysis indicated that at a 95 percent confidence level the observed F value is smaller than the critical F values. Therefore there is very weak to no evidence that the age of the pavement has any impact of the percent change in PQI. Similarly, the analysis further indicated that at a 95 percent confidence level there is limited to no evidence that the classification of the road section (i.e. arterial, collector or local) has any impact of the percent change in PQI.

For the final analysis, the data for all the road classification and age groups was combined and a comparison between two means, using the t-test, was carried out between the sample units with a utility cut and the sample units without a utility cut. The comparison showed that at a 95 percent confidence level the mean PQI for the sample units with a utility cut is significantly less than the mean PQI for the sample units without a utility cut.

7. PAVEMENT DEGRADATION FEE STRUCTURE

Upon completion of the computation of the indices and the statistical analysis, the PQI results were used to calculate the appropriate Pavement Degradation Fee (PDF) structure that could be implemented based on the performance data collected for the 72 road sections.

From the PQI analysis it was noted that regardless of the age or road classification of a particular pavement, the introduction of a utility cut resulted in the reduction of the PQI of that section by approximately 22 percent. The performance data gathered in the field was used to approximate the performance curve for the pavement sections that do not have a utility cut. Figure 8 shows a plot of PQI versus the road age. The trendline that was fit to the data points to obtain the performance curve for the pavement sections without a utility cut is also included in Figure 8.

In order to determine the percentage loss in serviceability over the remaining life of the pavement following the occurrence of a utility cut, a performance line was also developed for the pavement sections containing a utility cut. The second performance line was developed by reducing PQI at any given age by 22 percent, which was found to be the average reduction in PQI due to the introduction of a utility Cut. Figure 9 shows the performance lines for pavement sections not having a utility cut as well as those with a utility cut. The serviceability loss over the pavement life can be considered to be the area between the two lines.

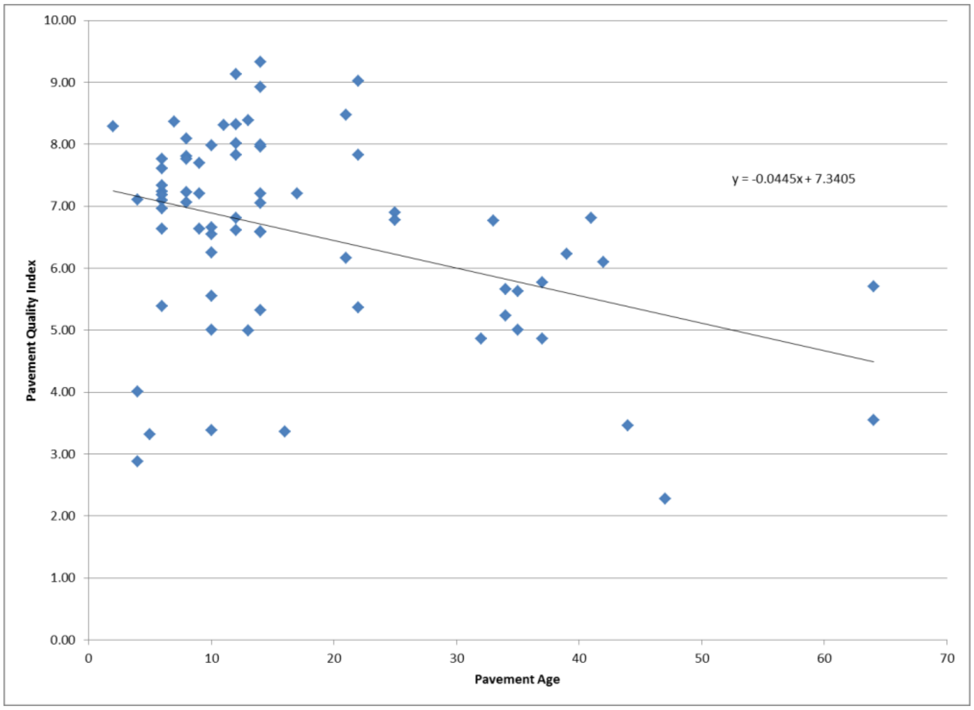

Figure 8: Performance Curve for Pavement Sections without a Utility Cut

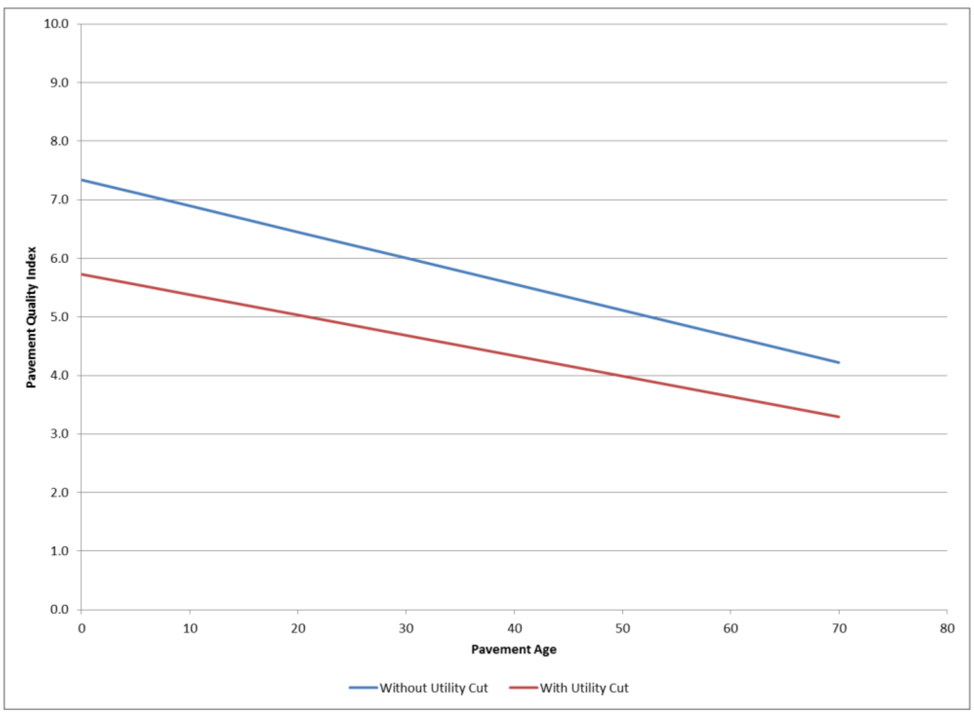

Figure 9: Performance Curve With and Without Utility Cut

From Figure 9 it can be seen that depending on the age of the pavement at which the utility cut is made, the area between the two curves will vary in spite of the fact that the instantaneous reduction in PQI due to the utility cut is about the same regardless of the pavement age. Therefore, in order to determine the percent serviceability loss over the pavement life for the pavement degradation fee structure the pavements were divided in to the age groups shown in Table 6. Also Table 6 shows the percent serviceability loss for each age group that was determined based on the statistical analysis.

The Pavement Degradation Fee (PDF) was determined using the equation below.

$$PDF = (\%\ Serviceability\ Loss \times Reconstruction\ Cost) + (Additional\ Maintenance\ Cost)$$

Table 6: Percent Serviceability Loss Due to Utility Cuts In Pavements of Different Age Ranges

AGE RANGE	PERCENT SERVICEABILITY LOSS
0 – 5	22%
6 – 10	20%
11 – 20	18%
21 - 30	15%
30 - 70	11%
> 70	0%

8. RECOMMENDATIONS and CONCLUSIONS

Based on the field data collection and subsequent analysis, Table 7 shows the pavement degradation fee structure recommended to be implemented to compensate the City for the loss in pavement life and the additional maintenance cost due to the utility cuts in the pavement sections.

Table 7: Pavement Degradation Fee Structure

Road Classification	Road Age at Time of Utility Cut	Pavement Degradation Fee ($/m²)
Arterial	0-5	$57
	5-10	$52
	10-20	$47
	20-30	$38
	30-70	$29
Collector	0-5	$51
	5-10	$47
	10-20	$42
	20-30	$34
	30-70	$26
Local	0-5	$46
	5-10	$42
	10-20	$38
	20-30	$30
	30-70	$23

The degradation fee in Table 7 is recommended to be applied to the size of the trench plus the zone of influence. The zone of influence will be one metre on each side of the trench, irrespective of the size, location, or layout (transverse, longitudinal, or diagonal) of the trench. Further, the zone of influence will be the same, i.e. one metre on each side of the trench, for each of the local, collector, or arterial classification of the roads.

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