Evaluation of the Automated Laser Rut Measurement System Used by the Ohio Department of Transportation

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This thesis titled

Evaluation of the Automated Laser Rut Measurement System Used by the Ohio Department of Transportation

by

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ABSTRACT

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Evaluation of the Automated Rut Measurement System Used by the Ohio Department of Transportation

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Pavement rutting can be an indicator that a section of roadway is in need of repair or replacement and can become a hazard to drivers. To better monitor pavement conditions throughout the state, the Ohio Department of Transportation (ODOT) purchased two road profilers with INO Laser Rut Measurement Systems (LRMS). The vehicle mounted systems provide ODOT pavement condition raters with a faster and safer method for evaluating pavement conditions. This study was intended to evaluate the accuracy, precision, and repeatability of the LRMS system and determine the correlation between manually collected data and data collected using the LRMS. The system's performance was evaluated by collecting rut measurements over two sections of pavement using the LRMS, the straight edge method, and a mechanical profiling system to compare results. The study showed that the LRMS produces accurate and repeatable results that are similar to those produced with a straight edge or profilometer. Minor adjustments to the Pavement Condition Rating (PCR) system are needed, however, to ensure that scores properly represent the condition of the pavement.

Approved: ____

Shad M. Sargand

Russ Professor of Civil Engineering

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1 INTRODUCTION

1.1 Background

Aging or under designed asphalt pavement can exhibit a number of physical distresses such as raveling, patching, rutting, potholes, settling, and cracking. It is important for these distresses to be monitored periodically to ensure that they do not develop into a safety hazard or affect ride quality. Pavement distresses such as these are indicators that a pavement section may require maintenance or replacement.

The Ohio Department of Transportation (ODOT) evaluates pavement conditions using its Pavement Condition Rating (PCR) System. Each evaluated roadway receives a score based on observed distresses. A roadway will be inspected for a number of different distresses, depending on the type of pavement. The inspection of a roadway involves the documentation of each type of observed distress and a description of its extent and severity. A roadway's PCR score begins at 100 and receives deductions based on the documented distresses. Examples of a condition rating key and a condition rating form for flexible pavement are shown in Figure 1.1 and Figure 1.2. The PCR for rutting in composite pavement is identical for flexible pavement.

Section: __________________ **KEY** Date: __________________

Log Mile: _______ to _______ **FLEXIBLE PAVEMENT CONDITION** Rated by: ________________

Sta:____________ to_______ **RATING FORM** # of Utility Cuts ____________

DISTRESS	Distress Weight	SEVERITY*			EXTENT**			STR ***
		L	M	H	O	F	E	
RAVELING	10	Slight Loss of Sand	Open Texture	Rough or pitted	<20%	20-50%	>50%	
BLEEDING	5	not rated	Bit and Agg visible	Black Surface	<10%	10-30%	>30%	
PATCHING	5	<1 ft².	<1 yd²	>1 yd²	<10/mile	10-20/mile	>20/mile	
DEBONDING	5	depth <1" area <1 yd²	<1", >1 yd² >1",<1 yd²	>1" and >1 yd²	<5/mile	5-10/mile	>10/mile	
CRACK SEALING DEFIC.	5	Not considered			<50%	>50%	No Sealant	
RUTTING	10	1/8" - 3/8"	3/8" - 3/4"	> 3/4"	<20%	20-50%	>50%	U
SETTLEMENTS	0	Noticeable effect on ride	Some Discomfort	Poor Ride	<2/mi	2-4/mi	>4/mi	
POTHOLES	10	depth <1" area <1 yd²	<1", >1 yd² >1",<1 yd²	>1" and >1 yd²	<5/mile	5-10/mile	>10/mile	U
WHEEL TRACK CRACKING	15	Single/multiple cracks <1/4"	Multiple cracks >1/4"	Alligator >1/4" Spalling with	<20%	20-50%	>50%	U
BLOCK & TRANSVERSE CRACKING	10	> 6' X 5' or Transverse Crk.	6' x 6' to 3' x3'	< 3' x 3'	<20%	20-50%	>50%	
LONGITUDINAL CRACKING	5	Single, <1/4", no Spalling	single/multiple 1/4-1", some Spalling	Multiple, >1", Spalling	< 50' per 100'	50-150' per 100'	>150' per 100'	U
EDGE CRACKING	10	Tight. <1/4"	>1/4", some Spalling	>1/4",moderate Spalling	<20%	20-50%	>50%	U
THERMAL CRACKING	10	<1/4"	1/4-1"	>1"	CS > 200'	CS 75-200'	CS <75'	

*L = LOW **O = OCCASIONAL ***STR = DISTRESS INCLUDED IN STRUCTURAL DEDUCT CALCULATIONS.
M = MEDIUM F = FREQUENT
H = HIGH E = EXTENSIVE

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Figure 1.1. PCR rating key for flexible pavement

Section: ____________________
Log mile: ______ to__________
Sta: __________ to__________

FLEXIBLE

Date: ____________________
Rated by: ______________
# of Utility Cuts ___________

PAVEMENT CONDITION RATING FORM

DISTRESS	DISTRESS WEIGHT	SEVERITY WT.*			EXTENT WT.**			DEDUCT POINTS***
		L	M	H	O	F	E	
RAVELING	10	0.3	0.6	1	0.5	0.8	1	
BLEEDING	5	0.8	0.8	1	0.6	0.9	1	
PATCHING	5	0.3	0.6	1	0.6	0.8	1	
DEBONDING	5	0.4	0.7	1	0.5	0.8	1	
CRACK SEALING DEFICIENCY	5	1	1	1	0.5	0.8	1	
RUTTING	10	0.3	0.7	1	0.6	0.8	1 T	
SETTLEMENT	0	0.0	0.0	0.0	0.0	0.0	0.0	
POTHOLES	10	0.4	0.8	1	0.5	0.8	1 T	
WHEEL TRACK CRACKING	15	0.4	0.7	1	0.5	0.7	1 T	
BLOCK AND TRANSVERSE CRACKING	10	0.4	0.7	1	0.5	0.7	1	
LONGITUDINAL CRACKING	5	0.4	0.7	1	0.5	0.7	1 T	
EDGE CRACKING	10	0.4	0.7	1	0.5	0.7	1 T	
THERMAL CRACKING	10	0.4	0.7	1	0.5	0.7	1	

*L = LOW **O = OCCASIONAL
M = MEDIUM F = FREQUENT
H = HIGH E = EXTENSIVE

TOTAL DEDUCT =
SUM OF STRUCTURAL DEDUCT (T) =
100 - TOTAL DEDUCT = PCR =

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Figure 1.2. PCR rating form for flexible pavement

This study focuses on the techniques used by ODOT to measure and evaluate rutting distresses. If rut depths are not measured accurately, the affected score could prevent roads that are in need of repair or replacement from receiving appropriate attention or cause ODOT funds to be spent where they are not needed.

1.2 Problem Statement

Since 1985, ODOT has been manually collecting rut depth data using a straight edge and dial gauge (S&G). This method is slow and dangerous to pavement condition raters when traffic control is not available. According to the PCR procedures, the rating team is instructed to stop at 1 mile intervals along the predetermined roadway section and evaluate a 100 foot section of pavement. While this method may be sufficient in many cases, there is potential for raters to overlook short sections of deeper than typical rutting. Also, there have been numerous instances, according to ODOT Infrastructure Management workers, when the level of traffic prevented them from obtaining the necessary number of rut depth measurements to properly evaluate a pavement section. To solve this problem, ODOT purchased two road profiler vehicles; one from Pathway Services and one from Dynatest. Both vehicles use rear-mounted INO Laser Rut Measurement Systems (LRMS). These systems utilize two 3D laser profilers and allow the collection of transverse road profiles and calculation of rut depth measurements while the vehicle is in motion, even at high speeds. With the LRMS, numerous rut measurements can be obtained at short intervals over the entire section in a much shorter period of time. The safety risk for the rating team is greatly reduced because they can obtain measurements without leaving the vehicle and without interfering with traffic flow.

As previously discussed, manual evaluations of rutting for the PCR are often based on few actual measurements because of traffic and time limitations. ODOT has collected a database of PCR ratings for rut depth based on manual measurements, LRMS data, or both. The two methods of evaluating rut depth may produce significantly different PCR scores for the same section of pavement. A method for reconciling the difference between the two methods is needed. Before this can be done however, the accuracy, precision, and repeatability of the LRMS system should be confirmed.

During the initial preparation for this project, it was discovered that the straight edge and dial gage being used by the ODOT technicians was only 4 ft in length. The ASTM standard for rut depth measurement (ASTM E 1703/E 1703M, 1995) specifies a minimum length of 1.73 m (5.67 ft) and recommends a length of 1.83 m (6 ft), 2 m (6.56 ft), 3 m (9.84 ft), 3.05 m (10 ft), or 3.66 m (12 ft). Not only is the ODOT straight edge limited by length, but the dial gage is fixed at the center of the bar. It is necessary to determine the possible effect of these factors on the rut depth measurements gathered by ODOT pavement raters.

1.3 Objectives

The main goals of this study were to evaluate the rut depth measurement collection techniques used by ODOT and to verify data gathered using the automated laser rut measurement system. To meet these goals, the following objectives were devised and met:

- Conduct tests on a section of rutted pavement at one or more locations using the LRMS, straight edges, and profilometer.
    - Evaluate the LRMS data for precision, accuracy, and repeatability using the S&G method and ORITE Profilometer as references.
    - Examine the potential effect of straight edge length on the accuracy of S&G measurements to determine whether the 4ft straight edge used by ODOT is adequate.
- Develop a method for extracting rutting distress scores from the LRMS data to be used with the ODOT pavement condition rating system.
- Recommend other parameters (maximum, minimum, etc.) that may be suggested by the data for the use and interpretation of INO rut depth measurements.

2 LITERATURE REVIEW

2.1 Introduction

This section will discuss literature related to several established methods of measuring rut depth and their benefits and limitations. While there have been a number of research studies examining rut measurement methodology, few have been conducted specifically on the INO Laser Rut Measurement System (LRMS). The alternative measurement methods used in this study were also used to select relevant sources.

Asphalt concrete, being a viscoelastic material, is subject to rutting and other deformations caused by repeated or prolonged heavy loading. This viscoelastic deformation generally is in the form of rutting or shoving. Rutting occurs when one or more pavement layers consolidate, producing an extended, longitudinal depression in the wheel path (Yoder & Witczak, 1975). Ruts can become hazardous to drivers because of the unevenness of the driving surface and their tendency to collect water. This type of surface distress may indicate that the pavement was not designed to adequately endure the heavy loads that it experiences and may signal a need for maintenance or replacement.

2.2 Manual Rut Depth Measurements

The most traditional technique for measuring rut depth is the straightedge method. This requires one to lay a straightedge across the wheel path perpendicular to the direction of traffic. The straightedge should contact the road at the two highest points on either side of the wheel path. The ASTM specification for this method requires that the straightedge be at least 1.73m (5.67ft) in length to ensure that it spans the entire width of the rut (ASTM E 1703/E 1703M, 1995). Using a gauge, several measurements along the length of the straightedge should be taken to find the deepest point in the rut. This method, while simple and accurate if proper technique is used, can be time consuming and difficult to perform especially with limited traffic control.

Figure 2.1. Measurement of rut using a straight edge and electronic dial gage

2.3 Automated Rut Depth Measurements

Throughout their development, automated transverse profile systems have typically used three different methods of determining rut depth. Two of these methods, the straight edge model and the wire model, are based on manual measurement methods. The third method, the pseudo-rut model, has been commonly used with rut-bar systems. These systems often provide only 3 or 5 measurements for determining rut depth and have been shown to be inaccurate and unreliable. This is mainly because the limited number of profile measurements allows it to be affected by vehicle wandering (FHWA-RD-01-27, 2001).

2.3.1 Straight Edge Model

The straight edge model assumes a 2-m virtual straight edge bridging the rut which is created by connecting the two highest points on either side of a rut with a straight line (Figure 2.2). The depth is usually measured at a right angle to the straight edge. When this is not the case, the slope angle of the virtual straight edge is ignored as the effect is often negligible (Bennet & Wang, 2002a). The 2-m virtual straight edge model is used by the LRMS system for calculating rut depth.

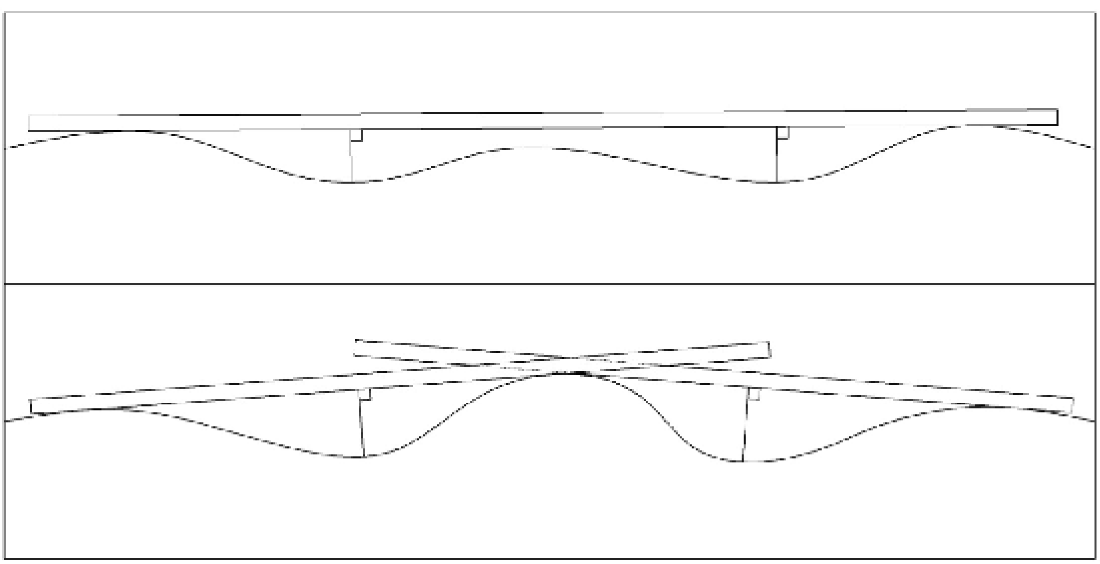

Figure 2.2. Virtual 2-m straight edge model

2.3.2 Wire Model

This model simulates a mass-less wire being stretched horizontally between the high points across the pavement. The wire begins at a high point to the left of the left wheel path and ends at another high point to the right of the right wheel path. The virtual wire may contact other high points and change slope as an actual wire would. In most cases, the wire model and the straight edge model would produce the same results. The only exception would be when the 2-m straight edge is too short to span the single or double rut (Figure 2.3) (Bennett & Wang, 2002a).

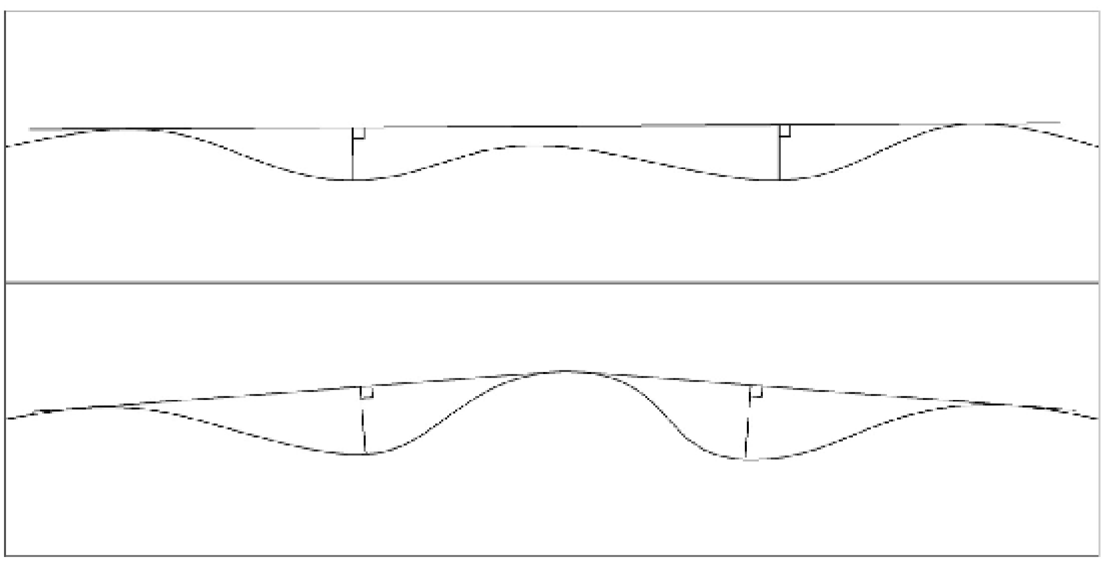

Figure 2.3. Virtual wire model for measuring rut depth

2.3.3 Pseudo-Rut Model

The pseudo-rut model bases the rut depth on the difference between the highest and lowest points measured. This is not a reliable method for determining rut-depth and can produce poor results. The pseudo-rut method was intended for use with profiler systems that produce a limited number of data points and is not suited for this study (Bennett & Wang, 2002a).

2.4 ORITE Profilometer

The Ohio Research Institute for Transportation and the Environment (ORITE) designed and constructed a mechanical profilometer for measuring surface deformation at the ORITE Accelerated Pavement Loading Facility. The device creates a profile by measuring the distance between the pavement surface and an aluminum beam that serves as a guide rail. A carriage hangs below the guide rail with a 12-in (30.5-cm) arm extending down to the pavement. A 2-in (5.08 cm) diameter wheel is connected to the end of the arm that allows it to roll over the pavement surface. The carriage is driven back and forth along the rail by an electric motor. Its movement is tracked using a quadrature rotary encoder. The angle of the arm changes as the wheel travels over the uneven pavement. This angle is measured to a precision of 0.025 degrees using an incremental rotary optical encoder. A DOS program, written specifically for the ORITE profilometer, uses the measured change in angle to calculate the tangential displacement of the wheel at the end of the arm. A change of 0.025 degrees measured by the rotary encoder would indicate approximately 0.005 inches (0.127 mm) of movement at the end of the arm. An inclinometer mounted at the center of the beam is used to measure the slope of the beam during each profile measurement. This allows profiles to be rotated or leveled to create a more accurate model of the pavement. The inclinometer makes it possible to level each profile in a series to produce an interpolated, three-dimensional profile of a segment of roadway (Richardson, 2003).

Figure 2.4. ORITE profilometer measuring a transverse profile on SR-682

In 2001, a similar device, called the Transverse Profile Beam (TPB), was designed by HTC Infrastructure Management Ltd. (HTC) and Dr. Christopher Bennett of Data Collection Ltd. (DCL) to meet the needs of Transit New Zealand at a low cost. Like the ORITE device, the TPB runs a wheel across the pavement surface below an aluminum beam. Both devices use a rotary encoder to measure the vertical displacement of the wheel; however the TPB measures vertically instead of using an arm. The TPB wheel is much larger in diameter (actual diameter unknown) than that of the ORITE profilometer. The TPB measures the horizontal position of the carriage with a precision of 2.97 mm (0.117 in) using a proximity sensor mounted to the carriage that produces a pulse when it passes one of the magnets mounted at known intervals along the beam (Bennett, 2002)

Measurements taken by the TPB were compared to straightedge measurements and repeated over a period of time to confirm that the TPB would produce consistent results. Bennett (2002) reported that the TPB results were within 2.5 mm (0.10 in) of the straightedge. The differences were attributed to the difference in precision between the two methods (the straightedge/wedge measurements were to the nearest mm) and the size of the TPB wheel. Repeated runs of the TPB showed a typical deviation of +/- 1.5 mm (0.06 in). The results of the study show that the TPB could produce reliable and accurate pavement profiles (Bennett, 2002). Given the similarities in design between the ORITE profilometer and the TPB, Bennett (2002) supports the validity of the data collected by the ORITE profilometer.

In order to measure the rut depth from the profilometer readings, a method for simulating a 2-m (6.56-ft) straight edge was developed using MATLAB. In order to find the rut depth, two ranges are specified by the user to indicate where the left and right ends of the straight edge may contact the pavement. Lines are drawn from each point within the left range to each point within the right range. Lines are limited to a length of 2 m. Every time a line is drawn, a vertical measurement is taken from the connecting line to the pavement surface at every point between the left and right ends. The largest measurement after all possible left and right endpoint combinations are considered is recorded as the rut depth. The rut width is recorded as well. This was done for each of the profiles collected in both wheel paths. An example of the resulting virtual straight edge created by the program is shown in Figure 2.5. Just like in the case of an actual straight edge measurement, the maximum possible depth is found when the virtual straight edge is tangent to the plotted curve at two points near the peaks on either side of the rut.

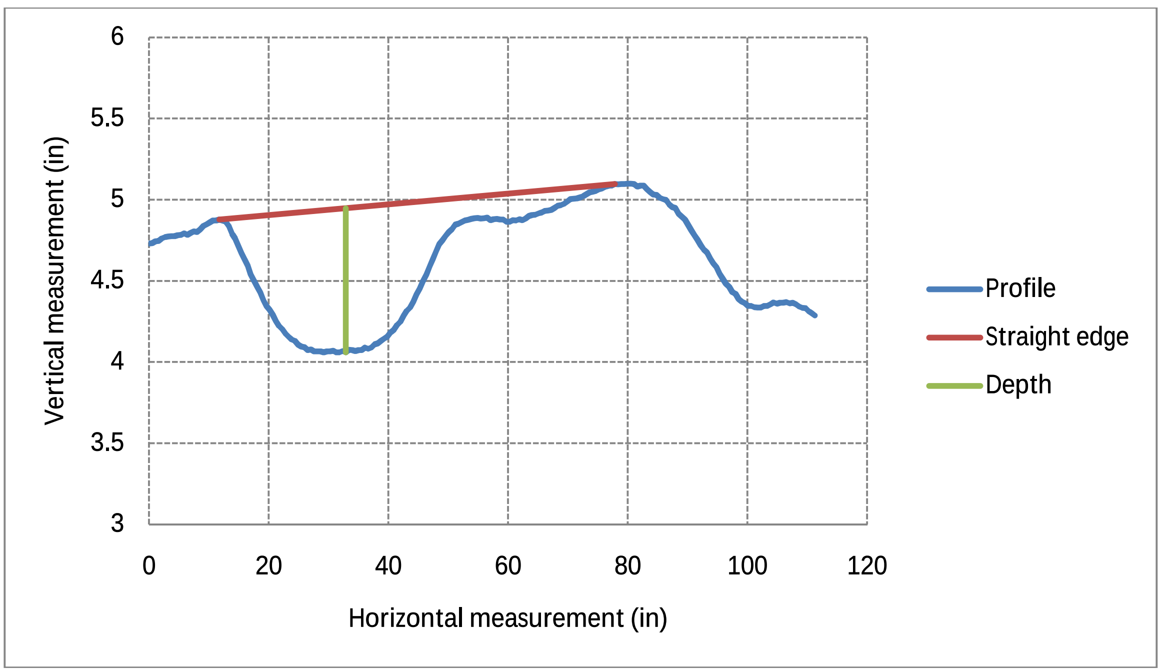

Figure 2.5. Typical virtual straight edge model using ORITE profilometer data from US-30 (1 in = 2.54 cm)

2.5 INO Laser Rut Measurement System

The INO laser rut measurement system used by ODOT utilizes two laser profilers mounted to the rear of a vehicle, as shown in Figure 2.6 and Figure 2.7. Each profiler provides part of the overall field of view. The profilers use high-power pulsed infrared laser line projectors and specially designed cameras to create a transverse profile of the roadway surface. The LRMS system reads the vehicle odometer to determine the location of each profile reading and to ensure that measurements are taken at the user-specified intervals. The system is controlled from within the vehicle by a driver or passenger. The rut measurement data are analyzed and can be viewed in real time. In this study, the program RSPWin v2.6.8 from Dynatest was used. A list of specifications for the LRMS taken from the Pavemetrics website (http://www.pavemetrics.com/en/lrms.html) is shown below:

- Number of laser profiles: 2
- Number of 3D points per profile (max): 1280
- Sampling rate: 30 or 150 profiles/s
- Profile spacing: adjustable
- Transversal field-of-view (nominal): 4 m (13.1 ft)
- Transversal resolution: ± 2 mm (0.08 in)
- Depth range of operation: 500 mm (19.7 in) (30 Hz) or 450 mm (17.7 in) (150 Hz)

- Depth accuracy (nominal): ±1 mm (0.04in)
- Laser profiler dimensions (approx.): 108 mm (4.25 in) (W) x 692 mm (27.2 in) (H) x 220 mm (8.7 in) (D)
- Laser profiler weight (approx.): 12 kg (26.5 lbs)
- Power consumption (max): 150 W at 120/240 VAC

Figure 2.6. INO Laser Rut Measurement System mounted on an ODOT profiler vehicle

Figure 2.7. INO Laser Rut Measurement System - one of two mounted laser profilers

The profiler vehicle used in this study was equipped by Dynatest Consultants, Inc. The output file, created in the RSPWin program, includes rut depth, rut width, rut area, and location (milepoint) for both wheel paths. The Dynatest system allows the user to not only adjust the profile spacing, but also to use rapid-fire mode which allows the system to collect data at the maximum 30 Hz sampling rate as opposed to a set distance interval. This feature was advantageous during this study as it allowed for a much higher density of data over the pavement test sections.

In 2002, a research study (Grondin et al. 2002) was funded by the Quebec Ministry of Transport (MTQ) to evaluate the INO Laser Rut Measurement System (LRMS). The goal of the study was to determine whether the system could meet the needs of the MTQ and to validate the precision and accuracy promised in the systems specifications. Most of the equipment used by MTQ is identical to what is used by ODOT, with the main exception being the computer and software.

In order to validate the rut depth measurements, Grondin et al. (2002) compiled data collected by the LRMS at twelve 400-m (1312-ft) sites. Six passes were made at each site; three on day one and three more on day two. Readings were taken at 1-m (3.3-ft) intervals and the average depth per 10 m (32.8 ft) was calculated. Multiple passes allowed the team to examine deviation of rut depth measurements. In order to test the LRMS for repeatability, a 2-km (1.24-mi) site was selected and measured five times. The team then conducted measurements on the twelve 400-m (1312-ft) sites. Afterward, the 2-km site was measured again and the results were compared to those obtained earlier in the day. 20 days later, the researchers performed three additional passes. The results show that the LRMS was accurate to 0.5 mm (0.02 in) (mean deviation) and produced reliable and repeatable measurements. The results produced in this research study can be compared to those in Grondin et al. (2002).

A 2010 study conducted by Tsai, Wang, and Li, published in the Transportation Research Record, compares the use of the Laser Crack Measurement System (LCMS) as a rut measurement device to the straight edge method. The LCMS is a vehicle-mounted pavement profiling system very similar to the LRMS. It also utilizes two laser profilers mounted to the rear of the vehicle that measure two 4-m transverse profiles. The main differences are the computer system and collection frequency. The LCMS is able to collect 2080 points per unit at a maximum rate of 5,600 profiles per second, which equates to measurement intervals as low as 5 mm at 100 km/s.

For this study, the raw data was interpreted and rut depths were calculated by the research team instead of commercial software. First, the system was tested statically in a controlled, laboratory setting where a curved board and metal bar were profiled. Afterward, the system was tested on two sections of pavement. In both settings, the LCMS measurements were compared to those taken using a straight edge and distance gage.

The results of the two tests differed slightly, however the LCMS measurements from the pavement test differed from the straight edge method slightly more than in the laboratory. The difference between straight edge and LCMS measurements taken in the laboratory ranged from 0.08 mm to 0.76 mm. During the pavement test, the difference ranged from 0.8 mm and 2.3 mm (straight edge measurements were greater for both tests). A greater difference is to be expected for the pavement test due to various uncontrollable influences such as vehicle wandering or the LCMS profile being measured at a slightly different location from the manual measurements. A large part of this difference however may be attributed to a flaw in the method used by Tsai, et al to draw the virtual straight edge for determining rut depth. According to the listed procedures, a line was drawn between the highest points on either side of the rut. These high points were to be used as the resting points for the virtual straight edge. An actual straight edge physically cannot rest on the highest points unless they are at precisely the same elevation. The straight edge would have to pass through the curved surface of the pavement near the high points. Also, the lower side of the straight edge would likely rest at a point beyond the highest point. An example of this is shown in Figure 2.8. This plot uses profilometer data gathered in the left wheel path on SR-682 to demonstrate the difference in virtual straight edge algorithms. As one can clearly see, the line connecting the highest points on either side of the rut would cause the rut depth to be underestimated slightly.

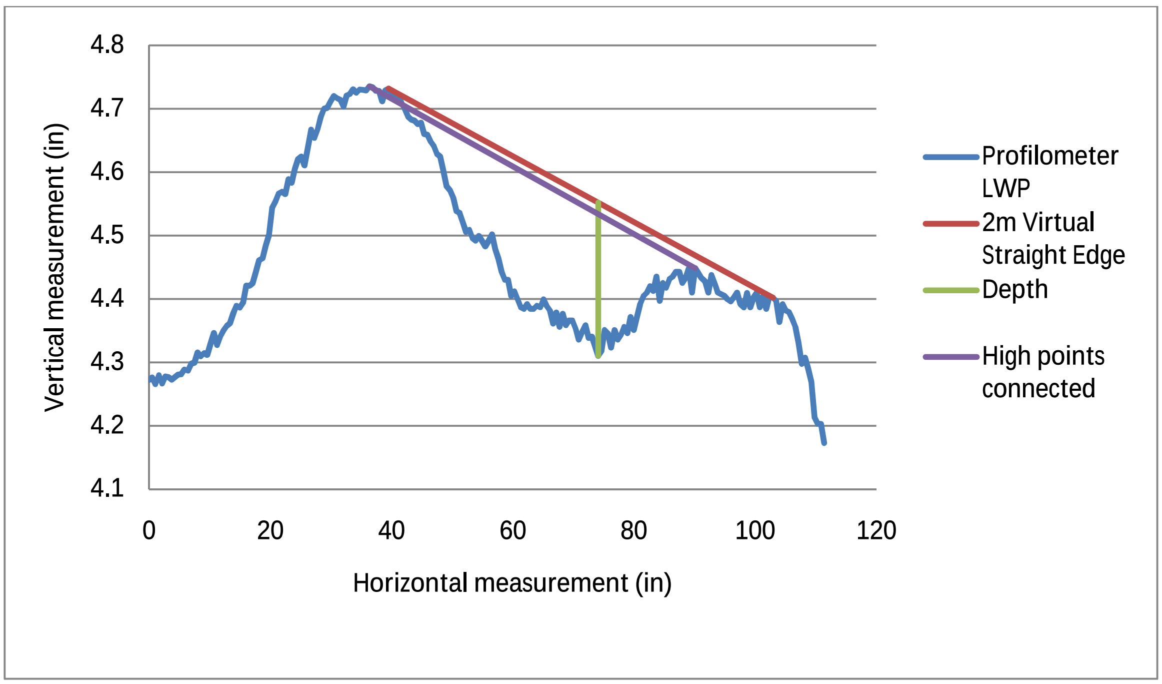

Figure 2.8. Illustrated difference in virtual straight edge model described in Tsai, et al (2010)

The field test results presented in Tsai, et al. (2010) show that 9 out of 10 rut depth measurements gathered by the LCMS were less than measurements taken using a straight edge. A similar relationship was observed in the laboratory test; however the difference was extremely small. In the laboratory, the board and metal bar may have been relatively level which would mean that the peaks measured on either side of the simulated rut were likely at the same level. This would reduce the impact of the rut depth algorithm discrepancy because the high points would be closer to the tangent points. In the field test, the pavement was most likely designed with some lateral slope to allow for water to drain. This could produce a significantly larger distance between the high points and tangent points and cause weaker precision in the field.

Tsai, et al. (2010) supports the validity and precision of the LCMS and, because of its close similarity to the LRMS. Because the difference between LCMS rut depth and straight edge measurements observed in this study was so little and because the effect of the rut depth algorithm discrepancy is so minor, the conclusions reached in the study can still be supported. If the algorithm were to be changed so that the virtual rut bar rested tangent to the pavement surface, the results of these tests may actually improve and strengthen the authors' arguments in support of the precision of the profiling system.

3 LABORATORY TEST OF THE LRMS, PROFILOMETER, AND S&G METHODS

3.1 Experimental Procedure

The first test was conducted at the Accelerated Pavement Loading Facility (APLF) in Lancaster, Ohio. This facility was designed for the testing of pavement in a controlled, indoor environment. Traffic load is simulated using a dual truck tire mounted to a carriage that runs the length of the pavement below a steel beam, applying a load specified by the researcher. This system causes rutting and other distresses that can be observed and measured to determine the performance of a pavement system. Because dual tire is always run along the same track, each tire creates its own narrow rut, resulting in a sort of double rut. These double ruts were measured using each rut measurement system with the goal of producing LRMS data that could be used to study its performance. At the time of this test, only the Pathway Services profiler vehicle was available. The Dynatest system was not included in this test.

At the time of this study, the pavement in the APLF was made up of four lanes approximately 41 ft in length. Each lane was made up of a different type of asphalt or pavement system. Three of these lanes were examined in this study. The fourth lane is positioned in a manner that prevented the ODOT profiler vehicle from being used properly.

The three pavement sections were measured at 1-ft intervals using the S&G and Profilometer. The depth of each side of the double rut was measured and recorded. It was believed that the larger of the two depth measurements would be the depth reported by the LRMS. Five runs were made with the profiler vehicle on each lane. The front bumper of the vehicle was aligned with first of the 1-ft measurement intervals, recording was started, and the operator accelerated until the vehicle was completely clear of the pavement section, at which point recording was stopped. The system recorded rut depth at 5-ft intervals.

Figure 3.1. Profilometer measuring rut depth at the Accelerated Pavement Loading Facility (APLF)

3.2 Results and Discussion

The rut depths collected using the LRMS differed dramatically from the profilometer and S&G. It was immediately evident that the system was not measuring the ruts at the APLF correctly. The output also contained numerous saturation errors. The results are shown in Figure 3.2 through Figure 3.4 with the data points that were flagged for errors removed.

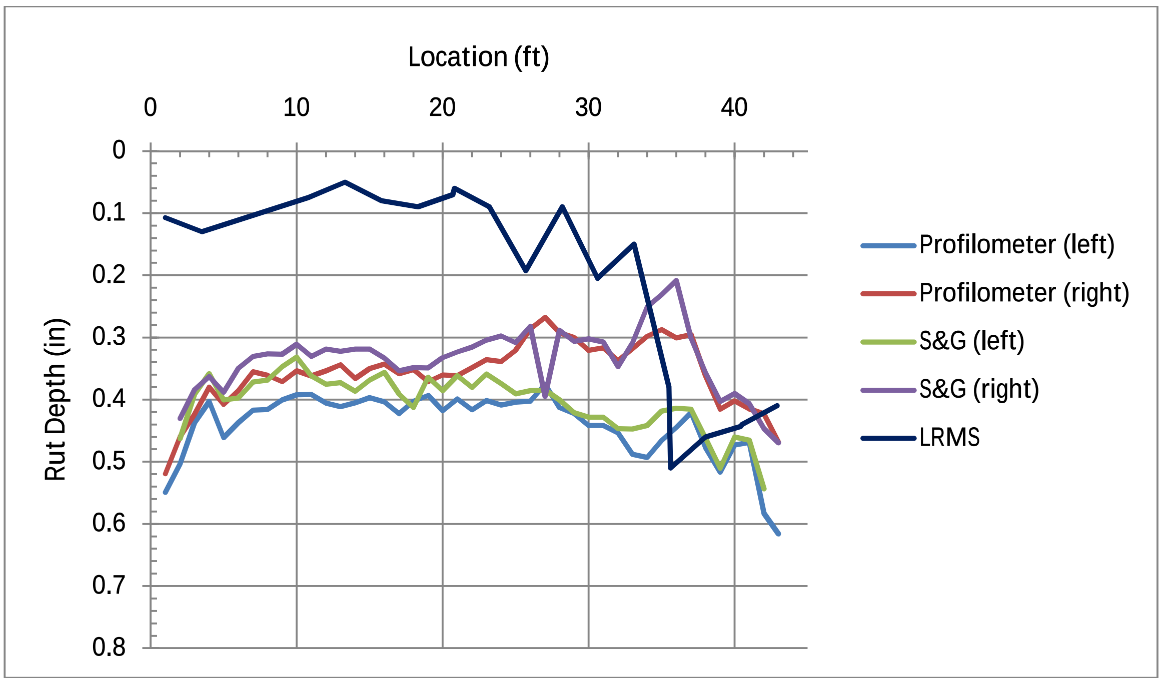

Figure 3.2. Rut depths measured in lane 2 at the APLF

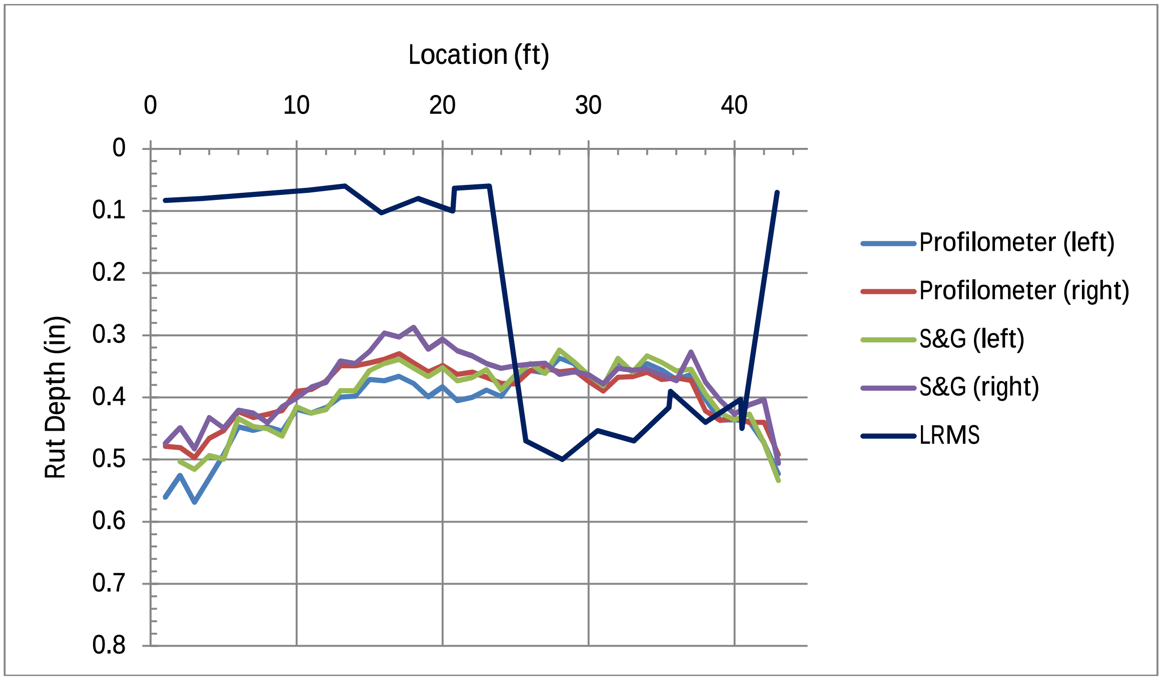

Figure 3.3. Rut depths measured in lane 3 at the APLF

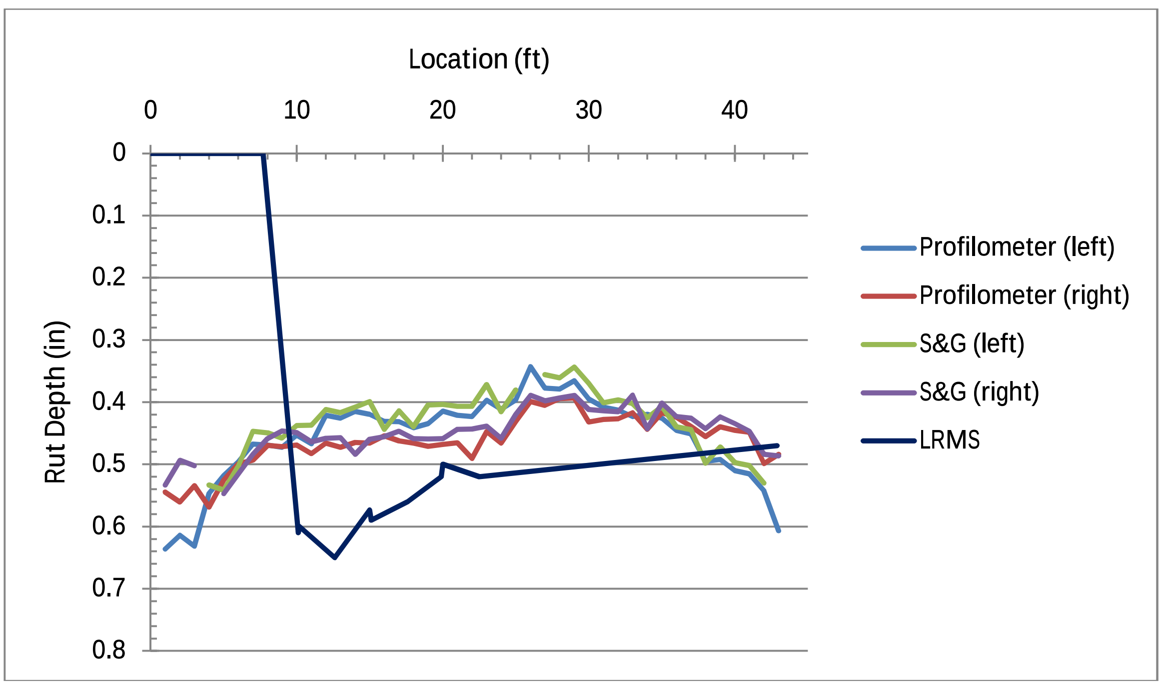

Figure 3.4. Rut depths measured in lane 4 at the APLF

A representative from Pathway Services was contacted to comment on the possible causes of such large discrepancies. He believed that the saturation errors and possibly the lack of precision were caused by interference caused by the indoor lighting at the facility. He also explained that the system should be in motion for at least 1000 ft leading into the pavement section to be measured. Due to the location of the facility and the fact that the profiler vehicle has to pass in and out of the facility on either end of the pavement section, it was determined that a 1000 ft lead-in was not practical for this test. It was decided that the LRMS data collected in this indoor test should be considered invalid and the focus of this study be shifted to the field tests only. Unfortunately, the Pathway Services system continued to produce inconsistent and inaccurate data in later tests as well.

4 FIELD TESTING OF THE LRMS, PROFILOMETER, AND S&G METHODS

4.1 Experimental Procedure

Two 200-ft (60.96 m) sections of pavement with rutting at a variety of severity levels were selected for data collection. Each 200-ft (60.96 m) section was measured and marked at 5 ft (1.52 m) intervals. At each interval, rut depth was measured in both the left and right wheel paths using the profilometer, 8 ft S&G, and 4 ft S&G. Workers from the ODOT Infrastructure Management division made five runs at each site with the Dynatest profiling vehicle over a greater length of pavement that contained each 200-ft (60.96 m) section. As the vehicle approached the test sections, the system was switched to rapid-fire mode in order to provide a greater number of measurements for analysis. For the US-30 test, data was also collect with the Pathway Services vehicle; however, the system was unable to produce usable data and was excluded from the analysis.

4.1.1 Localized Heavy Use/Severe Rutting on US-30

A site was selected on US-30 near Wooster, Ohio for testing. The 200-ft (60.96 m) section was in the westbound approach to a stoplight at the intersection of US-30 and SR-94 (see Figure 4.1). This area receives a significant amount of large truck traffic. The stopped or slow-moving, heavily loaded trucks had produced a section of extremely severe rutting and upheaving. Areas away from the intersection were typically characterized by light or medium rutting.

Figure 4.1. Test section at the intersection of US-30 and SR-94

Figure 4.2. Measuring rut depth on US-30 using the ORITE profilometer

ODOT workers made five runs each with the Dynatest and Pathway services pavement profiling vehicles and collected measurements at five foot intervals (with the exception of the rapid-fire segment at the test section when the Dynatest system was used). They began collection at milepost 24.863 and ended near milepost 23.330, covering a distance of 1.563 mi (2.515 km). The intersection of US-30 and SR-294 where the 200-ft (60.96 m) test section was located is at milepost 24.015. Data collection with the LRMS system is started and stopped by the operator as the vehicle is in motion. As a result, the accuracy of the starting point is dependent on the vehicle speed and reaction time of the operator. Fortunately, the extreme severity of rutting at the 200-ft

(60.96 m) test section provided a well-defined reference point for aligning the data from each run and aligning the LRMS data with the measurements taken with the profilometer and straight edges.

4.1.2 Light Use/Medium Rutting on SR-682

A second test site having a more typical section of distressed pavement was needed in order to evaluate the LRMS system under normal conditions. A section of SR-682 in Athens County, Ohio was chosen for its low to medium severity rutting. This section is similar to the pavement sections typically found in the PCR database.

Figure 4.3. Location of SR-682 test section

For this test, procedures similar to those used for the US-30 site were followed. A 200-ft (60.96 m) section of pavement at approximately mile point 1.51 was measured and marked at five foot (1.52 m) intervals. Workers from the ODOT Infrastructure Management office made five runs with the Dynatest LRMS system only. LRMS data was collected at five foot intervals beginning at milepoint 1 and ending at approximately milepoint 1.8, a distance of about 0.8 mi (1.3 km). As the vehicle approached the test section, rapid-fire mode was initiated, causing the system to record at 30 Hz intervals. Measurements were collected at 5-ft (1.52 m) intervals using the 4 ft straight edge, 8 ft straight edge, and profilometer on the 200-ft (60.96 m) section only. These measurements were then compared with the LRMS results.

Unlike the US-30 test, there was no clearly defined section of severe rutting that could be used as a reference point for aligning data sets. To compensate, a reference point was created at the start of the 200-ft test section by creating a sort of artificial rut that would be easy to distinguish from other areas of the pavement. This was achieved by laying temporary rumble strips longitudinally in the road on both sides of the right wheel path. This artificially raised the sides of the wheel path to simulate a deeper rut and produced a spike in depth measurements that was used to align each set of data (see Figure 4.5).

Figure 4.4. Rut measurement on SR-682 using the profilometer and 8-ft S&G

Figure 4.5. Temporary rumble strips used to create an artificially deep rut to be used as a reference point in the LRMS data

4.2 Results

4.2.1 Localized Heavy Use/Severe Rutting on US-30

When the LRMS measurements collected on US-30 were analyzed, it was immediately evident that the Pathway Services system was not functioning correctly. The plotted data showed large fluctuations in measured rut depth and no observable correlation between runs. The range of depths measured using the Pathway Services system differed drastically from the Dynatest data. The Pathway Services measurements collected over the 200-ft test section did not correspond with any of the other measurement methods either. The data output files showed a large number of saturation errors that also indicate that the measurements were flawed. A summary of the data and errors from the Pathway Services system is shown in Table 4.1.

Table 4.1. General summary of data collected on US-30 using the Pathway Services system

Data Set	Wheel path	Starting Milepost	Final Milepost	Total data points (n*)	Errors	Data points after errors removed (n)
Run 1	LWP	24.863	23.329	1821	161	1660
	RWP	24.863	23.329	1821	629	1192
Run 2	LWP	24.863	23.325	1783	78	1705
	RWP	24.863	23.325	1783	334	1449
Run 3	LWP	24.863	23.335	1608	14	1594
	RWP	24.863	23.335	1608	52	1556
Run 4	LWP	24.863	23.326	1683	0	1683
	RWP	24.863	23.326	1683	181	1502
Run 5	LWP	24.863	24.595	293	0	293
	RWP	24.863	24.595	293	2	291

Figure 4.6 through Figure 4.9 show Dynatest and Pathway Services data gathered in both wheel paths over the same sections of pavement. The Pathway Services measurements from the 200-ft test section are compared with the profilometer and straight edges in Figure 4.10 and Figure 4.11. The Pathway Services data points with saturation errors were removed from the data sets before these plots were made. As one can see in these figures, the Pathway Services plots show little or no similarity between runs and rut depth erratically fluctuating between 0.00 and 1.00 inches. Measurements from the left wheel path are slightly less erratic than the right, however there are still large spikes in the data and the plot from the 200-ft test section shows no correlation between the Pathway Services system and the other methods. Because of this, it was

decided that the data from this system was not usable and it was recommended that ODOT have the system inspected.

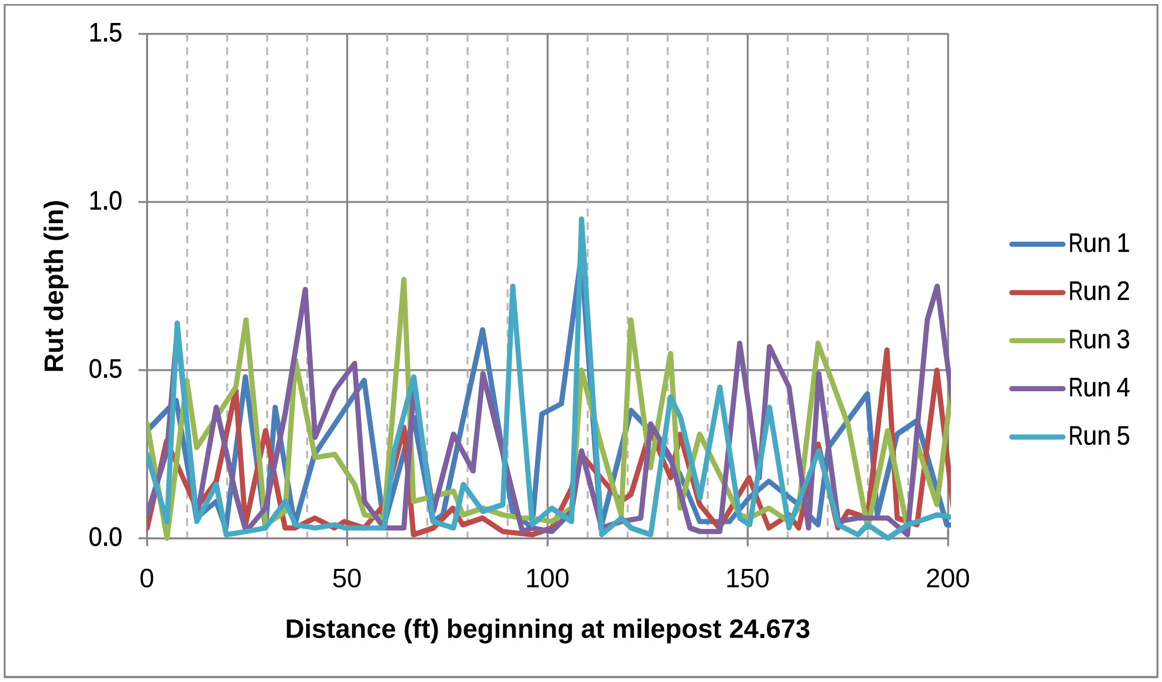

Figure 4.6. Sample plot of LRMS data from the Pathway Services system on US-30 (RWP)

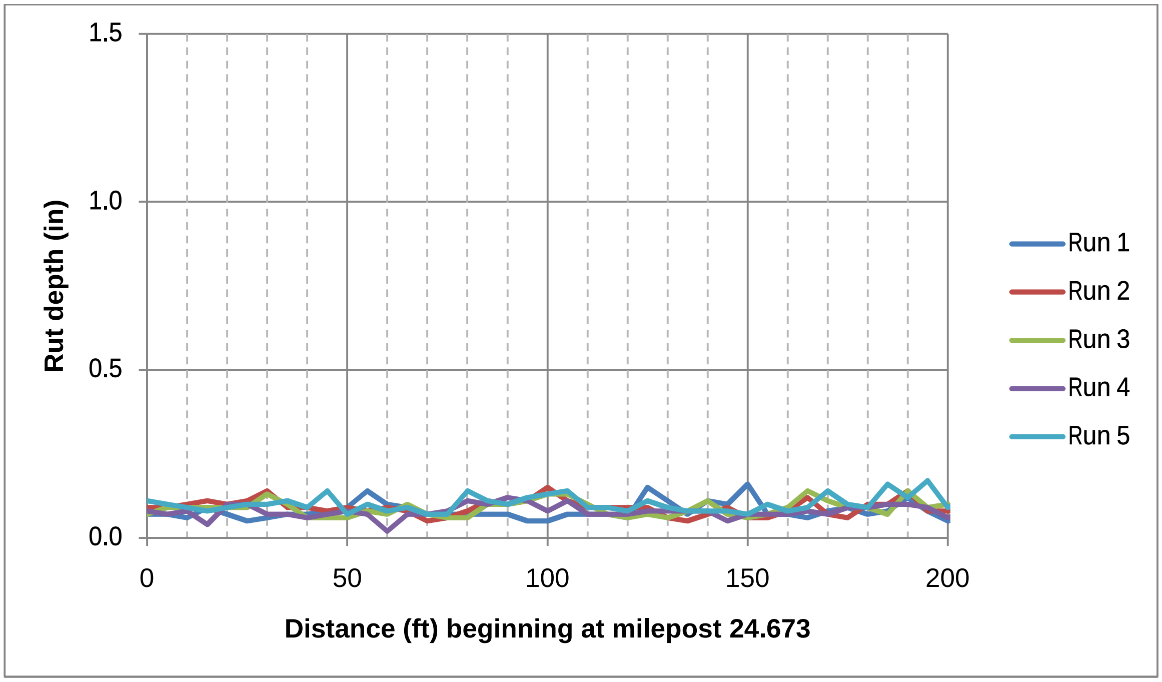

Figure 4.7. Sample plot of LRMS data from the Dynatest system on US-30 (RWP)

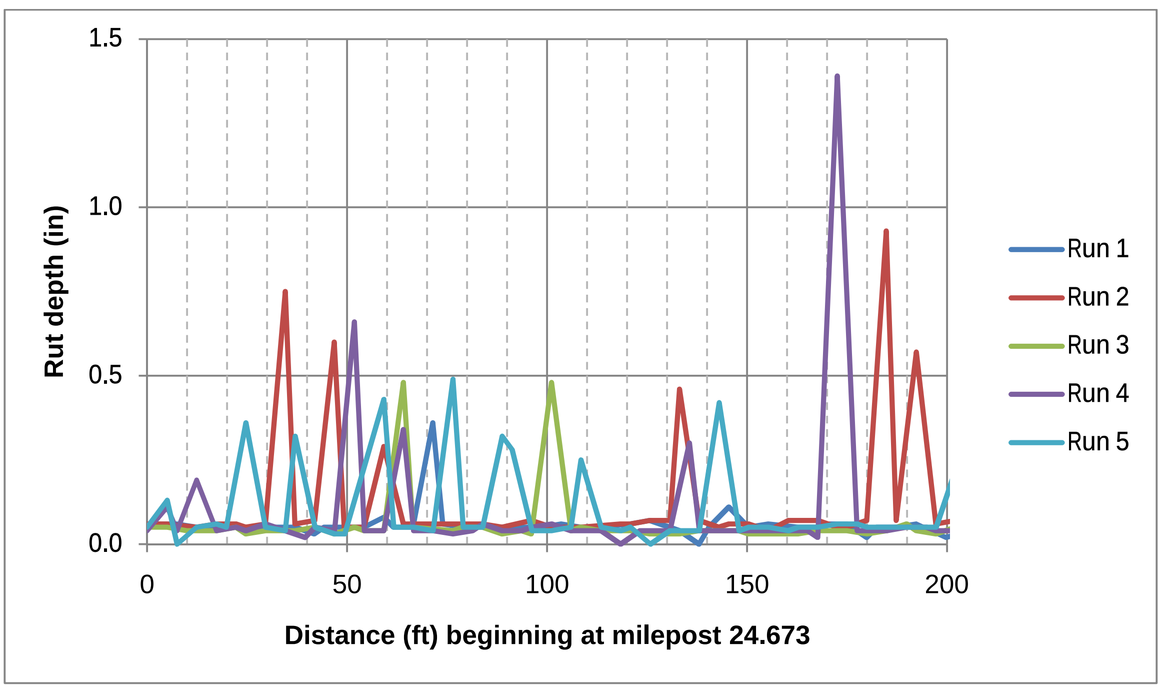

Figure 4.8. Sample plot of LRMS data from the Pathway Services system on US-30 (LWP)

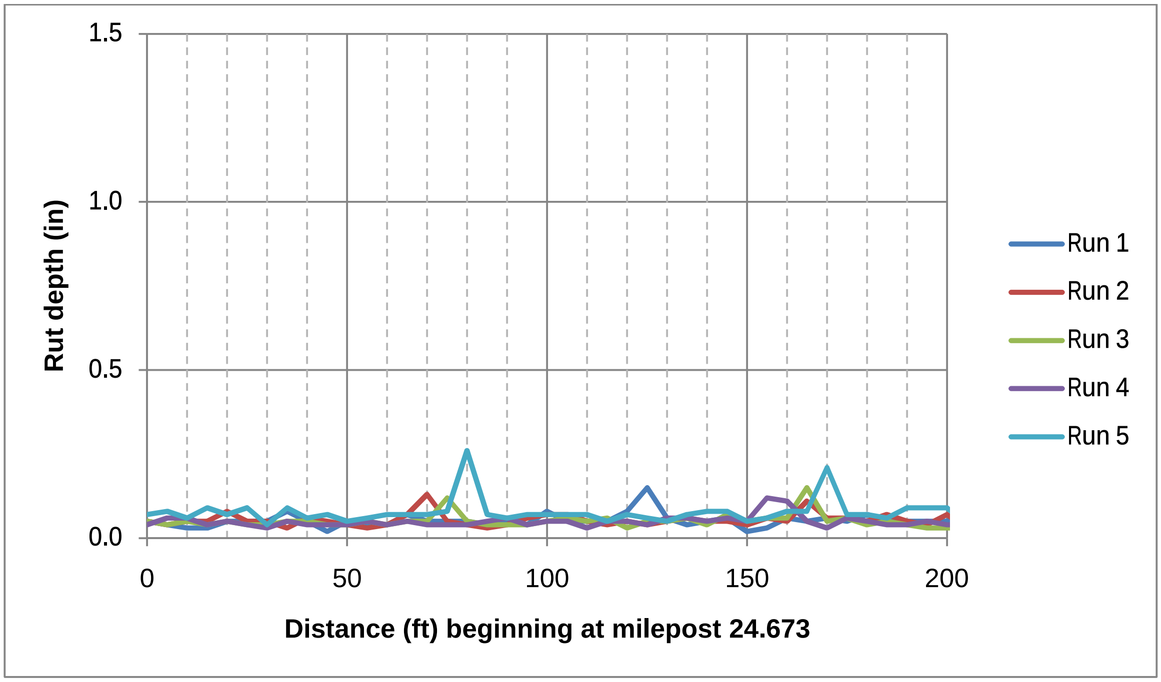

Figure 4.9. Sample plot of LRMS data from the Dynatest system on US-30 (LWP)

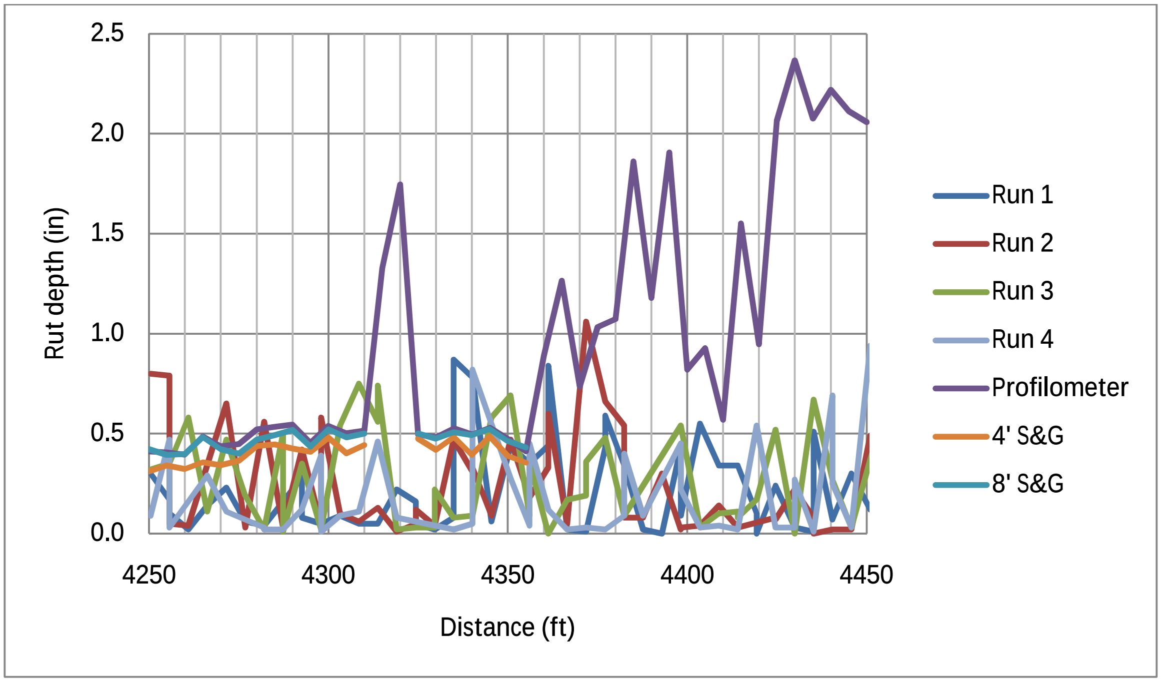

Figure 4.10. LRMS data from the Pathway Services system at the 200-ft test section on US-30 (RWP)

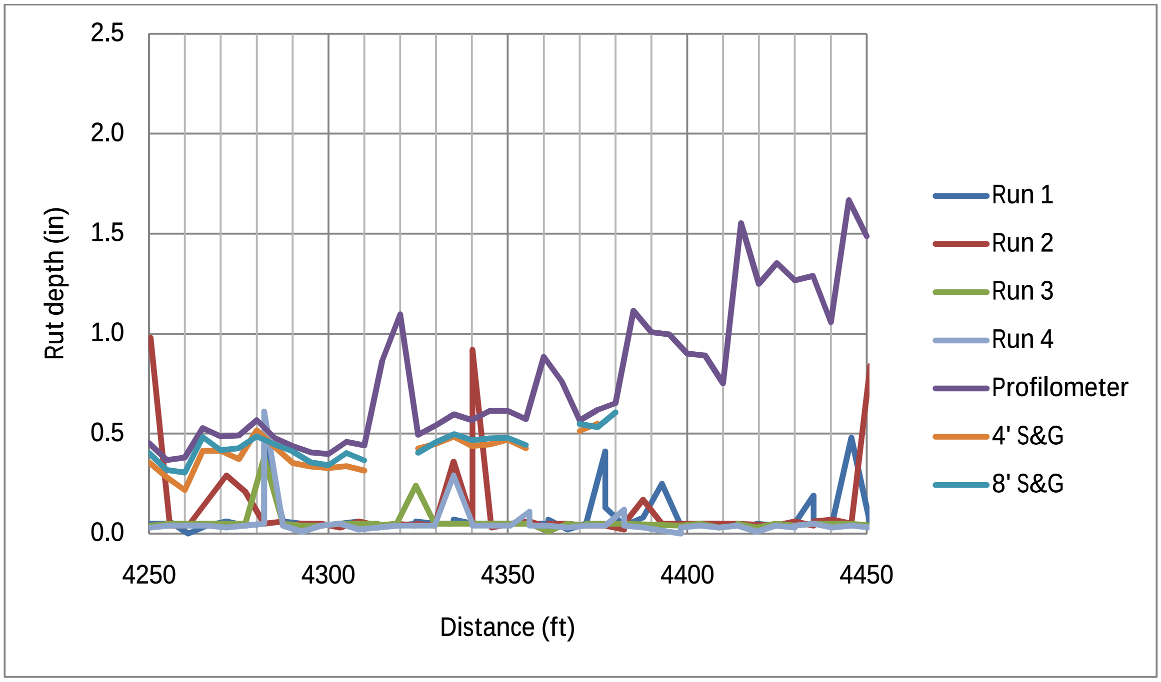

Figure 4.11. LRMS data from the Pathway Services system at the 200-ft test section on US-30 (LWP)

The inconsistency observed with the Pathway Services system raises some concern regarding the accuracy of data collected by ODOT for pavement rating. Past data should be checked for erratic rut depth readings. There may be a number of pavement sections that need to be re-profiled. Future use of the LRMS systems should be done with caution and data should be checked by the operator while on site if possible to determine if the measurements are reasonable and if any major, noticeable inconsistencies are present.

The system should also be checked regularly to ensure that measurements are repeatable. This could be done on a section of pavement with a range of rut depths that undergoes light use so that distresses do not change significantly over time. It is recommended that the selected pavement be profiled at least monthly to ensure that if the LRMS system malfunctions, a large amount of data and man-hours will not have been lost and many pavement sections do not need to be re-profiled. If the LRMS is being used frequently, checks may need to be run more often than just monthly.

The sets of data from the Dynatest LRMS system were examined in order to determine whether repeated runs produce similar results. The data collected using the Dynatest system is summarized in Table 4.2. A small number of points were missing from runs 2, 3, and 5. According to the ODOT workers, this was a result of the vehicle being forced to stop or reduce speed. The Dynatest system will not collect unless the vehicle is moving at a sufficient speed and data can be lost. These errors result in the omission of both the left and right rut measurements.

Table 4.2. General summary of data collected on US-30 using the Dynatest system

Data Set	Wheel path	Starting Milepost	Final Milepost	Total data points (n*)	Errors	Data points after errors removed (n)
Run 1	LWP	24.863	23.33933	1713	0	1713
	RWP	24.863	23.33933	1713	0	1713
Run 2	LWP	24.863	23.3327	1737	49	1688
	RWP	24.863	23.3327	1737	49	1688
Run 3	LWP	24.863	23.33175	1748	28	1720
	RWP	24.863	23.33175	1748	28	1720
Run 4	LWP	24.863	23.33364	1721	0	1721
	RWP	24.863	23.33364	1721	0	1721
Run 5	LWP	24.863	23.32986	1735	2	1733
	RWP	24.863	23.32986	1735	2	1733

A statistical analysis was conducted with IBM SPSS Statistics software using the analysis of variance (ANOVA) method and the Games-Howell post-hoc test. Pairs of data were tested to determine their difference using a significance level of 0.05. The results are shown in Table 4.3. Cells colored yellow show statistical dissimilarity. A natural log transformation was used on data from both wheel paths to achieve normality.

Table 4.3. Games-Howell post-hoc test on LRMS data from US-30

		Sig.	
Run # (I)	Run # (J)	LWP	RWP
Run 1	Run 2	.000	.000
	Run 3	.235	.001
	Run 4	.981	.392
	Run 5	.005	.000
Run 2	Run 1	.000	.000
	Run 3	.030	.972
	Run 4	.000	.037
	Run 5	.000	.117
Run 3	Run 1	.235	.001
	Run 2	.030	.972
	Run 4	.572	.191
	Run 5	.000	.023
Run 4	Run 1	.981	.392
	Run 2	.000	.037
	Run 3	.572	.191
	Run 5	.001	.000
Run 5	Run 1	.005	.000
	Run 2	.000	.117
	Run 3	.000	.023
	Run 4	.001	.000

The Games-Howell test results suggest that the similarity between the five runs made with the LRMS system is fairly weak, especially in the left wheel path. However, the distribution of rutting, shown in Figure 4.12 and Figure 4.13, suggest that the five runs would have all produced the same score using the ODOT pavement rating system.

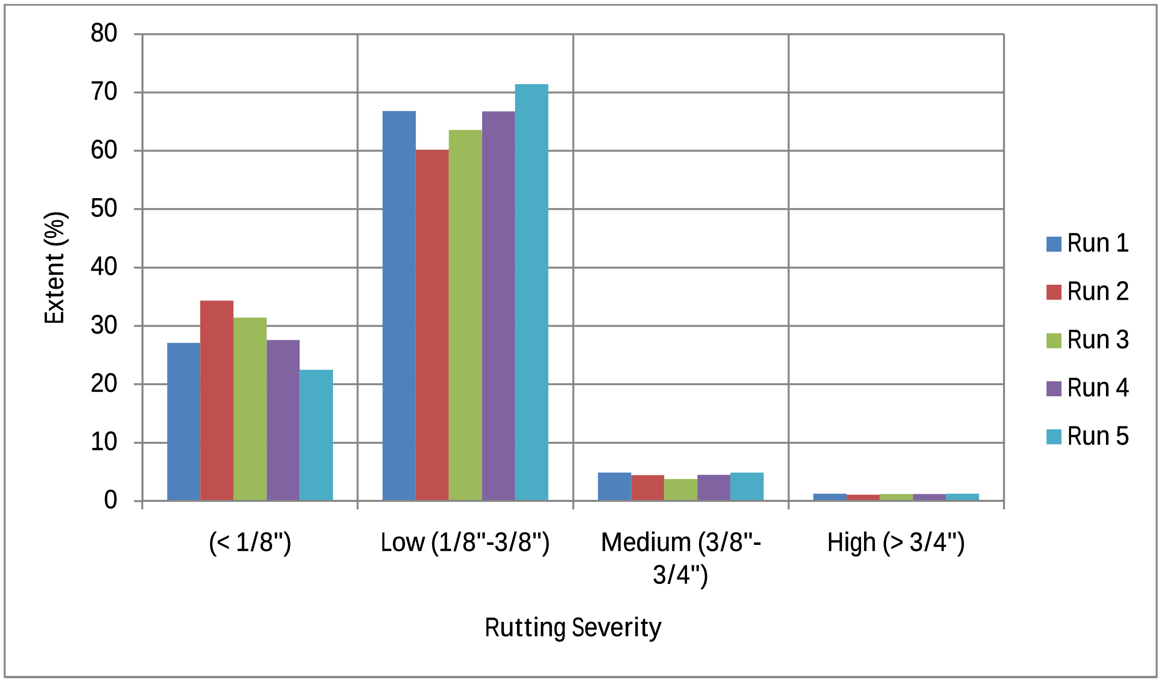

Figure 4.12. Distribution of rutting by severity on US-30 (LWP)

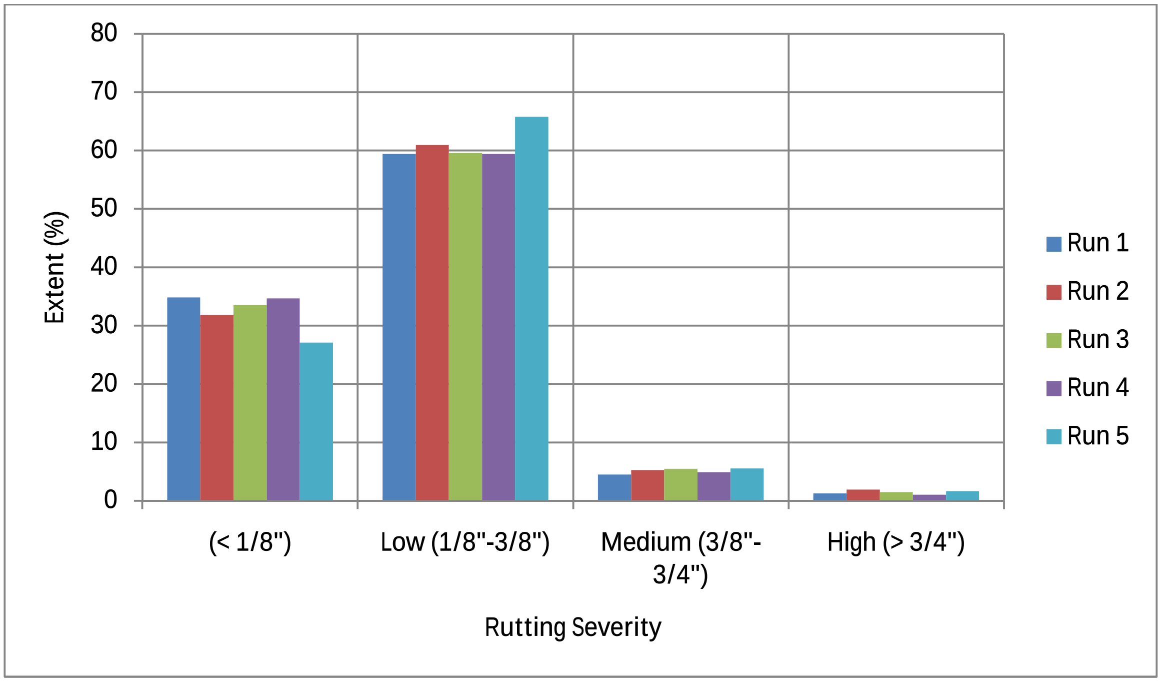

Figure 4.13. Distribution of rutting by severity on US-30 (RWP)

The 200-ft (60.96 m) test section was extracted from the LRMS data and compared with the profilometer and S&G data gathered at the test section. S&G measurements could not be obtained at many of the 5-ft (1.52 m) intervals due to the extreme severity of rutting at these locations. The dial gage was not able to reach the bottom of the rut. The profilometer was able to gather data at each interval however. The same ANOVA and Games-Howell tests were used in this analysis. Once again, a significance level of 0.05 was used. The natural log transformation was not necessary in this case. The results are shown in Table 4.4 and plots of the measurements are shown in Figure 4.14 and Figure 4.15. Unlike the previous test, the results of the ANOVA test on only the test section show strong statistical similarity and therefore imply strong repeatability. They also show that there was no statistical difference between the LRMS rut depth and alternative measurement methods.

Table 4.4. Games-Howell post-hoc test results on all data from the 200-ft (60.96 m) test section on US-30

Run # (I)	Run # (J)	Sig. LWP	Sig. RWP
Run 1	Run 2	1.000	1.000
	Run 3	1.000	1.000
	Run 4	1.000	.491
	Run 5	1.000	1.000
	Profilometer	.999	.999
	8 ft S&G	.752	1.000
	4 ft S&G	.232	.259
Run 2	Run 1	1.000	1.000
	Run 3	1.000	1.000
	Run 4	1.000	.538
	Run 5	1.000	1.000
	Profilometer	1.000	.996
	8 ft S&G	.543	.414
	4 ft S&G	.086	.660
Run 3	Run 1	1.000	1.000
	Run 2	1.000	1.000
	Run 4	1.000	.432
	Run 5	1.000	1.000
	Profilometer	.996	.999
	8 ft S&G	.610	.758
	4 ft S&G	.114	.449
Run 4	Run 1	1.000	.491
	Run 2	1.000	.538
	Run 3	1.000	.432
	Run 5	1.000	.396
	Profilometer	.999	.166
	8 ft S&G	.401	.027
	4 ft S&G	.051	1.000
Run 5	Run 1	1.000	1.000
	Run 2	1.000	1.000
	Run 3	1.000	1.000
	Run 4	1.000	.396
	Profilometer	.996	.999
	8 ft S&G	.480	1.000
	4 ft S&G	.065	.024

Run # (I)	Run # (J)	Sig. LWP	Sig. RWP
Profilometer	Run 1	.999	.999
	Run 2	1.000	.996
	Run 3	.996	.999
	Run 4	.999	.166
	Run 5	.996	.999
	8 ft S&G	.048	.961
	4 ft S&G	.004	.002
8 ft S&G	Run 1	.752	1.000
	Run 2	.543	.414
	Run 3	.610	.758
	Run 4	.401	.027
	Run 5	.480	1.000
	Profilometer	.048	.961
	4 ft S&G	.862	.017
4 ft S&G	Run 1	.232	.259
	Run 2	.086	.660
	Run 3	.114	.449
	Run 4	.051	1.000
	Run 5	.065	.024
	Profilometer	.004	.002
	8 ft S&G	.862	.017

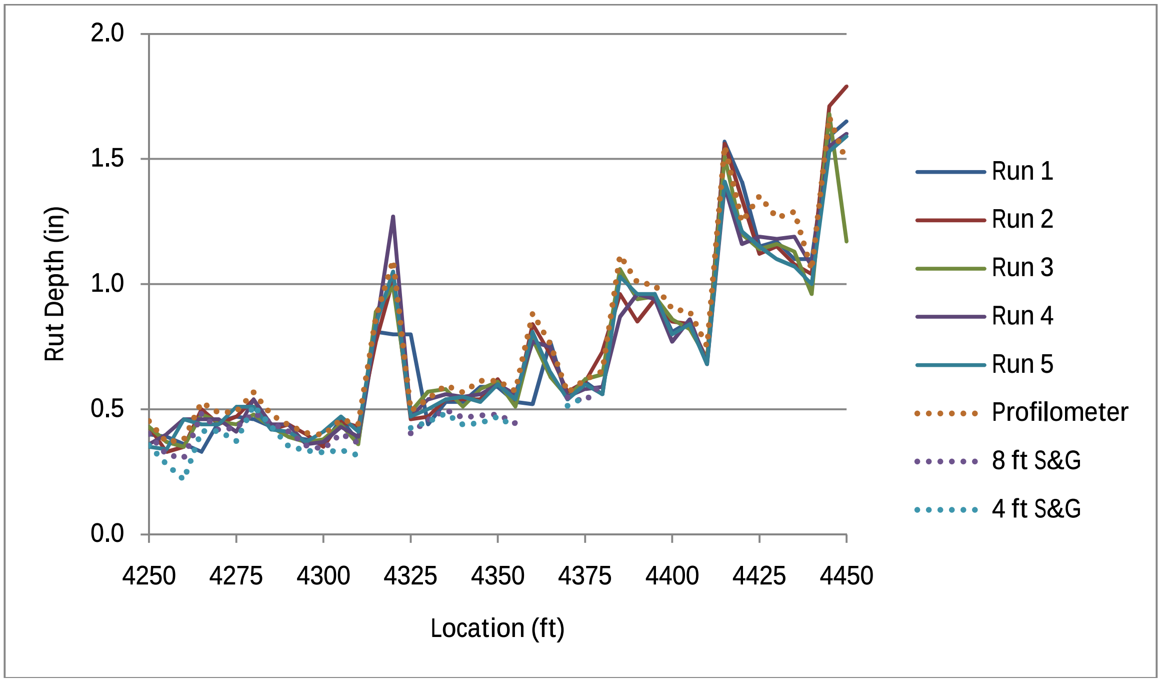

Figure 4.14. Rut depth measurements from 200 ft (60.96 m) test section on US-30 (LWP) (1 in = 25.4 mm)

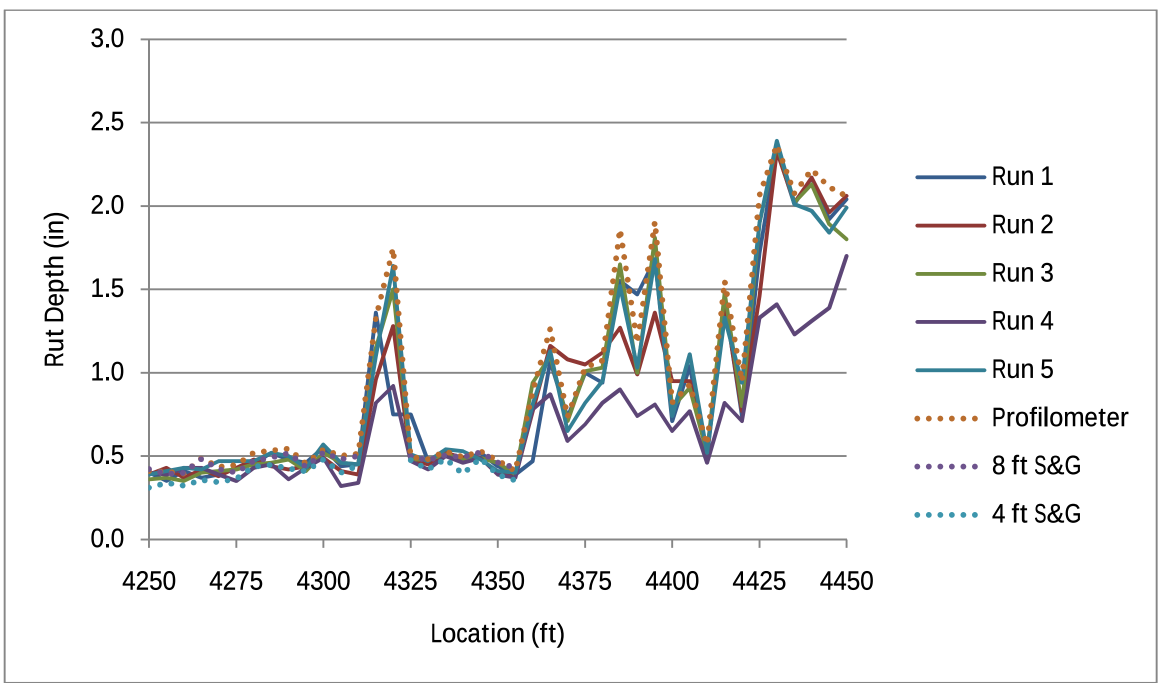

Figure 4.15. Rut depth measurements from 200-ft (60.96 m) test section on US-30 (RWP) (1 in = 25.4 mm)

4.2.2 Light Use/Medium Rutting on SR-682

The five runs collected with the Dynatest LRMS system were aligned using the reference point created with the temporary rumble strips and then compared using SPSS statistical analysis software. A summary of the collected data is shown in Table 4.5.

Table 4.5. General summary of data collected on SR-682 using the Dynatest system

Data Set	Wheel Path	Starting Milepost	Final Milepost	Total data points (n*)	Errors	Data points after errors removed (n)
Run 1	LWP	1	1.80303	968	0	968
	RWP	1	1.80303	968	0	968
Run 2	LWP	1	1.814898	973	0	973
	RWP	1	1.814898	973	0	973
Run 3	LWP	1	1.801384	981	0	981
	RWP	1	1.801384	981	0	981
Run 4	LWP	1	1.940341	1122	0	1122
	RWP	1	1.940341	1122	0	1122
Run 5	LWP	1	1.800189	980	0	980
	RWP	1	1.800189	980	0	980

Once the five runs were aligned using the artificial rut caused by the temporary rumble strips, ANOVA tests were conducted on the right and left wheel paths to determine whether the runs were statistically similar. The Games-Howell post-hoc test was used to provide a detailed comparison. A significance level of 0.05 was used. The results are shown in Table 4.6.

Table 4.6. Games-Howell post-hoc test results on LRMS data from SR-682

Run # (I)	Run # (J)	Sig.	
		LWP	RWP
Run 1	Run 2	.000	.999
	Run 3	.000	.751
	Run 4	.000	.875
	Run 5	.000	.650
Run 2	Run 1	.000	.999
	Run 3	.389	.613
	Run 4	.946	.767
	Run 5	.435	.511
Run 3	Run 1	.000	.751
	Run 2	.389	.613
	Run 4	.863	.999
	Run 5	1.000	1.000
Run 4	Run 1	.000	.875
	Run 2	.946	.767
	Run 3	.863	.999
	Run 5	.891	.994
Run 5	Run 1	.000	.650
	Run 2	.435	.511
	Run 3	1.000	1.000
	Run 4	.891	.994

The Games-Howell test shows a strong statistical similarity between each set of data from the right wheel path; however the left wheel path data from Run 1 do not correlate with the other data sets. There are a few instances where the measured rut depths from Run 1 are slightly less than the other runs over a short distance (see Figure 4.16). In these segments, the measured rut widths in Run 1 are also significantly less than the widths measured in other runs. This may suggest that the vehicle had drifted from the center of the lane or the laser system was being influenced by pavement deterioration observed at the center of the roadway (see Figure 4.17).

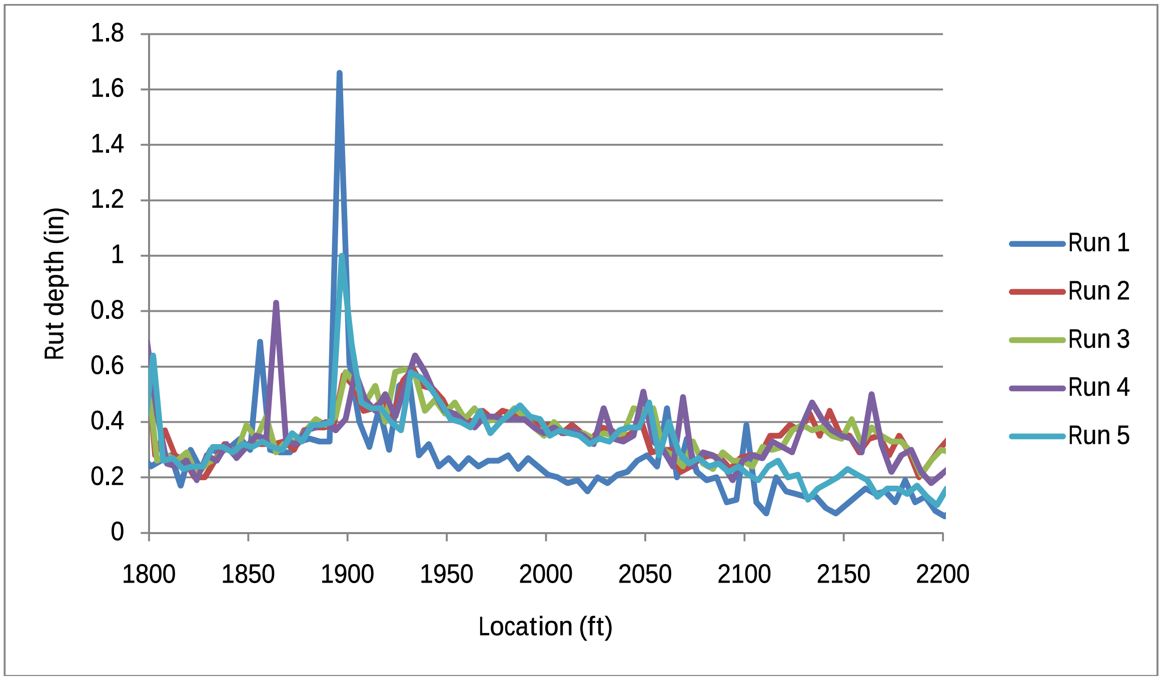

Figure 4.16. Rut depth measurements from LRMS in the left wheel path on SR-682 (1800-2200 ft) (1 in =25.4 mm)

Figure 4.17. Pavement deterioration on SR-682

Overall, the five runs show strong statistical similarity. There are some outlying data that created some dissimilarity in the first run; however, considering that these tests were run in an uncontrolled environment where the points do not align perfectly, pavement deterioration may influence measurements, and curves in the road may have influenced the driver's ability to remain at the center of the lane, the end results are convincing enough to deem the measurements repeatable. The distribution of data from SR-682 separated by PCR severity level is shown in Figure 4.18 and Figure 4.19. The distributions are similar between runs; however the inconsistency in the left wheel path data from run 1 is evident in Figure 4.18.

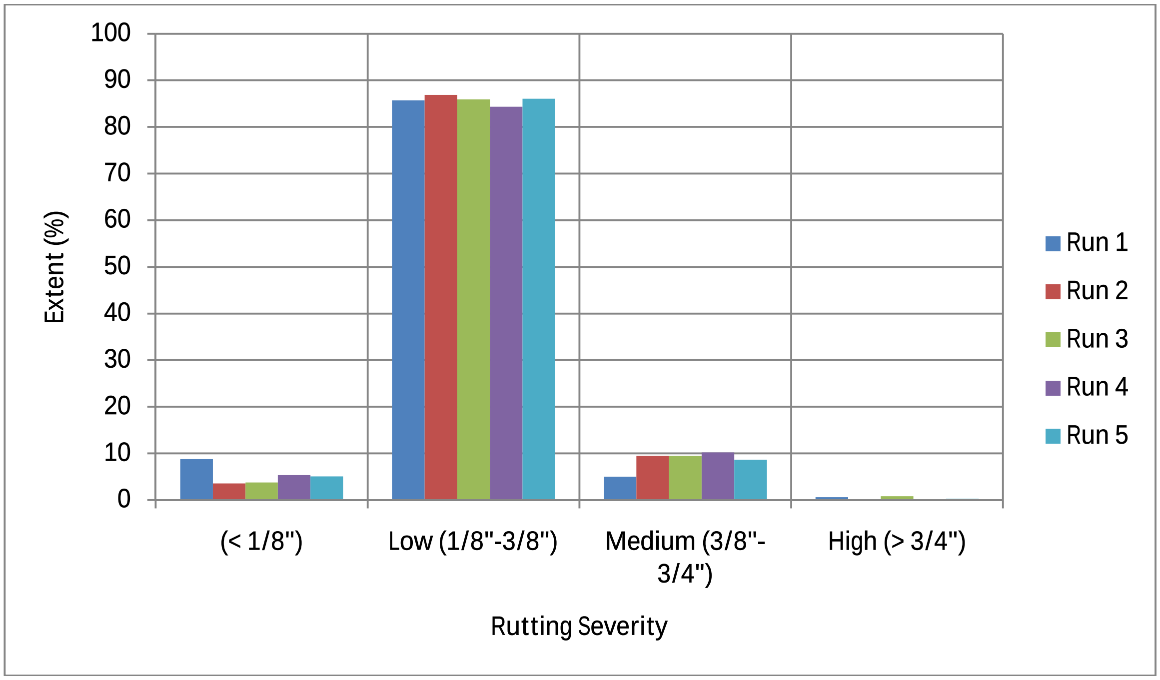

Figure 4.18. Distribution of rutting by severity on SR-682 (LWP)

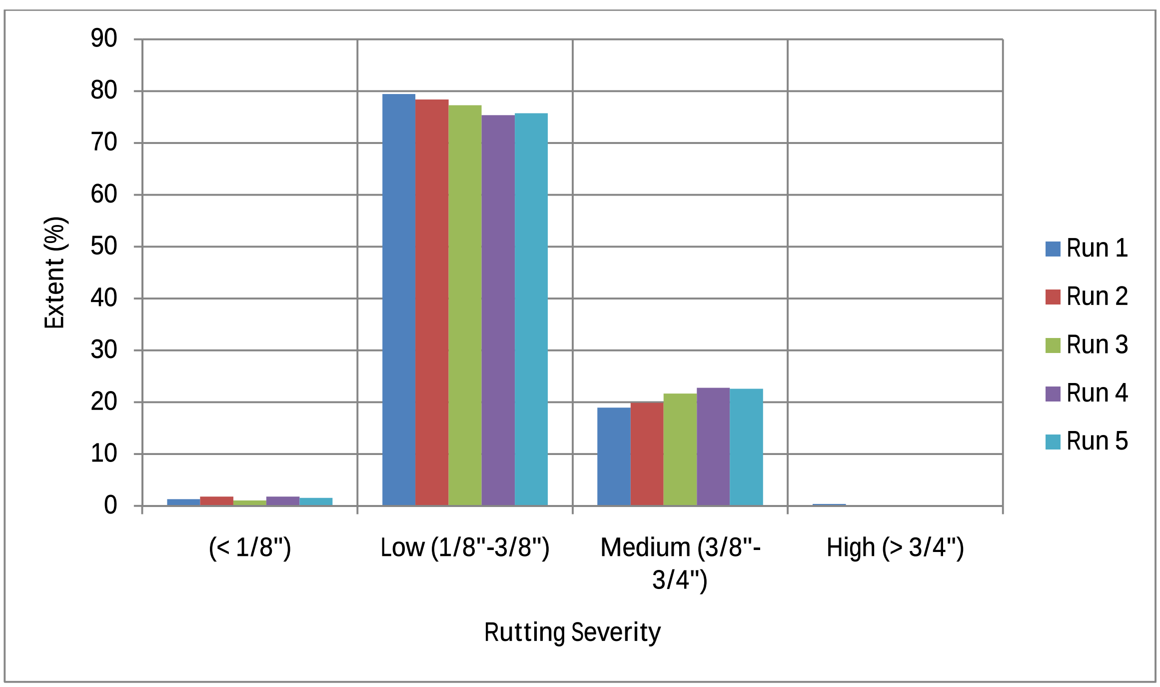

Figure 4.19. Distribution of rutting by severity on SR-682 (RWP)

A separate ANOVA analysis was conducted on the LRMS data from the 200-ft (60.96 m) test section. The results from the Games-Howell post hoc tests are shown in Table 4.7. The results of the test show that the five runs were statistically similar; however the right wheel path measurements from Run 3 show a fairly weak correlation with the rest of the data. As was observed previously with Run 1, there exist data from Run 3 that are less than the measurements from other runs. Similarly, the measured rut widths corresponding with these points are also noticeably less than what is shown in the other runs. Because there was little deterioration observed in the right wheel path, it is likely that this was caused by the profiler vehicle drifting away from the center of the lane. In future studies, it may be helpful to videotape the vehicle as it passes over a test section to determine if this is in fact the cause.

Table 4.7. Games-Howell post-hoc test results on LRMS, profilometer, and S&G data from the 200-ft (60.96 m) test section on SR-682

Run # (I)	Run # (J)	Sig. LWP	Sig. RWP
Run 1	Run 2	.843	1.000
	Run 3	1.000	.086
	Run 4	.973	.998
	Run 5	1.000	1.000
	Profilometer	.007	.966
	8 ft S&G	.459	.126
	4 ft S&G	.000	.000
Run 2	Run 1	.843	1.000
	Run 3	.927	.167
	Run 4	1.000	1.000
	Run 5	.794	1.000
	Profilometer	.000	.992
	8 ft S&G	1.000	.241
	4 ft S&G	.036	.000
Run 3	Run 1	1.000	.086
	Run 2	.927	.167
	Run 4	.994	.336
	Run 5	1.000	.202
	Profilometer	.005	.612
	8 ft S&G	.639	1.000
	4 ft S&G	.001	.448
Run 4	Run 1	.973	.998
	Run 2	1.000	1.000
	Run 3	.994	.336
	Run 5	.967	1.000
	Profilometer	.000	1.000
	8 ft S&G	.970	.461
	4 ft S&G	.005	.000
Run 5	Run 1	1.000	1.000
	Run 2	.794	1.000
	Run 3	1.000	.202
	Run 4	.967	1.000
	Profilometer	.000	.993
	8 ft S&G	.276	.287
	4 ft S&G	.000	.000
Profilometer	Run 1	.007	.966
	Run 2	.000	.992
	Run 3	.005	.612
	Run 4	.000	1.000
	Run 5	.000	.993
	8 ft S&G	.000	.756
	4 ft S&G	.000	.001
8 ft S&G	Run 1	.459	.126
	Run 2	1.000	.241
	Run 3	.639	1.000
	Run 4	.970	.461
	Run 5	.276	.287
	Profilometer	.000	.756
	4 ft S&G	.036	.189
4 ft S&G	Run 1	.000	.000
	Run 2	.036	.000
	Run 3	.001	.448
	Run 4	.005	.000
	Run 5	.000	.000
	Profilometer	.000	.001
	8 ft S&G	.036	.189

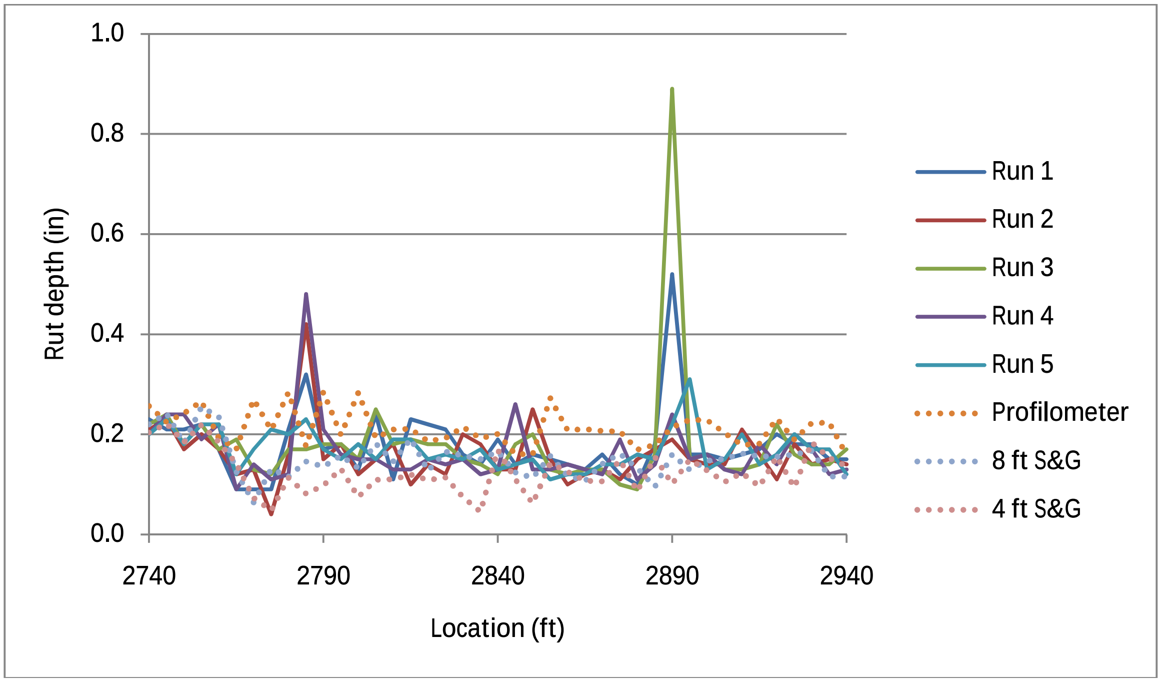

Figure 4.20. Rut depth measurements from the 200-ft (60.96 m) test section on SR-682 (LWP) (1 in = 25.4 mm)

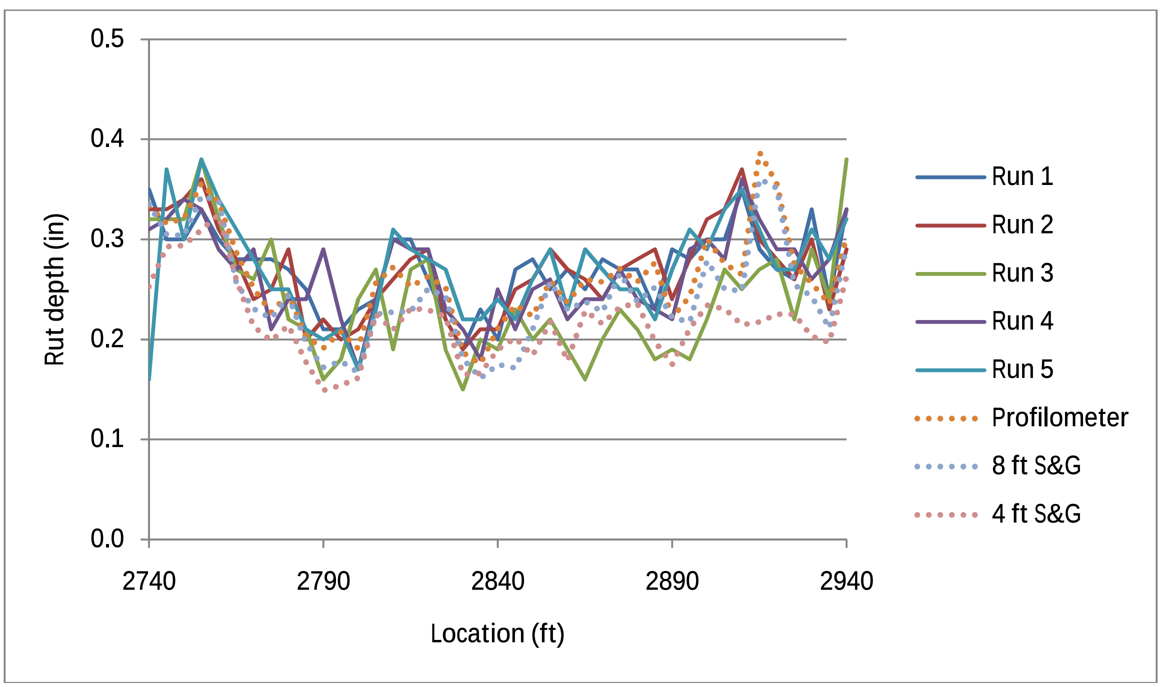

Figure 4.21. Rut depth measurements from the 200-ft (60.96 m) test section on SR-682 (RWP) (1 in = 25.4 mm)

The LRMS data correlate well with the 8 ft straight edge in all cases; however the profilometer measurements correlated with the LRMS readings only in the right wheel path. As one can see in Figure 4.20, the profilometer measurements are frequently higher than the other measurements. This is due to the deterioration in the left wheel path and near the centerline as shown in Figure 4.17. Small pits in the roadway surface are read by the profilometer wheel and create low points in the profile that are interpreted as the bottom of the rut by the rut depth algorithm discussed in Section 2.4. An example of this is shown in Figure 4.22. The LRMS system may not be influenced by this type of deterioration due to the shallow angle at which the laser hits the pavement surface. Its effects may also be diminished by the filtering used in the Dynatest software. The data from the profilometer in the left wheel path of SR-682 is assumed to be flawed and is disregarded in the comparison of measurement methods.

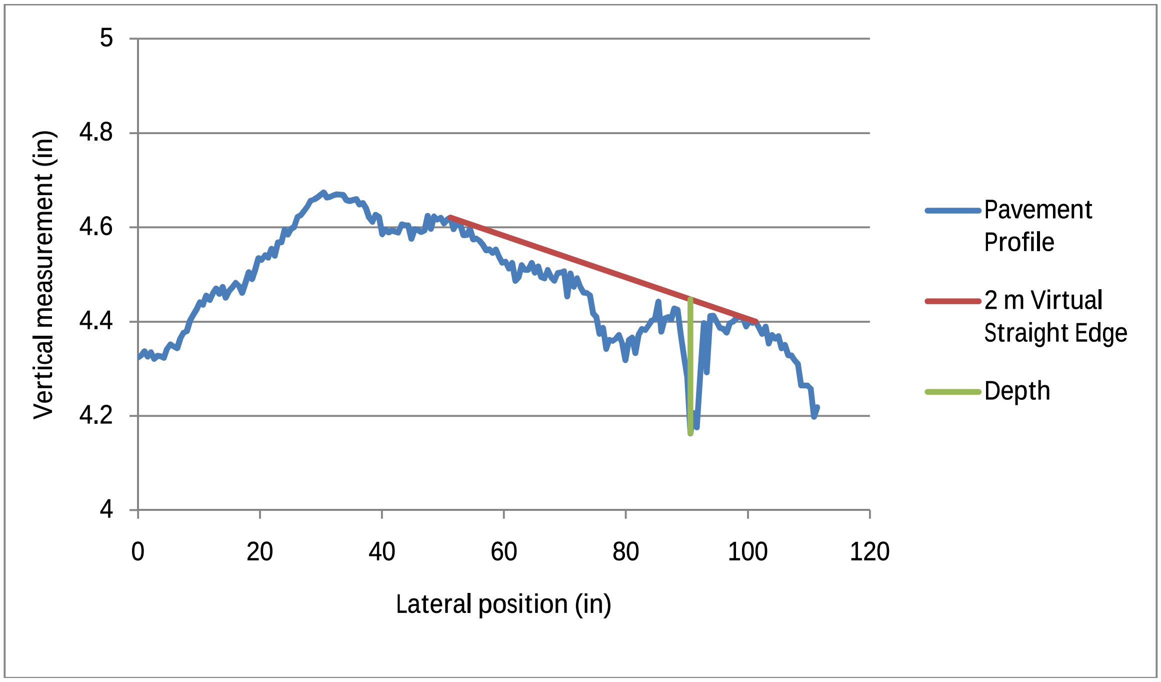

Figure 4.22. Pavement profile from profilometer on SR-682 (LWP) where depth measurement was influenced by pavement deterioration (@ 2780 ft) (1 in = 25.4 mm)

4.3 Discussion

The results of the LRMS tests and ANOVA analyses satisfactorily demonstrate repeatability. The US-30 test showed some weakness in repeatability; however the statistical analysis may be misleading because of the low severity of rutting over most of the pavement segment that was profiled. The variation in this test may have been statistically significant relative to the mean rut depth; however the variation was small enough to be considered acceptable. The mean absolute deviation for each test is listed in Table 4.8 and Table 4.9. The combined mean absolute deviations of 0.026 inches (0.660 mm) for US-30 and 0.030 inches (0.762 mm) for SR-682 are not high enough to suggest that the differences between runs could have a major impact on the overall characterization of a pavement section by the LRMS.

Table 4.8. Mean absolute deviation of LRMS data from US-30

	unit	LWP	RWP	Combined (LWP and RWP)
Number of points (n)	-	1607	1607	3214
Mean Absolute Deviation	(in)	0.024	0.028	0.026
	(mm)	0.61	0.71	0.66
Standard Deviation of Absolute Deviation	(in)	0.025	0.029	0.027
	(mm)	0.64	0.74	0.69
Upper 95% Confidence Interval	(in)	0.026	0.029	0.027
	(mm)	0.66	0.74	0.69
Lower 95% Confidence Interval	(in)	0.023	0.027	0.025
	(mm)	0.58	0.69	0.64

Table 4.9. Mean absolute deviation of LRMS data from SR-682

	unit	LWP	RWP	Combined (LWP and RWP)
Number of points (n)	-	845	845	1690
Mean Absolute Deviation	(in)	0.033	0.026	0.030
	(mm)	0.84	0.66	0.76
Standard Deviation of Absolute Deviation	(in)	0.036	0.021	0.030
	(mm)	0.91	0.53	0.76
Upper 95% Confidence Interval	(in)	0.036	0.027	0.031
	(mm)	0.91	0.69	0.79
Lower 95% Confidence Interval	(in)	0.031	0.025	0.028
	(mm)	0.79	0.64	0.71

As a tool for evaluating pavement conditions, the LRMS system shows satisfactory repeatability. However, in the SR-682 test, the extent of medium severity rutting in the right wheel path for all five runs is coincidentally near the 20% threshold between the “occasional” and “frequent” ratings. Runs 1 and 2 would have resulted in a medium-occasional rating, while Runs 3, 4, and 5 would have resulted in a medium-frequent rating. This variation is likely caused by the lateral position of the profiler vehicle in the lane and the exact location of each measurement. To compensate for this problem, an alternative rating system that considers the extent of rutting at all levels of severity may be appropriate. This is discussed further in the next section.

When compared to the profilometer and 8-ft straight edge, the LRMS showed a satisfactory level of accuracy and precision. With the exception of the profilometer data from the left wheel path of SR-682, the differences in measurements were statistically insignificant. Measurements taken by the 4 ft straight edge during both tests were generally inconsistent with the profilometer and 8-ft straight edge. Figure 4.23 shows a profile of US-30 created by the profilometer with a 2-m virtual straight edge and a 4 ft virtual straight edge. The 4-ft straight edge is clearly unable to span the entire rut. This may not always be the case, since the validity of the 4-ft straight edge measurement is dependent on the width of the rut; however, because the potential for significant error exists when using this length of straight edge, its use should be discontinued.

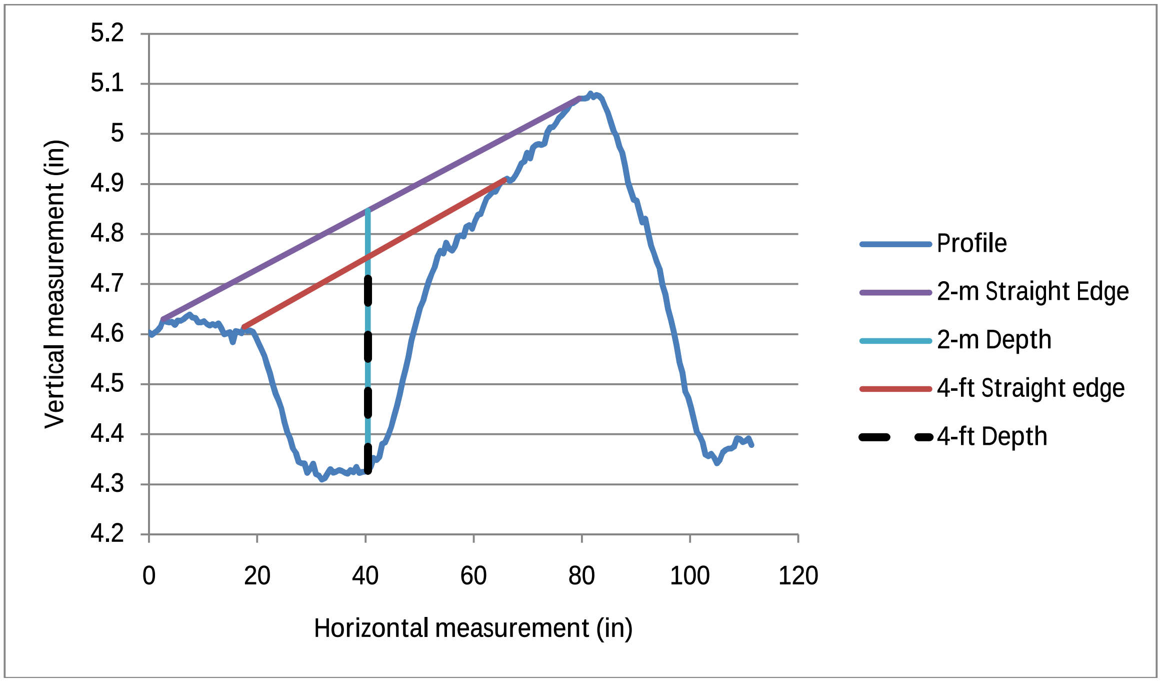

Figure 4.23. 2-m and 4-ft virtual straight edge models (1 in = 25.4 mm)

5 LRMS AND THE ODOT PAVEMENT CONDITION RATING SYSTEM

5.1 Procedure

The PCR ratings for rutting based on S&G measurements were compared to data collected in ODOT District 10 using the INO LRMS system on the Dynatest profiler. There were 397 locations found for which there exists a PCR score based on manual measurements as well as LRMS data. The following Ohio counties were represented in the data: Athens, Gallia, Hocking, Meigs, Monroe, Morgan, Noble, Vinton, and Washington.

The data files were imported into Microsoft Excel and separated into the necessary log point intervals to correspond with the S&G data. Each interval was assigned a PCR score based on rut depth and extent according to the key and rating form shown in Table 5.1 Table 5.2. A summary of the scores for each site can be found in Appendix C.

Extraction of the PCR scores was done in Excel, using a spreadsheet that was pre-made to allow one to simply paste the data from the files created by the Dynatest software. To do this, each file (extension ".HDR") was imported as a comma-delimited data set. The rows beginning with "5412" were isolated using the "sort" function, and then copied into the pre-made spreadsheet. The spreadsheet then counted the number of rut depth measurements that fell into each severity category and multiplied each of these counts by the measurement interval. These three numbers were divided by the overall length to find the extent of rutting in each severity category. The PCR rating key and rating form for flexible pavement from the ODOT PCR manual are shown in Figure 1.1

and Figure 1.2 (ODOT, 2006). The rating key and rating form for composite pavement differ slightly; however rutting is evaluated and scored the same way.

5.2 Results and Discussion of Comparison with S&G PCR Ratings

In Table 5.1, the distribution (percent) of PCR scores extracted from LRMS data, organized by corresponding S&G ratings, is shown. A sizable portion of the LRMS scores are in the MO and HO categories. This may indicate that a major cause of the higher PCR scores derived from the LRMS is the effect of isolated areas of medium or severe rutting distresses. These areas are likely missed during the manual rut measurement process.

Table 5.1. Distribution of LRMS PCR scores by corresponding S&G rating

		LRMS (%)									
		none	LO	LF	LE	MO	MF	ME	HO	HF	HE
S&G	none	15.26	10.00	3.16	0.53	28.95	5.79	2.11	33.16	1.05	
	LO	18.99	16.46	2.53		20.25	7.59	1.27	32.91		
	LF	21.54	18.46			40.00	4.62	3.08	10.77	1.54	
	LE	21.95	29.27	2.44		31.71	4.88	2.44	7.32		
	MO		5.26			31.58	10.53		52.63		
	MF					66.67			33.33		
	ME										
	HO										
	HF										
	HE										

Table 5.2. Average LRMS PCR scores grouped by corresponding S&G score

		Average
S&G	none (0)	4.03
	LO (1.8)	3.70
	LF (2.4)	3.26
	LE (3.0)	2.80
	MO (4.2)	5.17
	MF (5.6)	4.80
	ME (7.0)	N/A
	HO (6.0)	N/A
	HF (8.0)	N/A
	HE (10.0)	N/A

In order to more closely correlate the LRMS PCR with the S&G PCR, it may be necessary to reconsider the method used for rating pavements for rutting when the LRMS is used. The high number and density of data points produced with the automated system might otherwise cause small segments of pavement with higher distresses to have the greatest influence on the overall score, regardless of whether the small segments are truly representative of the overall section.

Of the pavement sections measured with the LRMS that were rated as either MO or HO, 25.4% had rutting at the highest measured severity over less than 1% of the total pavement section length. 64.9% of these sections had rutting at the highest measured severity over less than 5% of the total length. To ensure that the pavement rating is an accurate description of a section's overall conditions, a threshold for the "occasional" classification for extent may be more practical. For example: instead of an extent of 0-25% being classified as "occasional," 1-25% or 5-25% might be more appropriate. The effect this might have on PCR score discrepancies between rating methods is shown in Table 5.3 and Table 5.4.

Table 5.3. Effect on the overall average difference between LRMS and S&G PCR scores when the lower boundary of "occasional" rating range is changed

Range for "occasional" classification	0-25%	1-25%	2-25%	3-25%	4-25%	5-25%
Average difference in PCR scores (LRMS-S&G)	2.467	2.121	1.872	1.722	1.575	1.485

Table 5.4. Effect on the average differences between LRMS and S&G PCR scores when the lower boundary of "occasional" rating range is changed

		Average PCR Score from LRMS		
Range for "occasional" classification		**0-25%**	**1-25%**	**5-25%**
PCR Score from S&G	none (0)	4.03	3.67	2.97
	LO (1.8)	3.70	3.35	2.89
	LF (2.4)	3.26	2.97	2.44
	LE (3.0)	2.80	2.43	1.63
	MO (4.2)	5.17	4.91	4.54
	MF (5.6)	4.80	4.20	4.20
	ME (7.0)	N/A	N/A	N/A
	HO (6.0)	N/A	N/A	N/A
	HF (8.0)	N/A	N/A	N/A
	HE (10.0)	N/A	N/A	N/A

As Table 5.3 demonstrates, the 5%-25% range for the "occasional" rating dramatically reduces the difference in PCR score between methods. Raising the lower boundary to 5% would allow the LRMS data to produce a PCR score that more accurately represents the state of the pavement section being examined. Spikes in the data that may be caused by errors or other types of pavement deterioration instead of actual rutting would be unlikely to influence the PCR score. More importantly, small sections of heavy rutting that produce outliers in the data would not cause a mischaracterization of the overall pavement section.

Although altering the range for the “occasional” rating reduces the impact of using the LRMS in lieu of S&G, there remains a notable difference in scores. Other changes could be devised to further reduce the difference in scores; however because the tests conducted on US-30 and SR-682 showed that the LRMS can produce accurate, reliable, and repeatable results, doing so would require altering data that is already assumed to be correct. The remaining difference in LRMS and S&G scores after changing the “occasional” rating criteria should be attributed to the high density of measurements gathered by the LRMS.

While the 5%-25 range for “occasional” rutting is recommended specifically for the PCR score, sections of pavement with increased rutting that are not extensive enough to exceed 5% of the overall length of the site should not be ignored. Such sections in the data that would not count towards the overall PCR score may represent isolated asphalt stability issues that need addressed as potential wet accident locations. These sections should be properly treated as high stress locations per ODOT guidelines during the next rehabilitation. The existence of localized areas of severe rutting can be determined by checking the extent of rutting at each severity level while analyzing the .HDR file. If such an area is present, it can be easily located in the data using the conditional formatting tool in Microsoft Excel. Once the location is found, a follow-up visual inspection of the site is recommended.

6 SUMMARY AND CONCLUSIONS

6.1 Summary

This study was conducted to assess the performance of the laser system and develop a method for extracting PCR scores from rut depth data gathered with the LRMS. The Laser Rut Measurement System provides the Ohio Department of Transportation with a valuable tool for evaluating the condition of pavement infrastructure. The high density of measurements and the accuracy of the laser system allow for a much higher quality assessment of rutting distresses than the traditional manual measurement methods. The ODOT profiler vehicles also allow pavement raters to evaluate a pavement segment in a much shorter amount of time and in a safer manner. Manual measurement requires the pavement rater to be exposed to the hazards of traffic. The ODOT profiler vehicle has the ability to operate while moving with the flow of traffic, thereby dramatically reducing risk of injury. The effect of the length of the straight edge used for manual measurements was also examined.

To test the system's performance, two tests were conducted on selected pavement sections. The first test was performed on a west-bound section of US-30 in Wayne County, Ohio. This section is heavily used and had undergone light rutting over most of its length, with the exception of a severely rutted 200-ft (60.96 m) section at the approach to its intersection with SR-94. This section of severe rutting was also measured using the profilometer, 8 ft straight edge, and 4 ft straight edge. ODOT provided LRMS data from five runs made with the profiler vehicle over a section approximately 1.53 mi (2.46 km) in length that included the 200-ft (60.96 m) test section. The second test was over a lightly used section of SR-682 in Athens County, Ohio. This segment of SR-682 had undergone low-to-medium rutting over its entire length. A 200-ft (60.96 m) section was selected and rut depth was measured using each of the four methods. Again, ODOT provided LRMS data from five runs over a section approximately 0.80 mi (1.29 km) in length that included the 200-ft (60.96 m) test section.

Statistical analyses were conducted on the data gathered from the two tests using ANOVA tests and Games-Howell post-hoc tests. The results of only the LRMS were examined for accuracy and repeatability, since the other methods were presumed accurate. The statistical analysis of the data from US-30 showed weak statistical similarity when the entire length of profiled pavement was considered. When only the 200-ft (60.96 m) test section was considered, strong statistical similarity was found. When the data from SR-682 was analyzed, statistical similarity between runs was found for the entire pavement length as well as the 200-ft (60.96 m) test section at this site. The mean absolute deviations for the tests at SR-30 and SR-682 were 0.026 inches (0.660 mm) and 0.030 inches (0.762 mm) respectively. The distributions of measurements by PCR severity level over the entire pavement lengths show that the LRMS system is capable of producing the consistent and reliable PCR scores. Given that these tests were run under somewhat uncontrolled field conditions, it is believed that the results of these tests and analyses are evidence enough to conclude that the LRMS system produces repeatable and accurate results.

Rut depth data from the LRMS, profilometer, 8-ft S&G, and 4-ft S&G for the 200-ft (60.96 m) test sections were analyzed and compared using the ANOVA and Games-Howell tests to assess the precision of the LRMS system and to examine the impact of the shorter straight edge on rut depth measurements. With the exception of the left wheel path data from the profilometer on SR-682, the LRMS measurements at both sites strongly correlated with the profilometer and 8-ft S&G. The profilometer data from SR-682 were influenced by deterioration in the left wheel path that caused the rut depth algorithm to interpret pits in the pavement surface as the bottom of the rut. These data were considered invalid and were disregarded. The strong statistical similarity found in the results of the ANOVA and Games-Howell tests indicate that the LRMS produces accurate rut depth measurements. The 4-ft S&G however did not show strong similarity to the other measurement methods. The shorter length did not allow the straight edge to fully span the width of the rut in many cases. To prevent error and inaccuracy, the 4-ft S&G should be replaced with a device that meets the criteria listed in ASTM E 1703/E 1703M (1995).

6.2 Recommendations

The LRMS displayed sufficient precision, accuracy, and repeatability in this study and is capable of producing reliable information for pavement evaluation purposes. However, the LRMS system mounted on the Pathway Services profiling vehicle showed that the system may be susceptible to malfunction or require service periodically. To ensure that the system continues to operate properly, regular checks should be conducted to ensure that data is accurate. It is recommended that a section of light-use, low-traffic pavement with a range of rutting distress be selected for checks. The profiler vehicle should be run on this section monthly to ensure that readings are relatively unchanging. More frequent checks may be necessary if the profiler is undergoing heavy use. Checks conducted less frequently may be misleading due to changes in the pavement surface caused by environment or its continued use.

Throughout the LRMS data gathered at both sites, there are short sections where one of the five runs produces significantly lower rut depth values than the others. It is suspected that this was a result of the profiler vehicle wandering laterally. Further study may be needed to determine the extent to which this may affect results. It is important that the LRMS operators attempt to keep the vehicle traveling within the existing wheel paths to improve the likelihood of consistent results. Regardless, the LRMS system demonstrated adequate performance and proved itself a reliable method for measuring rut depth and characterizing pavement conditions. Statistical similarity was found between runs at both test sites suggesting that the LRMS is capable of producing precise and repeatable measurements. At both 200-ft test sections, the LRMS was able to produce rut depth measurements statistically similar to the profilometer and 8-ft S&G method. This shows that the LRMS was able to gather accurate rut depths as well. The 4-ft S&G, however, did not prove to be as accurate or precise as the other three methods used. The 4-ft straight edge was unable to properly span the entire width of the rut. It was further restricted by the fixed position of the dial gage. Because the error caused by the 4-ft S&G is entirely dependent on the rut width and the lateral position of the deepest part of the rut (both unknown), it was not practical to attempt to adjust past data gathered with this straight edge. It is highly recommended that ODOT replace this instrument with a straight edge 2-m or greater in length.

PCR scores can easily be extracted from the Dynatest .HDR files using the method described in Section 4.1. To prevent small, isolated areas of heavier rutting from mischaracterizing the pavement section, a range of 5-25% is suggested for the "occasional" extent classification. These isolated areas that do not account for 5% or more of the section length should still be reported and considered when performing rehabilitation. The presence of isolated and localized sections of severe rutting is represented in the extent values calculated during the analysis of the rutting files.

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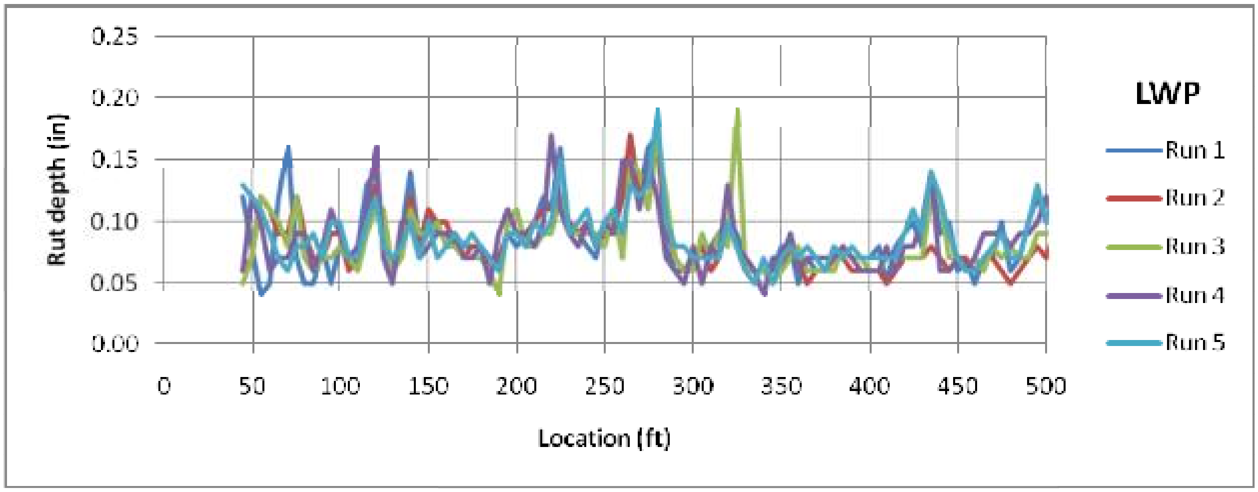
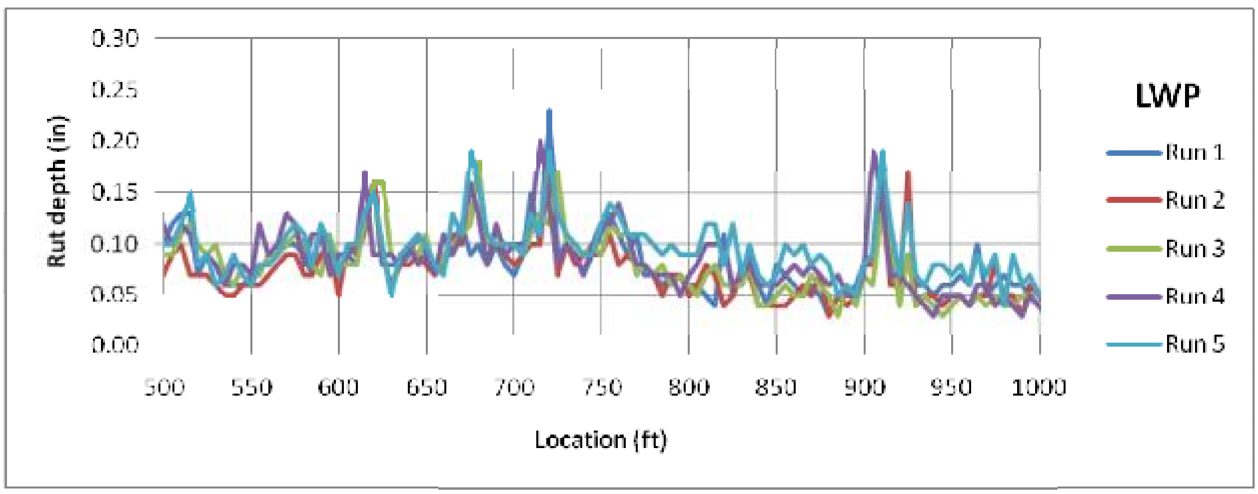
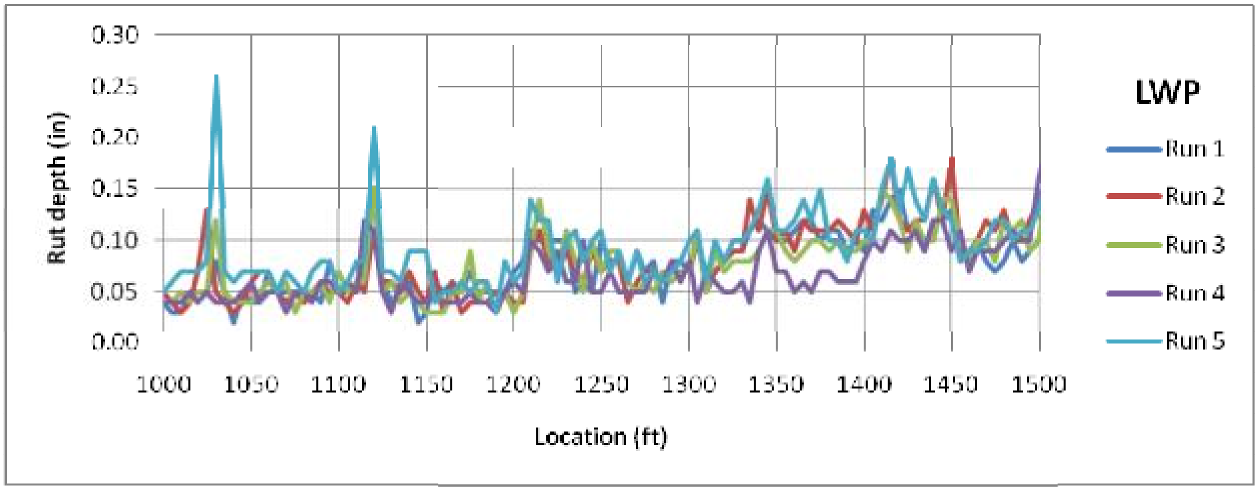
APPENDICES

Appendix A: US-30 Rut Measurements (LRMS)

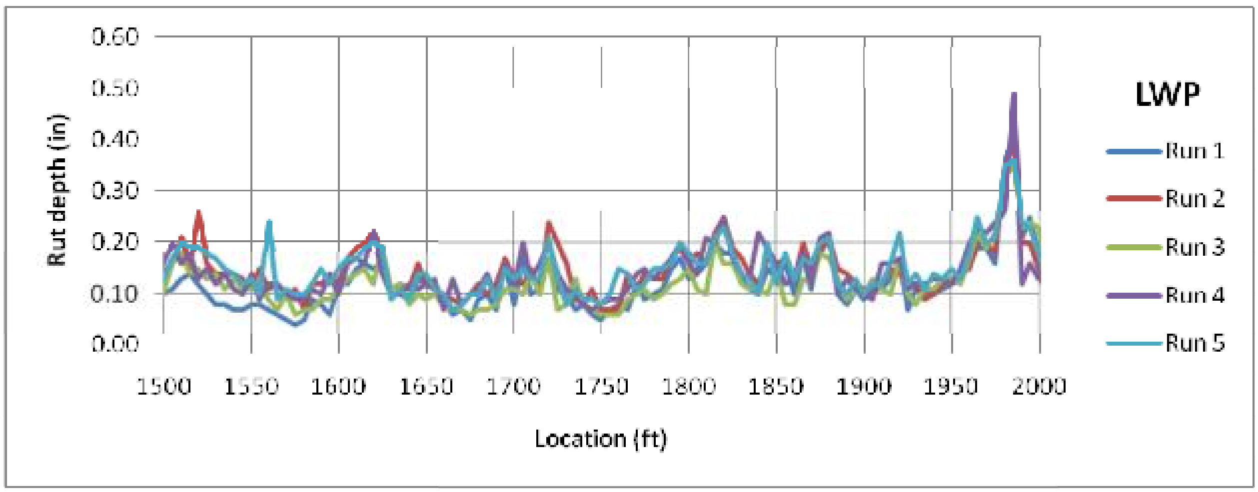
LWP = Left Wheel Path



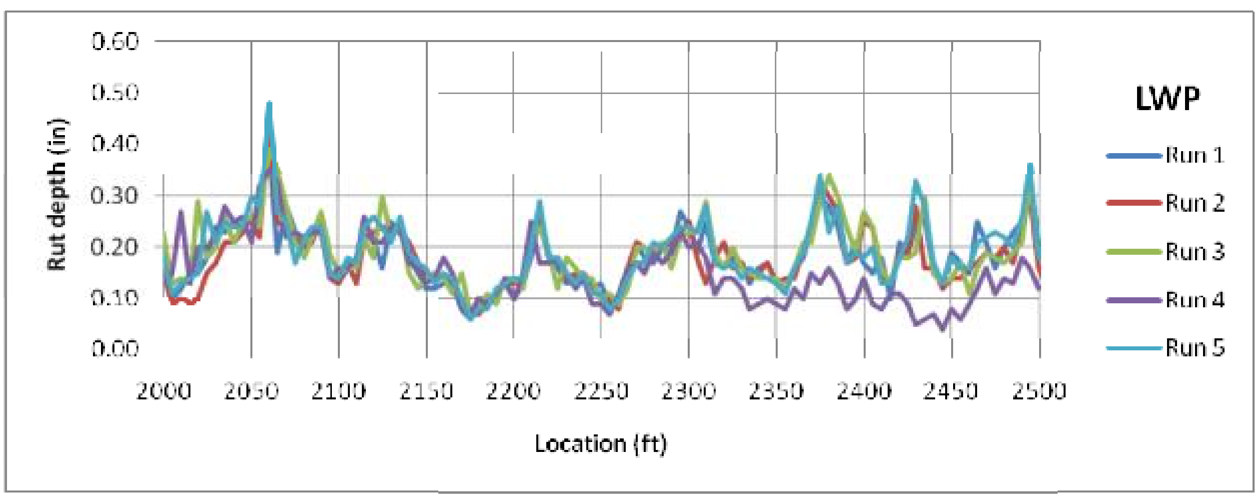




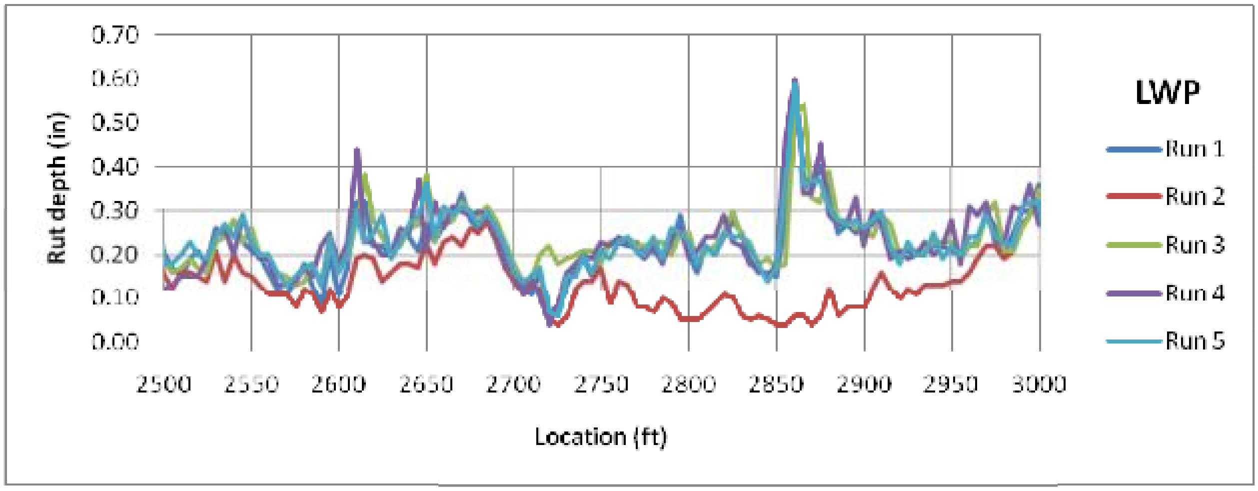
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Rut depth (in)
1000
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5

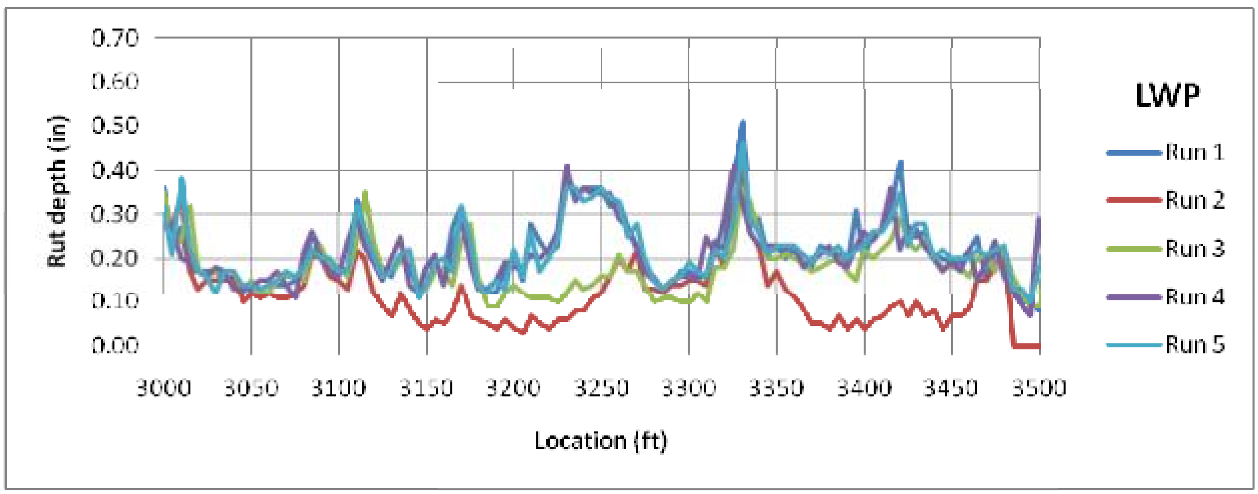


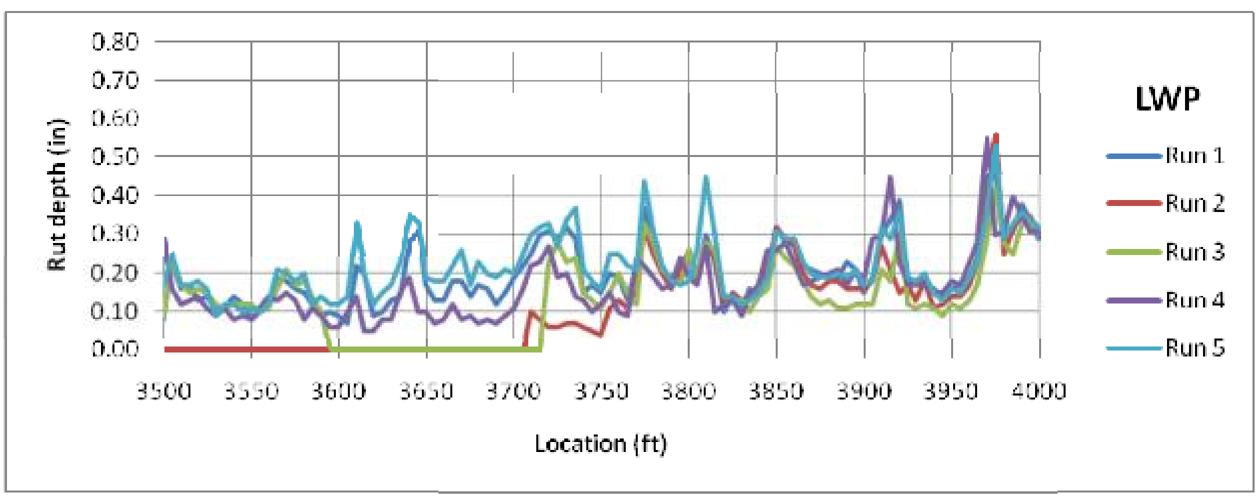
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Rut depth (in)
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5

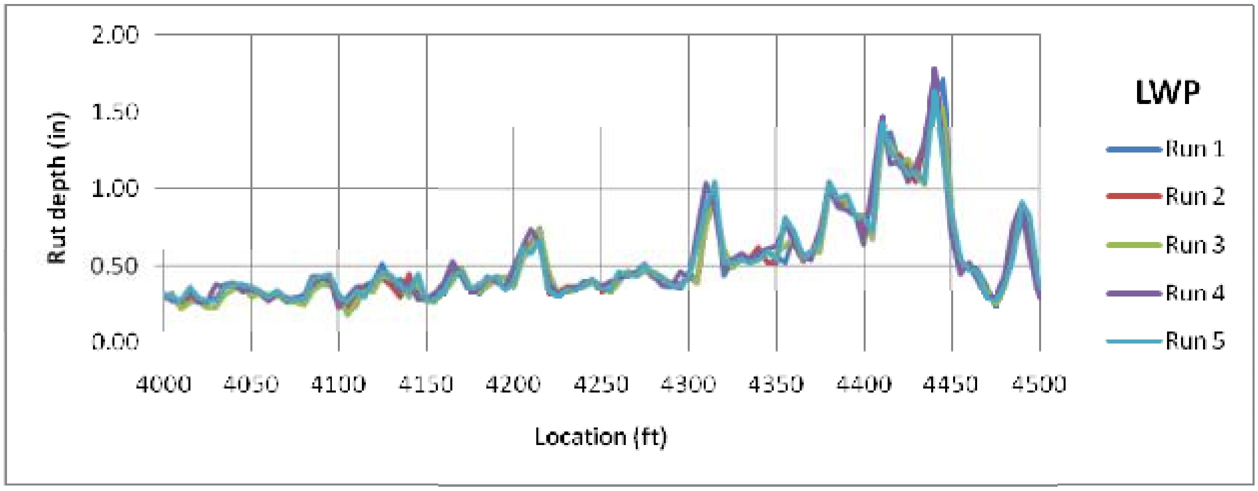


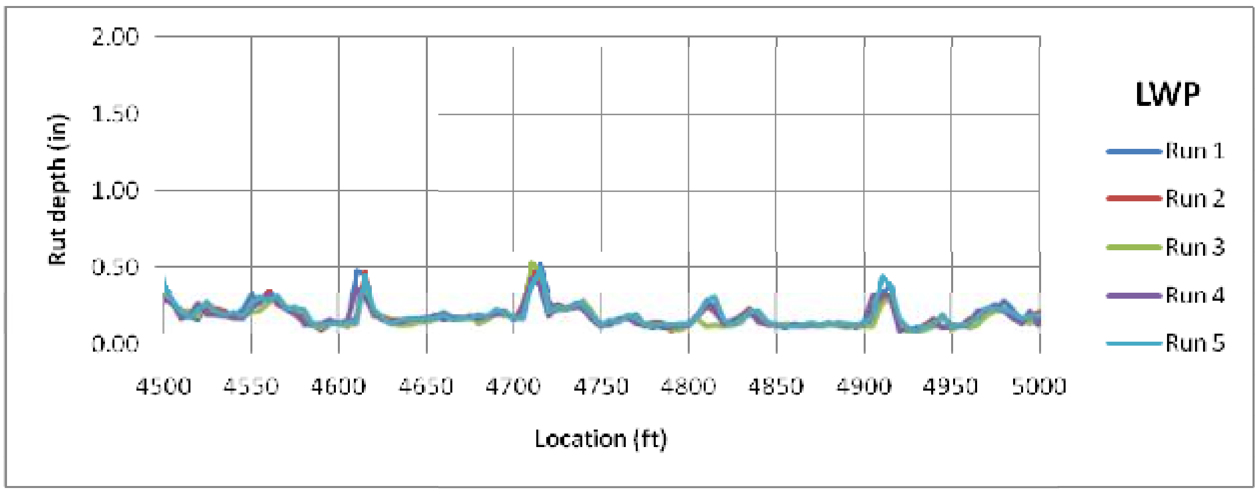
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Rut depth (in)
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5

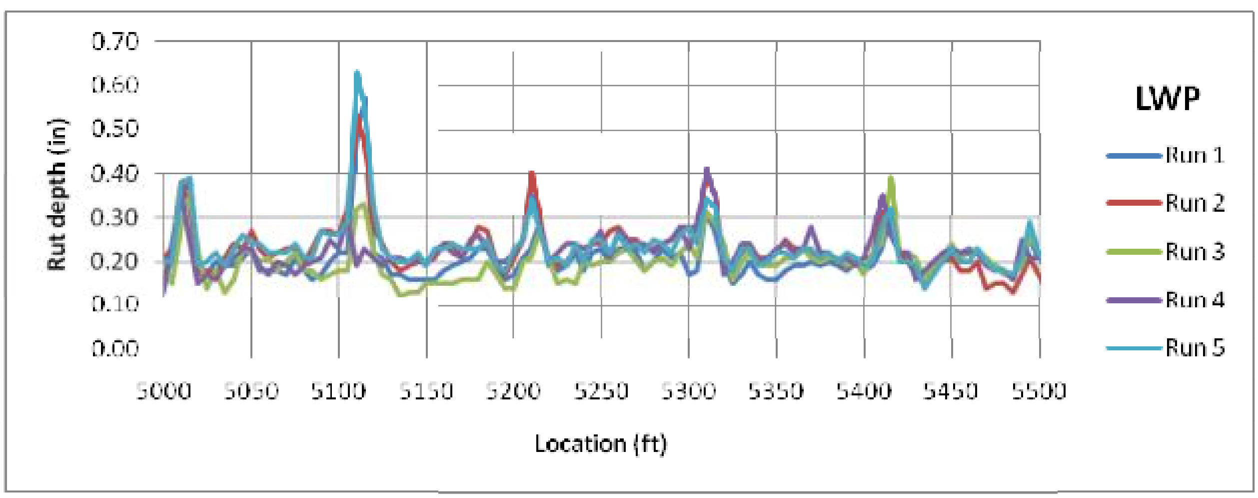

LWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
Location (ft)

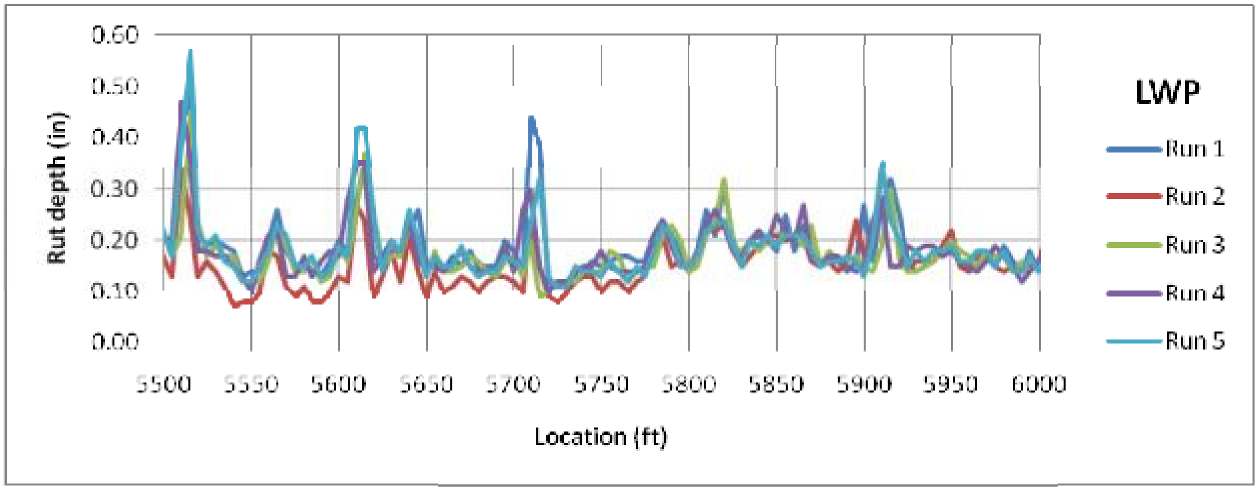

LWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
Location (ft)

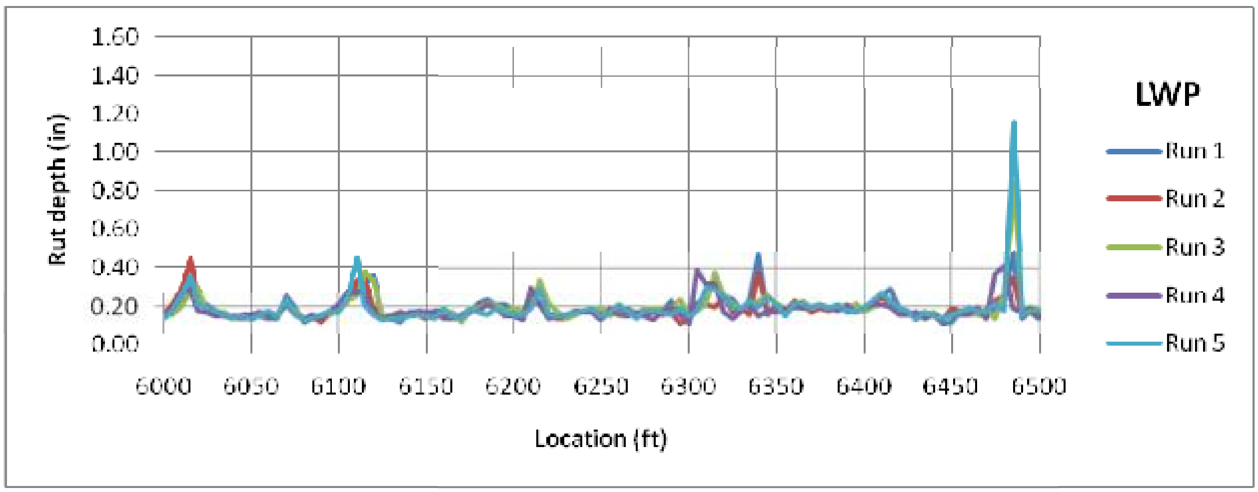

LWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
Location (ft)

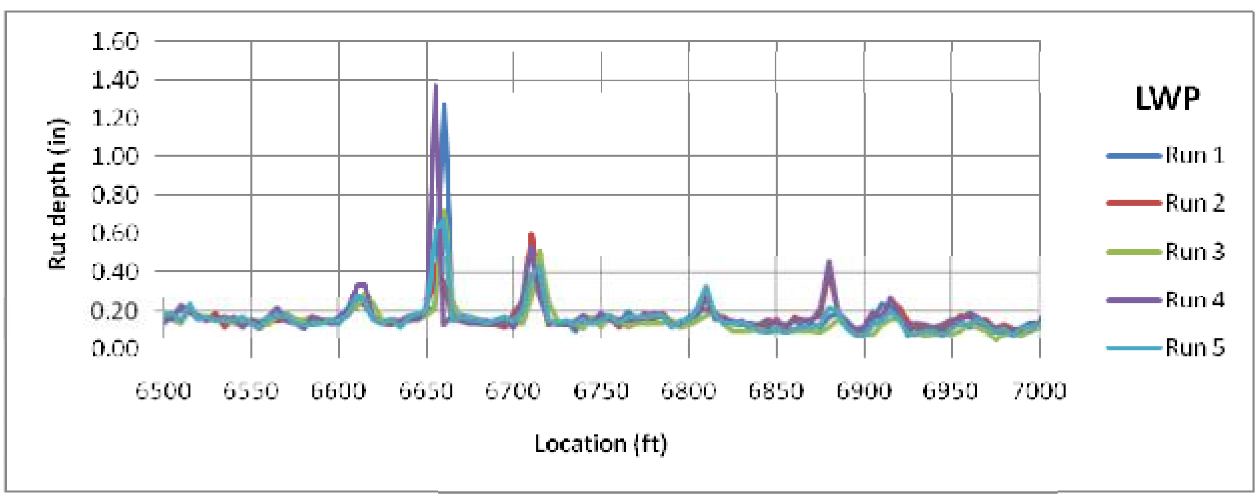

LWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
Location (ft)
2.00
1.50
1.00
0.50
0.00
4000
4050
4100
4150
4200
4250
4300
4350
4400
4450
4500

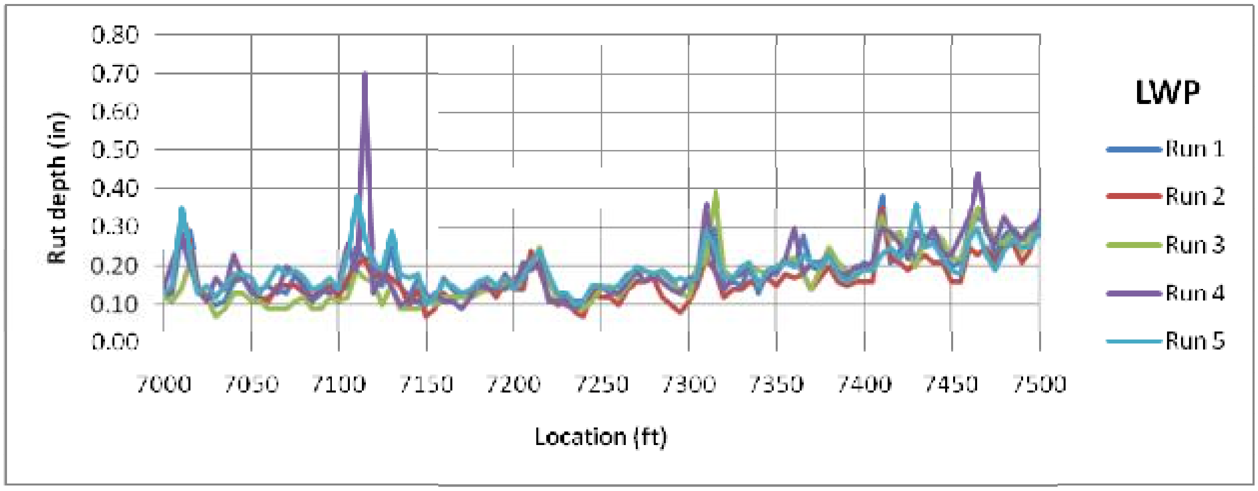

LWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
Location (ft)
2.00
1.50
1.00
0.50
0.00
4500
4550
4600
4650
4700
4750
4800
4850
4900
4950
5000

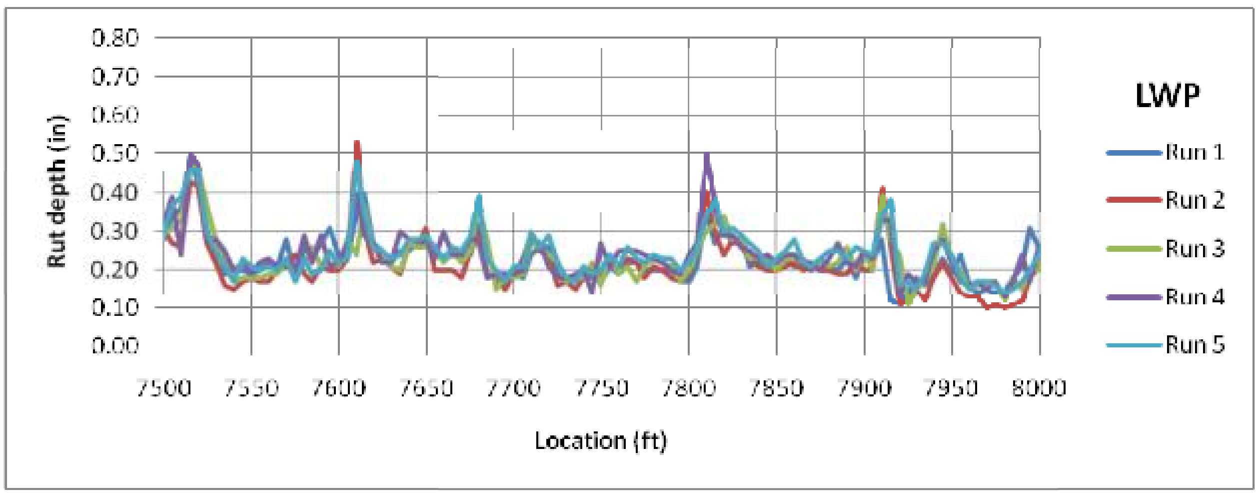

LWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
Location (ft)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
5000
5050
5100
5150
5200
5250
5300
5350
5400
5450
5500

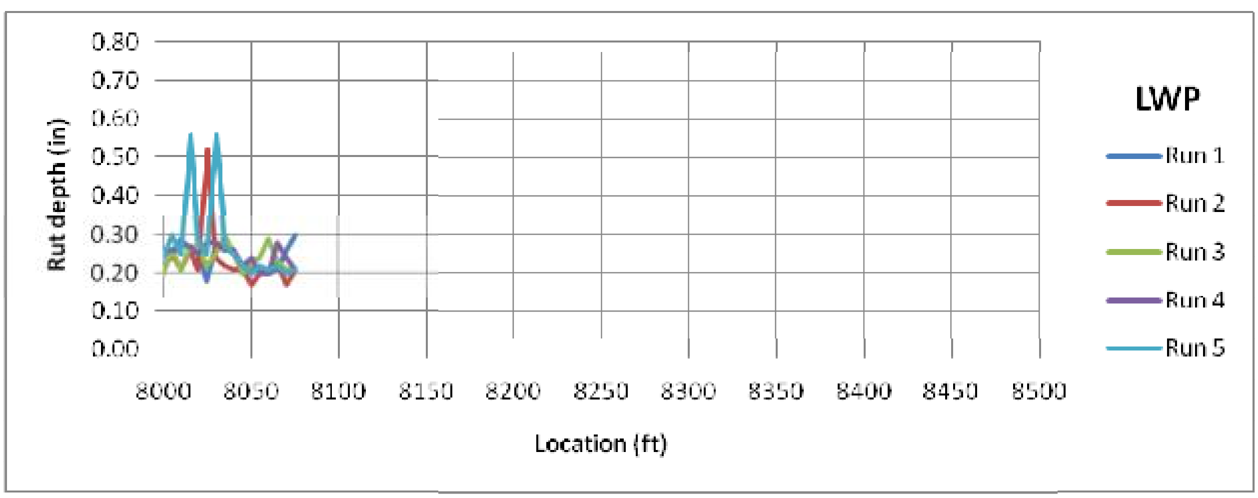

LWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
5500
5550
5600
5650
5700
5750
5800
5850
5900
5950
6000
Location (ft)


LWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
6000
6050
6100
6150
6200
6250
6300
6350
6400
6450
6500
Location (ft)

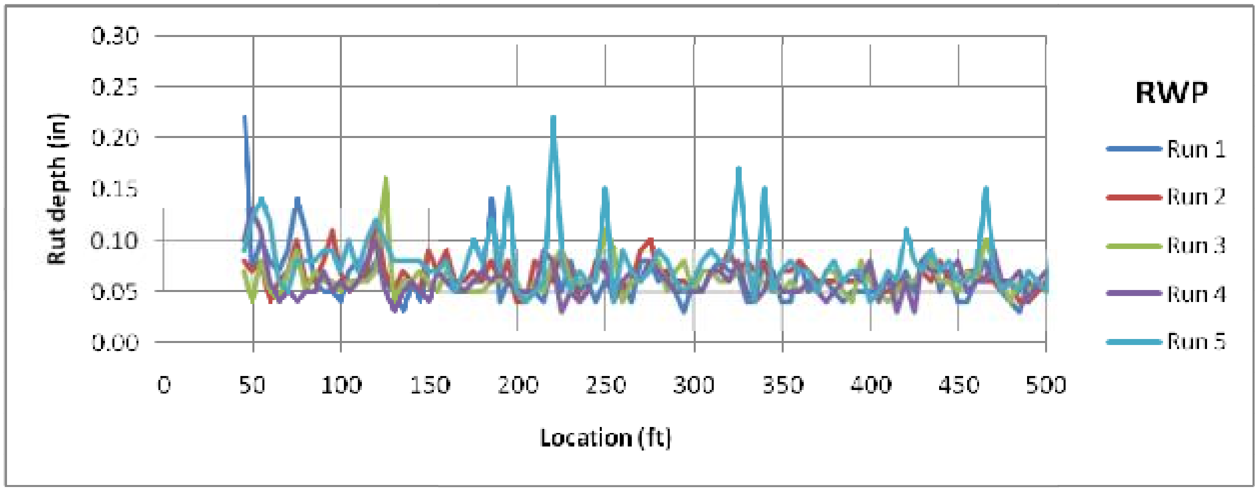

LWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
6500
6550
6600
6650
6700
6750
6800
6850
6900
6950
7000
Location (ft)

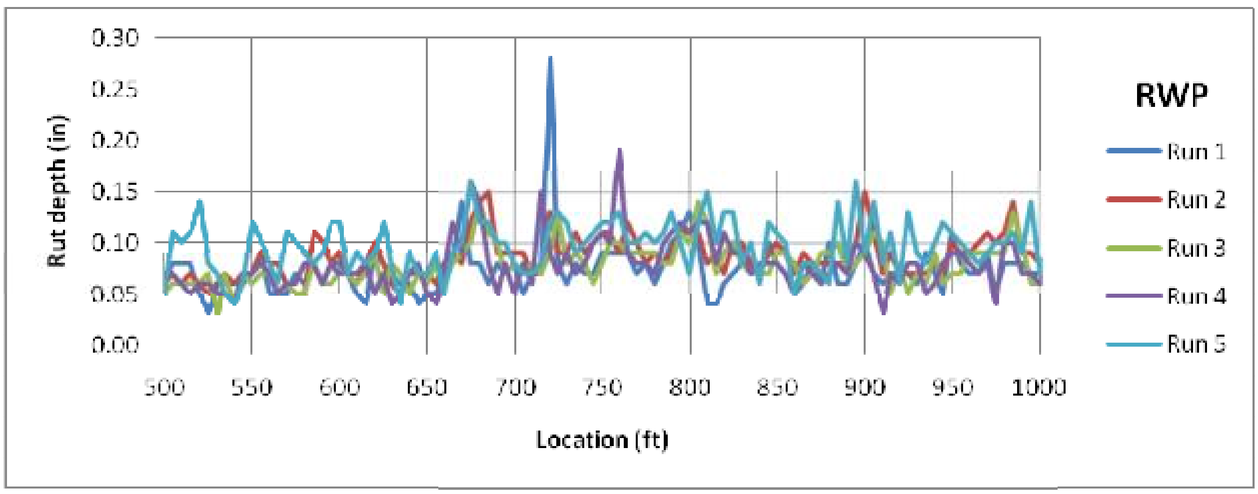

Rut depth (in)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
7000 7050 7100 7150 7200 7250 7300 7350 7400 7450 7500
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5

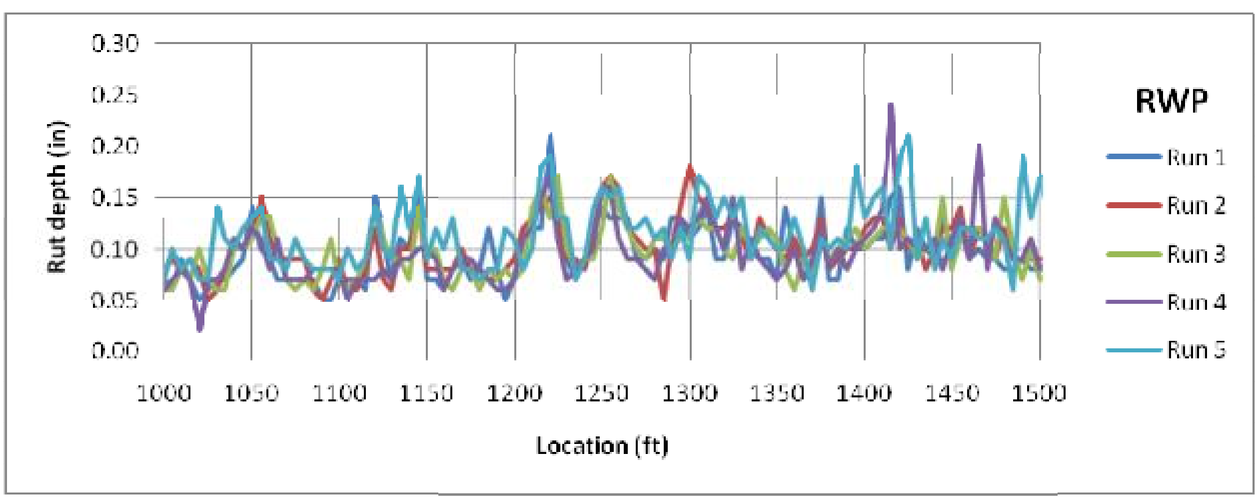

Rut depth (in)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
7500 7550 7600 7650 7700 7750 7800 7850 7900 7950 8000
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5

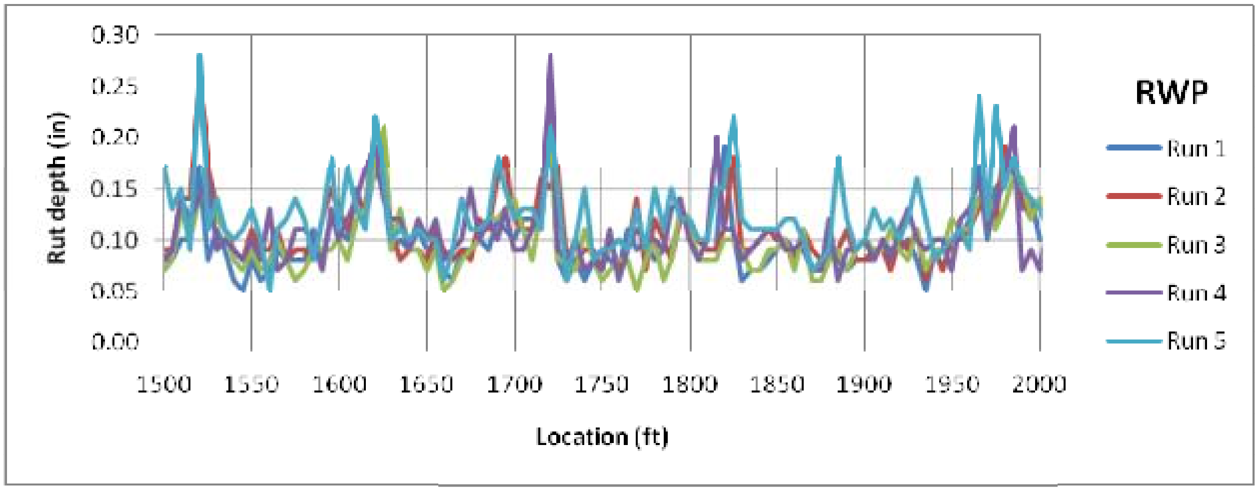

Rut depth (in)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
8000 8050 8100 8150 8200 8250 8300 8350 8400 8450 8500
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5

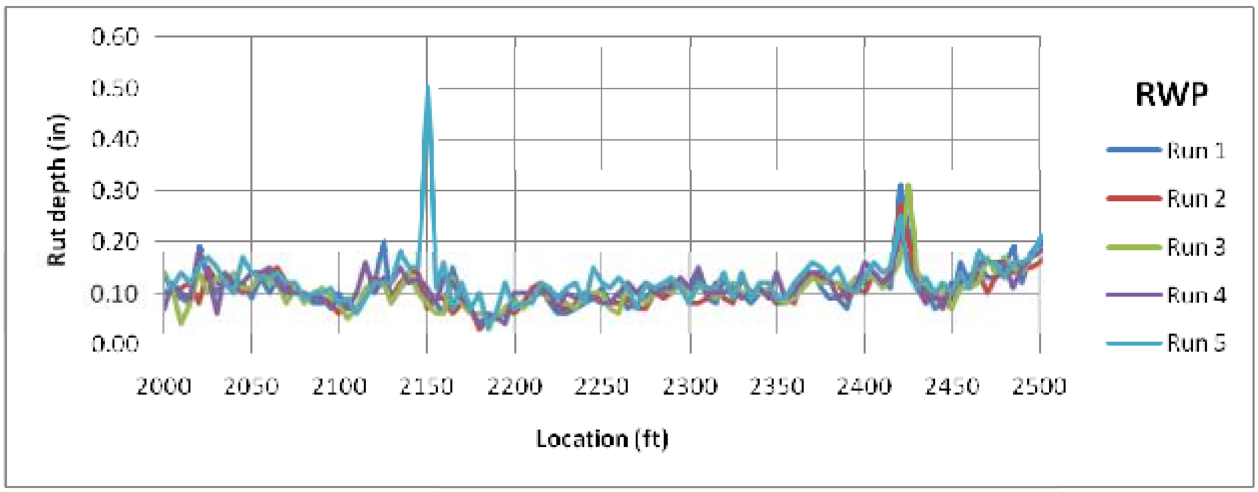
RWP = Right Wheel Path

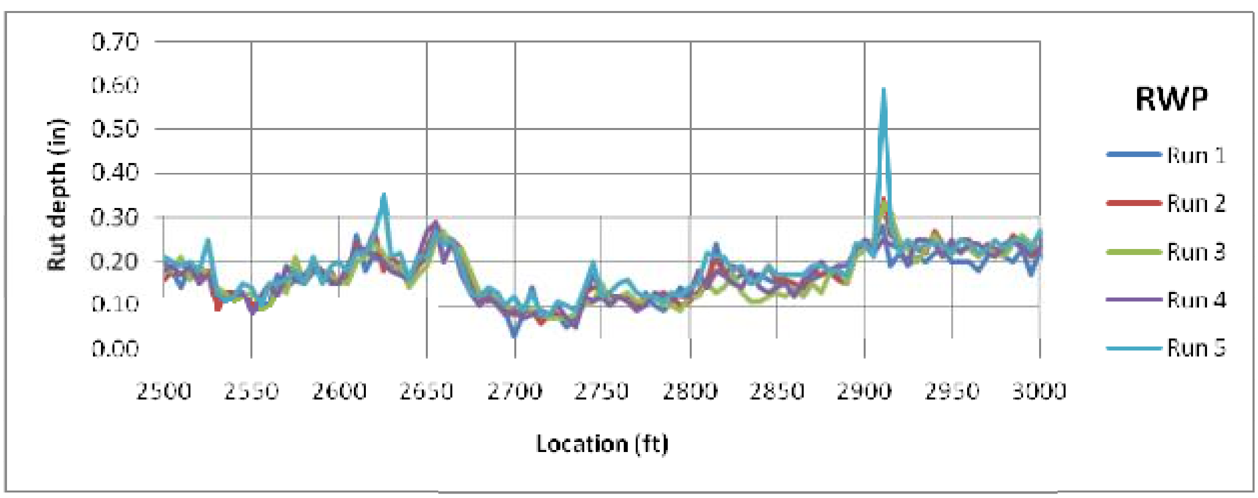


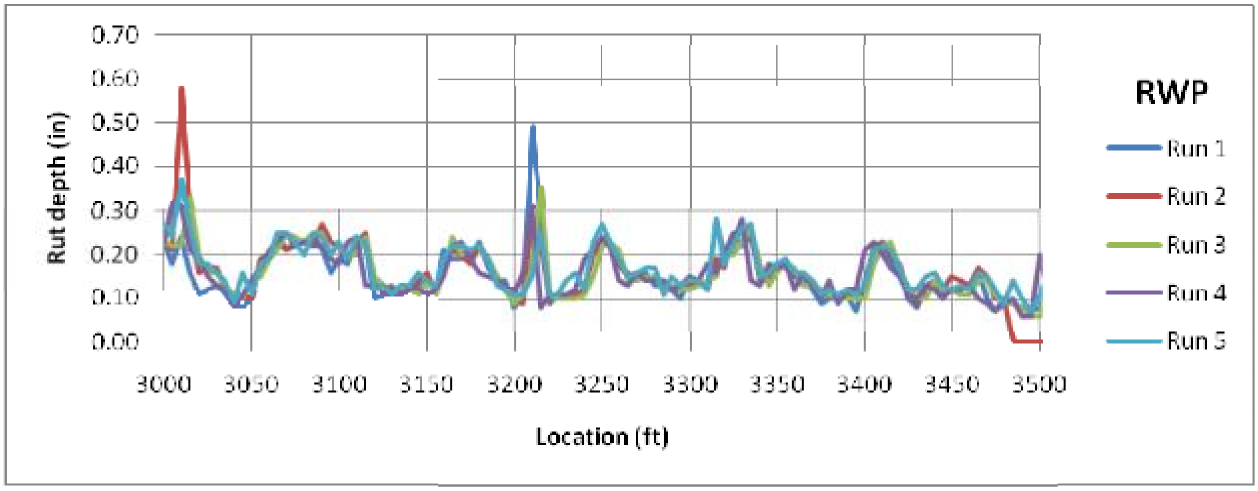


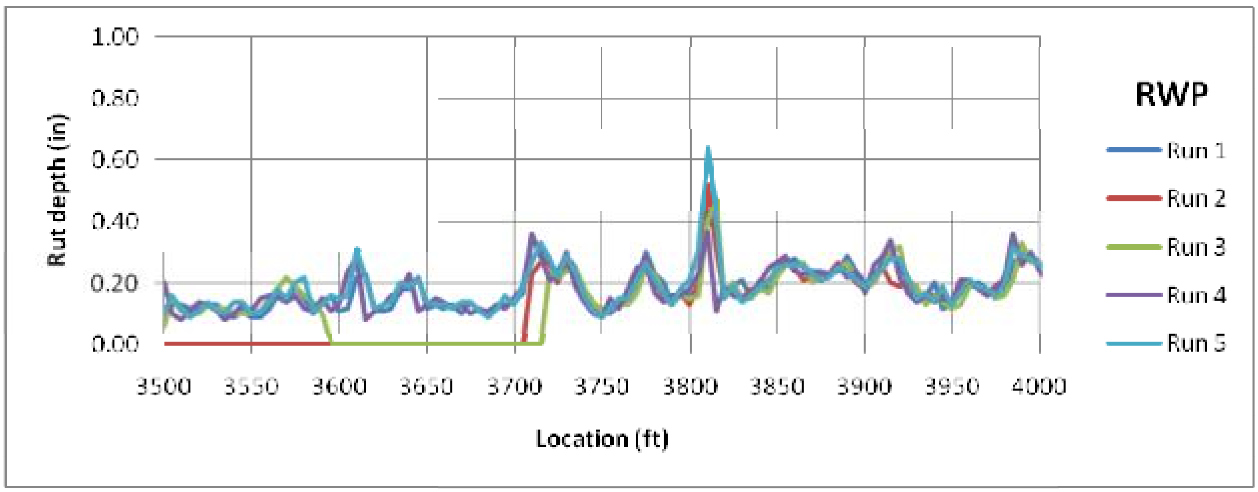


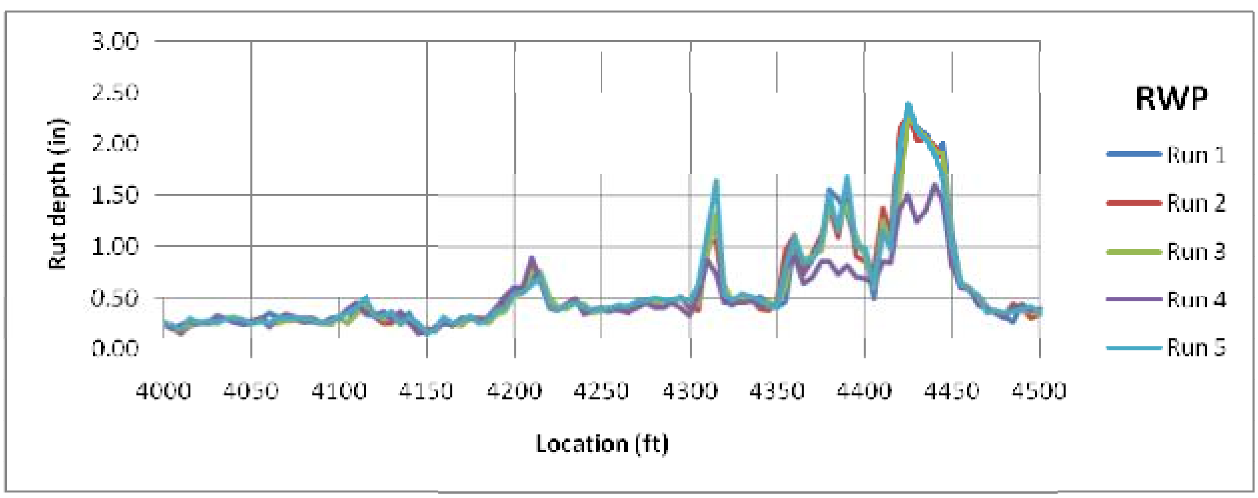

RWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
Location (ft)

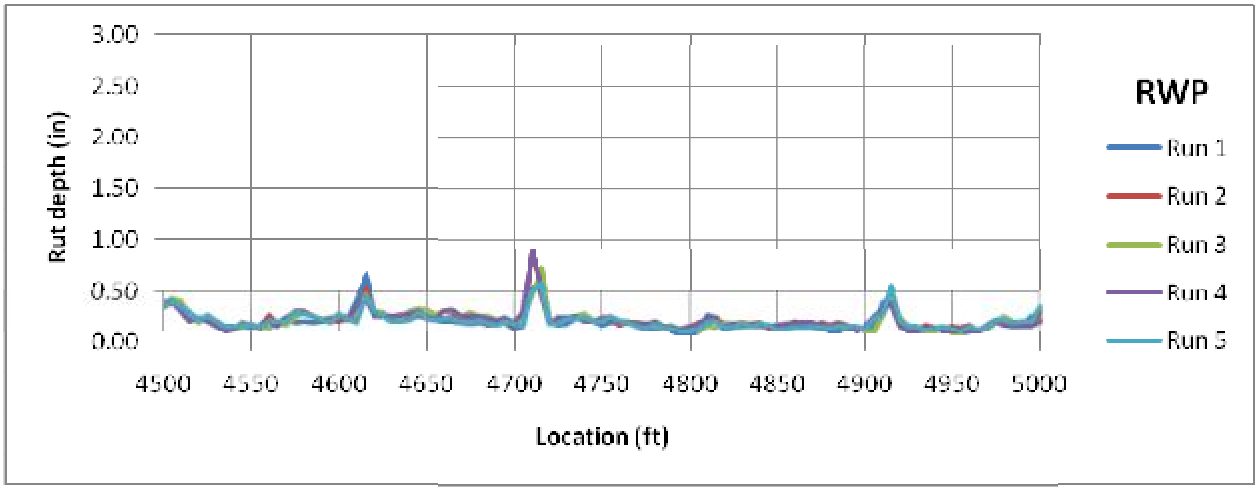

RWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
Location (ft)


RWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2500
2550
2600
2650
2700
2750
2800
2850
2900
2950
3000
Location (ft)

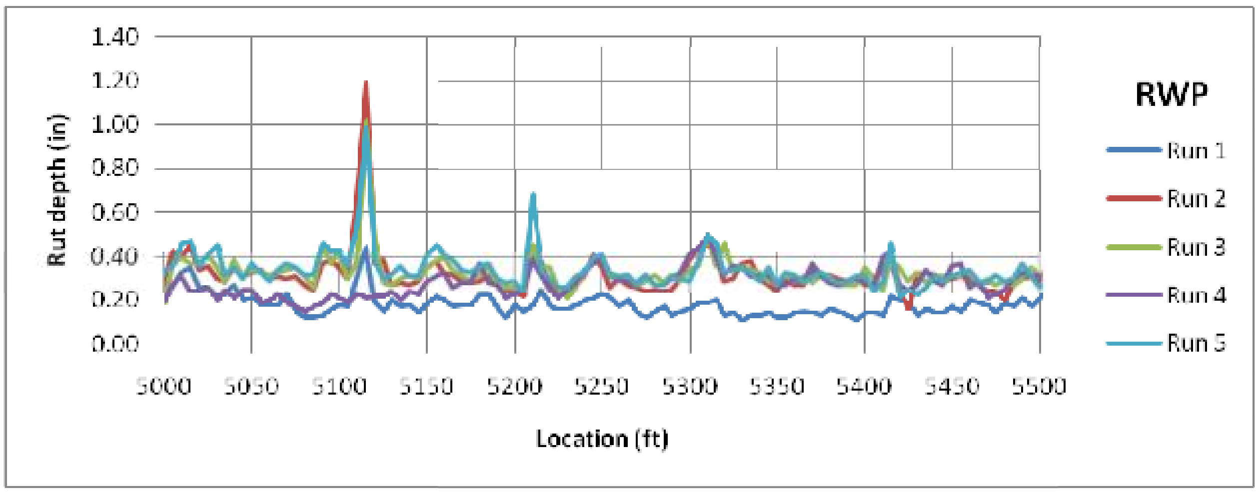

RWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
Location (ft)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3000 3050 3100 3150 3200 3250 3300 3350 3400 3450 3500


RWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
Location (ft)
1.00
0.80
0.60
0.40
0.20
0.00
3500 3550 3600 3650 3700 3750 3800 3850 3900 3950 4000

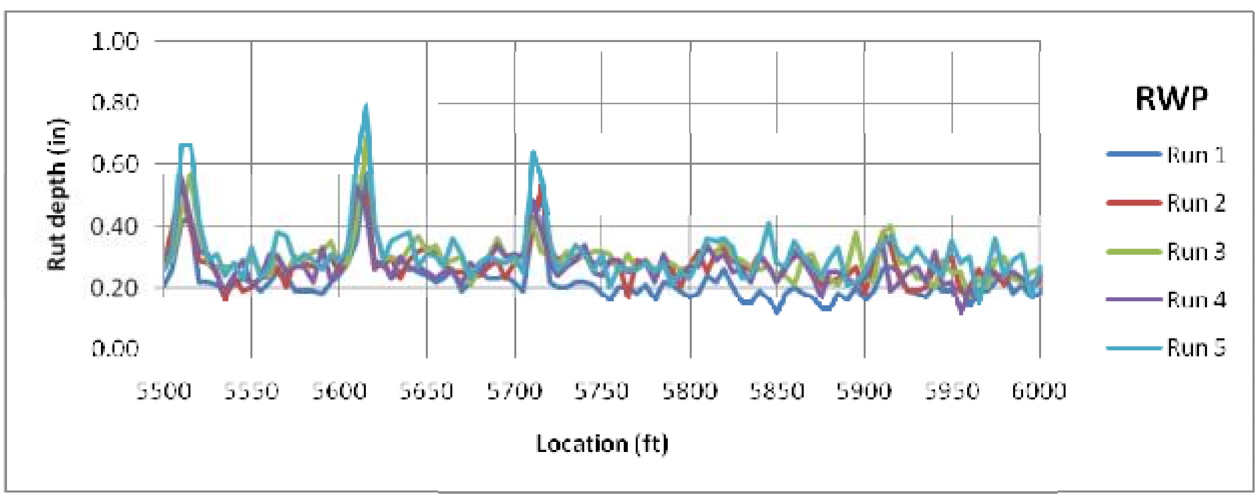

RWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
Location (ft)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
4000 4050 4100 4150 4200 4250 4300 4350 4400 4450 4500



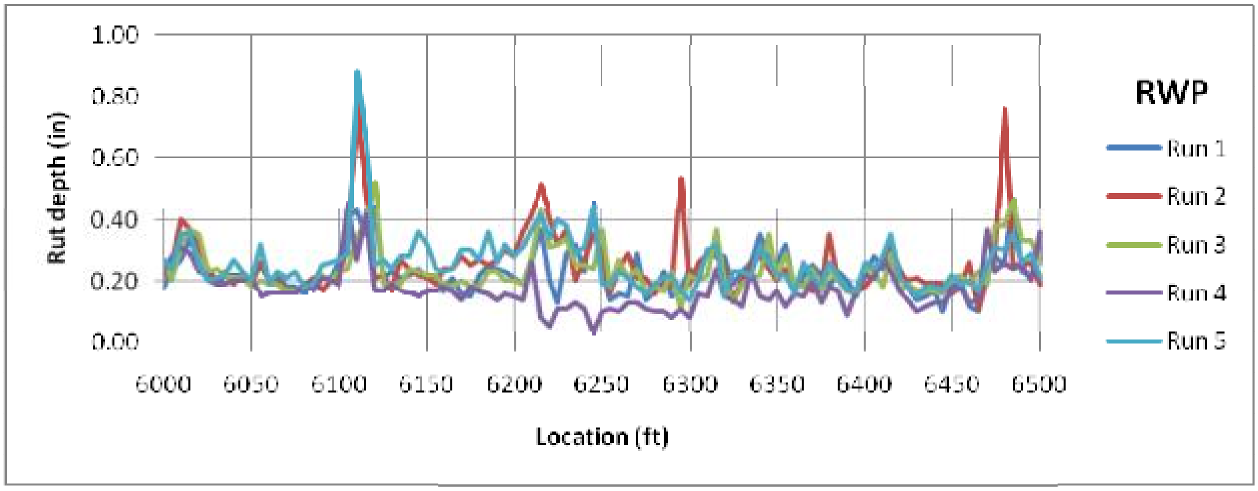
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Rut depth (in)
4500
4550
4600
4650
4700
4750
4800
4850
4900
4950
5000
Location (ft)
RWP
Run 1
Run 2
Run 3
Run 4
Run 5



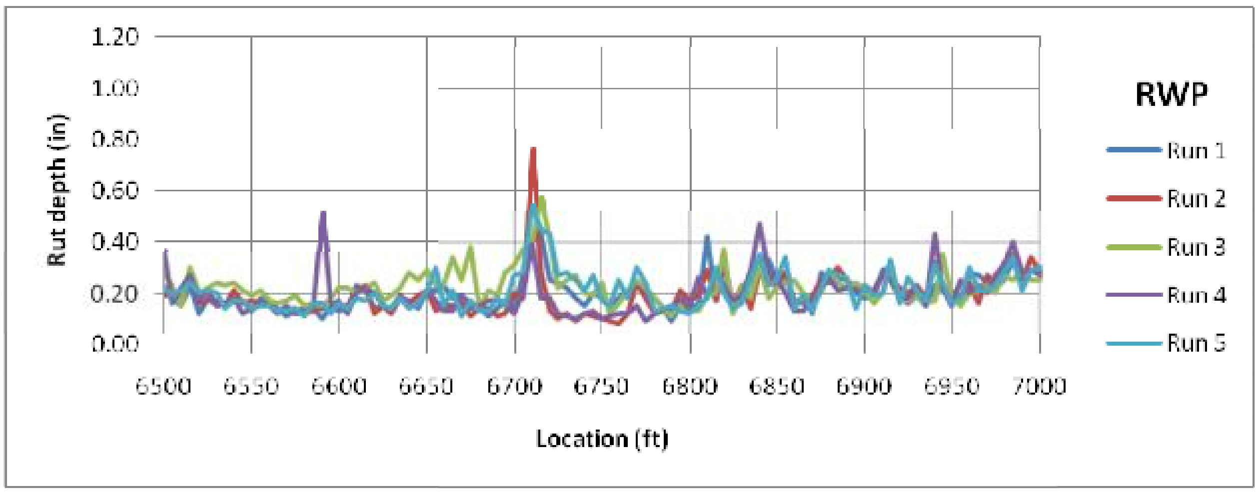
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Rut depth (in)
5000
5050
5100
5150
5200
5250
5300
5350
5400
5450
5500
Location (ft)
RWP
Run 1
Run 2
Run 3
Run 4
Run 5



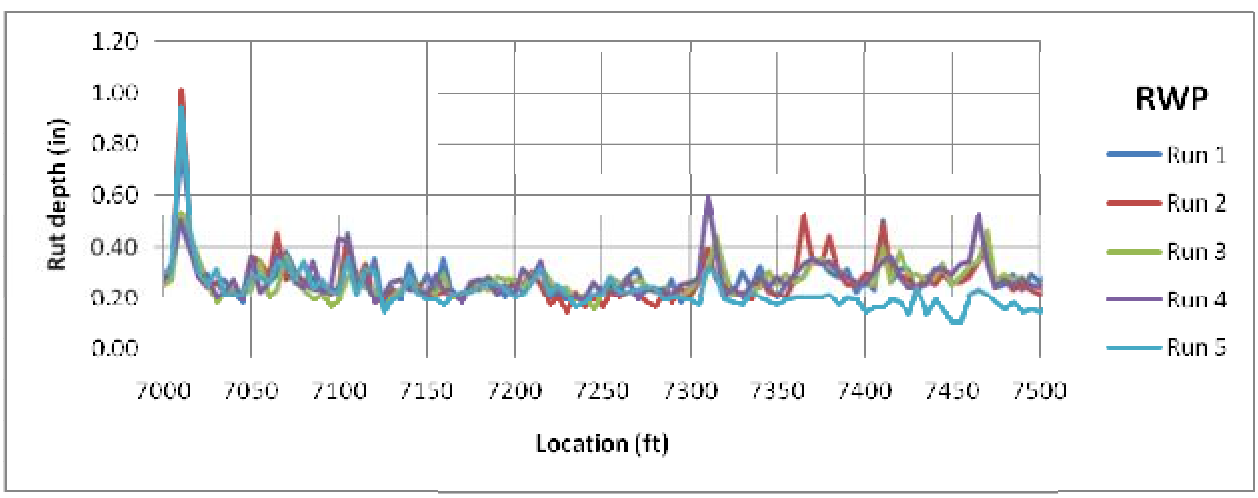
1.00
0.80
0.60
0.40
0.20
0.00
Rut depth (in)
5500
5550
5600
5650
5700
5750
5800
5850
5900
5950
6000
Location (ft)
RWP
Run 1
Run 2
Run 3
Run 4
Run 5



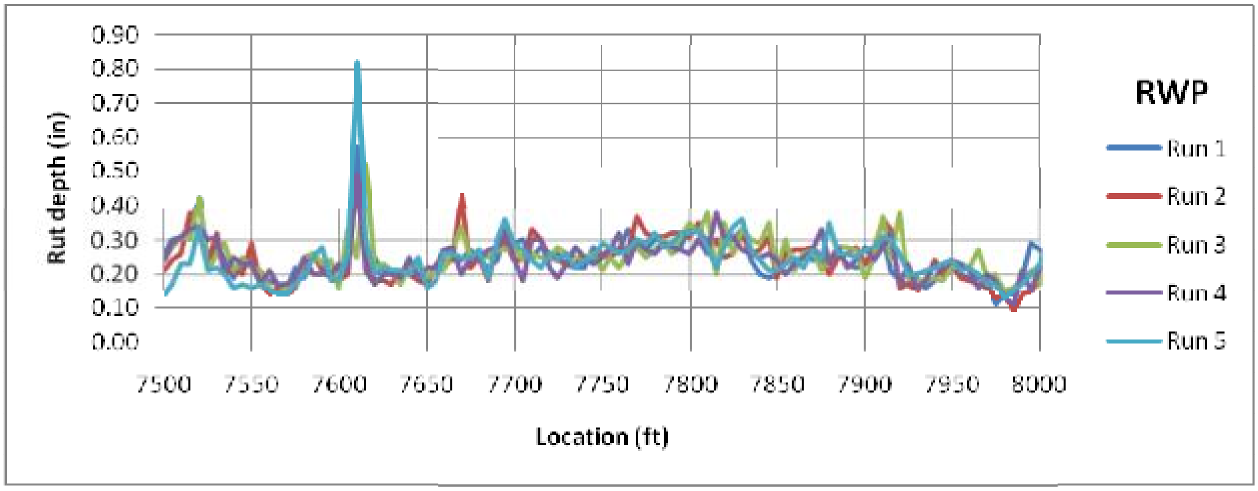
RWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
1.00
0.80
0.60
0.40
0.20
0.00
6000
6050
6100
6150
6200
6250
6300
6350
6400
6450
6500
Location (ft)

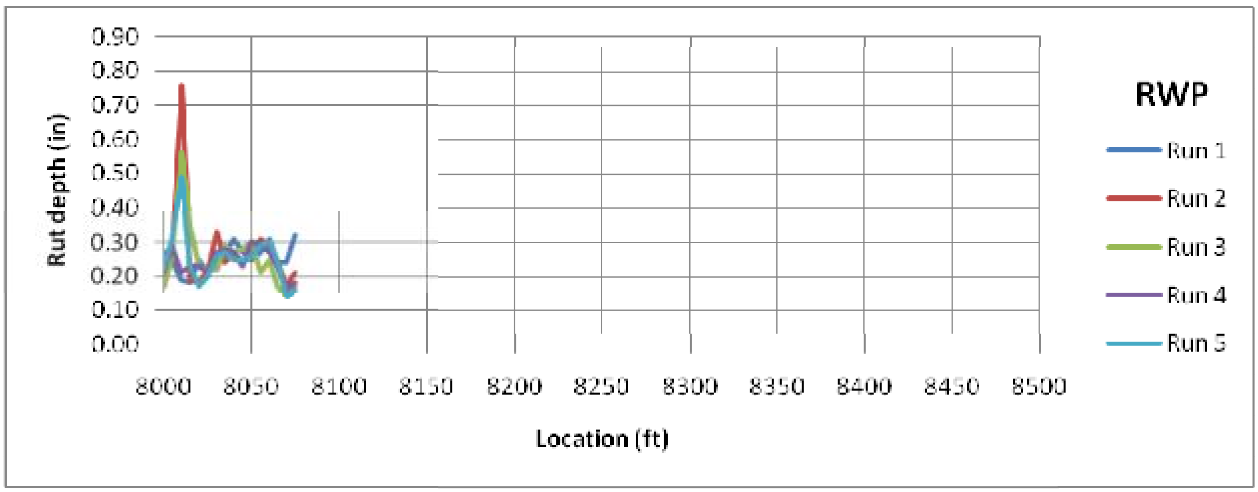


RWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
6500
6550
6600
6650
6700
6750
6800
6850
6900
6950
7000
Location (ft)



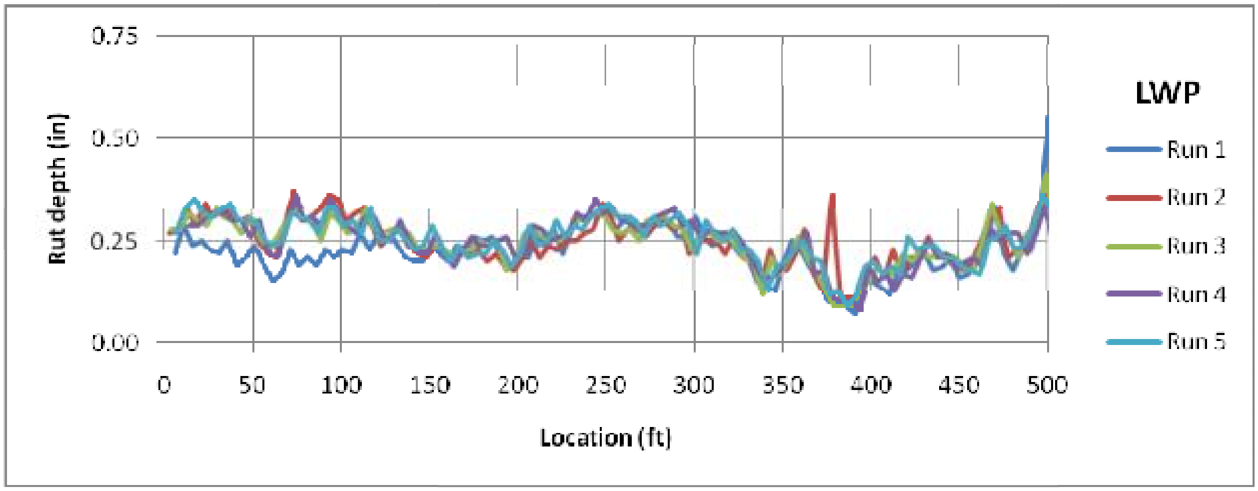
RWP
Run 1
Run 2
Run 3
Run 4
Run 5
Rut depth (in)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
7000
7050
7100
7150
7200
7250
7300
7350
7400
7450
7500
Location (ft)

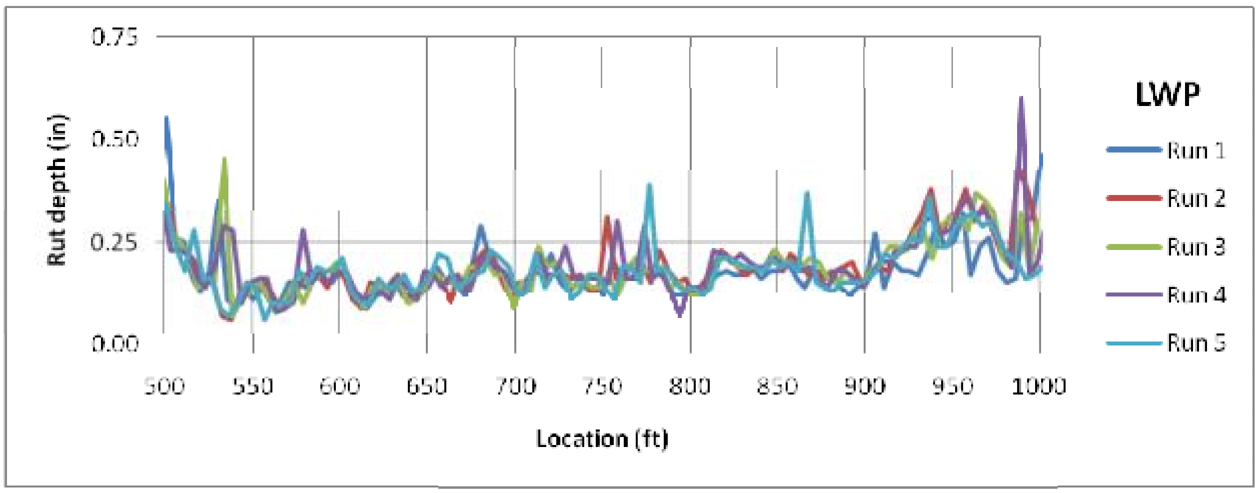

0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Rut depth (in)
7500
7550
7600
7650
7700
7750
7800
7850
7900
7950
8000
Location (ft)
RWP
Run 1
Run 2
Run 3
Run 4
Run 5

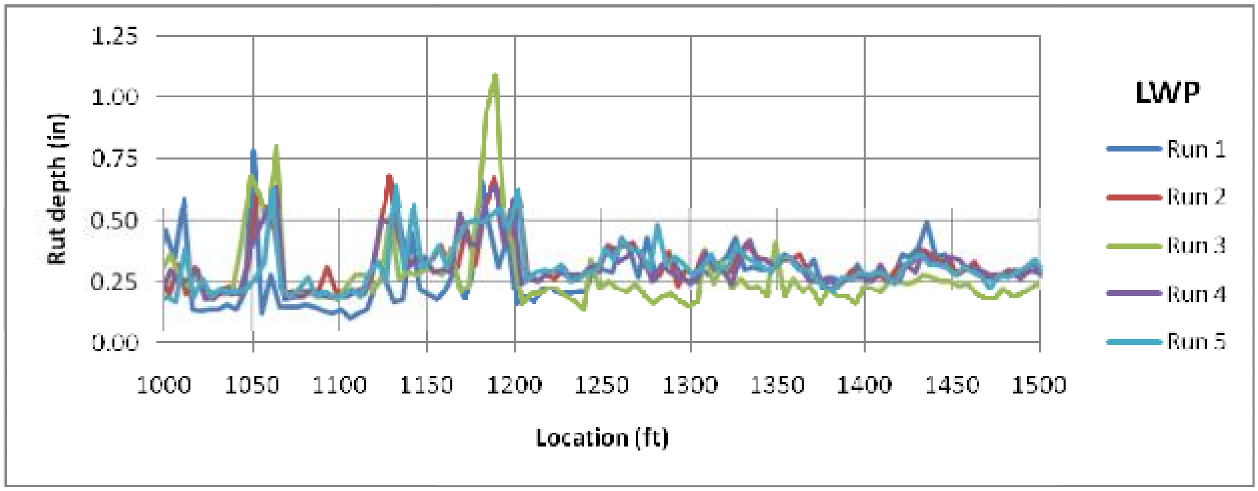

0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Rut depth (in)
8000
8050
8100
8150
8200
8250
8300
8350
8400
8450
8500
Location (ft)
RWP
Run 1
Run 2
Run 3
Run 4
Run 5

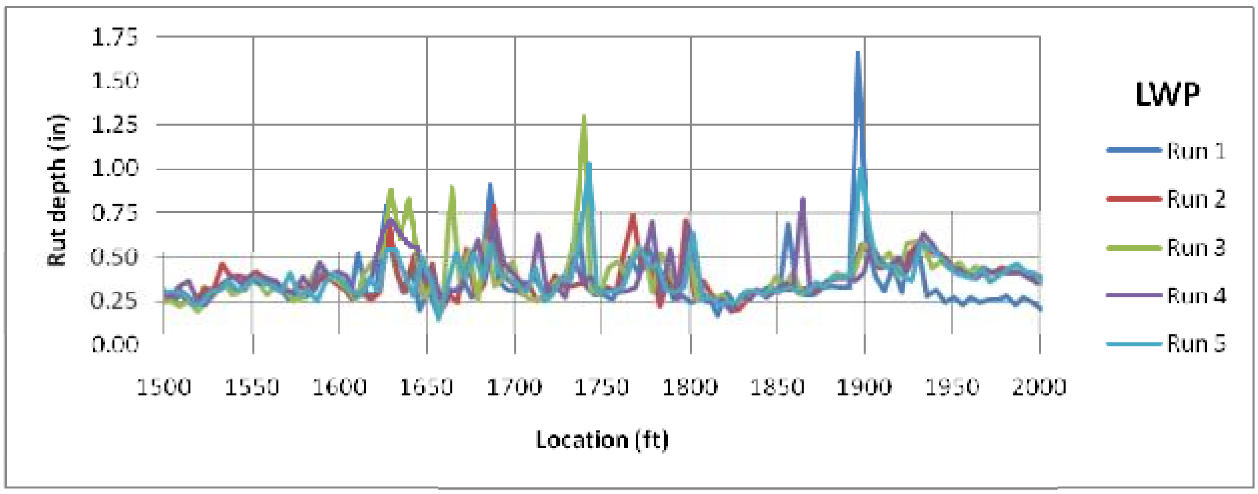
Appendix B: SR-682 Rut Measurements (LRMS)

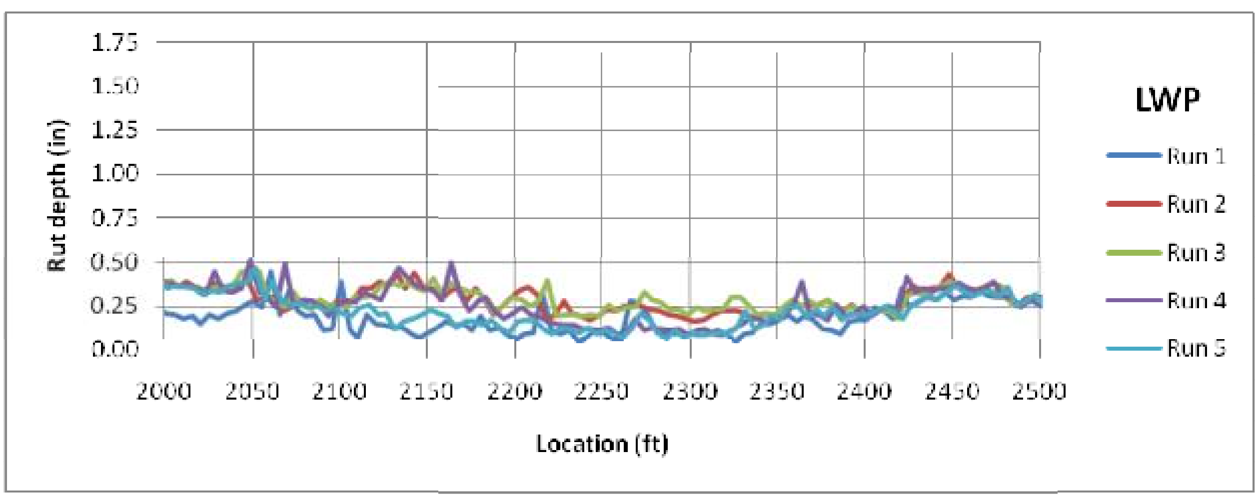
LWP = Left Wheel Path

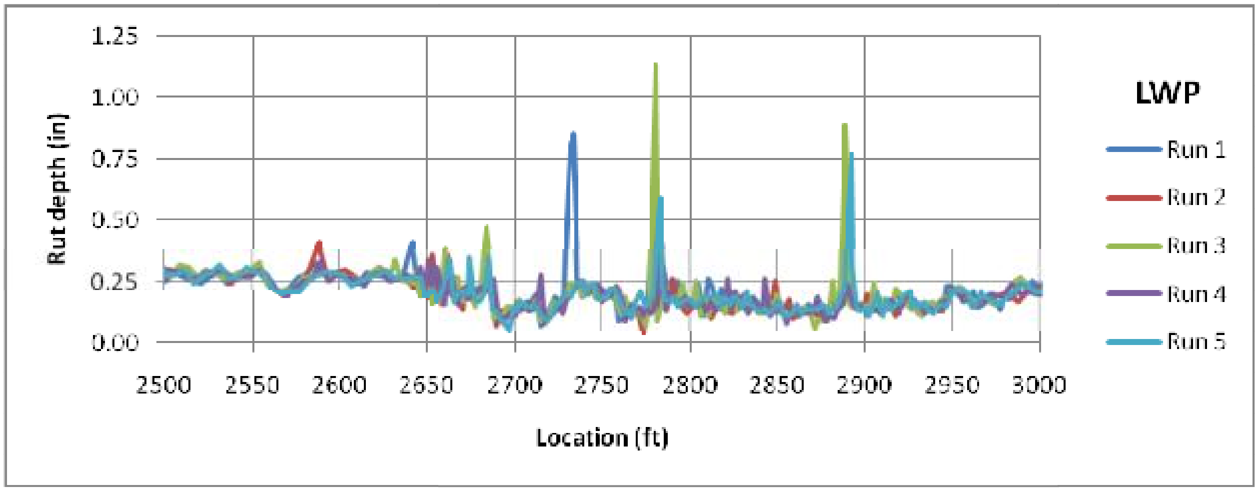




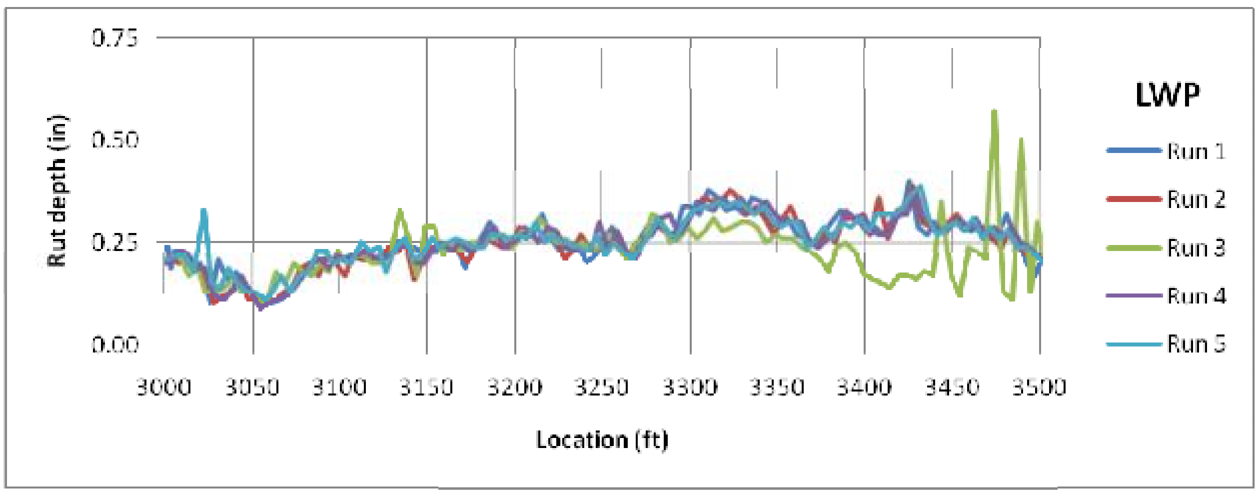

1.25
1.00
0.75
0.50
0.25
0.00
Rut depth (in)
1000
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5


1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Rut depth (in)
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5

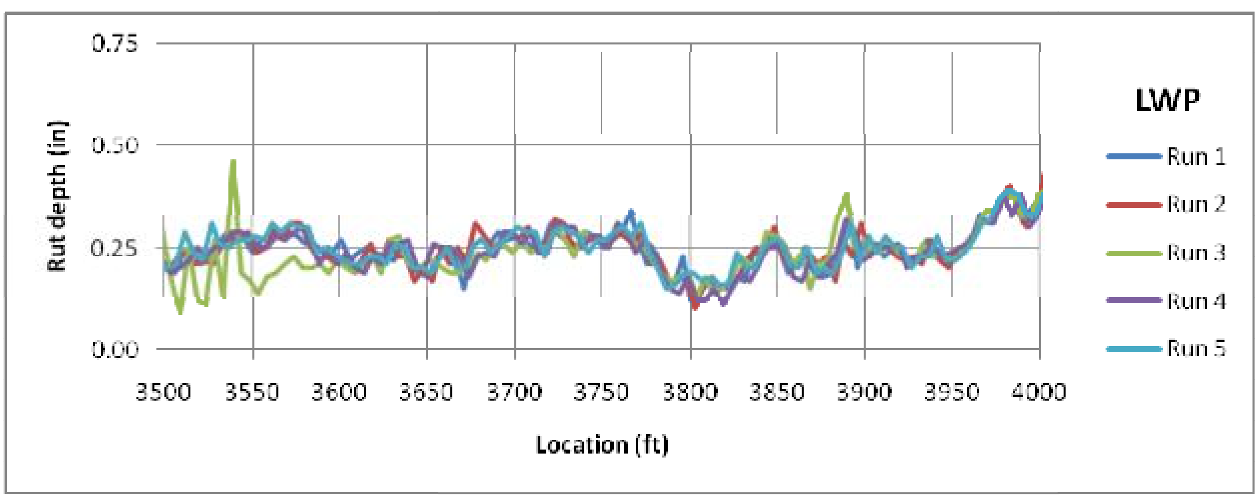

1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Rut depth (in)
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5



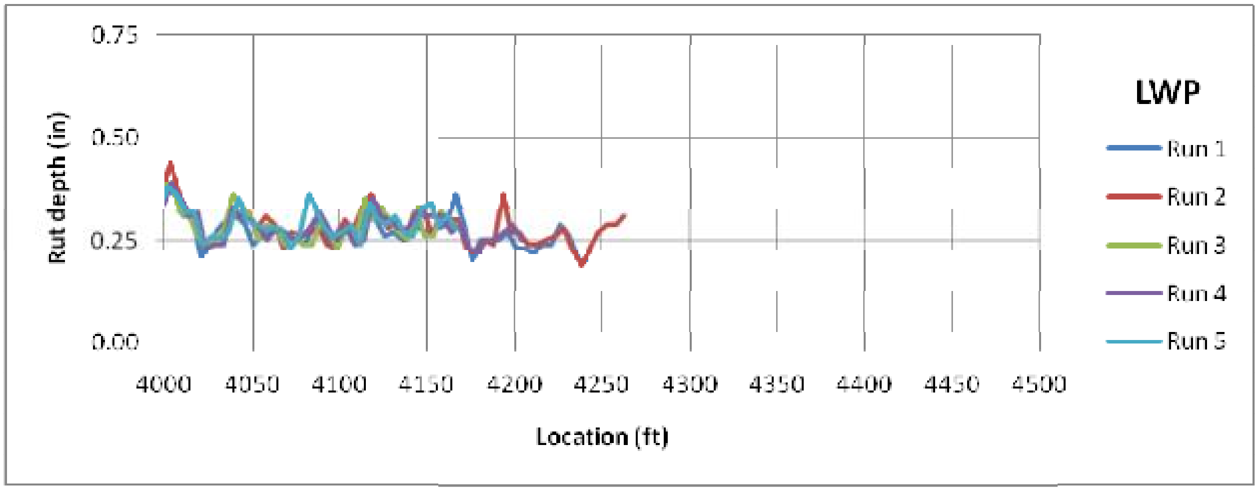
Rut depth (in)
1.25
1.00
0.75
0.50
0.25
0.00
2500
2550
2600
2650
2700
2750
2800
2850
2900
2950
3000
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5



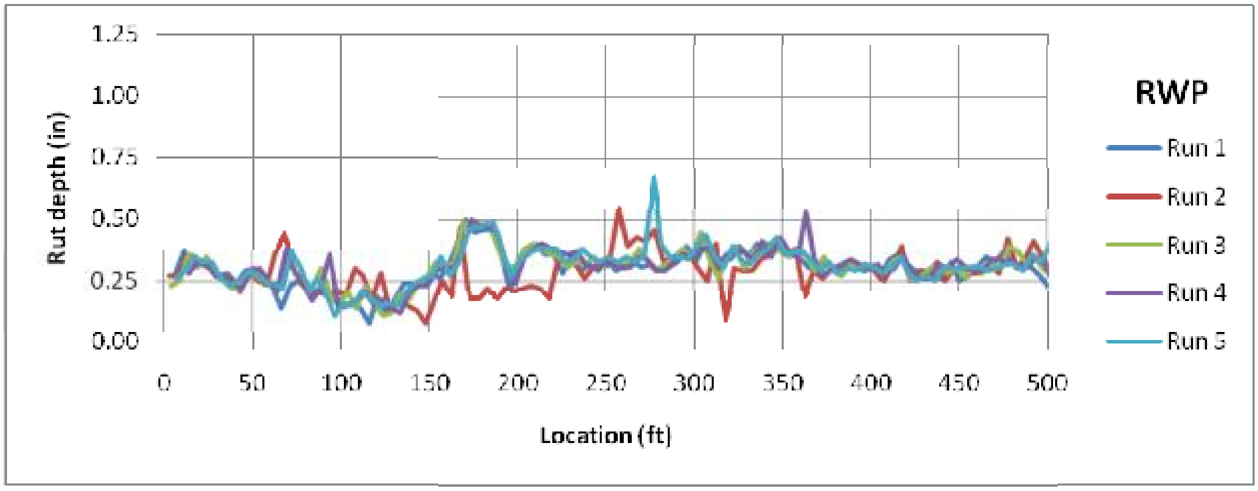
Rut depth (in)
0.75
0.50
0.25
0.00
3000
3050
3100
3150
3200
3250
3300
3350
3400
3450
3500
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5

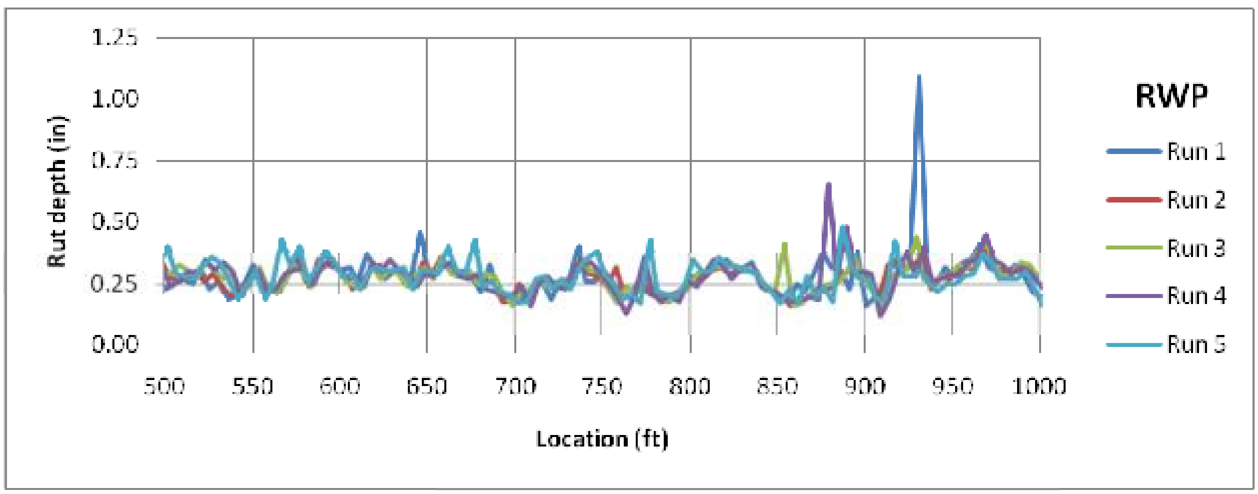


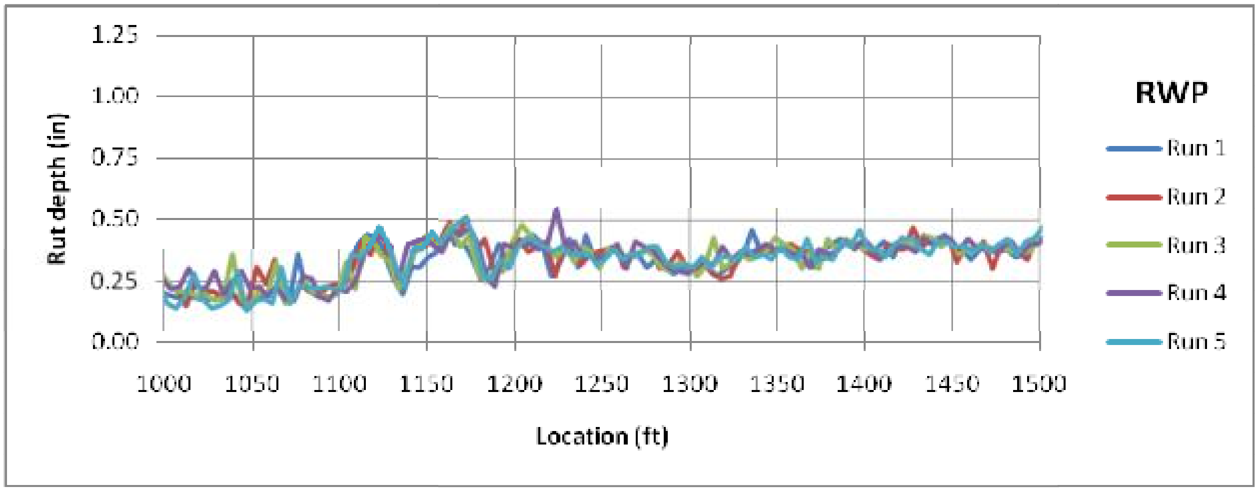
Rut depth (in)
0.75
0.50
0.25
0.00
3500
3550
3600
3650
3700
3750
3800
3850
3900
3950
4000
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5


0.75
0.50
0.25
0.00
Rut depth (in)
4000
4050
4100
4150
4200
4250
4300
4350
4400
4450
4500
Location (ft)
LWP
Run 1
Run 2
Run 3
Run 4
Run 5

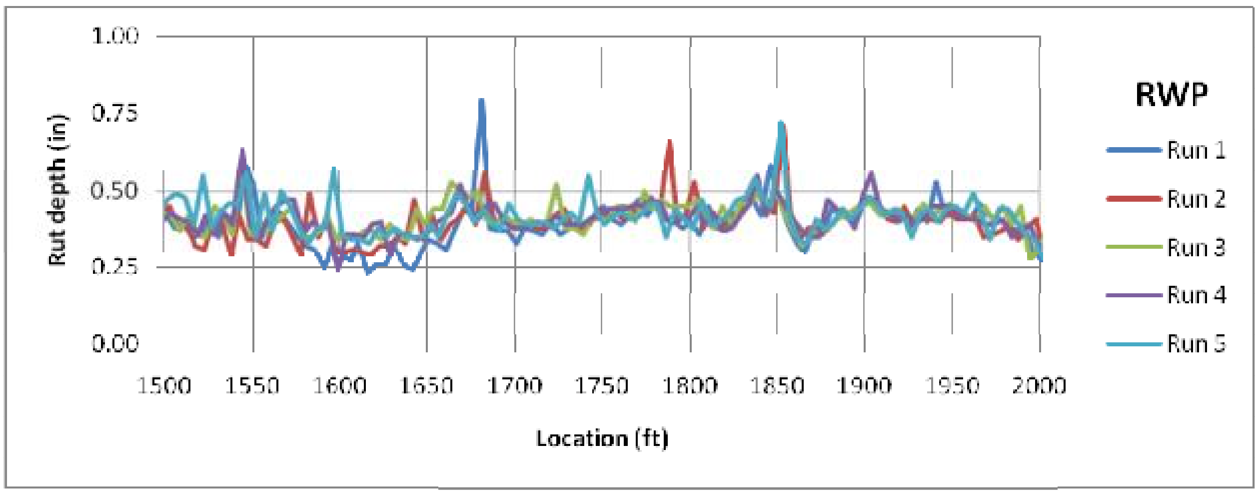
RWP = Right Wheel Path



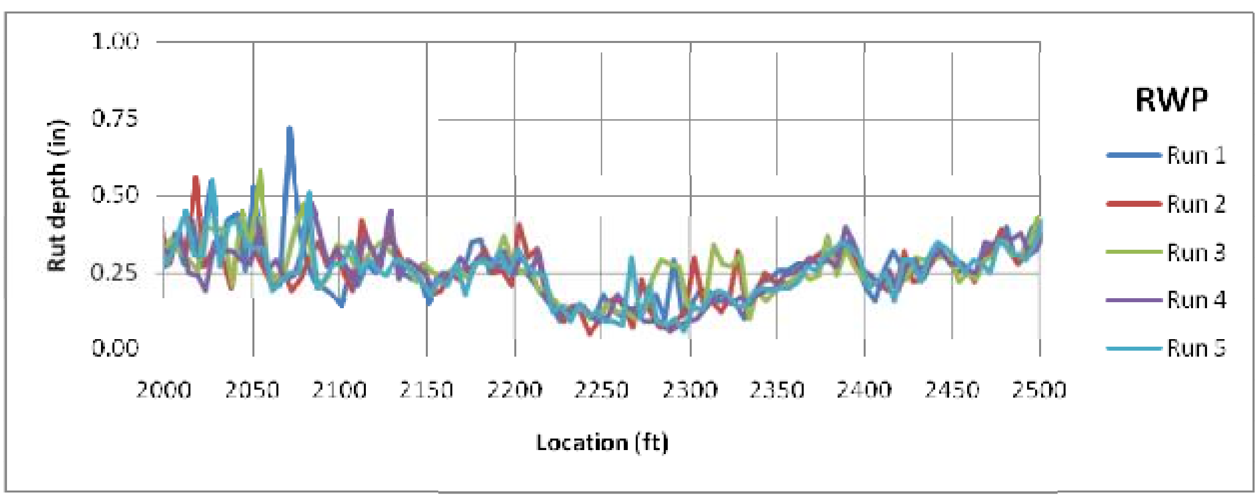




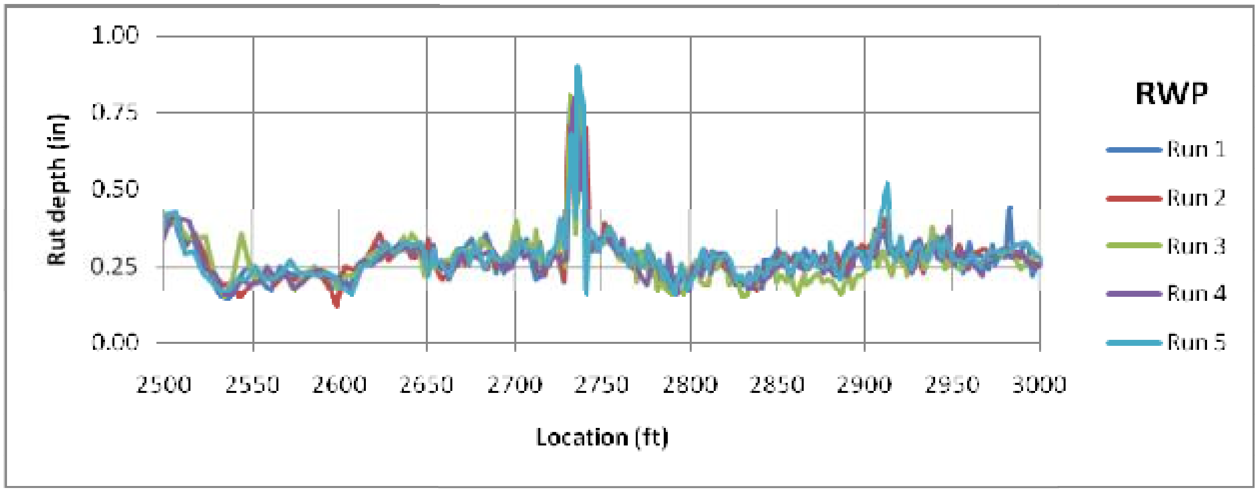
1.25
1.00
0.75
0.50
0.25
0.00
Rut depth (in)
1000
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500
Location (ft)
RWP
Run 1
Run 2
Run 3
Run 4
Run 5



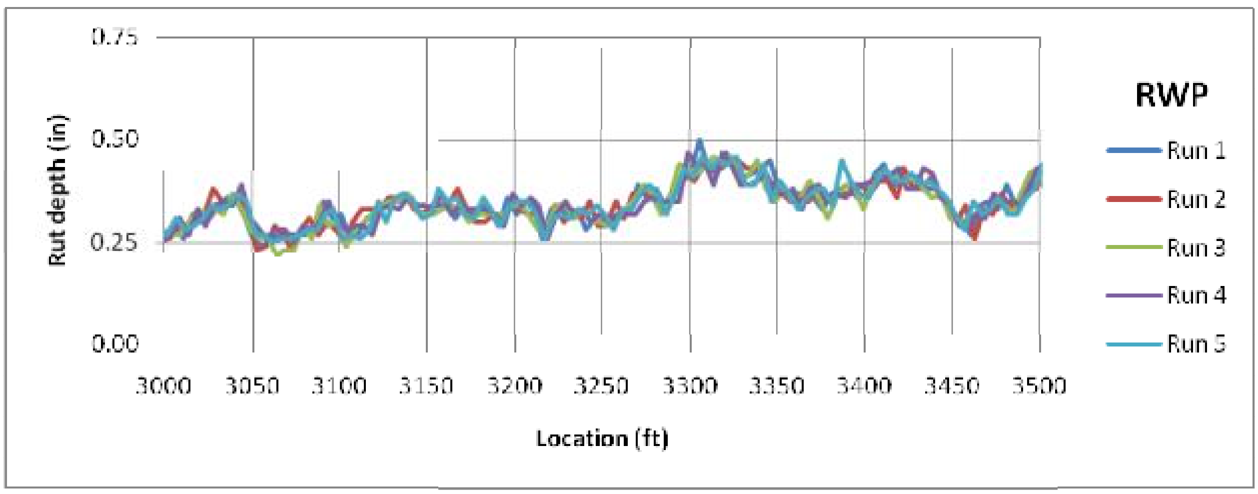
1.00
0.75
0.50
0.25
0.00
Rut depth (in)
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
Location (ft)
RWP
Run 1
Run 2
Run 3
Run 4
Run 5



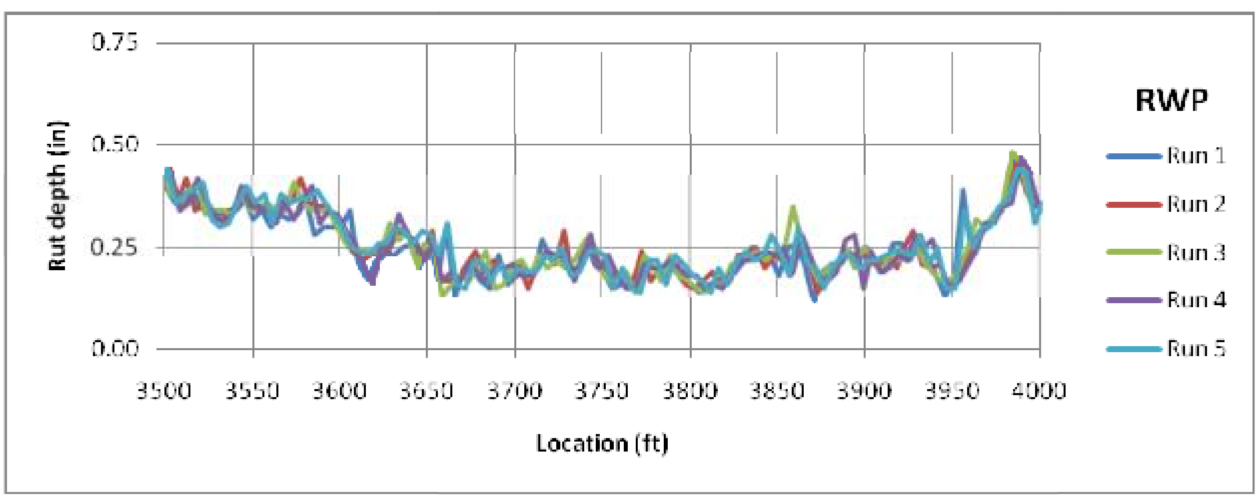
1.00
0.75
0.50
0.25
0.00
Rut depth (in)
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
Location (ft)
RWP
Run 1
Run 2
Run 3
Run 4
Run 5



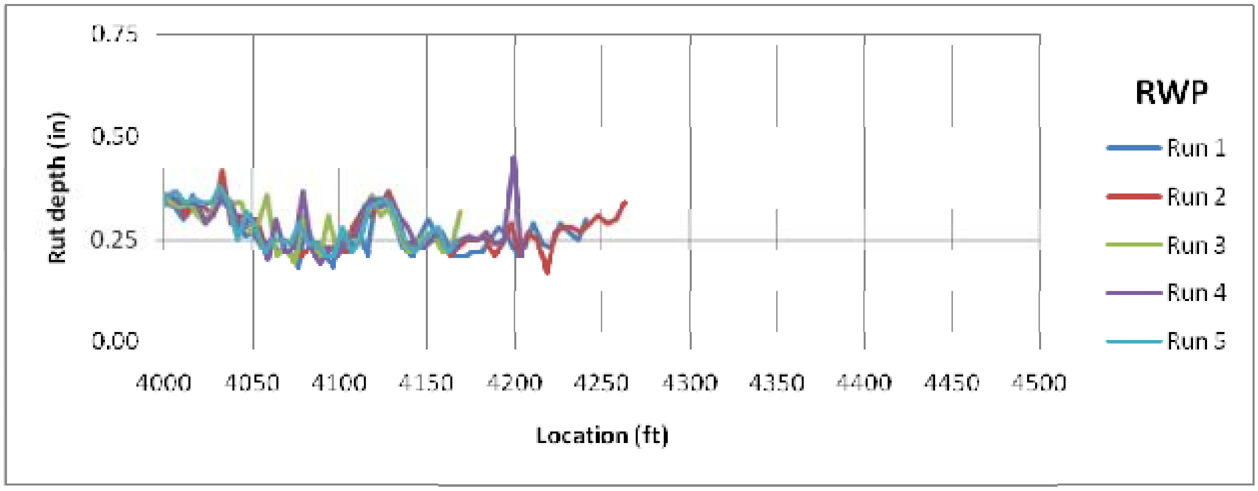
1.00
0.75
0.50
0.25
0.00
Rut depth (in)
2500
2550
2600
2650
2700
2750
2800
2850
2900
2950
3000
Location (ft)
RWP
Run 1
Run 2
Run 3
Run 4
Run 5



0.75
0.50
0.25
0.00
Rut depth (in)
3000
3050
3100
3150
3200
3250
3300
3350
3400
3450
3500
Location (ft)
RWP
Run 1
Run 2
Run 3
Run 4
Run 5



0.75
0.50
0.25
0.00
Rut depth (in)
3500
3550
3600
3650
3700
3750
3800
3850
3900
3950
4000
Location (ft)
RWP
Run 1
Run 2
Run 3
Run 4
Run 5



0.75
0.50
0.25
0.00
Rut depth (in)
4000
4050
4100
4150
4200
4250
4300
4350
4400
4450
4500
Location (ft)
RWP
Run 1
Run 2
Run 3
Run 4
Run 5

Appendix C: PCR Data from District 10 (S&G and LRMS)

County Abbrev	Trans Route		Milepost Start	Milepost End	Segment Length (mi)**	Pavement Type	PCR Ratings S&G	PCR Ratings LRMS	PCR Ratings LRMS (adj*)	PCR Scores S&G	PCR Scores LRMS	PCR Scores LRMS (adj*)
ATH	SR	00143	0	0.79	0.79	FLEXIBLE				0	0	0
ATH	SR	00144	0	4.63	4.63	FLEXIBLE		HO	HO	0	6	6
ATH	SR	00144	4.63	8.37	3.74	FLEXIBLE		MO	LO	0	4.2	1.8
ATH	SR	00144	8.37	13.84	5.47	FLEXIBLE		HO	MO	0	6	4.2
ATH	SR	00144	13.84	14.61	0.77	FLEXIBLE		HO	MF	0	6	5.6
ATH	SR	00681	7.28	7.79	0.51	FLEXIBLE				0	0	0
ATH	SR	00681	7.79	10.49	2.7	FLEXIBLE		LO		0	1.8	0
ATH	SR	00124	0	3.33	3.33	FLEXIBLE	LO	HO	LO	1.8	6	1.8
ATH	SR	00681	0	6.61	6.61	FLEXIBLE	LO	LF	LF	1.8	2.4	2.4
ATH	SR	00681	6.61	7.28	0.67	FLEXIBLE	LO			1.8	0	0
ATH	SR	00078	3.38	7.2	3.82	FLEXIBLE	LF	MO	LO	2.4	4.2	1.8
ATH	SR	00078	7.2	8.35	1.15	FLEXIBLE	LF	LO	LO	2.4	1.8	1.8
ATH	SR	00078	9.37	10.37	1	FLEXIBLE	LF	LO		2.4	1.8	0
ATH	SR	00078	10.37	10.88	0.51	FLEXIBLE	LF	MO	LF	2.4	4.2	2.4
ATH	SR	00356	0	4.77	4.77	FLEXIBLE	MO	MO	LO	4.2	4.2	1.8
ATH	SR	00013	12.88	15.44	2.56	COMPOSITE	MO	HO	MF	4.2	6	5.6
GAL	SR	00141	0	7.74	7.74	FLEXIBLE		HO	MO	0	6	4.2
GAL	SR	00141	7.74	9.04	1.3	FLEXIBLE		MO	MO	0	4.2	4.2
GAL	SR	00141	9.04	16.03	6.99	FLEXIBLE		HO	LO	0	6	1.8
GAL	SR	00141	16.03	20.82	4.79	FLEXIBLE		MO	LO	0	4.2	1.8
GAL	SR	00141	20.82	21.55	0.73	FLEXIBLE		HO	MO	0	6	4.2
GAL	SR	00218	0	3.89	3.89	FLEXIBLE		HO	MF	0	6	5.6
GAL	SR	00218	3.89	7.55	3.66	FLEXIBLE		HO	MO	0	6	4.2
GAL	SR	00218	7.55	11.6	4.05	FLEXIBLE		MO	MO	0	4.2	4.2
GAL	SR	00218	11.6	13.83	2.23	FLEXIBLE		HO	MF	0	6	5.6
GAL	SR	00218	13.83	17.09	3.26	FLEXIBLE		MO	MO	0	4.2	4.2
GAL	SR	00233	0	7.92	7.92	FLEXIBLE		HO	LO	0	6	1.8
GAL	SR	00325	0	6.53	6.53	FLEXIBLE				0	0	0
GAL	SR	00325	6.53	7.26	0.73	FLEXIBLE				0	0	0
GAL	SR	00325	12.02	14.18	2.16	FLEXIBLE		LO		0	1.8	0
GAL	SR	00553	0	0.31	0.31	FLEXIBLE				0	0	0
GAL	SR	00141	21.55	22.15	0.6	FLEXIBLE	LO	HO	MO	1.8	6	4.2

* Adjusted for 5-25% range for "occasional" classification

** 1 mi = 1.61 km

County Abbrev	Trans Route		Milepost		Segment Length (mi)**	Pavement Type	PCR Ratings			PCR Scores		
			Start	End			S&G	LRMS	LRMS (adj*)	S&G	LRMS	LRMS (adj*)
GAL	SR	00325	7.26	12.02	4.76	FLEXIBLE	LO	LO		1.8	1.8	0
GAL	SR	00553	0.31	2.33	2.02	FLEXIBLE	LF			2.4	0	0
HOC	SR	00056	0.53	9.44	8.91	FLEXIBLE		MO	LO	0	4.2	1.8
HOC	SR	00093	0	7.31	7.31	FLEXIBLE		HO	MO	0	6	4.2
HOC	SR	00093	7.31	9.94	2.63	FLEXIBLE		HO	HO	0	6	6
HOC	SR	00093	9.94	12.25	2.31	FLEXIBLE		HO	MO	0	6	4.2
HOC	SR	00093	13.68	18.34	4.66	FLEXIBLE		HO	MF	0	6	5.6
HOC	SR	00093	18.34	19.86	1.52	FLEXIBLE		MO	MO	0	4.2	4.2
HOC	SR	00093	19.86	23.47	3.61	FLEXIBLE		HO	MO	0	6	4.2
HOC	SR	00180	0.05	0.39	0.34	FLEXIBLE		MO	MO	0	4.2	4.2
HOC	SR	00278	0	0.25	0.25	FLEXIBLE		MO	MO	0	4.2	4.2
HOC	SR	00278	0.34	5.38	5.04	FLEXIBLE		HO	MO	0	6	4.2
HOC	SR	00312	0	0.4	0.4	FLEXIBLE		LO		0	1.8	0
HOC	SR	00327	3.8	4.56	0.76	FLEXIBLE				0	0	0
HOC	SR	00328	1.75	4.35	2.6	FLEXIBLE		HO	MO	0	6	4.2
HOC	SR	00328	4.35	6.3	1.95	FLEXIBLE		MO	MO	0	4.2	4.2
HOC	SR	00328	6.3	10.67	4.37	FLEXIBLE		MO	MO	0	4.2	4.2
HOC	SR	00374	3.74	6.15	2.41	FLEXIBLE		MO	MO	0	4.2	4.2
HOC	SR	00374	6.15	12.97	6.82	FLEXIBLE		HO	HO	0	6	6
HOC	SR	00374	12.97	13.29	0.32	FLEXIBLE		HF	HF	0	8	8
HOC	SR	00374	17.91	25.3	7.39	FLEXIBLE		HO	MO	0	6	4.2
HOC	SR	00595	3.03	7.08	4.05	FLEXIBLE		HO	HO	0	6	6
HOC	SR	00664	0	2.9	2.9	FLEXIBLE		LO		0	1.8	0
HOC	SR	00678	0	4	4	FLEXIBLE		HO	MO	0	6	4.2
HOC	SR	00056	0	0.53	0.53	FLEXIBLE	LO	HO	MO	1.8	6	4.2
HOC	SR	00056	14.96	21.29	6.33	FLEXIBLE	LO	HO	MF	1.8	6	5.6
HOC	SR	00093	13.08	13.68	0.6	FLEXIBLE	LO	LF	LF	1.8	2.4	2.4
HOC	SR	00180	0.39	2.36	1.97	FLEXIBLE	LO	HO	MO	1.8	6	4.2
HOC	SR	00180	2.36	7.35	4.99	FLEXIBLE	LO	HO	MO	1.8	6	4.2
HOC	SR	00180	16.08	16.32	0.24	FLEXIBLE	LO	MO	MO	1.8	4.2	4.2
HOC	SR	00216	0	4.68	4.68	FLEXIBLE	LO	HO	MF	1.8	6	5.6
HOC	SR	00327	0	3.8	3.8	FLEXIBLE	LO	LO	LO	1.8	1.8	1.8

* Adjusted for 5-25% range for "occasional" classification

** 1 mi = 1.61 km

County Abbrev	Trans Route		Milepost		Segment Length (mi)**	Pavement Type	PCR Ratings			PCR Scores		
			Start	End			S&G	LRMS	LRMS (adj*)	S&G	LRMS	LRMS (adj*)
HOC	SR	00664	16.33	21.61	5.28	FLEXIBLE	LO	LO		1.8	1.8	0
HOC	SR	00664	21.61	24.5	2.89	FLEXIBLE	LO	LO		1.8	1.8	0
HOC	SR	00093	12.62	13.08	0.46	FLEXIBLE	LF	MO	MO	2.4	4.2	4.2
HOC	SR	00664	5.31	12.07	6.76	FLEXIBLE	LF	MO	MO	2.4	4.2	4.2
HOC	SR	00664	12.07	15.05	2.98	FLEXIBLE	LF	HO	MO	2.4	6	4.2
HOC	SR	00664	15.93	16.33	0.4	FLEXIBLE	LF	LO		2.4	1.8	0
HOC	SR	00664	15.05	15.93	0.88	FLEXIBLE	LE	HO	HO	3	6	6
HOC	SR	00180	7.35	14.43	7.08	FLEXIBLE	MO	HO	MF	4.2	6	5.6
HOC	SR	00180	14.43	16.08	1.65	FLEXIBLE	MO	MO	MO	4.2	4.2	4.2
HOC	SR	00374	0	3.74	3.74	FLEXIBLE	MO	MO	MO	4.2	4.2	4.2
MEG	SR	00124	8.71	12.15	3.44	FLEXIBLE		HO	LO	0	6	1.8
MEG	SR	00124	20.66	20.8	0.14	FLEXIBLE		LF	LF	0	2.4	2.4
MEG	SR	00124	20.8	20.94	0.14	FLEXIBLE				0	0	0
MEG	SR	00124	29.55	31.46	1.91	FLEXIBLE		MO	LO	0	4.2	1.8
MEG	SR	00124	31.9	36.74	4.84	FLEXIBLE		MO	LO	0	4.2	1.8
MEG	SR	00124	36.74	38.55	1.81	FLEXIBLE		MO	LO	0	4.2	1.8
MEG	SR	00124	38.55	42.02	3.47	FLEXIBLE		MO	LO	0	4.2	1.8
MEG	SR	00124	42.02	45.04	3.02	FLEXIBLE		MO	LO	0	4.2	1.8
MEG	SR	00124	45.04	45.63	0.59	FLEXIBLE		MO	LO	0	4.2	1.8
MEG	SR	00124	45.63	45.91	0.28	FLEXIBLE		LO		0	1.8	0
MEG	SR	00124	51.22	57.29	6.07	FLEXIBLE		LO	LO	0	1.8	1.8
MEG	SR	00124	62.29	66.18	3.89	FLEXIBLE		MO	LO	0	4.2	1.8
MEG	SR	00124	66.18	66.93	0.75	FLEXIBLE				0	0	0
MEG	SR	00143	1.05	8.25	7.2	FLEXIBLE		HO	MO	0	6	4.2
MEG	SR	00143	15.5	19.36	3.86	FLEXIBLE		HO	HO	0	6	6
MEG	SR	00248	0	9.15	9.15	FLEXIBLE		MO	LO	0	4.2	1.8
MEG	SR	00681	0	4.76	4.76	FLEXIBLE		MO	LO	0	4.2	1.8
MEG	SR	00681	4.76	9.06	4.3	FLEXIBLE		MO		0	4.2	0
MEG	SR	00681	9.06	9.7	0.64	FLEXIBLE				0	0	0
MEG	SR	00681	9.7	17.49	7.79	FLEXIBLE		MO	LO	0	4.2	1.8
MEG	SR	00681	17.49	21.16	3.67	FLEXIBLE		MO		0	4.2	0
MEG	SR	00684	0.58	2.97	2.39	FLEXIBLE		MF	MF	0	5.6	5.6

* Adjusted for 5-25% range for "occasional" classification

** 1 mi = 1.61 km

County Abbrev	Trans Route		Milepost		Segment Length (mi)**	Pavement Type	PCR Ratings			PCR Scores		
			Start	End			S&G	LRMS	LRMS (adj*)	S&G	LRMS	LRMS (adj*)
MEG	SR	00689	0	4.16	4.16	FLEXIBLE		MF	MF	0	5.6	5.6
MEG	SR	00692	0	3.19	3.19	FLEXIBLE		MO	MO	0	4.2	4.2
MEG	SR	00833	0.08	0.37	0.29	COMPOSITE				0	0	0
MEG	SR	00833	0.37	2.84	2.47	COMPOSITE		MO	LO	0	4.2	1.8
MEG	SR	00124	0	8.71	8.71	FLEXIBLE	LO	HO	MF	1.8	6	5.6
MEG	SR	00124	23.74	29.04	5.3	FLEXIBLE	LO	MO	MO	1.8	4.2	4.2
MEG	SR	00124	29.04	29.55	0.51	FLEXIBLE	LO	MO	LO	1.8	4.2	1.8
MEG	SR	00124	45.91	47.36	1.45	FLEXIBLE	LO	MO	MO	1.8	4.2	4.2
MEG	SR	00124	47.36	51.22	3.86	FLEXIBLE	LO	LO	LO	1.8	1.8	1.8
MEG	SR	00124	57.29	62.29	5	FLEXIBLE	LO	MO	LO	1.8	4.2	1.8
MEG	SR	00681	21.16	28.94	7.78	FLEXIBLE	LO	LO	LO	1.8	1.8	1.8
MEG	SR	00124	22.52	22.73	0.21	FLEXIBLE	LF	LO	LO	2.4	1.8	1.8
MOE	SR	00007	0.33	0.83	0.5	FLEXIBLE		LO	LO	0	1.8	1.8
MOE	SR	00007	1.09	2.06	0.97	FLEXIBLE		LO	LO	0	1.8	1.8
MOE	SR	00007	12.41	13.37	0.96	FLEXIBLE		MO	MO	0	4.2	4.2
MOE	SR	00026	0	5.56	5.56	FLEXIBLE		HO	MO	0	6	4.2
MOE	SR	00026	5.56	7.76	2.2	FLEXIBLE		HO	MO	0	6	4.2
MOE	SR	00026	7.76	12.64	4.88	FLEXIBLE		HO	HO	0	6	6
MOE	SR	00026	12.64	14.76	2.12	FLEXIBLE		HO	HO	0	6	6
MOE	SR	00026	14.76	16.42	1.66	FLEXIBLE		MF	MF	0	5.6	5.6
MOE	SR	00026	16.42	17.14	0.72	FLEXIBLE		MO	LF	0	4.2	2.4
MOE	SR	00026	17.14	17.98	0.84	FLEXIBLE		HO	MO	0	6	4.2
MOE	SR	00026	21.37	29.7	8.33	FLEXIBLE		HO	MF	0	6	5.6
MOE	SR	00026	29.7	30.35	0.65	FLEXIBLE		HO	MF	0	6	5.6
MOE	SR	00078	0	2.03	2.03	FLEXIBLE		HO	MO	0	6	4.2
MOE	SR	00078	7.46	8.13	0.67	FLEXIBLE		MO	MO	0	4.2	4.2
MOE	SR	00078	8.13	8.78	0.65	FLEXIBLE		HO	MF	0	6	5.6
MOE	SR	00078	16.42	17.24	0.82	FLEXIBLE		MF	MF	0	5.6	5.6
MOE	SR	00078	17.24	23.5	6.26	FLEXIBLE		HO	MF	0	6	5.6
MOE	SR	00078	23.5	27.8	4.3	FLEXIBLE		ME	MF	0	7	5.6
MOE	SR	00145	0	0.79	0.79	FLEXIBLE		MO	LF	0	4.2	2.4
MOE	SR	00145	0.79	7.37	6.58	FLEXIBLE		HO	MO	0	6	4.2

* Adjusted for 5-25% range for "occasional" classification

** 1 mi = 1.61 km

County Abbrev	Trans Route		Milepost Start	End	Segment Length (mi)**	Pavement Type	PCR Ratings S&G	LRMS	LRMS (adj*)	PCR Scores S&G	LRMS	LRMS (adj*)
MOE	SR	00145	7.37	8.5	1.13	FLEXIBLE		ME	MF	0	7	5.6
MOE	SR	00145	8.5	15.36	6.86	FLEXIBLE		HO	MF	0	6	5.6
MOE	SR	00145	15.36	20.4	5.04	FLEXIBLE		MO	MO	0	4.2	4.2
MOE	SR	00145	20.4	21.41	1.01	FLEXIBLE				0	0	0
MOE	SR	00145	22.06	24.47	2.41	FLEXIBLE		MO	MO	0	4.2	4.2
MOE	SR	00145	24.47	25.8	1.33	FLEXIBLE		HO	MO	0	6	4.2
MOE	SR	00255	0	8.87	8.87	FLEXIBLE		HO	HO	0	6	6
MOE	SR	00260	4.33	5.52	1.19	FLEXIBLE		HO	HO	0	6	6
MOE	SR	00260	5.52	8.73	3.21	FLEXIBLE		HF	HF	0	8	8
MOE	SR	00260	8.73	11.32	2.59	FLEXIBLE		HO	HO	0	6	6
MOE	SR	00379	0	1.85	1.85	FLEXIBLE		HO	HO	0	6	6
MOE	SR	00536	0.64	12.58	11.94	FLEXIBLE		HO	MF	0	6	5.6
MOE	SR	00565	0	4.1	4.1	FLEXIBLE		HO	MF	0	6	5.6
MOE	SR	00800	17.92	18.39	0.47	FLEXIBLE				0	0	0
MOE	SR	00800	18.39	23.09	4.7	FLEXIBLE				0	0	0
MOE	SR	00800	23.09	26.04	2.95	FLEXIBLE		LO		0	1.8	0
MOE	SR	00007	0	0.33	0.33	COMPOSITE		LF	LF	0	2.4	2.4
MOE	SR	00007	0.83	1.09	0.26	COMPOSITE		LE	LF	0	3	2.4
MOE	SR	00007	2.06	2.21	0.15	COMPOSITE		LF	LF	0	2.4	2.4
MOE	SR	00007	8.5	12.41	3.91	COMPOSITE		MO	MO	0	4.2	4.2
MOE	SR	00007	13.37	13.95	0.58	COMPOSITE		LO		0	1.8	0
MOE	SR	00007	13.95	21.32	7.37	COMPOSITE		MO	MO	0	4.2	4.2
MOE	SR	00007	21.32	22.73	1.41	COMPOSITE		ME	MF	0	7	5.6
MOE	SR	00007	25.23	28.55	3.32	COMPOSITE		MO	MO	0	4.2	4.2
MOE	SR	00078	9.17	14.35	5.18	COMPOSITE		MF	MF	0	5.6	5.6
MOE	SR	00078	14.35	15.33	0.98	COMPOSITE				0	0	0
MOE	SR	00536	0	0.24	0.24	COMPOSITE		MF	MF	0	5.6	5.6
MOE	SR	00026	17.98	21.37	3.39	FLEXIBLE	LO	MF	MF	1.8	5.6	5.6
MOE	SR	00078	2.03	7.46	5.43	FLEXIBLE	LO	HO	HO	1.8	6	6
MOE	SR	00078	27.8	32.26	4.46	FLEXIBLE	LO	MF	MF	1.8	5.6	5.6
MOE	SR	00379	1.85	4.67	2.82	FLEXIBLE	LO	HO	HO	1.8	6	6
MOE	SR	00379	4.67	8.07	3.4	FLEXIBLE	LO	HO	HO	1.8	6	6

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** 1 mi = 1.61 km

County Abbrev	Trans Route		Milepost Start	Milepost End	Segment Length (mi)**	Pavement Type	PCR Ratings S&G	PCR Ratings LRMS	PCR Ratings LRMS (adj*)	PCR Scores S&G	PCR Scores LRMS	PCR Scores LRMS (adj*)
MOE	SR	00537	0	4.98	4.98	FLEXIBLE	LO	HO	HO	1.8	6	6
MOE	SR	00078	8.78	9.17	0.39	COMPOSITE	LO	MO	LF	1.8	4.2	2.4
MOE	SR	00078	15.33	15.72	0.39	COMPOSITE	LO	LO		1.8	1.8	0
MOE	SR	00078	15.72	16.42	0.7	FLEXIBLE	MO	MF	MF	4.2	5.6	5.6
MOE	SR	00007	2.21	8.5	6.29	COMPOSITE	MF	HO	LO	5.6	6	1.8
MRG	SR	00078	0	8.81	8.81	FLEXIBLE		HO	MO	0	6	4.2
MRG	SR	00078	8.81	10.25	1.44	FLEXIBLE		MO	MO	0	4.2	4.2
MRG	SR	00078	26.04	27.8	1.76	FLEXIBLE		MO	LO	0	4.2	1.8
MRG	SR	00083	10.32	15.58	5.26	FLEXIBLE		HO	MO	0	6	4.2
MRG	SR	00376	9.99	11.1	1.11	FLEXIBLE		MO	LO	0	4.2	1.8
MRG	SR	00376	11.1	13.24	2.14	FLEXIBLE		HO	MO	0	6	4.2
MRG	SR	00376	13.24	18.4	5.16	FLEXIBLE		HO	MO	0	6	4.2
MRG	SR	00376	18.4	19.43	1.03	FLEXIBLE		HO		0	6	0
MRG	SR	00078	10.25	15.69	5.44	FLEXIBLE	LO	MO	MO	1.8	4.2	4.2
MRG	SR	00078	15.69	16.8	1.11	FLEXIBLE	LO	MO	MO	1.8	4.2	4.2
MRG	SR	00060	17.99	21.82	3.83	COMPOSITE	LO			1.8	0	0
MRG	SR	00060	2.01	2.34	0.33	FLEXIBLE	LF	MO	MO	2.4	4.2	4.2
MRG	SR	00060	11.56	12.02	0.46	FLEXIBLE	LF	LO	LO	2.4	1.8	1.8
MRG	SR	00060	12.19	12.48	0.29	FLEXIBLE	LF			2.4	0	0
MRG	SR	00078	19.35	23.65	4.3	FLEXIBLE	LF	HO	MO	2.4	6	4.2
MRG	SR	00078	23.65	26.04	2.39	FLEXIBLE	LF	HO	MO	2.4	6	4.2
MRG	SR	00669	5.62	11.9	6.28	FLEXIBLE	LF	HO	MF	2.4	6	5.6
MRG	SR	00669	11.9	13.18	1.28	FLEXIBLE	LF	MO	LF	2.4	4.2	2.4
MRG	SR	00669	13.18	19.03	5.85	FLEXIBLE	LF	MO	LF	2.4	4.2	2.4
MRG	SR	00669	19.03	19.43	0.4	FLEXIBLE	LF	MO	LO	2.4	4.2	1.8
MRG	SR	00060	0	2.01	2.01	COMPOSITE	LF			2.4	0	0
MRG	SR	00060	2.34	3.32	0.98	COMPOSITE	LF			2.4	0	0
MRG	SR	00060	3.73	4.01	0.28	COMPOSITE	LF			2.4	0	0
MRG	SR	00060	4.01	9.36	5.35	COMPOSITE	LF	MO	LO	2.4	4.2	1.8
MRG	SR	00060	12.02	12.19	0.17	COMPOSITE	LF			2.4	0	0
MRG	SR	00060	12.86	17.99	5.13	COMPOSITE	LF			2.4	0	0
MRG	SR	00060	3.32	3.73	0.41	FLEXIBLE	LE			3	0	0

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** 1 mi = 1.61 km

County Abbrev	Trans Route		Milepost		Segment Length (mi)**	Pavement Type	PCR Ratings			PCR Scores		
			Start	End			S&G	LRMS	LRMS (adj*)	S&G	LRMS	LRMS (adj*)
MRG	SR	00669	0	0.44	0.44	FLEXIBLE	LE	HO	MO	3	6	4.2
MRG	SR	00060	11.23	11.56	0.33	COMPOSITE	LE	MO		3	4.2	0
MRG	SR	00060	12.48	12.86	0.38	COMPOSITE	LE			3	0	0
MRG	SR	00078	18.88	19.35	0.47	FLEXIBLE	MO	LO		4.2	1.8	0
MRG	SR	00078	27.8	30.58	2.78	FLEXIBLE	MO	HO	MO	4.2	6	4.2
MRG	SR	00284	0	4.05	4.05	FLEXIBLE	MO	MO	LO	4.2	4.2	1.8
MRG	SR	00555	23.02	27.12	4.1	FLEXIBLE	MO	HO	MO	4.2	6	4.2
MRG	SR	00669	0.44	2.65	2.21	FLEXIBLE	MO	HO	MO	4.2	6	4.2
MRG	SR	00060	9.36	11.23	1.87	COMPOSITE	MO	MO	MO	4.2	4.2	4.2
NOB	SR	00078	16.04	20.09	4.05	FLEXIBLE		MO		0	4.2	0
NOB	SR	00078	20.09	21.35	1.26	FLEXIBLE		MO	LO	0	4.2	1.8
NOB	SR	00083	0	6.77	6.77	FLEXIBLE		HO	MO	0	6	4.2
NOB	SR	00146	8.15	8.38	0.23	FLEXIBLE		LF	LF	0	2.4	2.4
NOB	SR	00146	8.38	8.85	0.47	FLEXIBLE		MO	MO	0	4.2	4.2
NOB	SR	00146	8.85	9.4	0.55	FLEXIBLE		MO	MO	0	4.2	4.2
NOB	SR	00146	9.4	18.02	8.62	FLEXIBLE		HO	MO	0	6	4.2
NOB	SR	00146	18.02	18.59	0.57	FLEXIBLE		LF	LF	0	2.4	2.4
NOB	SR	00147	17.03	21.04	4.01	FLEXIBLE		HO	MO	0	6	4.2
NOB	SR	00260	12.13	14.35	2.22	FLEXIBLE		HO	MO	0	6	4.2
NOB	SR	00265	0	0.32	0.32	FLEXIBLE		ME	MF	0	7	5.6
NOB	SR	00821	7.33	7.62	0.29	FLEXIBLE		LO		0	1.8	0
NOB	SR	00078	7.89	12.51	4.62	COMPOSITE				0	0	0
NOB	SR	00078	12.51	16.04	3.53	COMPOSITE		MF	MF	0	5.6	5.6
NOB	SR	00821	0.84	1.36	0.52	COMPOSITE		HO	LO	0	6	1.8
NOB	SR	00821	1.36	2.18	0.82	COMPOSITE		MO		0	4.2	0
NOB	SR	00821	2.18	7.33	5.15	COMPOSITE		LO		0	1.8	0
NOB	SR	00821	12.57	12.77	0.2	COMPOSITE		LO	LO	0	1.8	1.8
NOB	SR	00146	0	0.85	0.85	FLEXIBLE	LO	HO	MF	1.8	6	5.6
NOB	SR	00260	0	1.9	1.9	FLEXIBLE	LO	HO	HO	1.8	6	6
NOB	SR	00260	3.77	11.1	7.33	FLEXIBLE	LO	HO	MO	1.8	6	4.2
NOB	SR	00260	11.1	12.13	1.03	FLEXIBLE	LO	MO	LO	1.8	4.2	1.8
NOB	SR	00313	0	1.25	1.25	FLEXIBLE	LO	HO	MF	1.8	6	5.6

* Adjusted for 5-25% range for "occasional" classification

** 1 mi = 1.61 km

County Abbrev	Trans Route		Milepost Start	Milepost End	Segment Length (mi)**	Pavement Type	PCR Ratings S&G	PCR Ratings LRMS	PCR Ratings LRMS (adj*)	PCR Scores S&G	PCR Scores LRMS	PCR Scores LRMS (adj*)
NOB	SR	00313	1.25	6.21	4.96	FLEXIBLE	LO	HO	MF	1.8	6	5.6
NOB	SR	00340	0.71	7.08	6.37	FLEXIBLE	LO	HO	MO	1.8	6	4.2
NOB	SR	00513	5.57	9.38	3.81	FLEXIBLE	LO	HO	MF	1.8	6	5.6
NOB	SR	00513	9.46	10.1	0.64	FLEXIBLE	LO	HO	MF	1.8	6	5.6
NOB	SR	00564	4.32	8.91	4.59	FLEXIBLE	LO	MO	LO	1.8	4.2	1.8
NOB	SR	00564	8.91	10.66	1.75	FLEXIBLE	LO	MO	LO	1.8	4.2	1.8
NOB	SR	00724	0	2.75	2.75	FLEXIBLE	LO	MF	MF	1.8	5.6	5.6
NOB	SR	00761	0	1.9	1.9	FLEXIBLE	LO	MF	MF	1.8	5.6	5.6
NOB	SR	00821	0	0.84	0.84	COMPOSITE	LO	MO		1.8	4.2	0
NOB	SR	00145	0	9.18	9.18	FLEXIBLE	LF	HO	MO	2.4	6	4.2
NOB	SR	00145	9.18	12.39	3.21	FLEXIBLE	LF	MO	MO	2.4	4.2	4.2
NOB	SR	00564	0.01	1.44	1.43	FLEXIBLE	LF	MO	LF	2.4	4.2	2.4
NOB	SR	00564	1.44	4.32	2.88	FLEXIBLE	LF	MO	MO	2.4	4.2	4.2
NOB	SR	00564	10.66	13.48	2.82	FLEXIBLE	LF	LO	LO	2.4	1.8	1.8
NOB	SR	00565	0	2.88	2.88	FLEXIBLE	LF	MO	MO	2.4	4.2	4.2
NOB	SR	00821	11.97	12.24	0.27	FLEXIBLE	LF	MO		2.4	4.2	0
NOB	SR	00821	16.55	21.36	4.81	FLEXIBLE	LF	MO	MO	2.4	4.2	4.2
NOB	SR	00821	13.22	16.55	3.33	COMPOSITE	LF	MO	MO	2.4	4.2	4.2
NOB	SR	00821	13.09	13.22	0.13	FLEXIBLE	LE	MO	MO	3	4.2	4.2
NOB	SR	00821	8.3	8.62	0.32	COMPOSITE	LE	MO	LO	3	4.2	1.8
NOB	SR	00821	12.77	13.09	0.32	COMPOSITE	LE	MF	MF	3	5.6	5.6
NOB	SR	00146	0.85	8.15	7.3	FLEXIBLE	MO	HO	MF	4.2	6	5.6
NOB	SR	00340	0	0.71	0.71	FLEXIBLE	MO	MF	MF	4.2	5.6	5.6
NOB	SR	00513	0	0.42	0.42	FLEXIBLE	MO	HO	HO	4.2	6	6
NOB	SR	00513	0.42	5.57	5.15	FLEXIBLE	MO	HO	HO	4.2	6	6
NOB	SR	00513	10.1	12.45	2.35	FLEXIBLE	MO	HO	MF	4.2	6	5.6
NOB	SR	00672	0	0.37	0.37	FLEXIBLE	MO	HO	MF	4.2	6	5.6
NOB	SR	00821	7.62	8.3	0.68	COMPOSITE	MO	MO	LO	4.2	4.2	1.8
NOB	SR	00821	8.62	9	0.38	FLEXIBLE	MF	MO	MO	5.6	4.2	4.2
NOB	SR	00821	12.24	12.57	0.33	FLEXIBLE	MF	MO	LO	5.6	4.2	1.8
VIN	SR	00056	3.2	7.65	4.45	FLEXIBLE				0	0	0
VIN	SR	00327	0	2.24	2.24	FLEXIBLE				0	0	0

* Adjusted for 5-25% range for "occasional" classification

** 1 mi = 1.61 km

County Abbrev	Trans Route		Milepost Start	Milepost End	Segment Length (mi)**	Pavement Type	PCR Ratings S&G	PCR Ratings LRMS	PCR Ratings LRMS (adj*)	PCR Scores S&G	PCR Scores LRMS	PCR Scores LRMS (adj*)
VIN	SR	00056	0	3.2	3.2	FLEXIBLE	LO			1.8	0	0
VIN	SR	00327	2.24	4.94	2.7	FLEXIBLE	LO			1.8	0	0
VIN	SR	00671	0	4.58	4.58	FLEXIBLE	LO	LO		1.8	1.8	0
VIN	SR	00689	0	3.36	3.36	FLEXIBLE	LO	MO	MO	1.8	4.2	4.2
VIN	SR	00327	6.89	13.56	6.67	FLEXIBLE	LF	MO		2.4	4.2	0
VIN	US	00050	4.91	9.19	4.28	FLEXIBLE				0	0	0
VIN	US	00050	12.08	13.67	1.59	FLEXIBLE				0	0	0
VIN	US	00050	0	4.91	4.91	COMPOSITE				0	0	0
VIN	US	00050	9.19	10.68	1.49	COMPOSITE				0	0	0
VIN	US	00050	17.75	18.23	0.48	COMPOSITE				0	0	0
VIN	US	00050	18.23	19.76	1.53	COMPOSITE		MO		0	4.2	0
VIN	US	00050	13.67	16.34	2.67	FLEXIBLE	LO			1.8	0	0
VIN	US	00050	16.34	16.56	0.22	COMPOSITE	LO			1.8	0	0
VIN	US	00050	23.1	26.5	3.4	COMPOSITE	LO	LO		1.8	1.8	0
VIN	US	00050	26.5	30.16	3.66	COMPOSITE	LO	LO		1.8	1.8	0
VIN	US	00050	10.68	12.08	1.4	FLEXIBLE	LF	LO		2.4	1.8	0
VIN	US	00050	17.58	17.75	0.17	FLEXIBLE	LF			2.4	0	0
VIN	US	00050	16.56	16.68	0.12	COMPOSITE	LF			2.4	0	0
VIN	US	00050	19.76	23.1	3.34	COMPOSITE	LF	LO		2.4	1.8	0
VIN	US	00050	16.68	17.58	0.9	COMPOSITE	LE			3	0	0
WAS	SR	00007	33.12	34.12	1	FLEXIBLE				0	0	0
WAS	SR	00007	36.26	37.24	0.98	FLEXIBLE		MO		0	4.2	0
WAS	SR	00026	12.57	19.03	6.46	FLEXIBLE		HO	HO	0	6	6
WAS	SR	00026	19.03	20.84	1.81	FLEXIBLE		HO	HO	0	6	6
WAS	SR	00060	5.15	5.74	0.59	FLEXIBLE				0	0	0
WAS	SR	00260	0	0.3	0.3	FLEXIBLE		LO	LO	0	1.8	1.8
WAS	SR	00550	20.74	21.6	0.86	FLEXIBLE		MO	MO	0	4.2	4.2
WAS	SR	00555	7.48	9.94	2.46	FLEXIBLE		MF	MF	0	5.6	5.6
WAS	SR	00555	9.94	16.1	6.16	FLEXIBLE		MO	MO	0	4.2	4.2
WAS	SR	00555	16.1	19.41	3.31	FLEXIBLE		HO	MO	0	6	4.2
WAS	SR	00676	4.52	4.78	0.26	FLEXIBLE		MO	MO	0	4.2	4.2
WAS	SR	00676	4.78	5.41	0.63	FLEXIBLE		MF	MF	0	5.6	5.6

* Adjusted for 5-25% range for "occasional" classification

** 1 mi = 1.61 km

County Abbrev	Trans Route		Milepost		Segment Length (mi)**	Pavement Type	PCR Ratings			PCR Scores		
			Start	End			S&G	LRMS	LRMS (adj*)	S&G	LRMS	LRMS (adj*)
WAS	SR	00676	16.91	19.88	2.97	FLEXIBLE		HO	MF	0	6	5.6
WAS	SR	00676	19.88	22.05	2.17	FLEXIBLE		HO	MF	0	6	5.6
WAS	SR	00676	22.05	22.49	0.44	FLEXIBLE		MF	MF	0	5.6	5.6
WAS	SR	00676	22.49	23.06	0.57	FLEXIBLE		HO	HO	0	6	6
WAS	SR	00676	23.06	24.03	0.97	FLEXIBLE		HO	MO	0	6	4.2
WAS	SR	00807	0	0.24	0.24	FLEXIBLE		HO	MO	0	6	4.2
WAS	SR	00821	11.76	12.21	0.45	FLEXIBLE		HO	LO	0	6	1.8
WAS	SR	00007	24.51	24.86	0.35	COMPOSITE		LF	LF	0	2.4	2.4
WAS	SR	00007	24.51	24.86	0.35	COMPOSITE		LO	LO	0	1.8	1.8
WAS	SR	00007	24.86	26.01	1.15	COMPOSITE				0	0	0
WAS	SR	00007	24.86	26.01	1.15	COMPOSITE		LO		0	1.8	0
WAS	SR	00007	26.01	28.29	2.28	COMPOSITE		MO		0	4.2	0
WAS	SR	00007	26.01	28.29	2.28	COMPOSITE				0	0	0
WAS	SR	00007	28.29	31.59	3.3	COMPOSITE		MO		0	4.2	0
WAS	SR	00007	34.12	36.26	2.14	COMPOSITE		LO		0	1.8	0
WAS	SR	00060	5.74	10.3	4.56	COMPOSITE				0	0	0
WAS	SR	00060	10.3	10.95	0.65	COMPOSITE				0	0	0
WAS	SR	00060	10.95	11.24	0.29	COMPOSITE				0	0	0
WAS	SR	00124	2.82	4.34	1.52	COMPOSITE		MO	LO	0	4.2	1.8
WAS	SR	00550	1.28	2.5	1.22	COMPOSITE		MF	MF	0	5.6	5.6
WAS	SR	00618	0	1.48	1.48	COMPOSITE		MO	MO	0	4.2	4.2
WAS	SR	00618	1.48	3.23	1.75	COMPOSITE		MO		0	4.2	0
WAS	SR	00618	4	5.19	1.19	COMPOSITE		MO	LF	0	4.2	2.4
WAS	SR	00676	24.03	24.43	0.4	COMPOSITE		MO	MO	0	4.2	4.2
WAS	SR	00821	12.21	18.92	6.71	COMPOSITE		HO	MO	0	6	4.2
WAS	SR	00821	18.92	19.18	0.26	COMPOSITE		LO		0	1.8	0
WAS	SR	00821	19.18	19.58	0.4	COMPOSITE		LO		0	1.8	0
WAS	SR	00007	38.94	39.94	1	FLEXIBLE	LO			1.8	0	0
WAS	SR	00007	47.48	48.21	0.73	FLEXIBLE	LO			1.8	0	0
WAS	SR	00026	2.37	7	4.63	FLEXIBLE	LO	HO	MO	1.8	6	4.2
WAS	SR	00026	7	12.54	5.54	FLEXIBLE	LO	HO	HO	1.8	6	6
WAS	SR	00026	21.81	29.96	8.15	FLEXIBLE	LO	HO	LO	1.8	6	1.8

* Adjusted for 5-25% range for "occasional" classification

** 1 mi = 1.61 km

County Abbrev	Trans Route		Milepost		Segment Length (mi)**	Pavement Type	PCR Ratings			PCR Scores		
			Start	End			S&G	LRMS	LRMS (adj*)	S&G	LRMS	LRMS (adj*)
WAS	SR	00060	1.32	1.84	0.52	FLEXIBLE	LO			1.8	0	0
WAS	SR	00060	1.84	2.73	0.89	FLEXIBLE	LO			1.8	0	0
WAS	SR	00124	0	2.82	2.82	FLEXIBLE	LO	MO	MO	1.8	4.2	4.2
WAS	SR	00260	0.3	0.47	0.17	FLEXIBLE	LO	LO	LO	1.8	1.8	1.8
WAS	SR	00260	0.47	9.76	9.29	FLEXIBLE	LO	HO	MO	1.8	6	4.2
WAS	SR	00260	9.98	11	1.02	FLEXIBLE	LO	HO	HO	1.8	6	6
WAS	SR	00550	18.42	18.91	0.49	FLEXIBLE	LO	MF	MF	1.8	5.6	5.6
WAS	SR	00555	0	7.48	7.48	FLEXIBLE	LO	MF	MF	1.8	5.6	5.6
WAS	SR	00676	0	4.52	4.52	FLEXIBLE	LO	HO	MO	1.8	6	4.2
WAS	SR	00821	0.48	2.27	1.79	FLEXIBLE	LO			1.8	0	0
WAS	SR	00821	2.27	3.41	1.14	FLEXIBLE	LO	LO		1.8	1.8	0
WAS	SR	00007	39.94	40.16	0.22	COMPOSITE	LO			1.8	0	0
WAS	SR	00060	2.73	2.9	0.17	COMPOSITE	LO			1.8	0	0
WAS	SR	00550	0	0.89	0.89	COMPOSITE	LO	ME	MF	1.8	7	5.6
WAS	SR	00550	15.16	18.42	3.26	COMPOSITE	LO	MO	MO	1.8	4.2	4.2
WAS	SR	00550	21.6	21.86	0.26	COMPOSITE	LO	MO	MO	1.8	4.2	4.2
WAS	SR	00618	7	7.45	0.45	COMPOSITE	LO			1.8	0	0
WAS	SR	00821	5.18	6.17	0.99	COMPOSITE	LO			1.8	0	0
WAS	SR	00821	19.58	20.77	1.19	COMPOSITE	LO	LO		1.8	1.8	0
WAS	SR	00007	44.2	45.56	1.36	FLEXIBLE	LF	LO		2.4	1.8	0
WAS	SR	00026	20.84	21.81	0.97	FLEXIBLE	LF	MO	LF	2.4	4.2	2.4
WAS	SR	00145	0	0.48	0.48	FLEXIBLE	LF			2.4	0	0
WAS	SR	00145	0.48	3.25	2.77	FLEXIBLE	LF	MO	LO	2.4	4.2	1.8
WAS	SR	00550	0.89	1.28	0.39	FLEXIBLE	LF	MO	MO	2.4	4.2	4.2
WAS	SR	00550	14.78	15.16	0.38	FLEXIBLE	LF	MO	MO	2.4	4.2	4.2
WAS	SR	00676	5.41	10.52	5.11	FLEXIBLE	LF	HO	MF	2.4	6	5.6
WAS	SR	00676	10.52	12.27	1.75	FLEXIBLE	LF	MF	MF	2.4	5.6	5.6
WAS	SR	00676	12.42	16.91	4.49	FLEXIBLE	LF	ME	MF	2.4	7	5.6
WAS	SR	00007	23.06	23.94	0.88	COMPOSITE	LF	MO	MO	2.4	4.2	4.2
WAS	SR	00007	24.28	24.51	0.23	COMPOSITE	LF			2.4	0	0
WAS	SR	00007	42.22	44.2	1.98	COMPOSITE	LF	LO		2.4	1.8	0
WAS	SR	00007	45.56	47.48	1.92	COMPOSITE	LF			2.4	0	0

* Adjusted for 5-25% range for "occasional" classification

** 1 mi = 1.61 km

County Abbrev	Trans Route		Milepost Start	End	Segment Length (mi)**	Pavement Type	PCR Ratings S&G	LRMS	LRMS (adj*)	PCR Scores S&G	LRMS	LRMS (adj*)
WAS	SR	00007	49.43	51.06	1.63	COMPOSITE	LF	HF	HF	2.4	8	8
WAS	SR	00007	51.06	51.33	0.27	COMPOSITE	LF	MO		2.4	4.2	0
WAS	SR	00007	51.33	52.17	0.84	COMPOSITE	LF	LO	LO	2.4	1.8	1.8
WAS	SR	00026	2.03	2.37	0.34	COMPOSITE	LF	MO	MO	2.4	4.2	4.2
WAS	SR	00060	3.07	3.6	0.53	COMPOSITE	LF			2.4	0	0
WAS	SR	00550	2.5	9.01	6.51	COMPOSITE	LF	ME	MF	2.4	7	5.6
WAS	SR	00550	10.56	14.78	4.22	COMPOSITE	LF	MO	MO	2.4	4.2	4.2
WAS	SR	00550	18.91	20.09	1.18	COMPOSITE	LF	MO	MO	2.4	4.2	4.2
WAS	SR	00550	20.09	20.74	0.65	COMPOSITE	LF	MF	MF	2.4	5.6	5.6
WAS	SR	00821	6.17	6.97	0.8	COMPOSITE	LF			2.4	0	0
WAS	SR	00821	6.97	10.3	3.33	COMPOSITE	LF	LO	LO	2.4	1.8	1.8
WAS	SR	00821	10.3	10.5	0.2	COMPOSITE	LF	MF	MF	2.4	5.6	5.6
WAS	SR	00821	10.5	11.76	1.26	COMPOSITE	LF	HO	MF	2.4	6	5.6
WAS	SR	00007	31.59	33.01	1.42	FLEXIBLE	LE	MO	MO	3	4.2	4.2
WAS	SR	00007	31.59	33.01	1.42	FLEXIBLE	LE	MO	LF	3	4.2	2.4
WAS	SR	00007	33.01	33.12	0.11	FLEXIBLE	LE			3	0	0
WAS	SR	00007	40.16	42.22	2.06	FLEXIBLE	LE	LO		3	1.8	0
WAS	SR	00007	48.91	49.43	0.52	FLEXIBLE	LE	MO		3	4.2	0
WAS	SR	00060	20.13	20.75	0.62	FLEXIBLE	LE	MO		3	4.2	0
WAS	SR	00339	0	0.45	0.45	FLEXIBLE	LE	LO		3	1.8	0
WAS	SR	00339	0.45	1.41	0.96	FLEXIBLE	LE			3	0	0
WAS	SR	00339	1.41	4.39	2.98	FLEXIBLE	LE			3	0	0
WAS	SR	00339	4.39	8.57	4.18	FLEXIBLE	LE	LO		3	1.8	0
WAS	SR	00339	8.57	13.64	5.07	FLEXIBLE	LE	LO		3	1.8	0
WAS	SR	00339	13.64	16.56	2.92	FLEXIBLE	LE	MO		3	4.2	0
WAS	SR	00339	16.56	18.59	2.03	FLEXIBLE	LE			3	0	0
WAS	SR	00339	18.59	20.44	1.85	FLEXIBLE	LE	MO	LO	3	4.2	1.8
WAS	SR	00821	4.4	5.18	0.78	FLEXIBLE	LE	LO	LO	3	1.8	1.8
WAS	SR	00007	37.24	38.94	1.7	COMPOSITE	LE	HO	MF	3	6	5.6
WAS	SR	00007	48.21	48.91	0.7	COMPOSITE	LE			3	0	0
WAS	SR	00007	52.17	54.03	1.86	COMPOSITE	LE	LO		3	1.8	0
WAS	SR	00026	0.34	1.28	0.94	COMPOSITE	LE	MO	MO	3	4.2	4.2

* Adjusted for 5-25% range for "occasional" classification

** 1 mi = 1.61 km

County Abbrev	Trans Route		Milepost Start	Milepost End	Segment Length (mi)**	Pavement Type	PCR Ratings S&G	PCR Ratings LRMS	PCR Ratings LRMS (adj*)	PCR Scores S&G	PCR Scores LRMS	PCR Scores LRMS (adj*)
WAS	SR	00026	1.28	2.03	0.75	COMPOSITE	LE	LF	LF	3	2.4	2.4
WAS	SR	00032	9.41	9.72	0.31	COMPOSITE	LE	MO	MO	3	4.2	4.2
WAS	SR	00032	9.72	10.44	0.72	COMPOSITE	LE	LO	LO	3	1.8	1.8
WAS	SR	00060	3.6	5.15	1.55	COMPOSITE	LE	LO		3	1.8	0
WAS	SR	00060	11.24	19.73	8.49	COMPOSITE	LE	MO	LO	3	4.2	1.8
WAS	SR	00060	19.73	20.13	0.4	COMPOSITE	LE	MF	MF	3	5.6	5.6
WAS	SR	00060	20.75	21.05	0.3	COMPOSITE	LE			3	0	0
WAS	SR	00060	21.05	24.09	3.04	COMPOSITE	LE	MO	LO	3	4.2	1.8
WAS	SR	00550	9.01	10.56	1.55	COMPOSITE	LE	ME	MF	3	7	5.6
WAS	SR	00618	3.23	4	0.77	COMPOSITE	LE	LO		3	1.8	0
WAS	SR	00618	5.19	6.23	1.04	COMPOSITE	LE	LO		3	1.8	0
WAS	SR	00821	0	0.48	0.48	COMPOSITE	LE	LO	LO	3	1.8	1.8
WAS	SR	00821	3.41	4.4	0.99	COMPOSITE	LE	LO		3	1.8	0

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