192-RU8485

RUTGERS PAVEMENT RESOURCE CENTER

RIDE QUALITY TOOLS

January 2011

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In cooperation with

New Jersey
Department of Transportation
Bureau of Research
and
U. S. Department of Transportation
Federal Highway Administration

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Abstract

The Pavement Technology Unit had been inundated with requests from contractors to provide International Roughness Index (IRI) testing during various construction phases. With the release of the NJDOT Ride Quality specification, contractors can receive a financial penalty or bonus depending on the IRI values of the pavement surface after the final surface course has been placed and compacted. However, many of these contractors have been asking for testing of the intermediate layers during construction, in an attempt to validate the smoothness of these layers prior to the placement of the final surface layer. In an effort to support these requests and improve the final pavement smoothness, the Pavement Technology Unit has requested the evaluation and implementation of portable walk-behind pavement surface profile measurement devices that can determine the IRI of intermediate units as requested. After evaluation, the selected portable walk-behind pavement surface profile measurement device were recommended and implemented by the NJDOT Regional offices to provide on-site support to the asphalt industry. The tasks performed include:

- Evaluation of current walk behind systems
- Purchase of four walk behind systems based on initial evaluation
- Training of central pavement and material engineers and region materials engineers on the walk-behind systems (data collection, maintenance, and analysis)
- Purchase a bare minimum high speed profile that contains texture lasers.
    - Modify the system to incorporate video, GPS, rut bar measurements and additional flexibility for future additions (tire/pavement noise)
    - Require shock mounting on racks because boards popping out – may want to mount horizontally instead of vertically (more problems occurring on computers on top of racks)
    - Consolidate the digital cameras control and storage on one computer
    - Interview Pavement Tech. staff to discuss reoccurring mechanical problems with current technology
    - Prepare Specification for transport vehicle (e.g., Ford chateau van model).

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EXECUTIVE SUMMARY

The primary objective of the 2006 RPRC program is to utilize the extensive laboratory and field pavement testing equipment and staff expertise of the Rutgers Pavement Resource Center to assist the NJ Department of Transportation in developing a pavement management strategy that optimizes network condition utilizing available capital resources. The two primary goals of the current program are: 1) retooling of the Pavement Management System and 2) development and implementation of advanced ground penetrating radar system and filling gaps in the database of state highway pavement structures. Ongoing support for implementation of Mechanistic-Empirical Pavement Design is also planned on an as needed basis to support the Department's $290 million fiscal year 2007 and later year's pavement investment.

The condition of New Jersey's pavement investment has declined steadily over the past decade as available resources have been committed to other needs. The significant backlog of pavement maintenance has resulted in significant vehicle operating costs to NJ motorists, reportedly twice the national average. A fresh approach to pavement management utilizing the latest technology is needed to help restore New Jersey's highway infrastructure to a state of good repair with limited available resources. The Rutgers Pavement Resource Center is an extension of the NJDOT Pavement Technology Unit and functions as the primary research and technology arm. It is organized to rapidly respond to the Department's need for implementation of advanced pavement evaluation and asset management technologies. The products will include asset management tools, database architecture, material testing and evaluation, validation and implementation of new technologies, methodologies and materials. The program will work closely with DOT staff and its consultants to fulfill its mission.

The proposed services to be provided by the joint NJDOT/Rutgers pavement engineering program will include field and laboratory testing and evaluation, development of advanced pavement information systems, and specialized training/educational programs for NJDOT and its consulting pavement engineers. This proposal addresses the evaluation and implementation of new pavement profile tools to enhance the ride quality and safety of the State's road network.

INTRODUCTION

The Pavement Technology Unit had been inundated with requests from contractors to provide International Roughness Index (IRI) testing during various construction phases. With the release of the NJDOT Ride Quality specification, contractors can receive a financial penalty or bonus depending on the IRI values of the pavement surface after the final surface course has been placed and compacted. However, many of these contractors have been asking for testing of the intermediate layers during construction, in an attempt to validate the smoothness of these layers prior to the placement of the final surface layer. In an effort to support these requests and improve the final pavement smoothness, the Pavement Technology Unit has requested the evaluation and implementation of portable walk-behind pavement surface profile measurement devices that can determine the IRI of intermediate units as requested. After evaluation, the selected portable walk-behind pavement surface profile measurement device will be recommended and implemented by the NJDOT Regional offices to provide on-site support to the asphalt industry. The tasks performed include:

- Evaluation of current walk behind systems
- Purchase of four walk behind systems based on initial evaluation
- Training of central pavement and material engineers and region materials engineers on the walk-behind systems (data collection, maintenance, and analysis)
- Purchase a bare minimum high speed profile that contains texture lasers.
- Modify the system to incorporate video, GPS, rut bar measurements and additional flexibility for future additions (tire/pavement noise)
- Require shock mounting on racks because boards popping out – may want to mount horizontally instead of vertically (more problems occurring on computers on top of racks)
- Consolidate the digital cameras control and storage on one computer
- Interview Pavement Tech. staff to discuss reoccurring mechanical problems with current technology
- Prepare Specification for transport vehicle (e.g., Ford chateau van model).

Work Performed

The Rutgers Pavement Resource Program began work on this task in the Summer of 2007. The team met several times with the Pavement management, Drainage, and Design group within the New Jersey Department of Transportation to go over the final products and tasks. At this time, an extensive literature search was also performed. Under the tasks, the team agreed to interview and evaluate walk-behind IRI units in preparation for recommendations in the future. (Appendix A)

It became evident to the team that they were going to research and evaluate several walk-behind and portable pavement profiler units. They included the ICC SurPRO 200 and SSI Walking Profiler, model CS8800 in addition to the NJDOT's ARRB Walking Profiler. The PRP team would also evaluate the Dynatest Portable Road Surface Profilometer Mark IV, Roadware GRP ARAN Road

Profiler, and the ARRB Hawkeye 1000 series.(Appendix B)

After an initial review, the Research Team purchased the ICC SurPRO 2000 Walking Profiler for evaluation on pavement and bridge deck surfaces. The PRP team also worked with other vendors to demonstrate the Dynatest Portable Road Surface Profilometer Mark IV and the Roadware GRP ARAN RoadProfiler prior to purchase.

Part of the process was the identification of a consistent test strip in order to validate the results with each piece of machinery. It was important that the pavements selected would be used, safe from traffic, and consistent. The Research Team worked with the New Jersey Department of Transportation to locate, evaluate, and secure a proper test site.

Through the literature search and demonstration projects, the Research Team was able to develop a Pavement Profile Certification Procedures Manual for the NJDOT. Their work involved the coordination of a third party reviewer at the Federal Highway Administration and the NJDOT.

The final quarter of 2008 was eventful for the Research Team. Using data delivered from the ICC SurPRO 2000 Walking Profiler and from the demonstrations from the Dynatest Mark III and Mark IV profilers, the Research Team began an evaluation of the data. The Research Team drew a comparison between the Roadware and Dynatest profilers and with this information; the Team developed a draft specification for the NJDOT to use for the purchase of a new full size profiler.

Throughout much of 2009, the Research Team worked with the NJDOT to finalize the purchase of a reference walking profiler and portable profilers for the implementation of the ride quality specification. They also worked with the FHWA to finalize the Pavement Profile Certification Procedures Manual for use on the actual certification site on the New Jersey Turnpike and the training of operators. (Appendix C)

Through the course of data manipulation and experimenting, the Research Team identified an issue with the integration of route, direction, and milepost information into the video images collected by the Dynatest imaging systems. After receiving a draft version of the Dynatest Viewer software (Pilot), the Research Team reviewed the poor image quality and returned the cameras to Dynatest for evaluation and repair.

By the end of 2010, the Research Team completed the evaluation of the data collected by the SurPRO of the three regional and Trenton based staffs. The data was evaluated and returned to the NJDOT for its use.

CONCLUSION

The Pavement Resource Program at the Center for Advanced Infrastructure and Transportation at Rutgers University was pleased to participate as an extension and partner with the New Jersey Department of Transportation to perform a variety of tasks put before them.

APPENDIX A

EVALUATION AND IMPLEMENTATION OF PORTABLE IRI DEVICES FOR NJDOT PMS and Bridge ENGINEERS

In the past year, the Pavement Technology Unit has been inundated with requests from contractors to provide International Roughness Index (IRI) testing during various construction phases. With the release of the NJDOT Ride Quality specification, contractors can receive a financial penalty or bonus depending on the IRI values of the pavement surface after the final surface course has been placed and compacted. However, many of these contractors have been asking for testing of the intermediate layers during construction, in an attempt to validate the smoothness of these layers prior to placement of the final surface layer. In an effort to support these request and improve the final pavement smoothness, the Pavement Technology Unit has requested the evaluation and implementation of portable walk-behind pavement surface profile measurement devices that can determine the IRI of intermediate layers as requested. After evaluation, the selected portable walk-behind pavement surface profile measurement device will be recommended and implemented by the NJDOT PMS offices to provide on-site support to the asphalt industry.

In addition, portable walk-behind pavement surface profile measurement device can be used as the “referee” in addressing difference in the contractor payment/bonus for pavement smoothness. In past research studies, the walk behind systems have been used as the “gold standard” for profiler validation and would be used in NJ to correlate IRI values from various high speed profiler against the IRI measured with the “golden” profiler. This effort would reduce conflict that can occur between the contractor and the NJDOT due to differences in IRI measurements based on different profiler manufacturers.

The portable walk-behind pavement surface profile measurement device will also be evaluated to assess the ride quality of Bridge deck structures. Since the device is pushed by hand, the assessment of bridge deck profile ride quality can be made soon after the bridge deck is constructed when corrective actions can be taken to improve the end results.

For more information and pictures visit the ICC SurPRO 2000 website.

http://www.surproprofiler.com/index.php

APPENDIX B

May 2009

Rutgers The State University of New Jer

Center for Advanced Infrastructure and Transportation -CAIT

For:

State of New Jersey
Department of Transportation

Profiler Comparison

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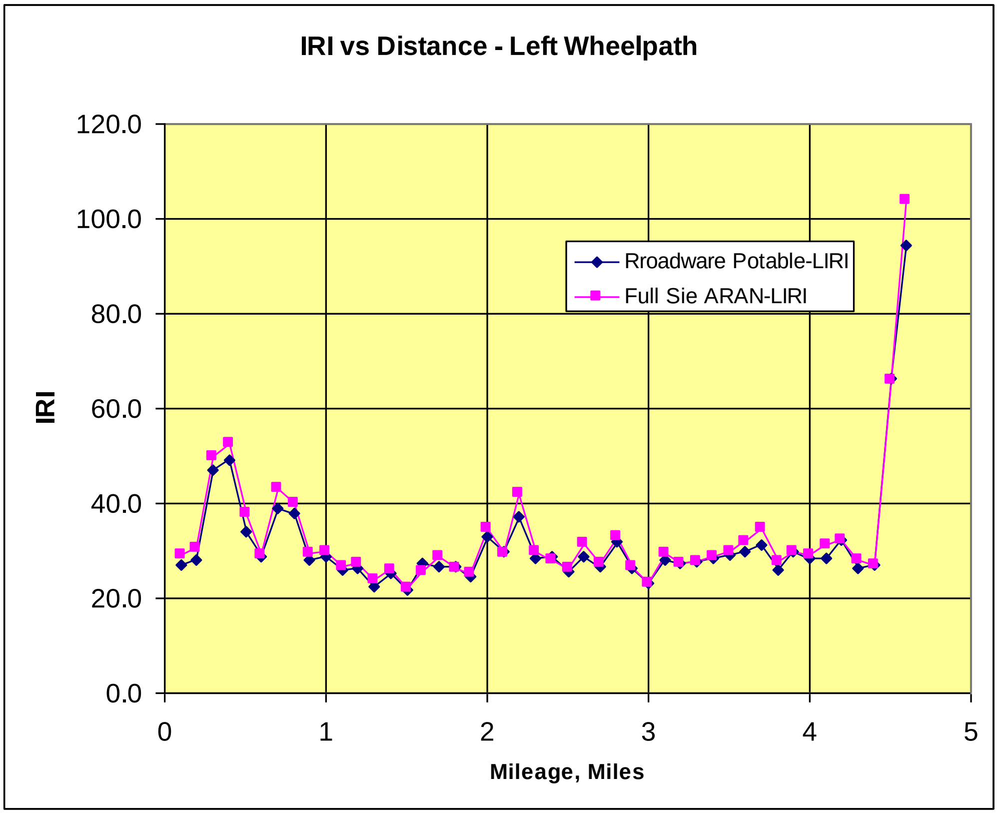
The following report provides a summary of the analysis performed on portable and full size pavement profilers. The figures provide a comparison between the portable and full size profiler, and the repeatability of the profilers on 14 test sites covering a range of pavement roughness levels.

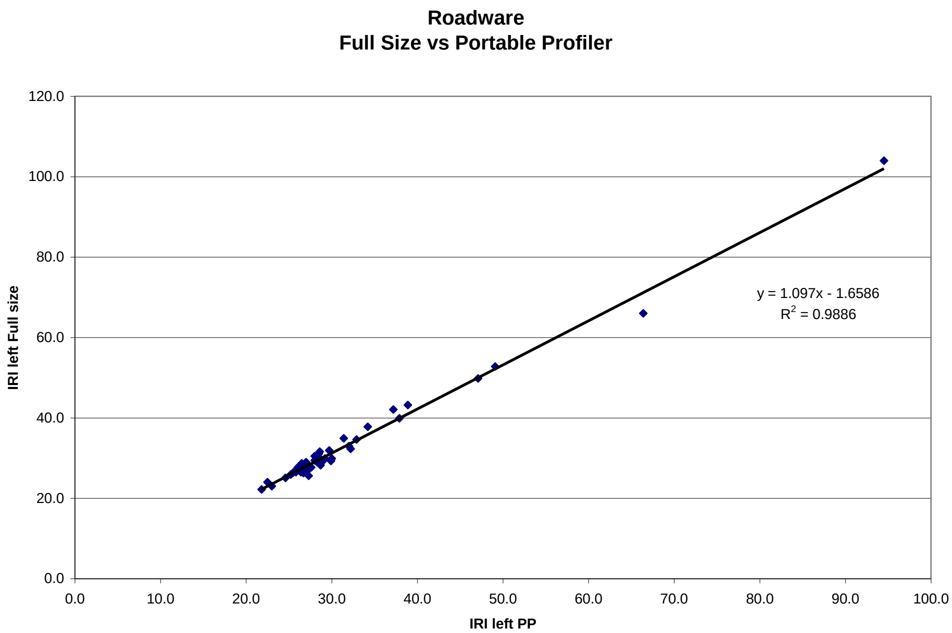
As can be seen in the graphic figures as well as the statistical analysis, the comparison between the profiles and IRI for the portable and full size profilers is very good. The R^2 correlations (>0.95) indicates a near perfect relationship between the portable and full size profilers.

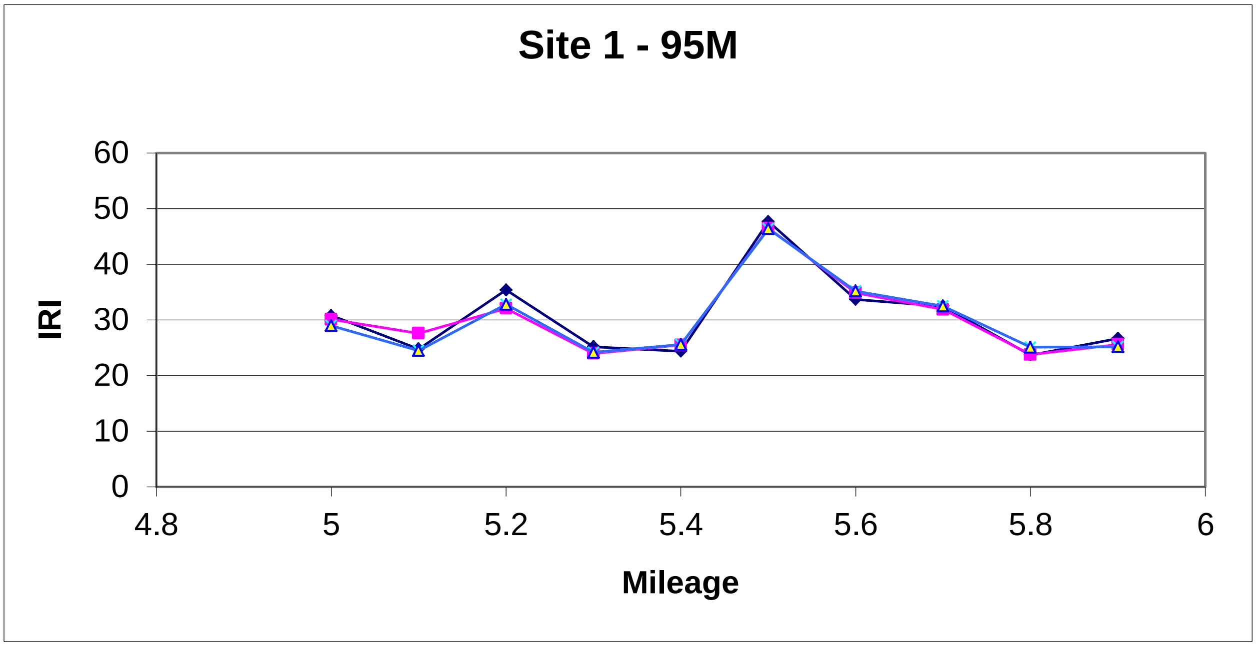
This is not surprising since the components (laser height sensors, accelerometers, distance measurement instruments) in the portable and full size profilers are the same and the analysis software is the same.

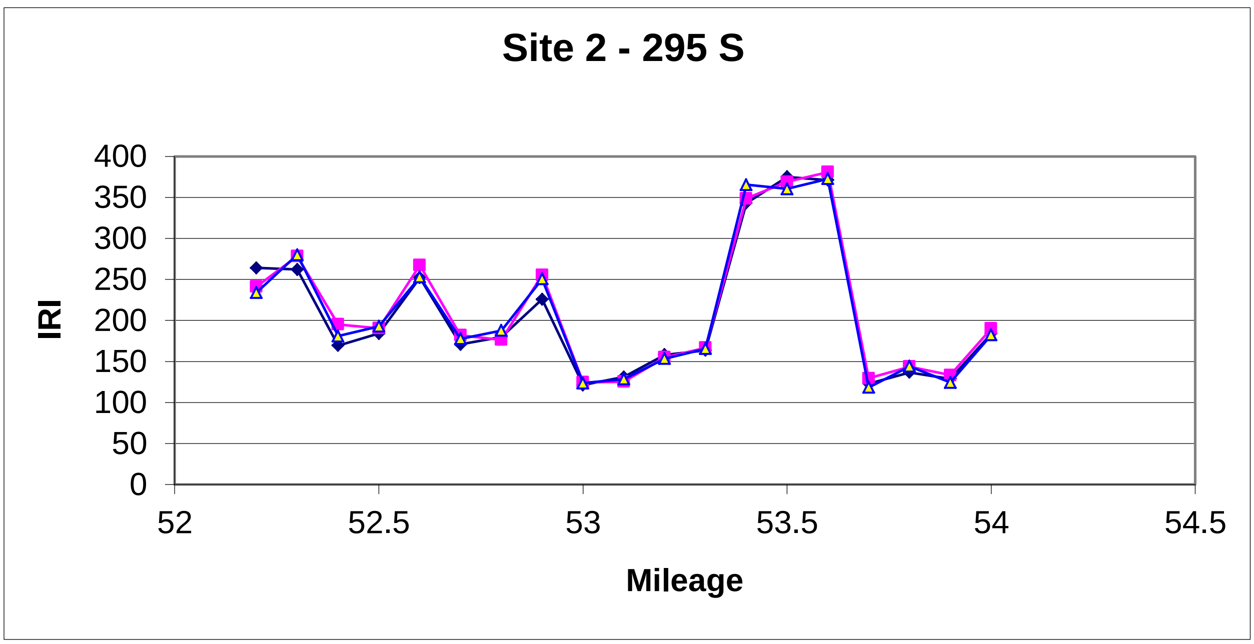
The differences in the profiler data from this demo can be attributed to wander in the wheelpaths in the repeat runs, and the lack of auto start tape at the beginning of the test sites.

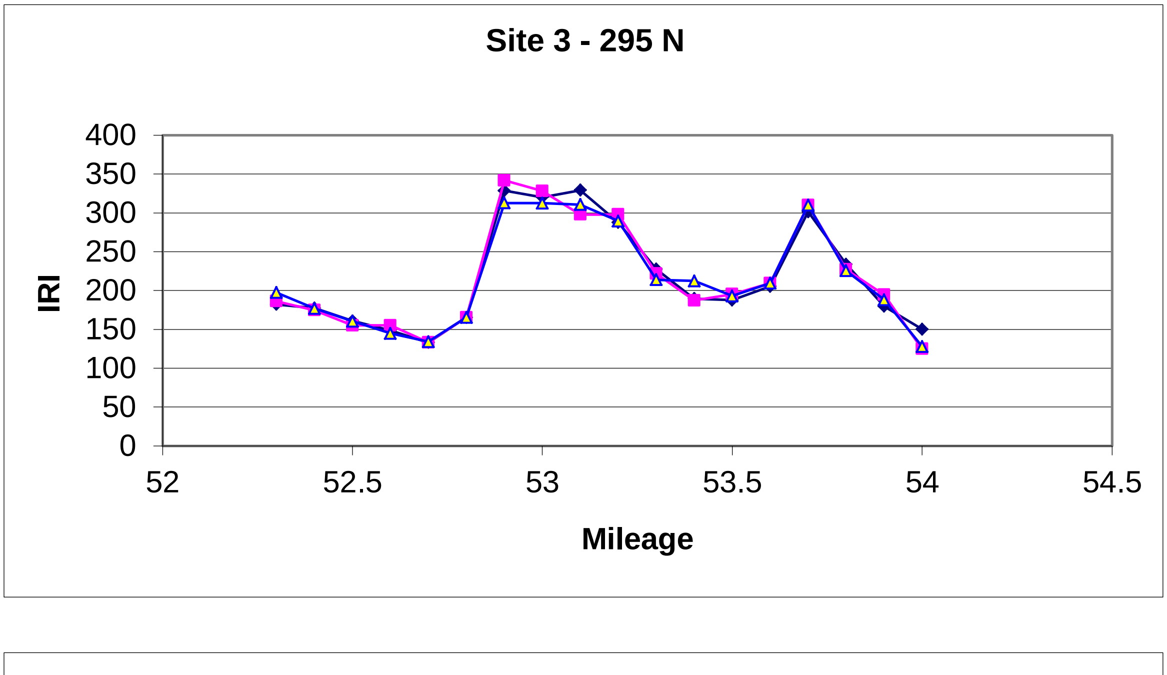
Roadware Profilers




Roadware
Full Size vs Portable Profiler
IRI left Full size
IRI left PP
y = 1.097x - 1.6586
R2 = 0.9886
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0


Site 1 - 95M
IRI
Mileage
60
50
40
30
20
10
0
4.8
5
5.2
5.4
5.6
5.8
6


Site 2 - 295 S
IRI
Mileage
400
350
300
250
200
150
100
50
0
52
52.5
53
53.5
54
54.5


Site 3 - 295 N
IRI
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250
200
150
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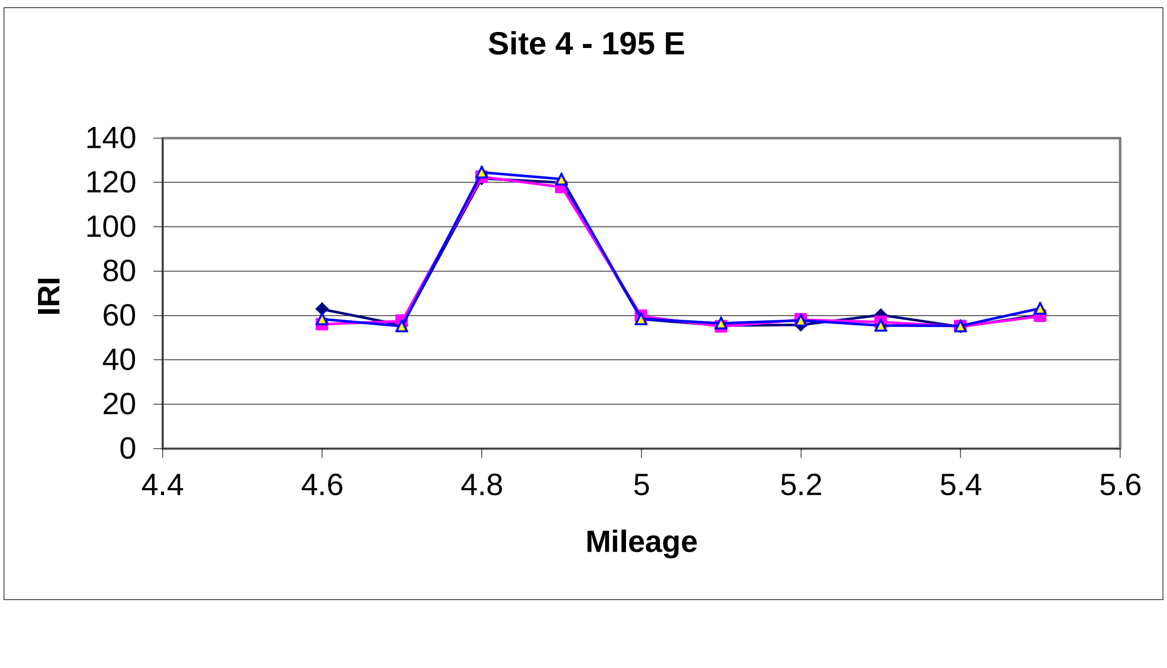
50
0
52
52.5
53
53.5
54
54.5
Mileage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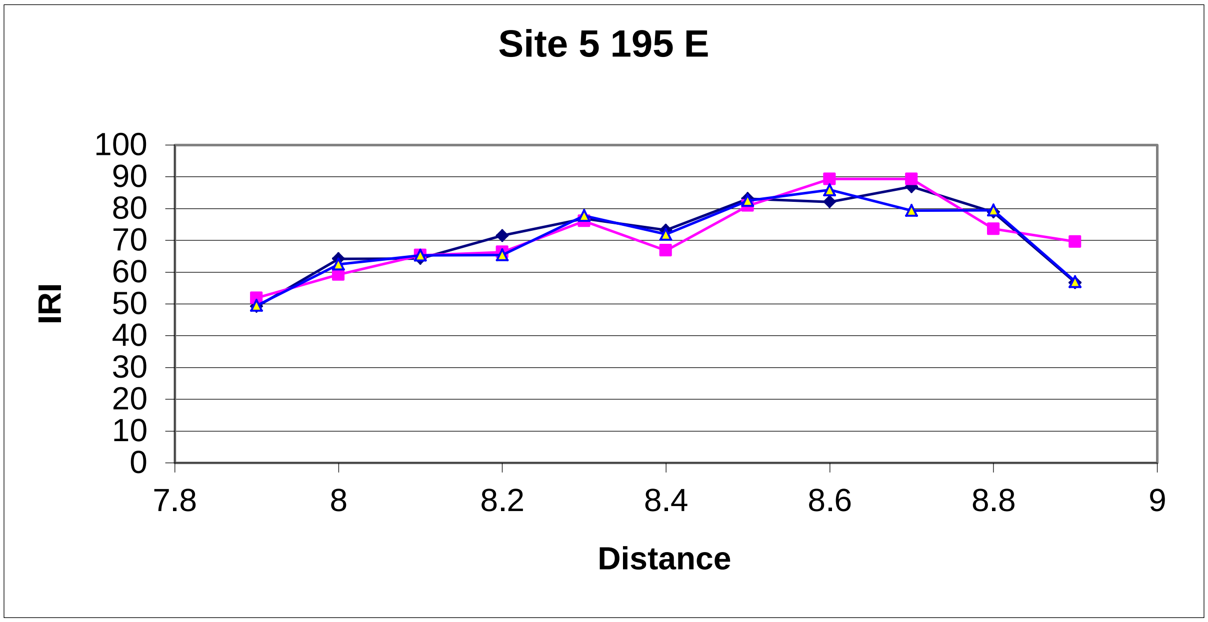
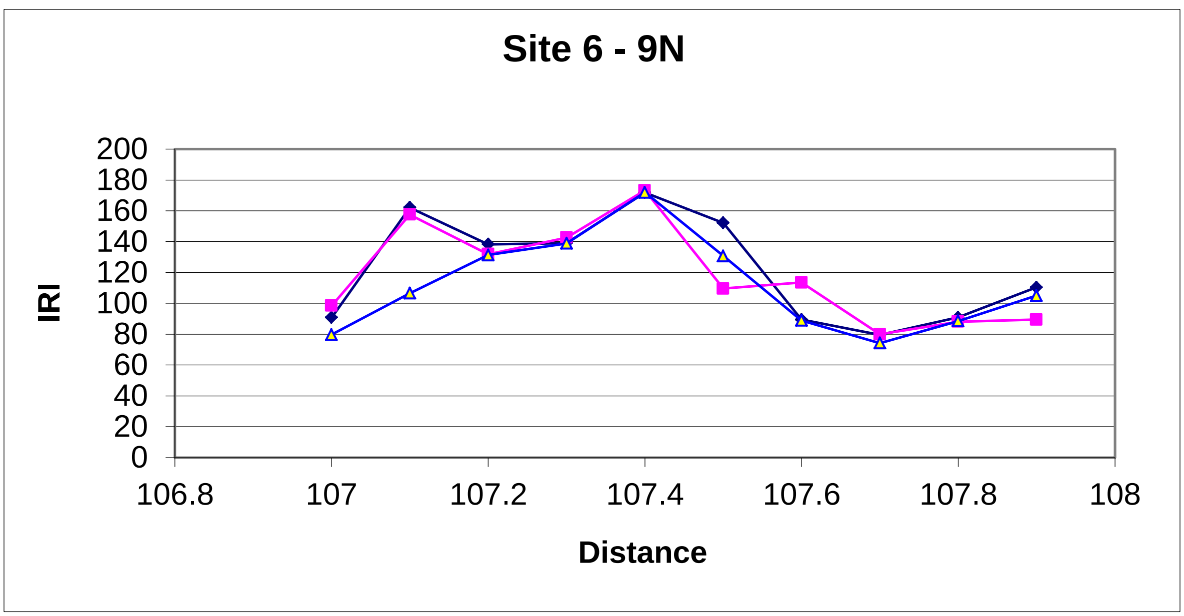
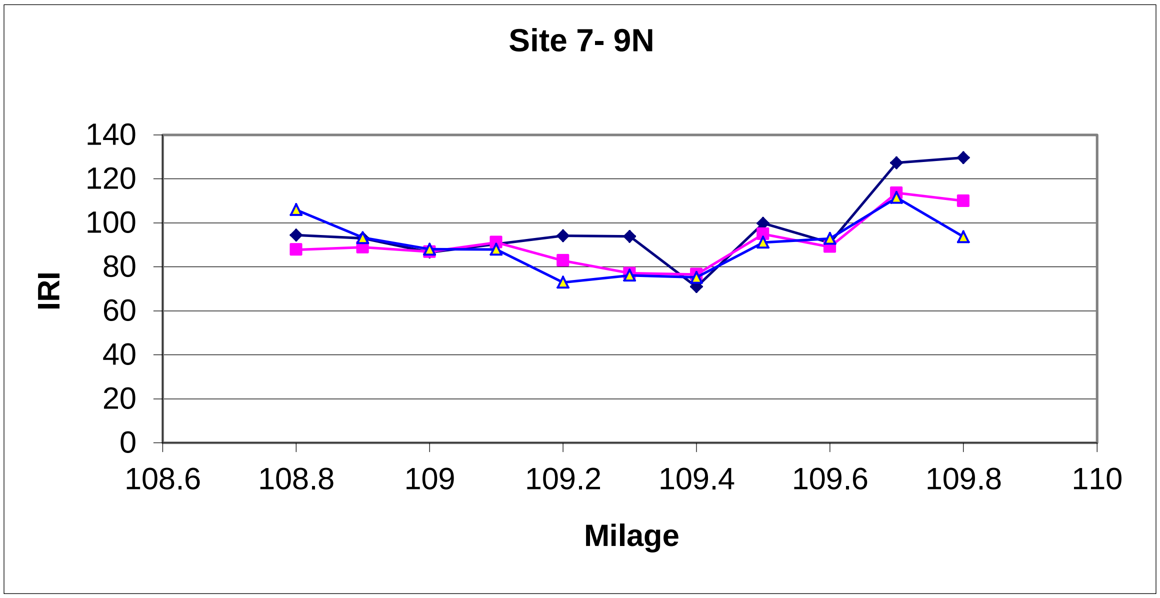
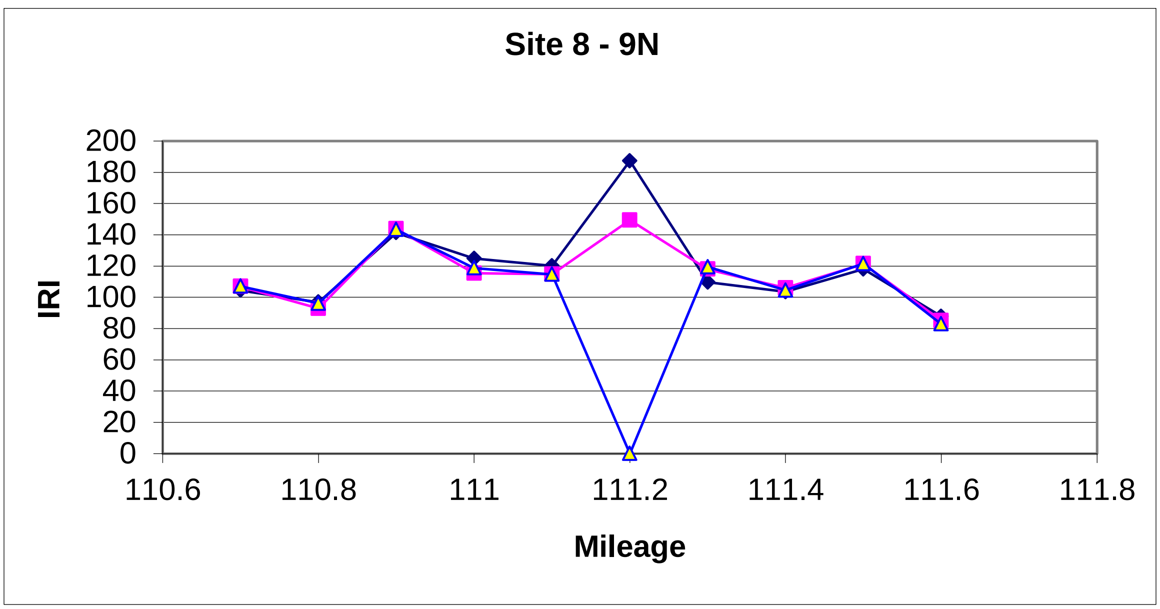
IRI
140
120
100
80
60
40
20
0
4.4
4.6
4.8
5
5.2
5.4
5.6
Mileage


Site 5 195 E
IRI
100
90
80
70
60
50
40
30
20
10
0
7.8
8
8.2
8.4
8.6
8.8
9
Distance


Site 6 - 9N
IRI
200
180
160
140
120
100
80
60
40
20
0
106.8
107
107.2
107.4
107.6
107.8
108
Distance


Site 7- 9N
IRI
140
120
100
80
60
40
20
0
108.6
108.8
109
109.2
109.4
109.6
109.8
110
Milage


Site 8 - 9N
IRI
200
180
160
140
120
100
80
60
40
20
0
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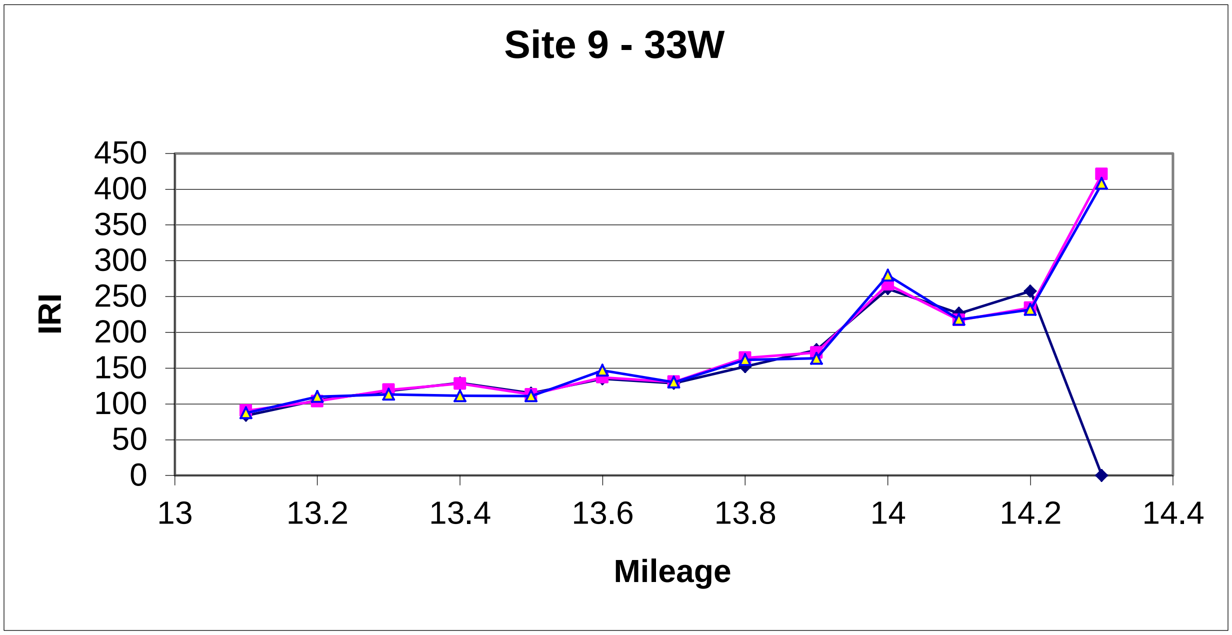
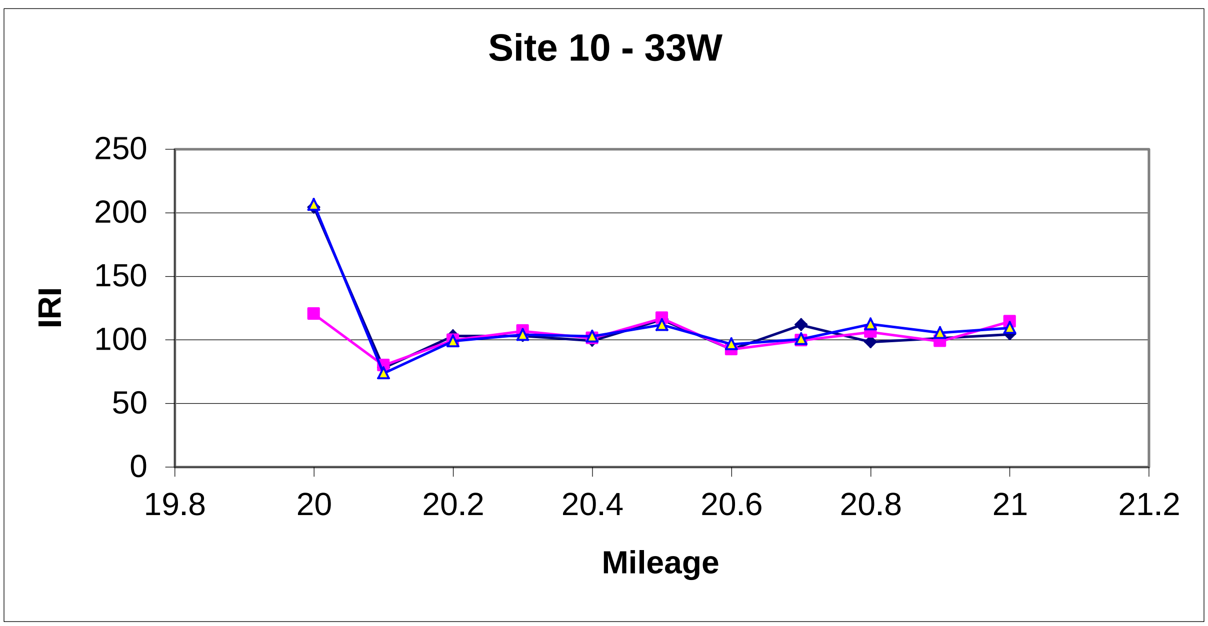
110.8
111
111.2
111.4
111.6
111.8
Mileage


Site 9 - 33W
IRI
Mileage
450
400
350
300
250
200
150
100
50
0
13
13.2
13.4
13.6
13.8
14
14.2
14.4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IRI
Mileage
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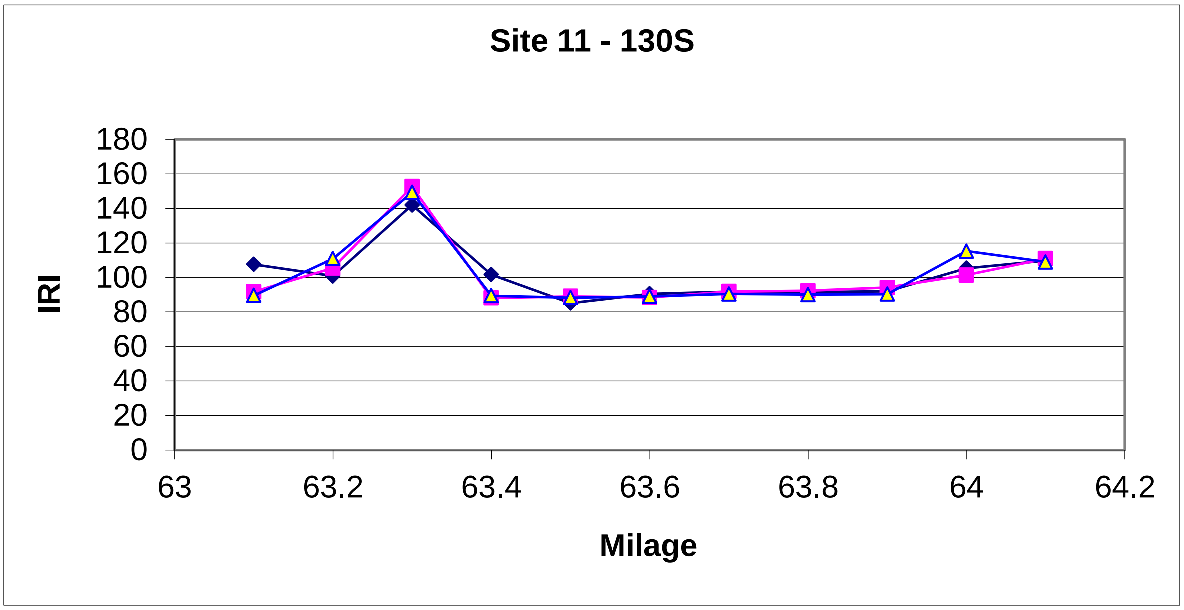
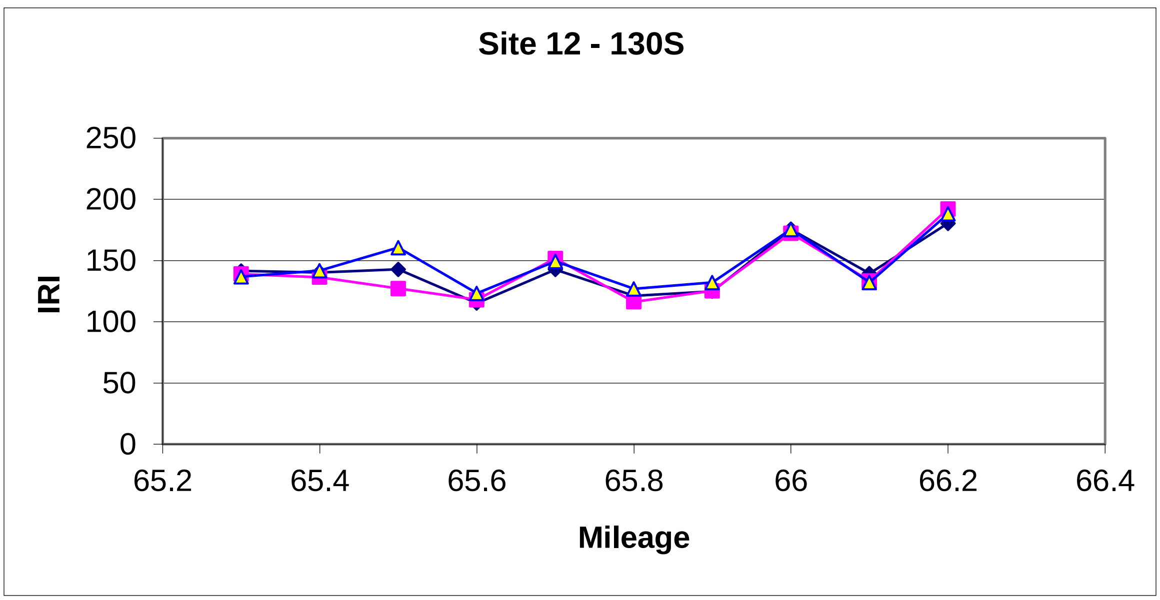
20.8
21
21.2


Site 11 - 130S
IRI
180
160
140
120
100
80
60
40
20
0
63
63.2
63.4
63.6
63.8
64
64.2
Milage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200
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100
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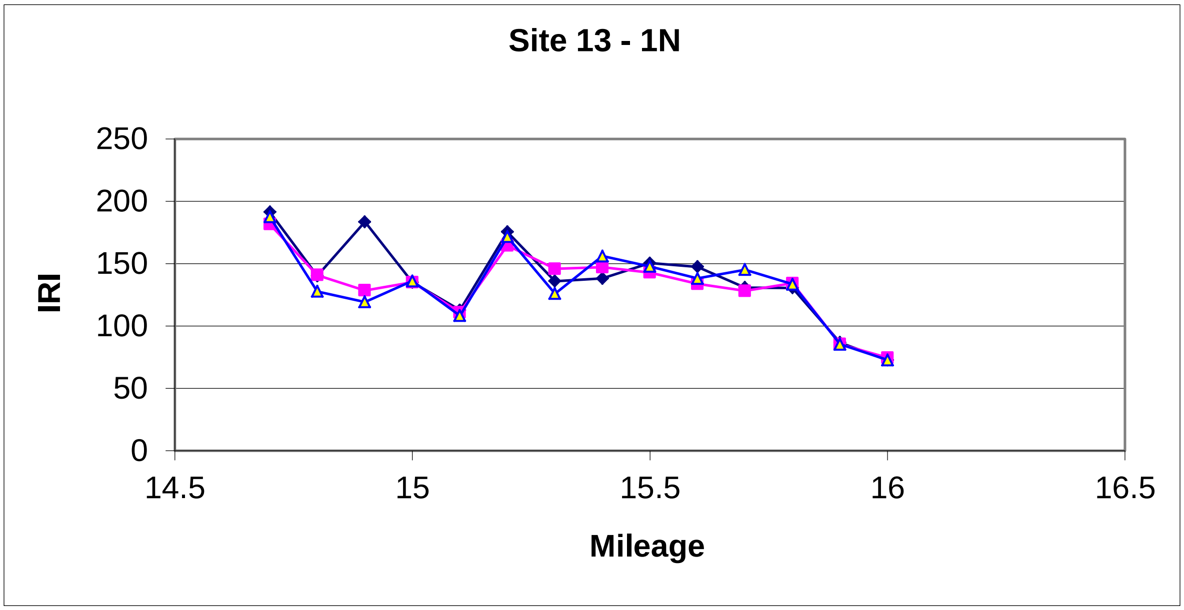
65.2
65.4
65.6
65.8
66
66.2
66.4
Mileage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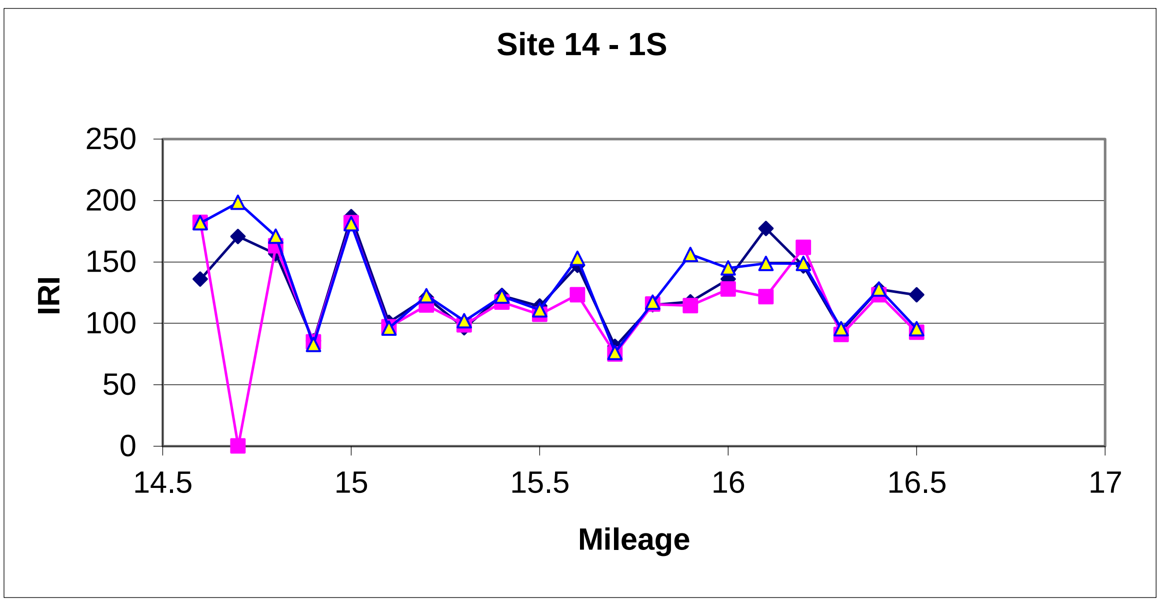
IRI
250
200
150
100
50
0
14.5
15
15.5
16
16.5
Mileage


Site 14 - 1S
IRI
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200
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100
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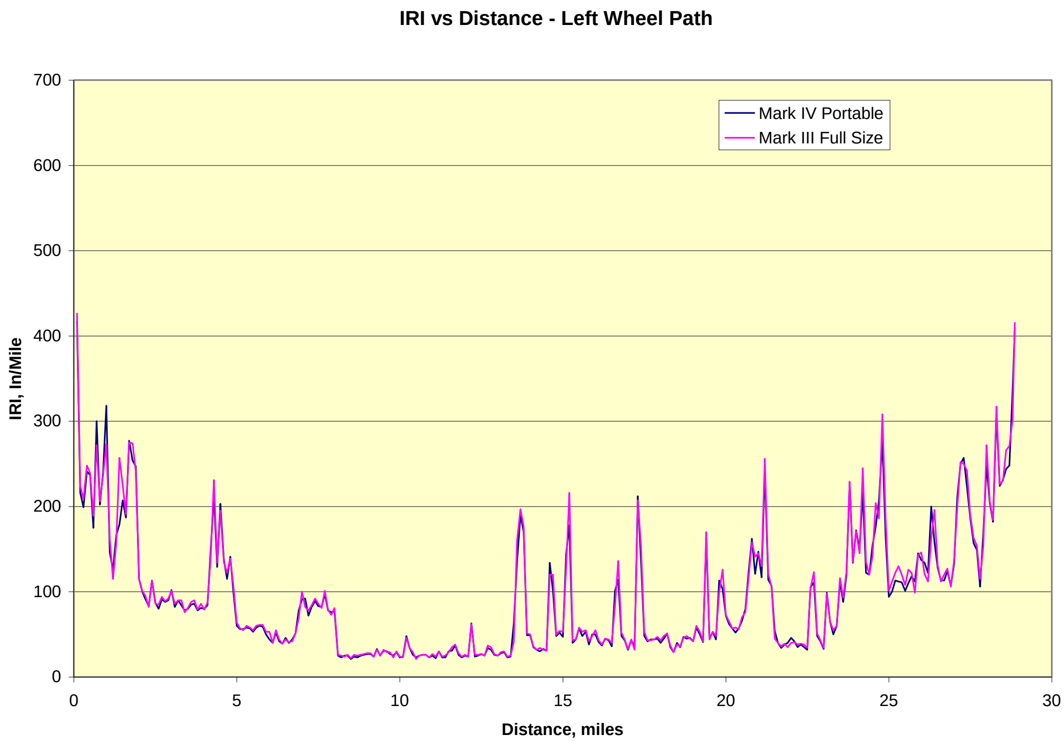
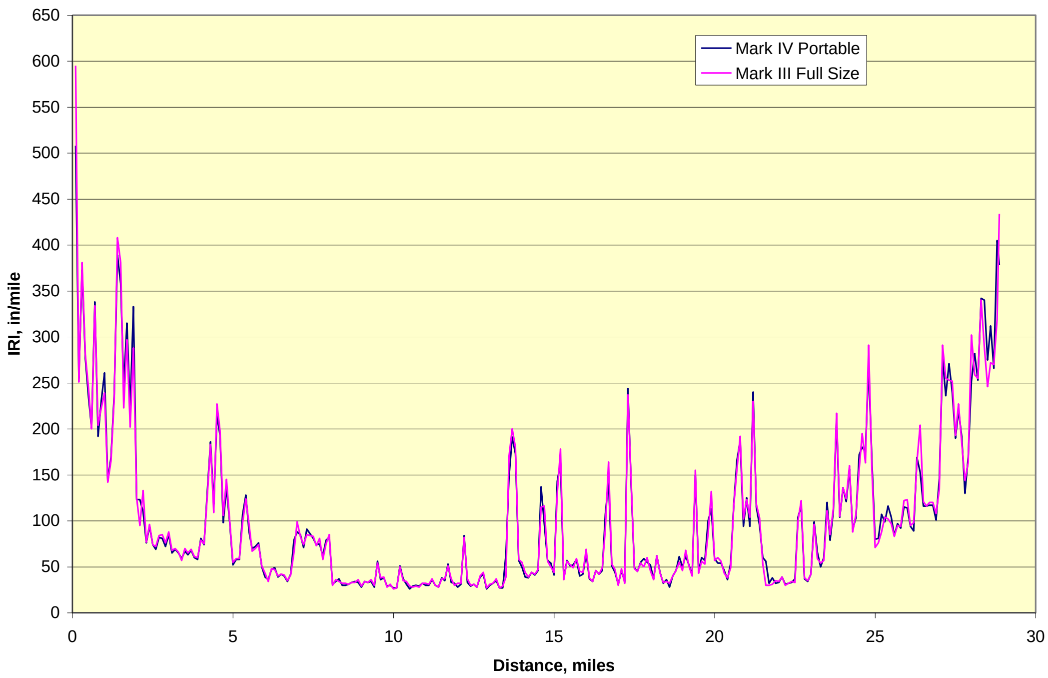
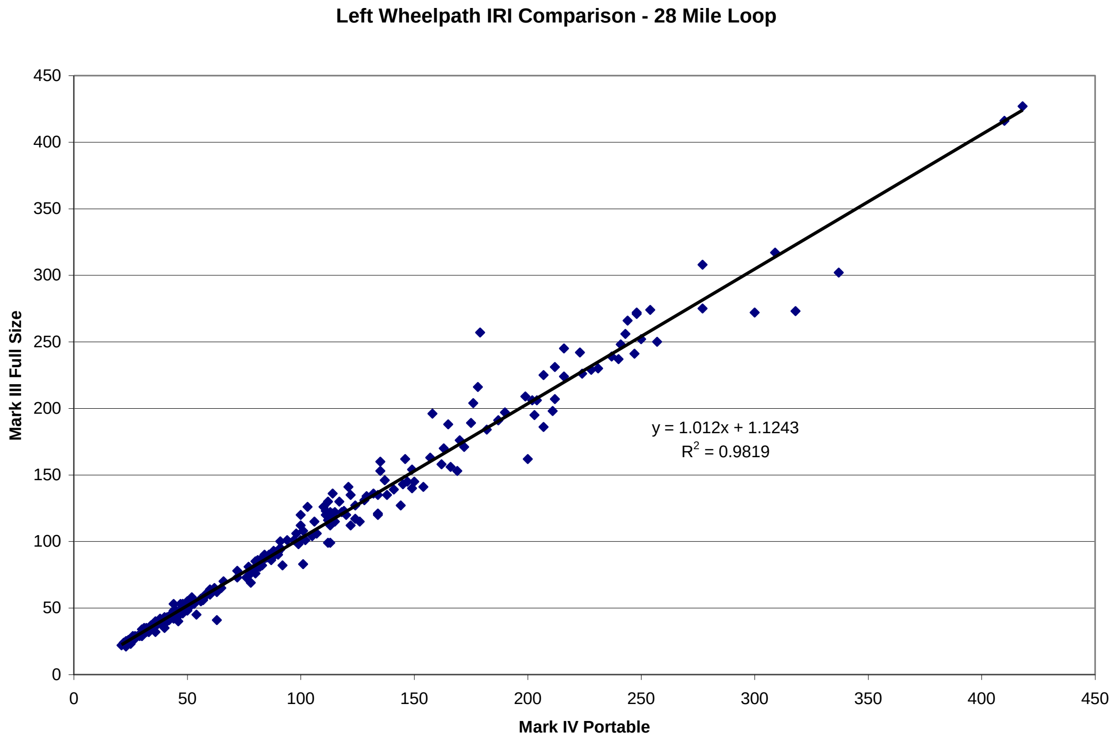
14.5
15
15.5
16
16.5
17
Mileage

Dynatest Profilers



IRI vs Distance - Right Wheelpath




Left Wheelpath IRI Comparison - 28 Mile Loop
Mark III Full Size
Mark IV Portable
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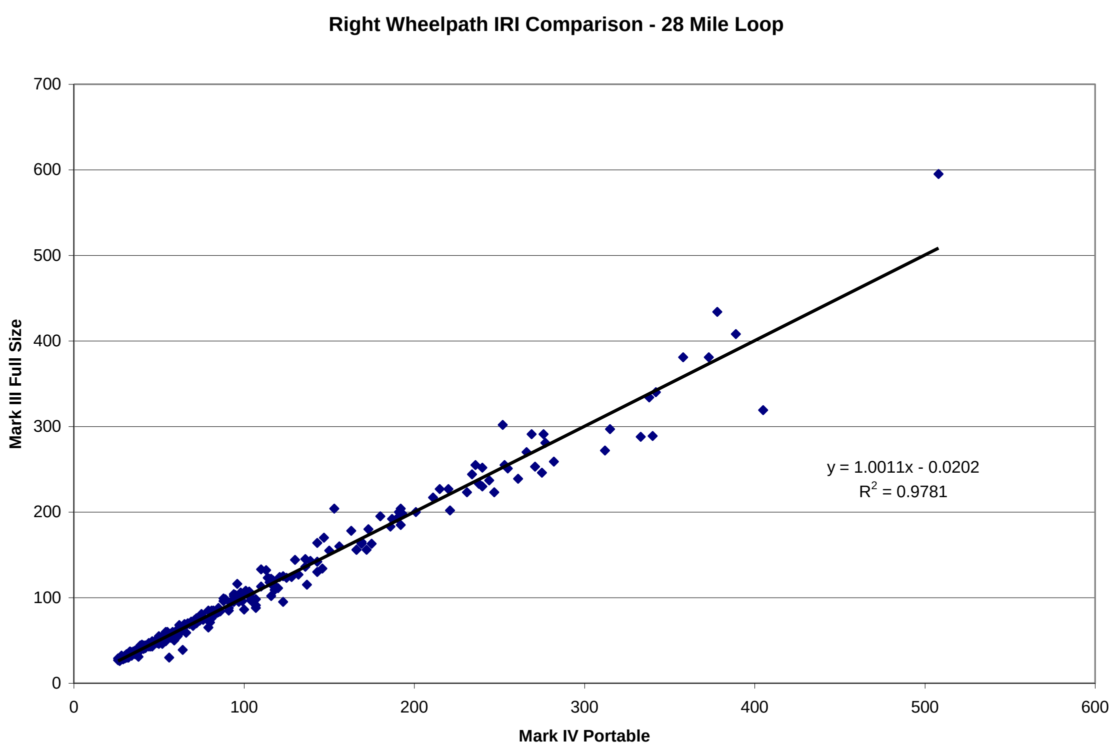
R^2 = 0.9819
0
50
100
150
200
250
300
350
400
450


Right Wheelpath IRI Comparison - 28 Mile Loop
Mark III Full Size
Mark IV Portable
y = 1.0011x - 0.0202
R^2 = 0.9781
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100
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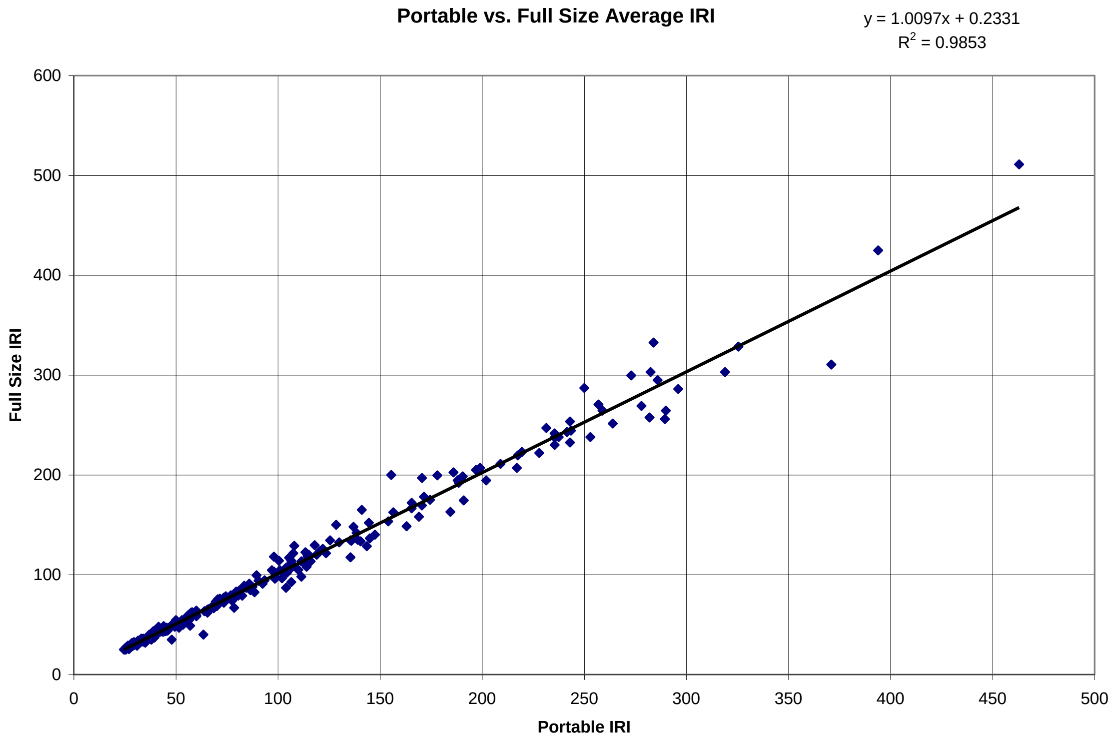
300
400
500
600
700


Portable vs. Full Size Average IRI
y = 1.0097x + 0.2331
R^2 = 0.9853
Full Size IRI
Portable IRI
0
100
200
300
400
500
600
0
50
100
150
200
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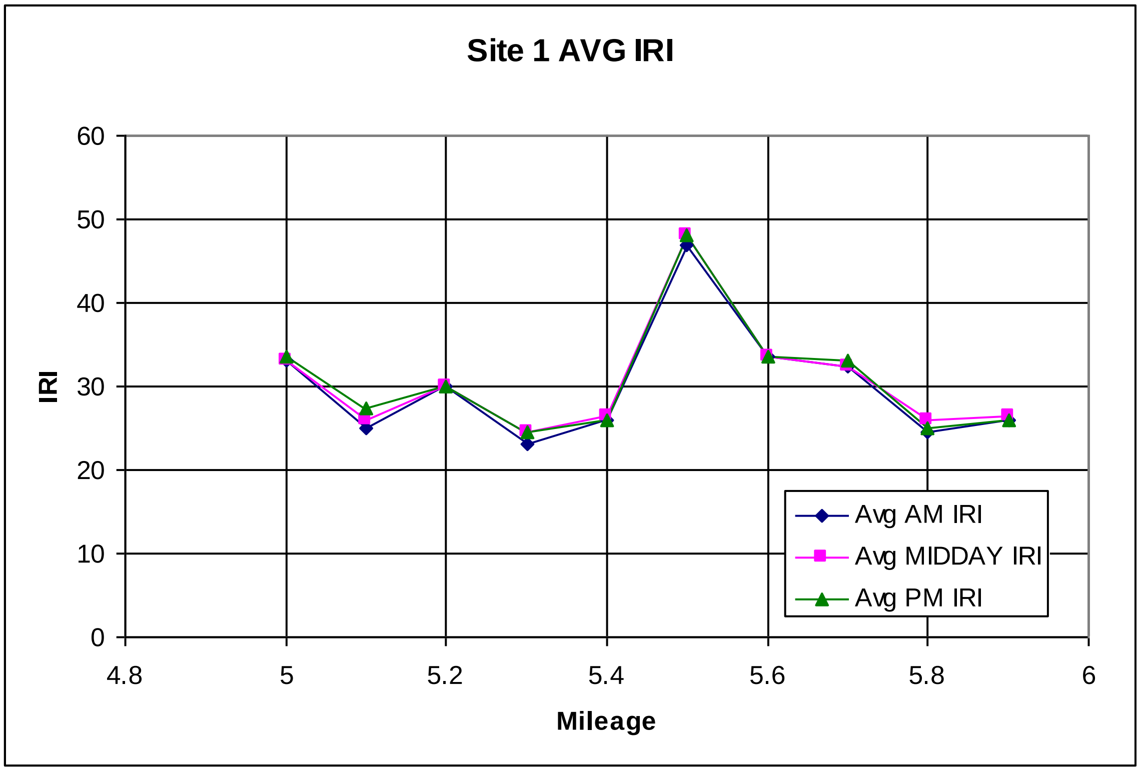
300
350
400
450
500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40
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20
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IRI
4.8
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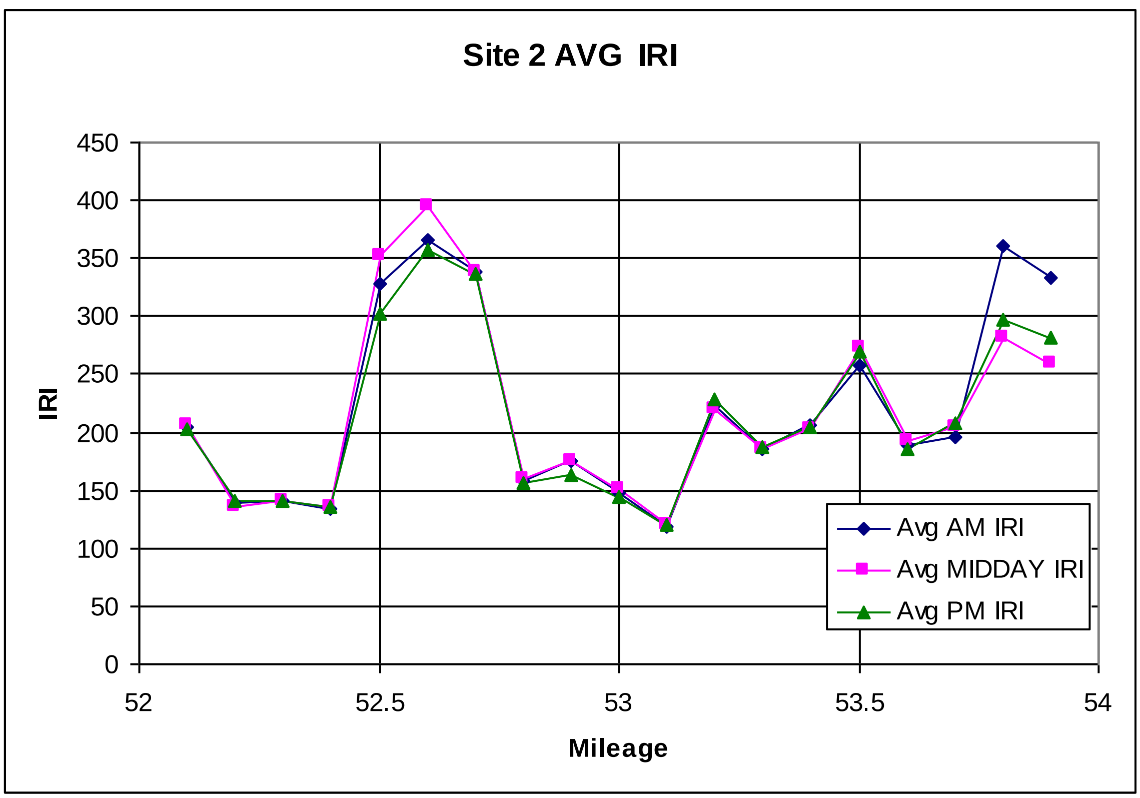
Mileage
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI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450
400
350
300
250
200
150
100
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IRI
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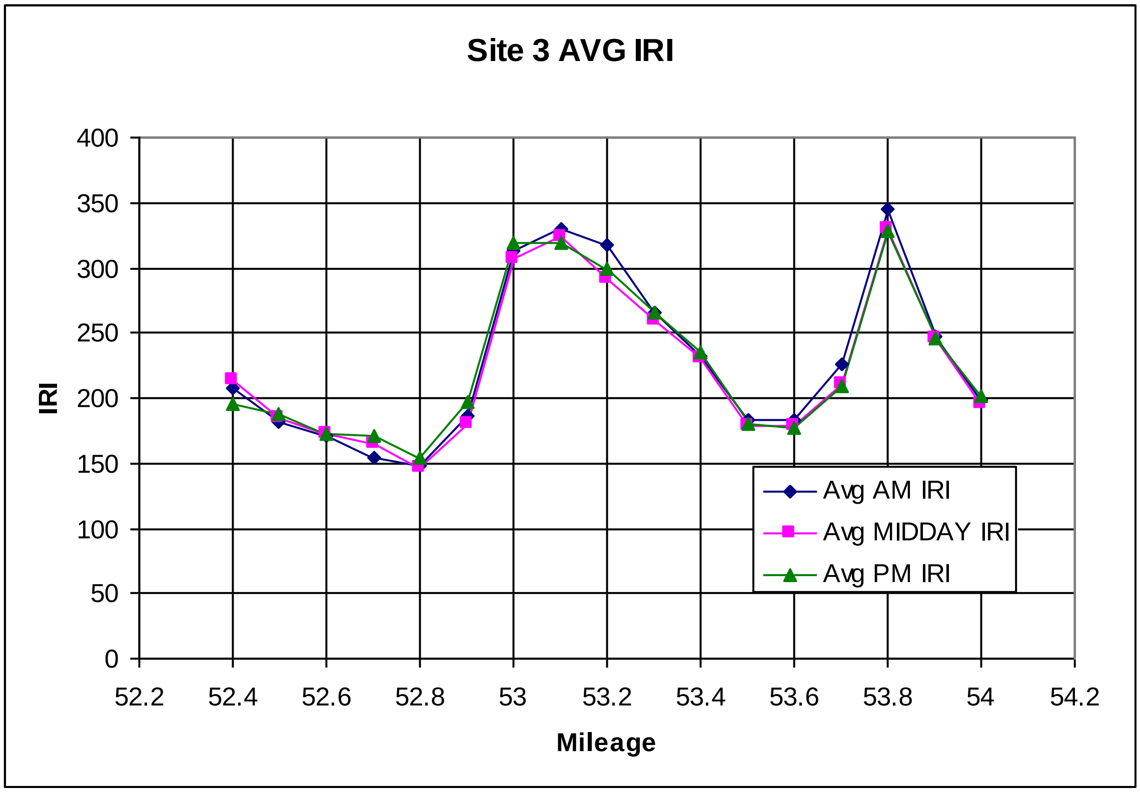
Mileage
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI



Site 3 AVG IRI
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350
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200
150
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IRI
52.2
52.4
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Mileage
Avg AM IRI
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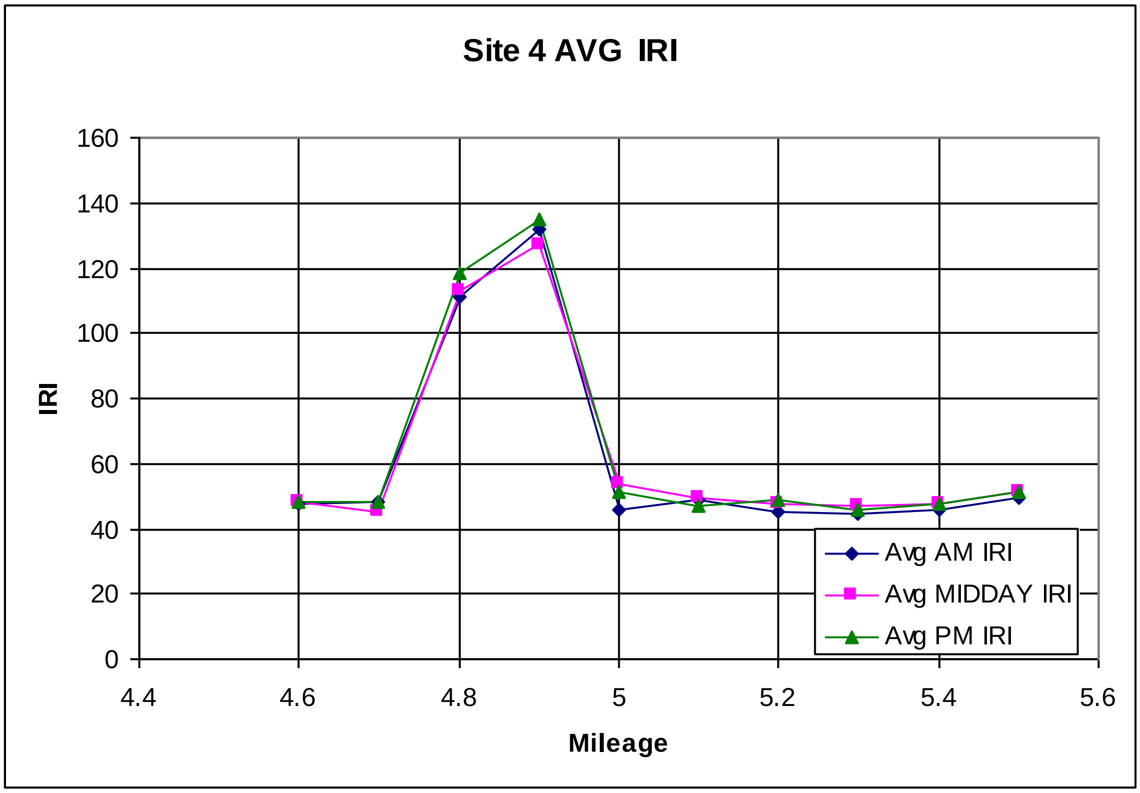

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IRI
160
140
120
100
80
60
40
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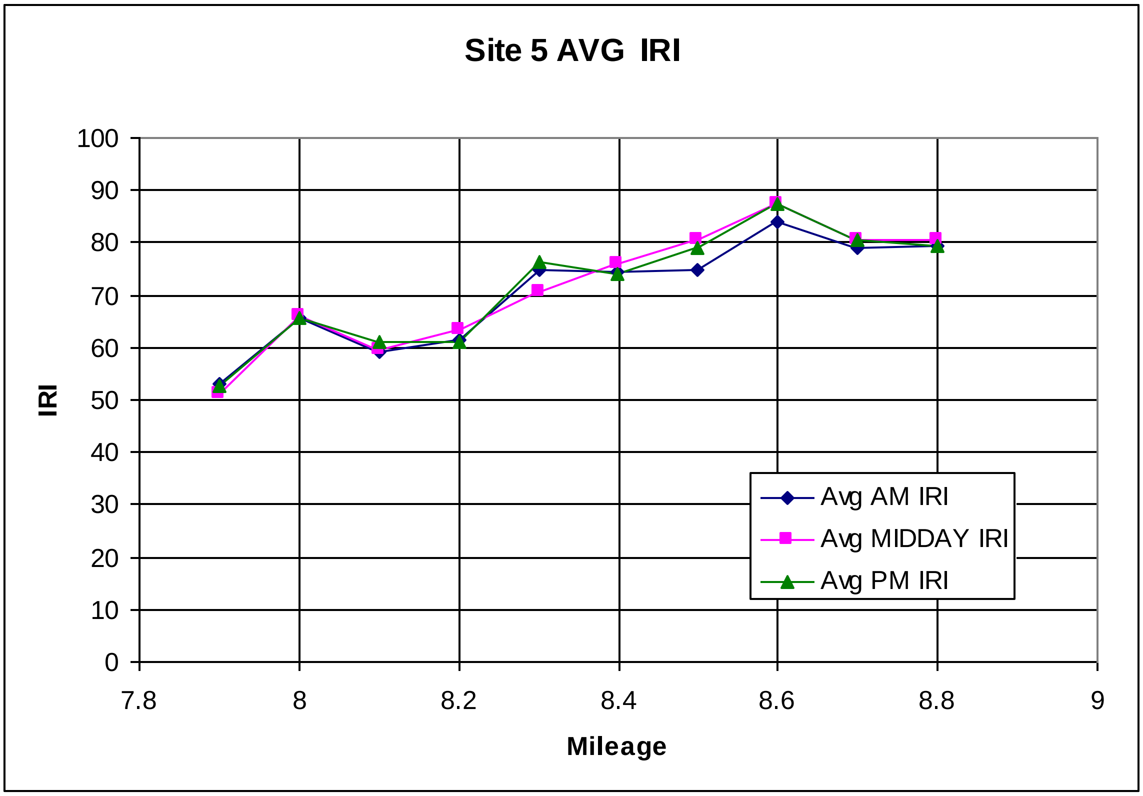
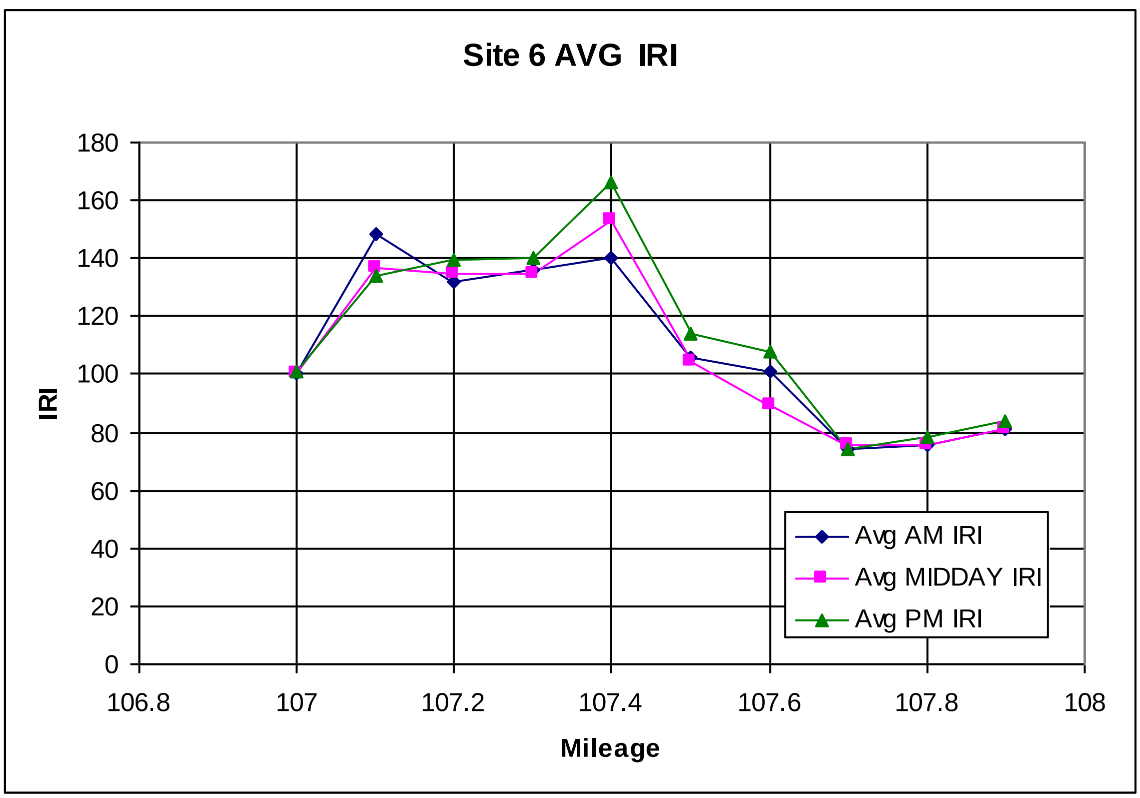
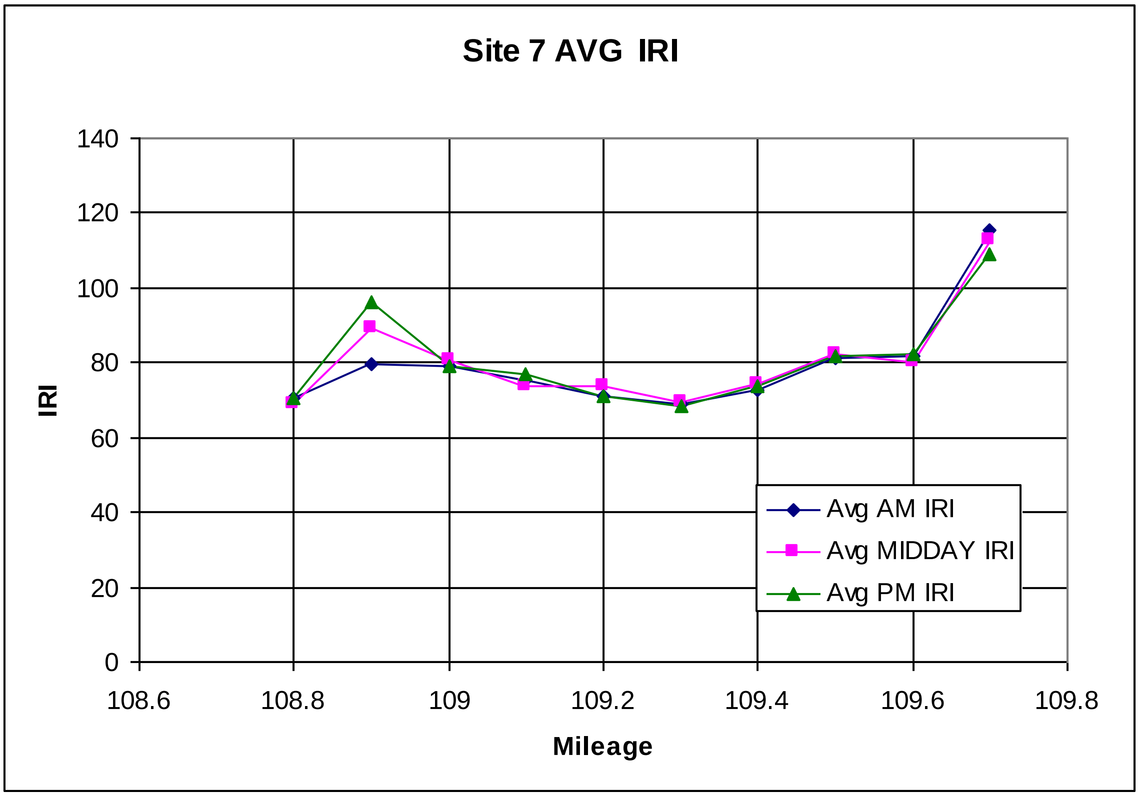
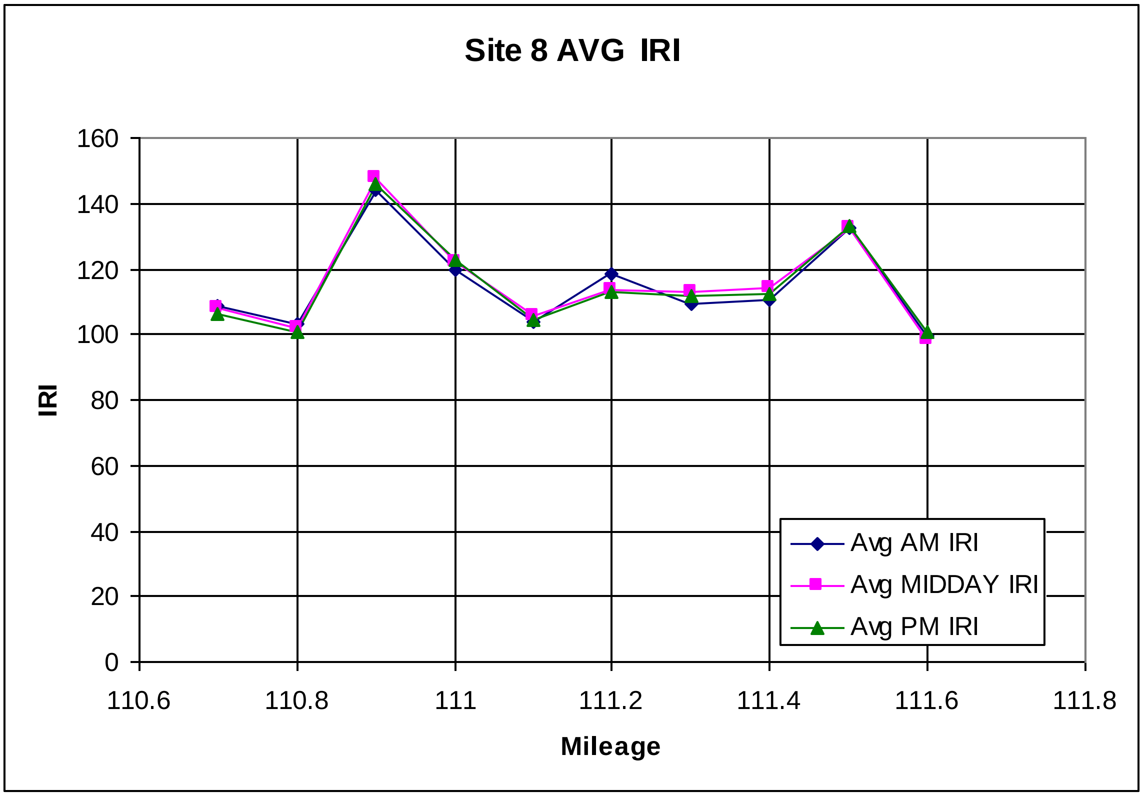
5.6
Mileage
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI

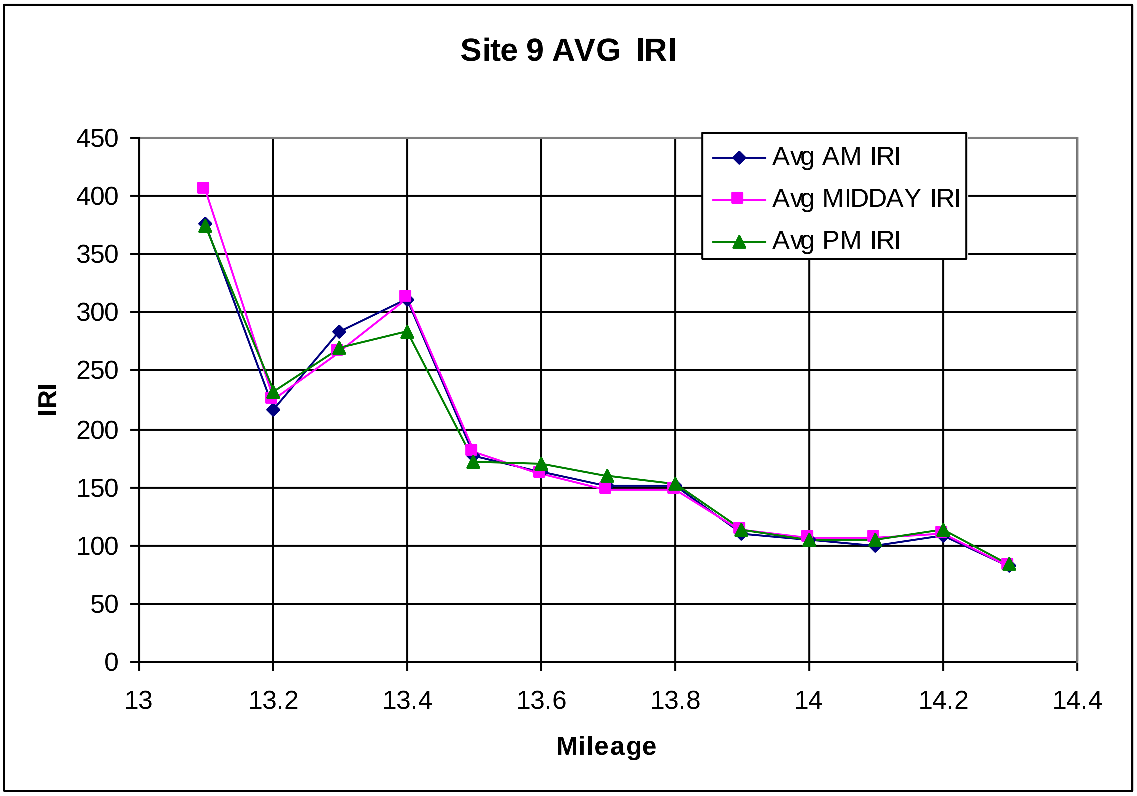

Site 5 AVG IRI
IRI
100
90
80
70
60
50
40
30
20
10
0
7.8
8
8.2
8.4
8.6
8.8
9
Mileage
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI

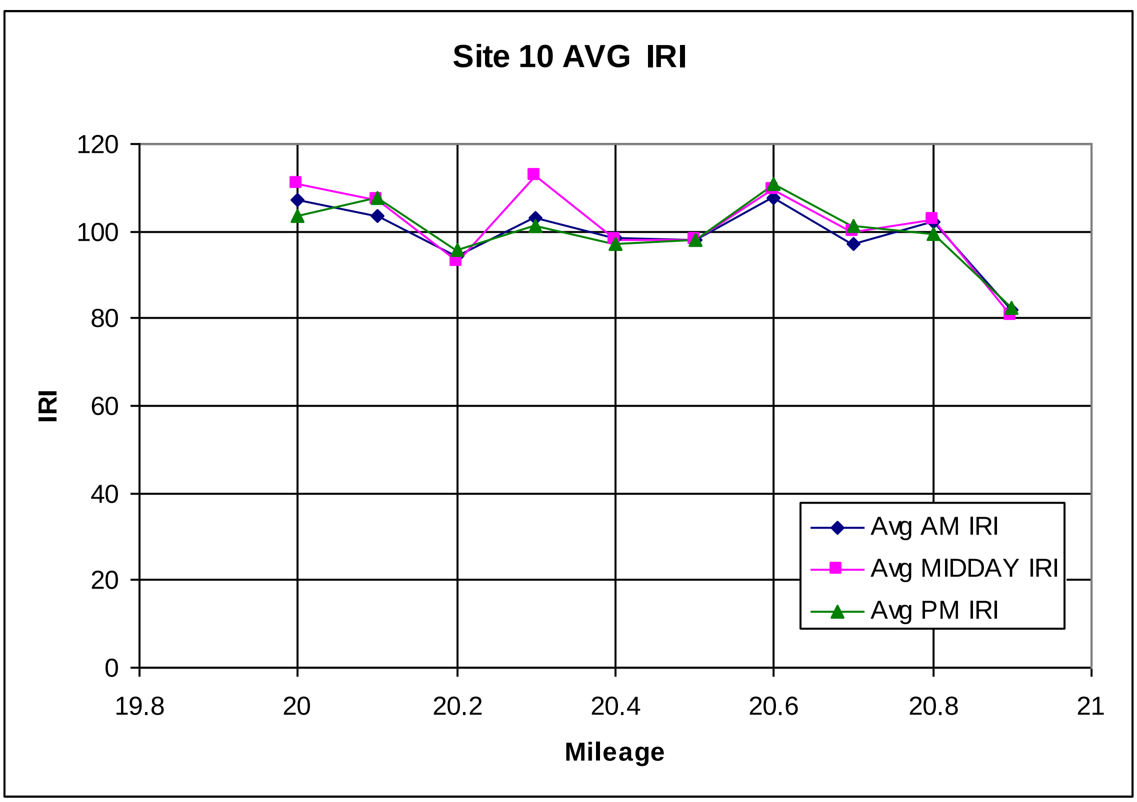

Site 6 AVG IRI
IRI
180
160
140
120
100
80
60
40
20
0
106.8
107
107.2
107.4
107.6
107.8
108
Mileage
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI

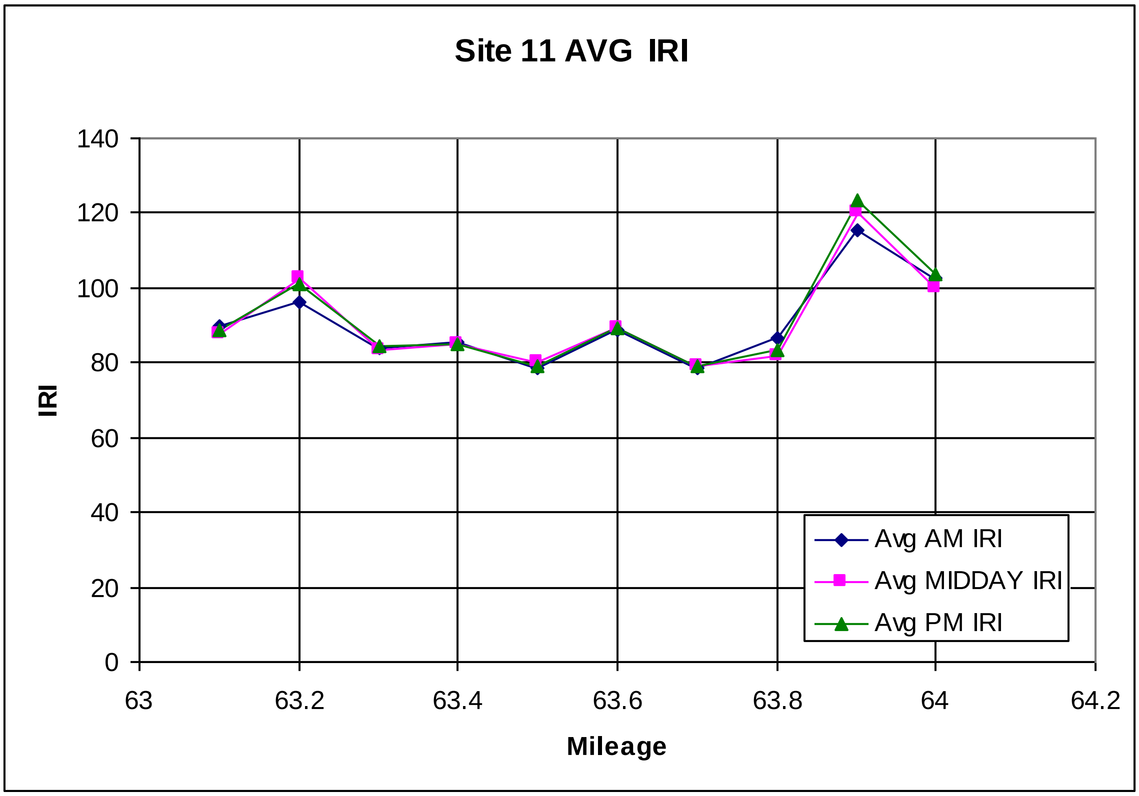

Site 7 AVG IRI
IRI
Mileage
140
120
100
80
60
40
20
0
108.6
108.8
109
109.2
109.4
109.6
109.8
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI

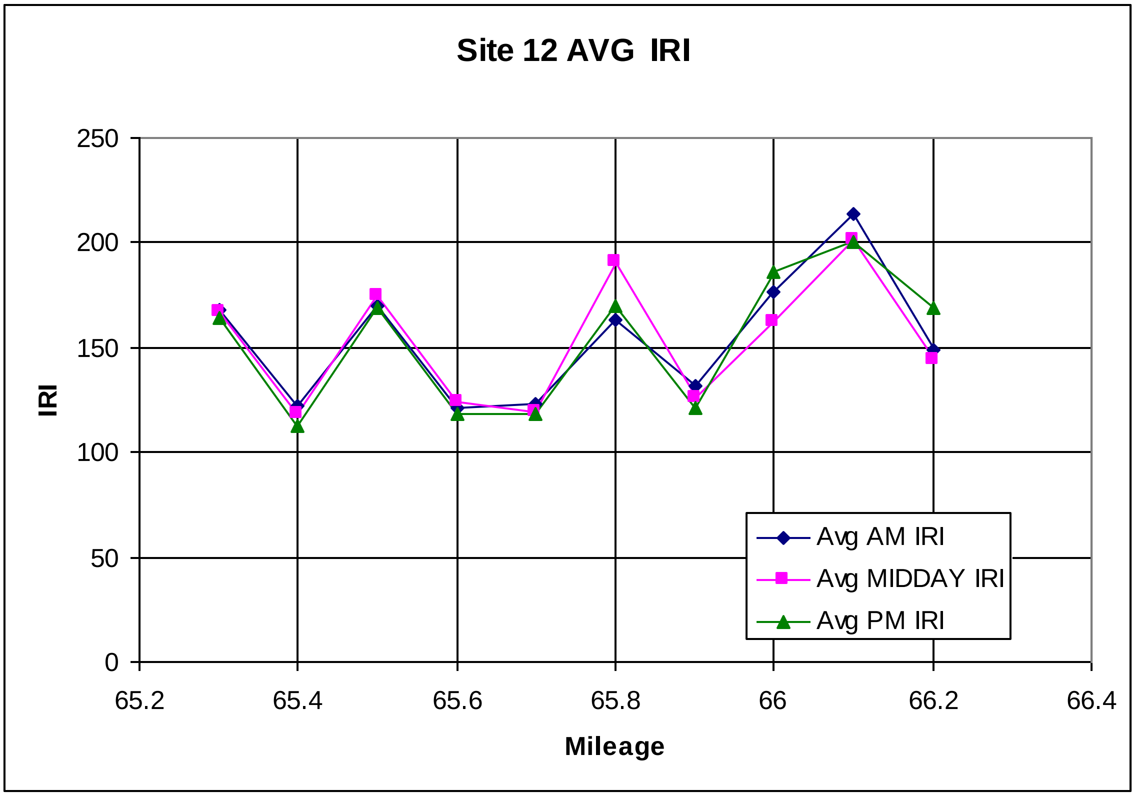


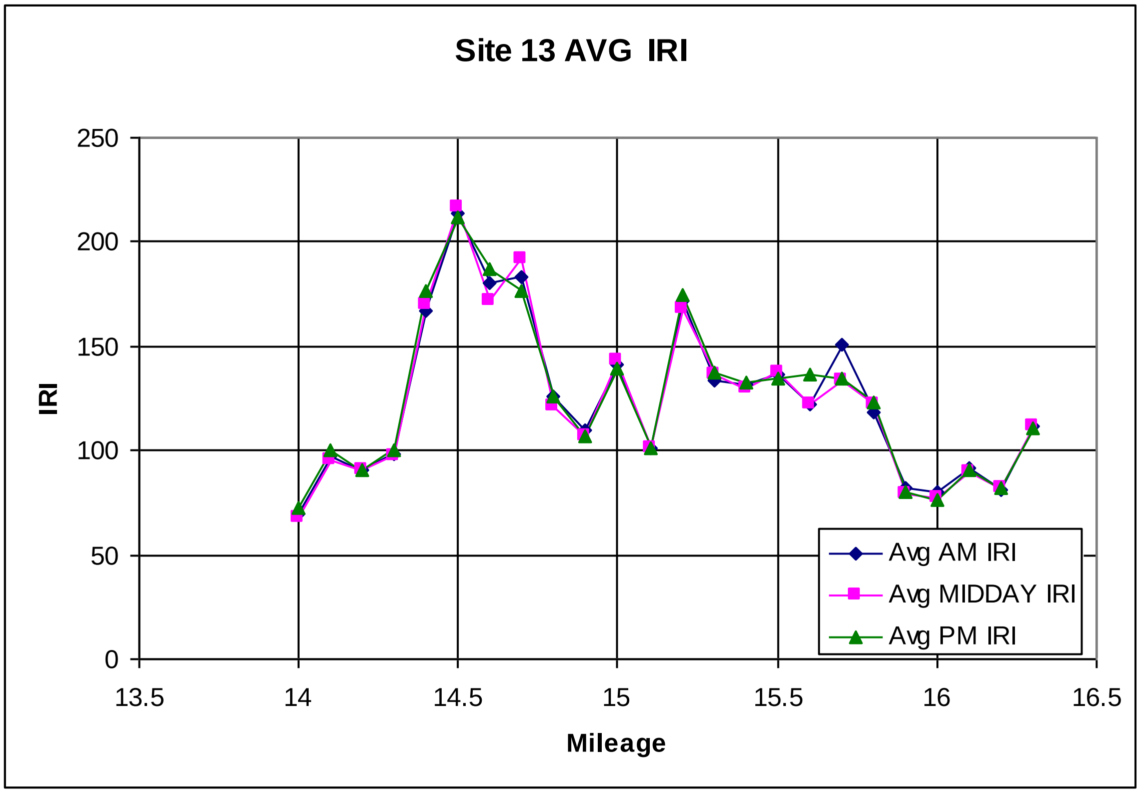
Site 8 AVG IRI
IRI
Mileage
0
20
40
60
80
100
120
140
160
110.6
110.8
111
111.2
111.4
111.6
111.8
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI

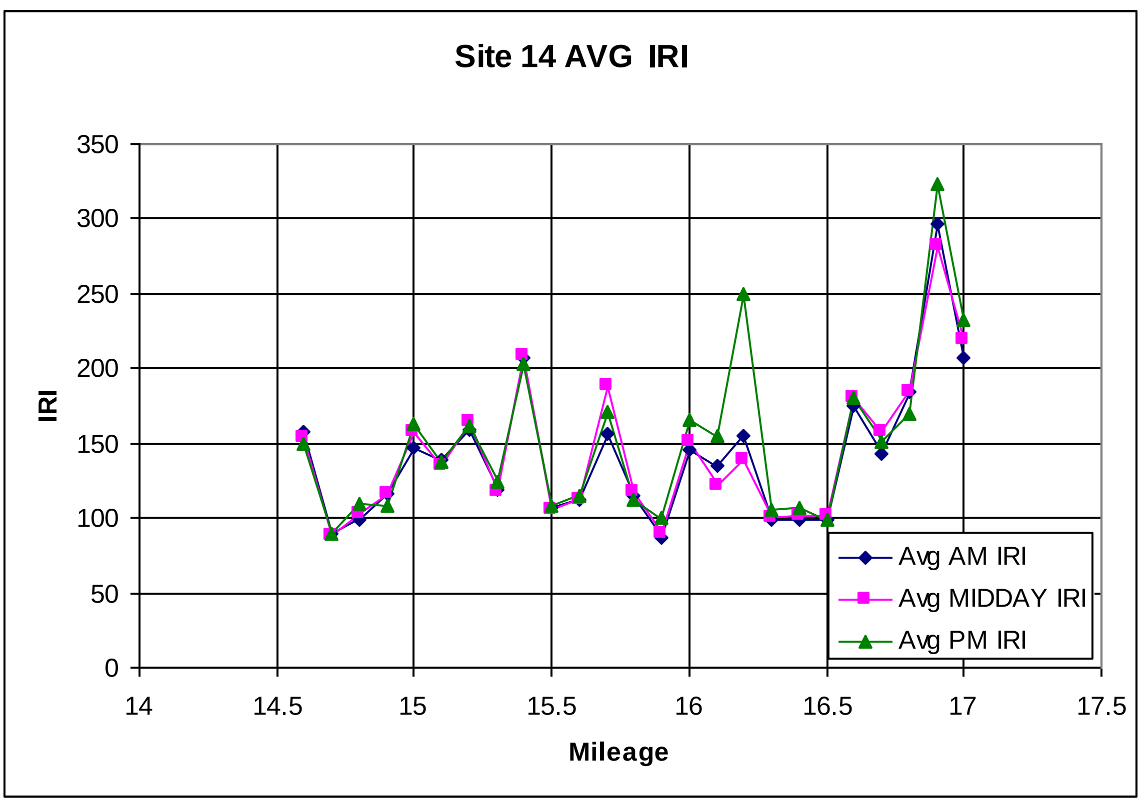

Site 9 AVG IRI
450
400
350
300
250
200
150
100
50
0
IRI
13
13.2
13.4
13.6
13.8
14
14.2
14.4
Mileage
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI


Site 10 AVG IRI
120
100
80
60
40
20
0
IRI
19.8
20
20.2
20.4
20.6
20.8
21
Mileage
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI


Site 11 AVG IRI
IRI
Mileage
140
120
100
80
60
40
20
0
63
63.2
63.4
63.6
63.8
64
64.2
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI


Site 12 AVG IRI
250
200
150
100
50
0
IRI
65.2
65.4
65.6
65.8
66
66.2
66.4
Mileage
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI


Site 13 AVG IRI
IRI
250
200
150
100
50
0
13.5
14
14.5
15
15.5
16
16.5
Mileage
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI


Site 14 AVG IRI
IRI
350
300
250
200
150
100
50
0
14
14.5
15
15.5
16
16.5
17
17.5
Mileage
Avg AM IRI
Avg MIDDAY IRI
Avg PM IRI

Web Sites

Dynatest Portable Profiler

http://www.dynatest.com/functional-portable-rsp.php

Dynatest Full size Profiler

http://www.dynatest.com/functional-rsp.php

Roadware ARAN Full size Profiler

http://www.roadware.com/products_services/aran/

Roadware Portable Profiler

http://www.roadware.com/products_services/roadprofiler/

APPENDIX C

Rutgers The State University of New Jersey

Center for Advanced Infrastructure and Transportation

NJDOT Pavement Profiler Operation and Certification
For:

State of New Jersey
Department of Transportation

Pavement and Drainage Management Systems and Technology

Prepared by:

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May 2009

Rutgers The State University of New Jersey

CENTER FOR ADVANCED INFRASTRUCTURE
AND TRANSPORTATION

NJDOT PAVEMENT PROFILER OPERATION AND CERTIFICATION

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Certification of Inertial Profiling Systems

The following outlines the NJDOT Pavement Profiler Certification program. The program outlines the procedures used to **verify the calibration** of the subsystems on the inertial profiler, certify the profiler operator, set up verification test sites and perform cross correlations of pavement profiles from the reference profiler, lightweight, portable, and high speed profilers.

(Comment: the accelerometer and the distance measuring instrument (DMI) in the profiler can be calibrated, but the operator can only perform a verification of the calibration of the height-sensor. Laser sensors are calibrated in the factory and cannot be calibrated by the user. During certification, we will verify these components are working satisfactorily.)

This practice describes minimum performance requirements for inertial profilers to be used for quality control/quality assurance (QC/QA) of surface smoothness on NJDOT paving projects where the profile-based smoothness construction specification is applicable.

The practice describes a certification procedure for test equipment used to measure a longitudinal surface profile based on an inertial reference system that is mounted on a transport vehicle. The minimum requirements stipulated herein are intended to address the need for accurate and repeatable profile measurements during construction and for Network Level IRI data collection to support the Department's Pavement Management System.

PROFILER EQUIPMENT CALIBRATION VERIFICATION

***GENERAL*— THIS PRACTICE DESCRIBES THE PROCEDURE FOR VERIFYING THE CALIBRATION OF AN INERTIAL PROFILER. THIS PRACTICE IS MEANT TO BE PERFORMED AS A QUALITY ASSURANCE (QA) TEST FOR USE WITH THE APPROPRIATE SMOOTHNESS SPECIFICATION FOR PAVING OPERATIONS. IT IS NOT MEANT TO BE REQUIRED AS A QUALITY CONTROL (QC) PROCEDURE TO MONITOR DAILY PAVING OPERATIONS; HOWEVER, THIS METHOD IS RECOMMENDED WHEN INERTIAL PROFILERS ARE USED FOR QC TESTING AND FOR NETWORK LEVEL DATA COLLECTION.**

This section refers to-calibration or verification procedures for the following profiler subsystems:

- Height Sensor
- Accelerometer
- Distance Measuring Instrument (DMI)

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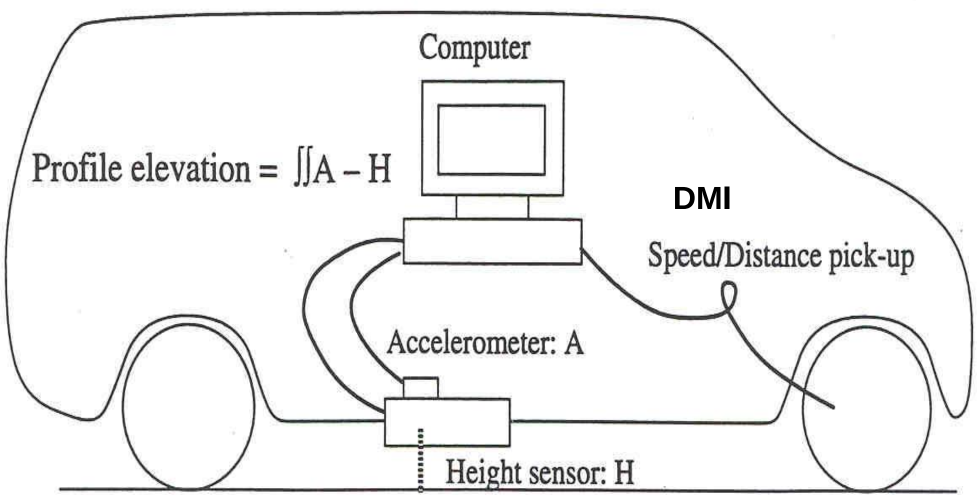

The block test is used to verify that the height sensor is functioning properly, the bounce test is used to check system stability to ensure that both the accelerometer and height sensor are functioning properly, and the distance test is used to verify that the distance measurement instrument (DMI) is recording distances accurately.

(Comment: The block check is used to verify that the height sensor in the profiler is functioning properly. The bounce test is an overall check to see if the accelerometer is canceling out vehicle movement as measured by the height sensor, and this test will detect problems with both the height sensor and the accelerometer. If the system passes the block test and does not pass the bounce test the problem is likely to be in the accelerometer. It should be noted that the block check does not calibrate the height sensor and the bounce test does not calibrate the accelerometer.)

It is highly recommended that operators calibrate the accelerometers and the DMI immediately prior to certification. (The operator should perform the block check and bounce test daily prior to data collection. They should calibrate the accelerometers and DMI at intervals recommended by the manufacturer.)

The Profiler Certification **must** be performed annually prior to the paving season and before network level IRI measurement for the PMS.

Note: For consistent pavement profile determination, maintain the cold air pressure on the wheels of the housing vehicle according to the manufacturer's specification. The housing vehicle and all system components shall be in good repair and proven to be within the manufacturer's specifications. The operator of the inertial profiler shall have all tools and components necessary to adjust and operate the inertial profiler according to the manufacturer's instructions.

Verification of Height Sensor Accuracy or Calibration:

The Block Test is done to ensure the accuracy of each height sensor.

The block test is performed after the profiler is turned on to warm up the equipment per the manufacture's recommendations. This test is performed on each height-sensor in the profiler.

This test will be conducted with the inertial profiler on a relatively flat and level area. Its purpose is to check the height measurements (in inches) from the height sensor(s) using blocks of known heights. During the test, do not lean on the profiler or cause it to move in any way. Under windy conditions, it may be necessary to perform this test indoors.

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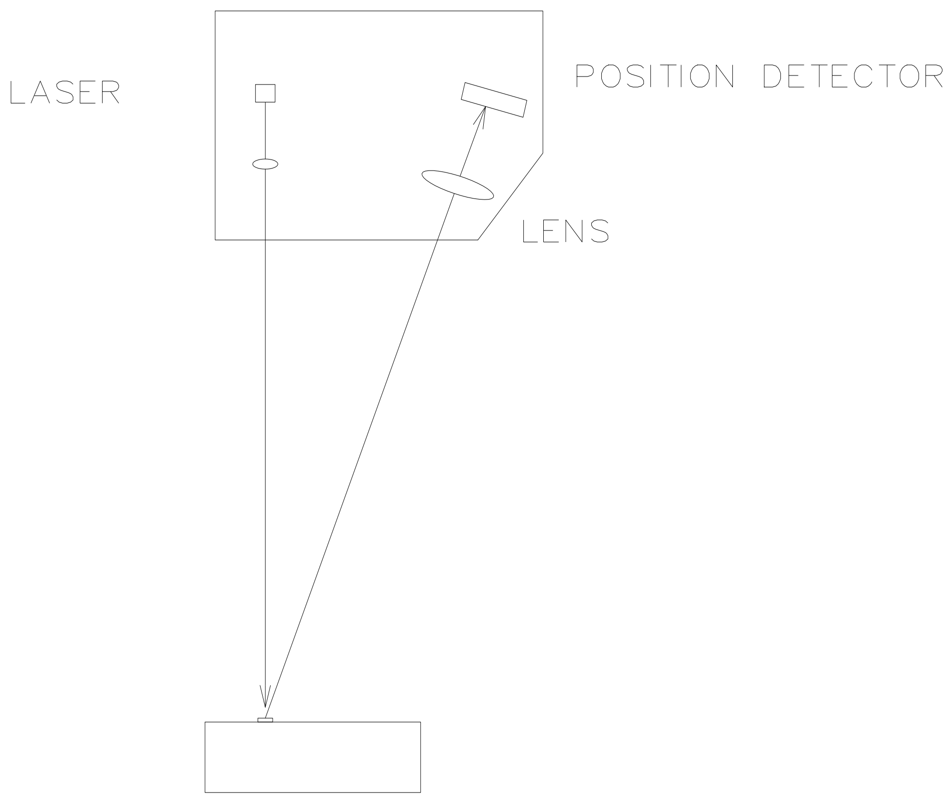


The monthly test procedure consists of the following steps:

- Position a smooth base plate under the height sensor of the profiler and take ten height measurements.
- Position a 0.25-in. block underneath the height sensor on top of the base plate and take ten height measurements.
- Carefully remove the 0.25-in. block from the base plate and replace it with a 0.50-in. block. Make another set of ten height measurements.
- Carefully replace the 0.50-in. block with a 1.00-in. block and take another set of ten height measurements.
- Finally, carefully replace the 1.00-in. block with a 2.00-in. block and take the last set of ten height measurements.

A daily test, used prior to operation, simplifies this procedure by adding and removing the 1.00 inch and 2.00 inch block

Note: The thickness of the blocks should be measured to an accuracy of 0.001 in using a suitable instrument. Measure the thickness of the gauge blocks at three different positions on each side of the block. For each block, an average thickness shall be determined from the measurements made which shall be used in checking the height sensors as described in this test. The average thickness shall be marked on each gauge block. **The above procedure for determining the average block thickness must be performed every three months.**

The difference between each measurement on a gauge block and the average of the ten measurements on the base plate is determined to get the thickness of the gauge block as measured by the height sensor. This calculation is done for all ten measurements on the given gauge block. The absolute values of the differences between the computed thickness and the known average block thickness are then determined. **To pass the height sensor check test, the average of the absolute differences must be less than or equal to 0.01 inch for each gauge block.**

The heights will be recorded in a table as follows:

Format of the Data File for the Height Sensor Check Test													
Record	**Base Plate, BP(i)**	**Height 0.25-inch Block, H(i)**	**Calculated Thickness, CT(i) =ABP-H(i)**	**Abs Diff, Abs(D(i)=CT(i)-MT)**	**Height 0.5-inch Block**	**Calculated Thickness, CT(i) =ABP-H(i)**	**Abs Diff, Abs(D(i)=CT(i)-MT)**	**Height 1-inch Block**	**Calculated Thickness, CT(i) =ABP-H(i)**	**Abs Diff, Abs(D(i)=CT(i)-MT)**	**Height 2-inch Block**	**Calculated Thickness, CT(i) =ABP-H(i)**	**Abs Diff, Abs(D(i)=CT(i)-MT)**
1	BP(1)	H(1)	CT(1)=ABP-H(1)	Abs('D(1)=CT(1)-MT)									
2	BP(2)	H(2)	CT(2)=ABP-H(2)	Abs('D(2)=CT(2)-MT)									
3	BP(3)	H(3)	CT(3)=ABP-H(3)	Abs('D(3)=CT(3)-MT)									
4	BP(4)	H(4)	CT(4)=ABP-H(4)	Abs('D(4)=CT(4)-MT)									
5	BP(5)	H(5)	CT(5)=ABP-H(5)	Abs('D(5)=CT(5)-MT)									
6	BP(6)	H(6)	CT(6)=ABP-H(6)	Abs('D(6)=CT(6)-MT)									
7	BP(7)	H(7)	CT(7)=ABP-H(7)	Abs('D(7)=CT(7)-MT)									
8	BP(8)	H(8)	CT(8)=ABP-H(8)	Abs('D(8)=CT(8)-MT)									
9	BP(9)	H(9)	CT(9)=ABP-H(9)	Abs('D(9)=CT(9)-MT)									
10	BP(10)	H(10)	CT(10)=ABP-H(10)	Abs('D(10)=CT(10)-MT)									
Avg	ABP		MT	AVG Diff		MT	AVG Diff		MT	AVG Diff		MT	AVG Diff

BP(i) = Base Plate height measurements
ABP = Average of Base Plate Heights
CT(i) = Calculated Thickness of the gage block
CT(i) = Difference between Average Base Plate Height and the individual block heights
* MT=Average of the measured thickness of the gauge blocks
Abs Diff= Absolute difference between the individual measured thickness and the average measured thickness of the gage block.
AVG Diff = Average of Absolute difference Diff
* For each block, an average thickness shall be determined from the measurements made which shall be used in checking the height sensors as described in this test. The average thickness shall be marked on each gauge block.

To pass the height sensor check test, the average of the absolute differences must be less than or equal to 0.01 inch for each gauge block.

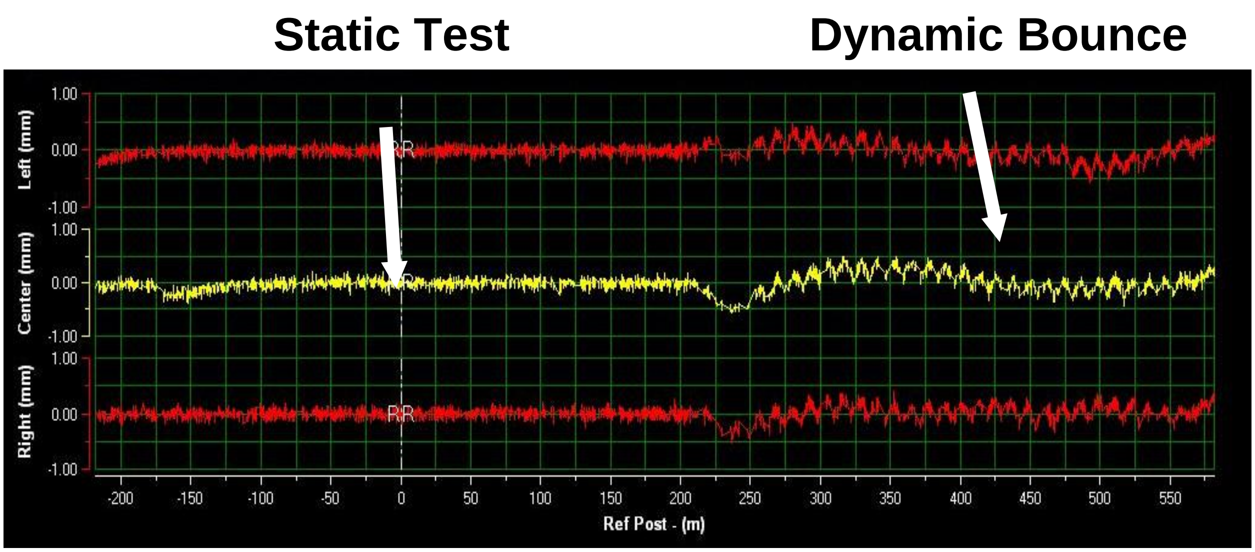
Bounce Test

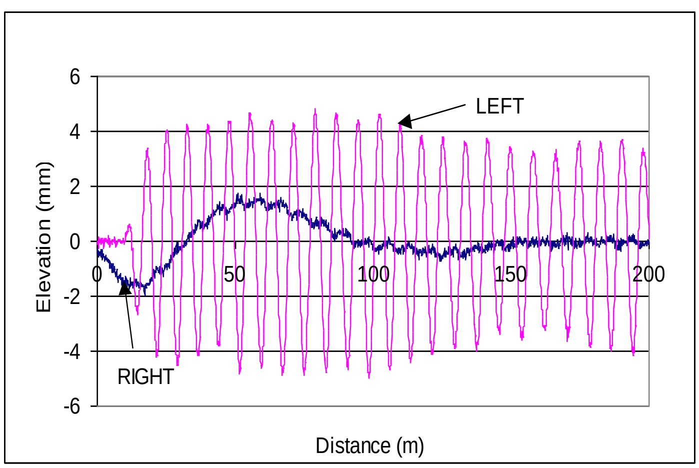
The bounce test is performed to verify the system stability and checks that both the height sensor and the accelerometer are functioning properly.

To perform the "bounce test" the vehicle is stationary but the electronics are provided an internal signal so that travel at normal data collection speeds is simulated (50 mph). The equipment is placed on level, smooth pavement. Place a clipboard or other non-reflective surface on the pavement under each laser sensor so that the texture of the pavement will not affect the test.

The first step is to collect IRI data with the vehicle as motionless as possible. Simulate the IRI data collection for the time it takes to collect data on several 0.1-mile (528 feet) segments. The observed IRI value for a 528 ft long segment should be below 3 in. per mile. Next, the sensor(s) should be moved vertically for a total displacement of approximately 2 in. (a yardstick may be helpful until the operator gets used to the procedure). The typical approach is to push the mounting system (bumper) at the center of the vehicle down an inch or so and let the vehicle suspension rebound to create the total travel of 1 in

The operator must be able to observe and maintain a consistent rocking motion exceeding two inches for the time required to simulate 528 ft of travel for a simulated speed of 60 mph. The software shall calculate IRI for 528 ft of simulated travel. The observed IRI values should be below 8 in. per mile for a 0.1-mile segment. The theoretical value for both phases of the "bounce test" is 0, and newer equipment should provide lower numbers.





Error in the Left Accelerometer or height sensor.

Verification of Distance Measuring System:

This test is used to verify the calibration of the distance measuring instrument system in the profiler by comparing the distance measured by the DMI in the vehicle to that established by a steel surveying tape.

Adjust the cold tire pressure to the manufacturer's recommended value. Because tire pressures increase as the air inside them warms up to operating temperature causing the tire diameter to expand, drive around the site for at least 5 miles to warm up the tires prior to collecting data for this test.

(Comment: The manufacturers recommended tire pressure will vary with type of vehicle. Hence, it is not appropriate to specify a tire pressure. The best procedure to calibrate the DMI is to first check the cold tire pressure, warm the tire and then calibrate the DMI. This calibration factor will be valid for the hot tire pressure at the time of calibration. Thereafter, when you make measurements, if you check the cold tire pressure and warm the tires the tire pressure should be at the hot tire pressure that correspond to the value when the DMI was calibrated.)

Test Section:

The DMI verification section shall be a straight and level roadway at least 528 ft in length. Measure the length of the section accurately to within 0.05 percent (3 inch) using a steel survey measurement tape since the distance to be measured is the travel length the wheels encounter. Clearly mark the starting and ending points of the test section with reflective tape or a cone with a reflective tape. Use the profiler's auto-start trigger to activate the start and end of the data collection. Run the profiler at a constant speed that matches the proposed testing speed.

Test Procedure:

Check the tire air pressure on the wheels of the housing vehicle and maintain according to the manufacturer's recommendations.

Allow electronic equipment to warm-up in accordance with the manufacturer's recommendations. Prior to running the test site, warm of the tires by driving for 5 to 10 miles. Perform three runs over the test section, initiating and terminating data collection at the test section using the auto-trigger. Either a cone with a reflective tape placed on the side of the road or a reflective tape placed on the pavement surface can be used to auto-trigger at the start and the end of the section. At the end of each run, the reading from the profiler's DMI is recorded. After completion of three runs, the absolute difference between the DMI readings and the known distance of the path tested shall be computed for each run. The average of the three absolute differences must be less than or equal to within 0.15 percent of the length of the test section to pass the test. For 528 ft test sections, the average of the three absolute differences must be less than or equal to 9 inches. The DMI may be calibrated at the test section prior to performing the three runs.

If the profiler's DMI does not meet this requirement, the operator of the profiler shall calibrate the DMI based on the known distance of the test section. After entering the new calibration factor, the operator shall again make three runs over the delineated path and measure the distance with the profiler's DMI on each run. The average of the absolute differences between the known distance and the DMI readings after calibration shall be computed to check if it is within the specified tolerance of 0.15 percent of the length of the test section or 9 inch for a 528 ft test section. If the profiler's DMI does not meet this requirement, a second calibration shall be made. If after the second calibration the profiler still fails to meet the specified tolerance, no further testing will be conducted and the profiler shall be considered to have failed certification.

The DMI shall be calibrated monthly during the construction or Network PMS testing season.

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OPERATOR QUALIFICATION

Operators of inertial profilers used for QA testing of pavement ride quality must pass a proficiency test and be certified to operate an inertial profiler. Applicants for certification will be tested on the following**:**

NJDOT ride smoothness specification,
Operating inertial profilers,
Collection of profile data, and
Evaluating quality of data collected and IRI value calculated.

Applicants for certification shall undergo both written and practical examinations. They must pass both portions of the test to be certified. Prior to taking the proficiency test, applicants should have completed a profile training course such as NHI Course 131100 and must have undergone training on the use of the specific inertial profiler they will be operating in the field. Applicants must know how to calibrate the accelerometers and the distance measuring system, perform a verification of the calibration of the height sensor (block check), perform the bounce test, and collect profile data with the inertial profiler.

Upon passing the proficiency test, successful applicants will be given an identification card, which will verify that they are certified to operate the inertial profiler for QA testing on paving projects. The card shall identify the specific type or brand of inertial profiler that the operator is certified to operate. This card will be valid for a period of 12 months from the date of issue unless revoked because of misuse. The agency will maintain records of operator and profiler certification

EQUIPMENT CERTIFICATION

DYNAMIC CERTIFICATION TESTING—CERTIFICATION TESTS SHALL BE CONDUCTED AT A SITE APPROVED BY THE NJDOT, WHICH INVOLVE TEST SECTIONS, REFERENCE PROFILES, AND DEVICES USED TO ESTABLISH REFERENCE PROFILES AS DESCRIBED IN THE FOLLOWING:

The certification of the profilers is conducted in two steps. The first step is to assess the repeatability of the High Speed Profilers, and the second step is to assess the accuracy of High Speed Profilers

Repeatability refers to the assessment of a single profiler's ability to repeatedly measure the overall roughness as well as the spatial distribution of roughness along a single profile trace.

Accuracy refers to the assessment of the Portable or High Speed Profiler's ability to reproduce the profile trace measured by the Reference **profiler which is deemed to be correct**.

Minimum Requirements: The profiler must have passed the block test, bounce test, and DMI verification test. The inertial profiling system must meet all requirements and specification found in AASHTO MP 11-07, Standard Equipment Specification for Inertial Profiler.

Operating Parameters **-** The inertial profiler must be capable of providing relative elevation measurements that meet the following requirements:

Reporting Interval - the interval at which relative profile elevations are reported must be less than or equal to two inches.

Cutoff Wavelength - *the algorithm for filtering the profile data should use a cutoff wavelength of 300 feet.*

Certification Test Sections Selection—

Perform dynamic certification testing on a smooth and medium-smooth section. As determined from a reference profiler, the smooth section shall have a mean IRI within the range of 30 to 75 in. per mile while the medium-smooth section shall have a mean IRI within the range of 95 to 135 in. per mile. For Network level PMS testing a third site with a mean IRI between 150 and 250 in. per mile shall be used.

Test surface macro texture should reflect common NJDOT new pavement surfaces. Additional sites may be established for coarse textured mixtures as needed.

Each test section will be at least 528 ft in length with a lead-in distance of at least 300 ft and a safe stopping distance.

Test sections should be tangent sections with no significant grade (>3%) or grade change, and shall be free of cracks in the traveled wheel paths.

The reference site will be painted with a dot every 10 feet or a continuous stripe in the wheel paths and the beginning and end of the test section will be marked with reflective tape to prompt the auto start trigger of the high speed profile data collection. The distance between the wheel paths should be 67 inches between (65 and 70) inches.

Testing Procedure and Analyses for Reference Profile, Portable, and High Speed Profilers (HSP)—

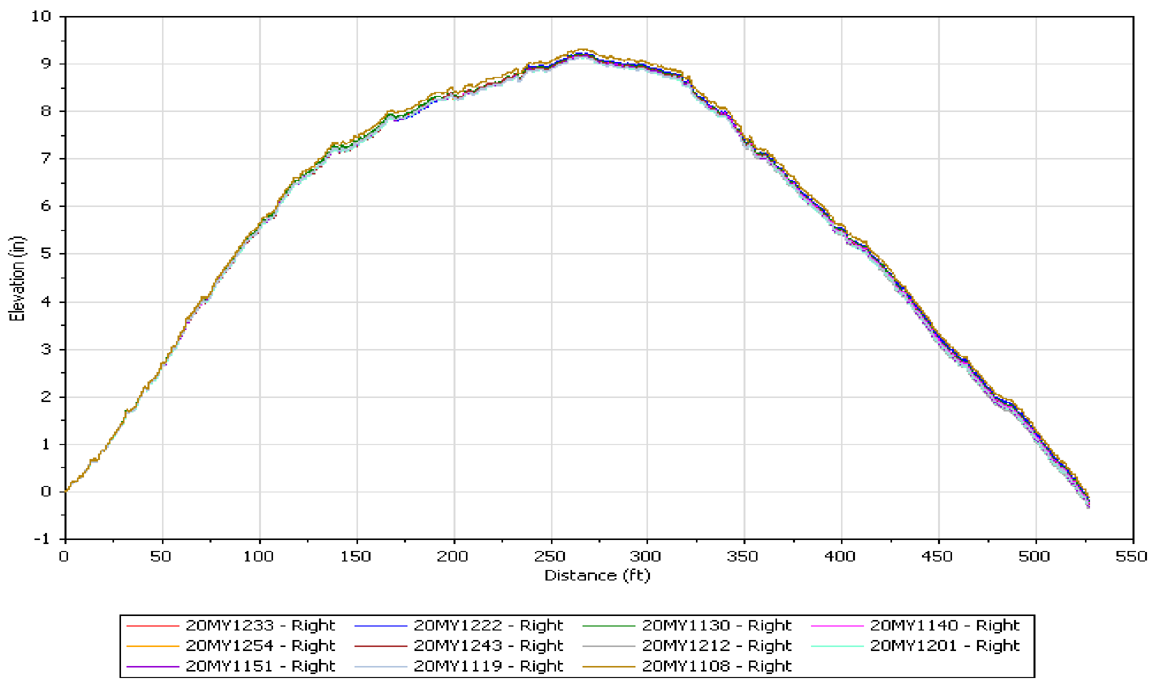
Reference Profiles

The reference profile for each test section shall be measured using the ICC SurPRO 2000 in accordance with ASTM E 2133 **Standard Test Method for Using a Rolling Inclinometer to Measure Longitudinal and Transverse Profiles of a Traveled Surface**

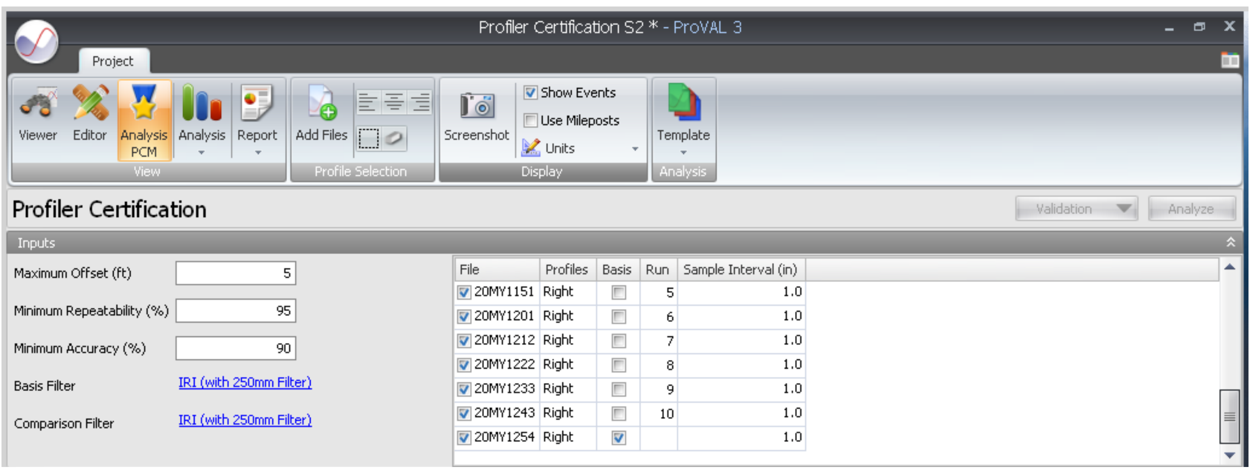
(Comment: The (1) the average IRI of the multiple runs will be used if IRI of the reference profiler is being compared with the HSP profiler IRI, (2) a representative reference profile (for each wheel path) will be selected to perform cross correlation with the profiles from the portable or high speed profiler if the cross correlation method is being used.)

Eleven runs of the ICC SurPRO 2000 reference profile (for each wheel path) will be used to perform cross correlation of the reference profiler and representative profiles of the reference profile (for each wheel path) will be used to perform cross correlation with the portable and high speed profiler, if the cross correlation method is being used. This representative profiles will be based on the reference profile that represents the best cross correlation rating. (Comment: The repeatability of the cross correlation for the reference profiles must be higher than 0.95).

The eleven repeat runs will be viewed for repeatability.



The ProVAL Profiler Certification Analysis screen will be setup to analyze the reference profiler data. The minimum repeatability will be set to 95% and the minimum accuracy will be set to 90%. Each of the eleven profiles will be evaluated as the base profile compared to the other 10 runs. * The Sample interval of the reference profiler must be less than 2.75 inch.



The analysis report will summarize the repeatability and accuracy results as shown below.

Repeatability - Right Correlations (%)

Run	2	3	4	5	6	7	8	9	10
1	99	99	99	99	99	99	97	99	99
2		99	99	99	100	99	97	99	99
3			99	99	99	99	97	99	99
4				99	99	99	97	99	99
5					99	99	97	99	99
6						99	97	99	99
7							97	99	99
8								97	98
9									99

Repeatability - Right Offsets (ft)

Run	2	3	4	5	6	7	8	9	10
1	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.2
2		0.0	0.0	0.0	-0.1	0.0	-0.1	0.0	0.0
3			0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0
4				0.1	0.0	0.0	-0.1	0.1	0.1
5					-0.1	-0.1	-0.1	0.0	0.0
6						0.0	0.0	0.1	0.1
7							0.0	0.1	0.1
8								0.1	0.1
9									0.0

Accuracy (%)

Run	Right
10	99
9	99
8	99
7	99
6	99
5	99
4	99
3	97
2	99
1	99

Statistics

Statistic	Repeatability - Right	Accuracy - Right
Comparison Count	45	10
% Passing	100	100
Mean	99	99
Minimum	97	97
Maximum	100	99
Standard Deviation	0.8	0.6
Grade	Passed	Passed

Left	File	Profile	IRI (in/mi)	Mean Rep	Right	File	Profile	IRI (in/mi)	Mean Rep	MRI
1	20MY0844	Left	79.25	96	1	20MY1108	Right	107.07	99	93.16
2	20MY0858	Left	83.44	96	2	20MY1119	Right	107.43	99	95.435
3	20MY0910	Left	79.79	96	3	20MY1130	Right	107.06	99	93.425
4	20MY0921	Left	81.87	96	4	20MY1140	Right	107.2	99	94.535

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5	20MY0938	Left	78.55	96	5	20MY1151	Right	107.89	99	93.22
6	20MY0949	Left	80.53	96	6	20MY1201	Right	107.12	99	93.825
7	20MY1001	Left	80.14	96	7	20MY1212	Right	107.51	99	93.825
8	20MY1014	Left	83.22	96	8	20MY1222	Right	109.08	99	96.15
9	20MY1025	Left	79	96	9	20MY1233	Right	108	99	93.5
10	20MY1035	Left	80.11	96	10	20MY1243	Right	108.24	99	94.175
11	20MY1058	Left	80.44	96	11	20MY1254	Right	107.7	99	94.07
		average	80.57636					107.6636		94.12
		STDEV	1.620495					0.617208		0.9381

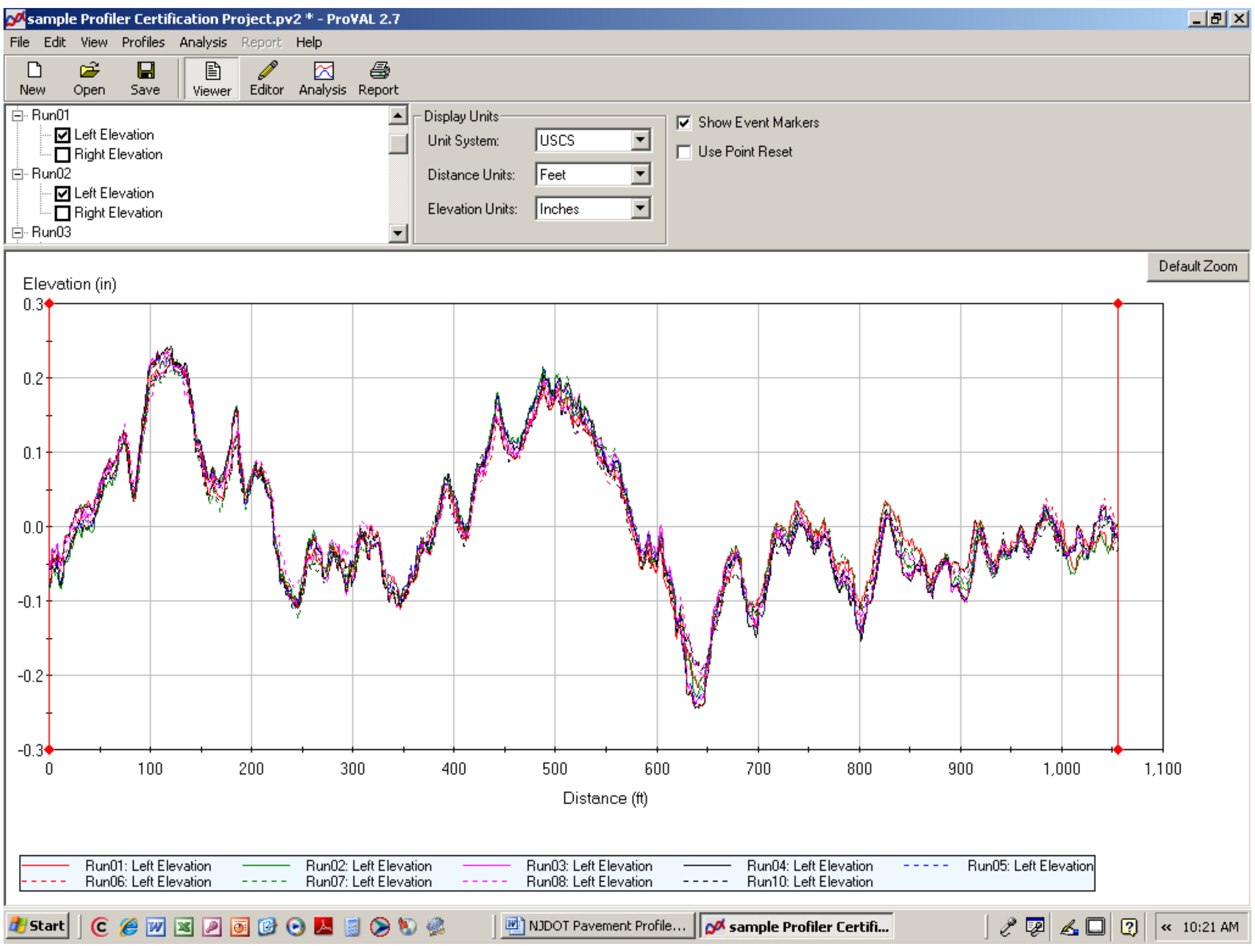
The highlighted profiles will be used in the cross correlation with the portable and high speed profilers. The Mean repeatability scores represent the score when that profile was used as the basis for comparison.

Portable and High Speed Profiler (HSP)

The distance between the wheel paths should be located at 67 inches depending on the profiler (Comment: The laser should be between (65 and 70) inches.) The portable and high speed profilers will perform ten data collection runs in the direction of travel. The profiler shall start and terminate data collection using the auto-trigger

Test Data Analyses

After loading the profile traces (ERD files) from the portable and the High Speed Profilers into ProVAL, visually inspect the profile traces in each wheel path to ensure that no visible profile anomalies exist in the data. If visual anomalies are present, additional runs shall be performed to replace the runs with anomalies or 10 additional runs of the portable or high speed profilers will be performed.



Test data will be analyzed in accordance with the ***Profile Certification Analysis*** *option in the ProVAL program which performs* *<u>Cross Correlation Analysis Method A</u>* *as described in the following to establish the repeatability and accuracy of the test equipment:*

Cross Correlation:

Cross correlation is superior to direct comparison of IRI index values because it compares the overall roughness and its spatial distribution. The method yields ratings of agreement under a given set of test conditions that do not reward compensating error. (Karamihas, 2002)

Equipment Repeatability—

Evaluate repeatability using cross correlation of IRI filtered output. On each wheel path, cross correlate each of the ten profiles to each of the remaining nine. A total of 45 comparisons will be made. The repeatability "Grade" for each wheel path is the average of all 45 values. A score of 0.92 or greater is required on all wheel paths. For PMS Network site, an additional two values will be determined for the rough section with a score of 0.90.

Checking the ten runs for the portable and high speed profilers in the "Comparison" column and pressing the "analysis" button will check the profilers ability to repeatedly measure the profile trace in each wheel path.

RESULTS

The results provide summary of the input targets and analyses.

Inputs

Maximum Offset (ft): 99.00
Minimum Repeatability (%): 92.0
Minimum Accuracy (%): 90.0
Basis Filter: IRI (with 250mm Filter)
Comparison Filter: IRI (with 250mm Filter)

Statistics

Statistic	Repeatability - Left	Repeatability - Right	Accuracy - Left	Accuracy - Right
Comparison Count	28	28	8	8
% Passing	57	68	0	50
Mean	92	93	81	89
Minimum	86	86	77	84
Maximum	96	97	86	93
Standard Deviation	2.4	2.5	2.6	2.9
Grade	Passed	Passed	Failed	Failed

Accuracy (%)

Run	Left	Right
8	77	84
6	81	90
9	86	93
10	81	91
5	82	87
2	80	91
7	80	87
4	79	88

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Repeatability - Left Correlations (%)

Run	4	5	6	7	8	9	10
2	92	86	92	91	93	92	89
4		91	95	92	95	94	92
5			91	90	91	88	87
6				91	96	95	92
7					91	92	89
8						95	92
9							92

Repeatability - Right Correlations (%)

Run	4	5	6	7	8	9	10
2	94	90	94	93	93	91	86
4		94	97	94	97	95	91
5			95	93	95	91	89
6				93	96	93	91
7					94	95	91
8						95	91
9							93

Repeatability - Left Offsets (ft)

Run	4	5	6	7	8	9	10
2	1.2	-2.8	-2.4	-2.0	-3.4	0.5	1.6
4		-3.7	-3.6	-3.2	-4.5	-0.7	0.5
5			0.3	0.6	-0.7	3.1	4.5
6				0.5	-0.9	2.9	4.1
7					-1.3	2.6	3.7
8						3.9	5.0
9							1.2

Repeatability - Right Offsets (ft)

Run	4	5	6	7	8	9	10
2	1.0	-2.8	-2.6	-2.2	-3.6	0.3	1.4
4		-3.7	-3.6	-3.2	-4.5	-0.7	0.5
5			0.3	0.8	-0.5	3.3	4.3
6				0.5	-0.9	2.9	4.1
7					-1.3	2.6	3.7
8						3.9	5.0
9							1.2

Equipment Accuracy—

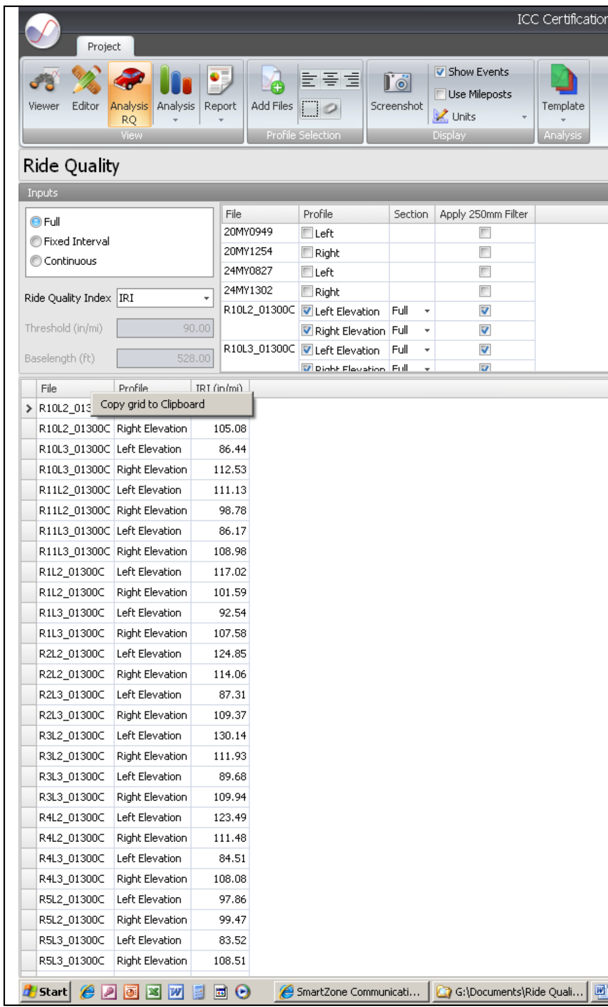
Choose a representative profile (represents the best cross correlation rating) from the ten runs of the reference profile to act as the reference or base profile. This profile will act as the "true" profile to assess the accuracy of the portable and high speed profiles.

Evaluate accuracy using cross correlation of IRI filtered output. On each wheel paths, cross correlate each of the ten profiles to the reference profile. The accuracy "Grade" for each wheel paths is the average of the ten individual cross correlation values. A score of 0.90 or greater is required on all traces.

Calculate the accuracy score of each profile trace. For dual-path profilers, four scores will be determined, two for each test section. For PMS Network site, an additional two will be determined for the rough section.
Ride Statistic Verification

After the portable or high speed profilers have passed the repeatability and accuracy test, the next step is to verify the IRI values.

The IRI will be determined for each profile run for each 528 ft section in each wheel path using **the latest version of** ProVAL Ride Statistics. The IRI data can be exported to Excel by copying the results table to the clipboard. The average, standard deviation and Coefficient of Variation (COV) of the ten runs can be determined in Excel.



	LIRI (in/mi)	RIRI (in/mi)	MRI (in/mi)
Run01	27.4	26.4	26.9
Run02	30.5	38.1	34.3
Run03	31.2	36.6	33.9
Run04	31.3	40.2	35.7
Run05	31.1	37.8	34.5
Run06	31.6	38.6	35.1
Run07	27.4	27.4	27.4
Run08	27	25.4	26.2
Run09	27.6	27.5	27.6
Run10	26.2	25.7	25.9
Avg	29.13	32.37	30.75
Std Dev	2.17	6.30	4.22
COV	7.44	19.47	13.72

Coefficient of Variation = STDEV/Mean*100
Acceptable COV < 3%

A standard deviation of the ten runs will be determined for each 528 ft section <u>for each wheel path</u>. The standard deviations for each 528 ft section for each wheel path shall not exceed 5% of the average IRI value based on the reference profile. If the standard deviation exceed 3.0 in/mile, the ten runs shall be repeated.

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High Speed Profiler CERTIFICATION PROCEDURE

Colorado Certification Acceptance

The high speed profiler operator shall perform ten runs in the intended direction of travel. The high speed profile operator shall generate digital reports for each run indicating the left & right wheel path profile trace for each 528 ft section in an ERD file format for use in ProVAL.

ACCEPTANCE DETERMINATION

An average and standard deviation of the MRI (Average of the wheel path IRIs) of the ten runs will be determined for each 528 ft section for each wheel path. The high speed profile will be considered acceptable when the standard deviation for each 528 ft section does not exceed 3.0 in/mile and the average MRI does not vary from the MRI of the reference profiler values by more than 6.0 in/mile.

CERTIFICATION

After a high speed profile is determined to be acceptable, a Certificate will be issued listing:

- high speed profile serial number
- high speed profile VIN number
- high speed profile Make & Model
- Height sensor serial numbers
- Accelerometer serial numbers
- Certification Date
- Expiration Date

The certification will expire after one year

VERIFYING CALIBRATION—THE FOLLOWING VERIFICATION PROCEDURE IS REQUIRED FOR QA TESTING AND IS RECOMMENDED WHEN AN INERTIAL PROFILER IS TO BE USED AS A QC INSTRUMENT ON A DAILY BASIS.

Verification of Computed Ride Statistics (IRI)—

The test equipment software must be capable of computing and reporting the IRI of each profile trace tested. The repeatability of these ride statistics shall be determined in the following manner:

1. Ten IRI values are computed using the profiles from the ten repeat runs made on a given profile trace.
2. For each test profile trace, the coefficients of variation of the IRIs is computed. For dual-sensor profilers, four coefficients of variation are computed—one per trace per test section.

   Coefficient of Variation

   This is the ratio of the standard deviation to the mean:

$$\text{coefficient of variation} = \frac{\text{standard deviation}}{\text{mean}} x100$$

3. To pass the repeatability test based on the computed ride statistics, each coefficient of variation of the IRIs determined in step 2 must not exceed 3 percent.

Note—The value of 3 percent for coefficient of variation is based on a 528-ft test section length.

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The accuracy of the IRI statistic shall be determined in the following manner:

Determine the IRI values for each of the ten repeat runs made on a given profile trace. There will be a total of 20 values for dual-sensor profiles.

Determine the absolute difference between the profiler IRI 20 values and the corresponding reference IRI value(s).

4. Determine the average of the absolute differences determined in step 2. Two values will result for a dual-sensor profiler.
5. Determine the percentage difference between the average of the absolute differences and the corresponding reference IRI by dividing the average absolute difference(s) determined in step 3 by the reference IRI and multiplying by 100.
6. The percentage difference determined in step 5 must not exceed 5 percent for any profile trace.

IRI COMPARISONS

For comparison purposes, the IRI from the high speed profile *can be correlated to the IRI of the Reference profiler using the following procedure.*

Calculate the average of the MRI (average of the LIRI and RIRI) from the ten runs for the Reference and high speed profile *for each test site.*

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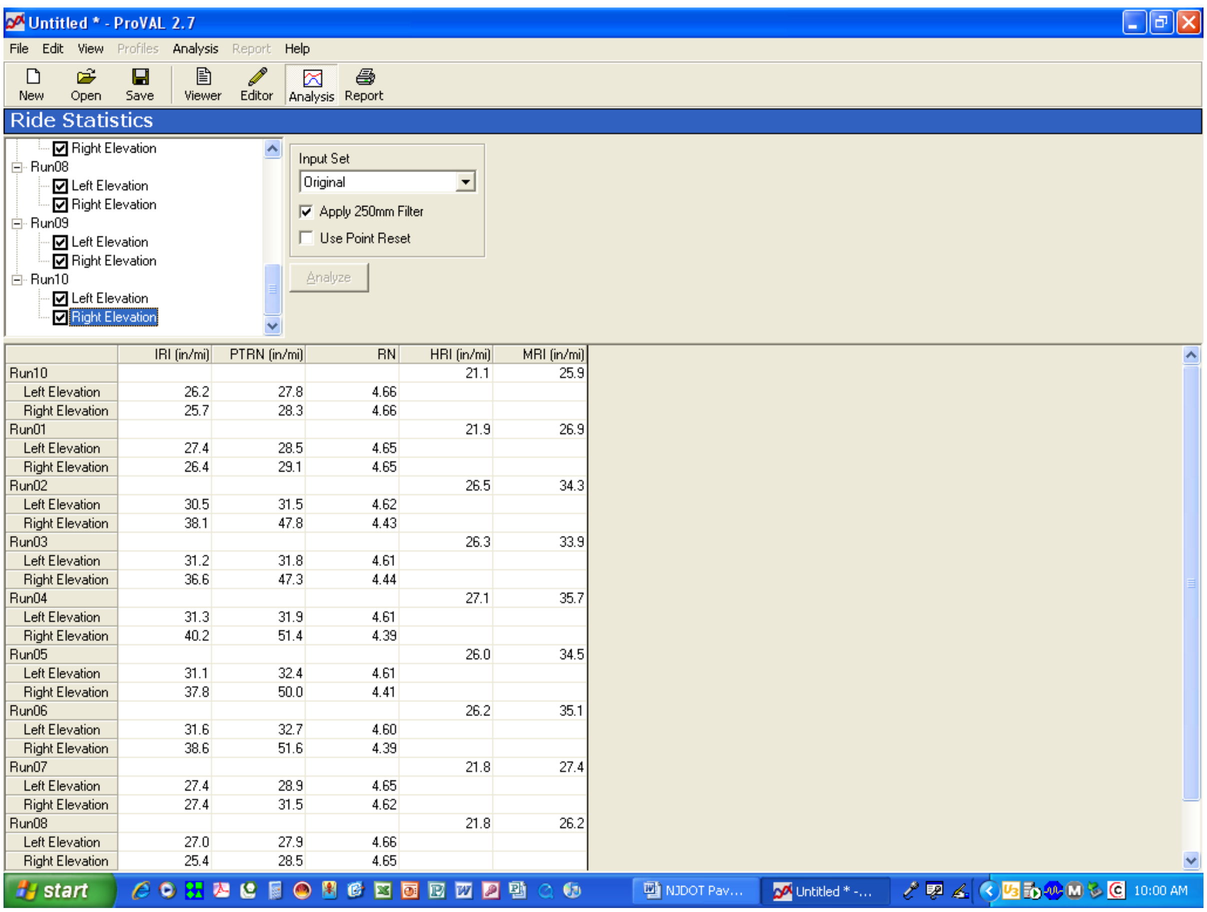
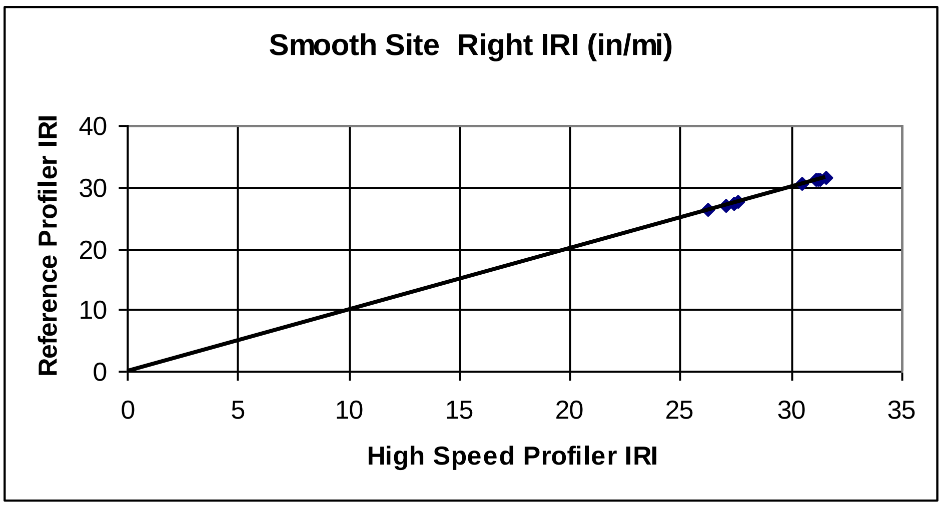
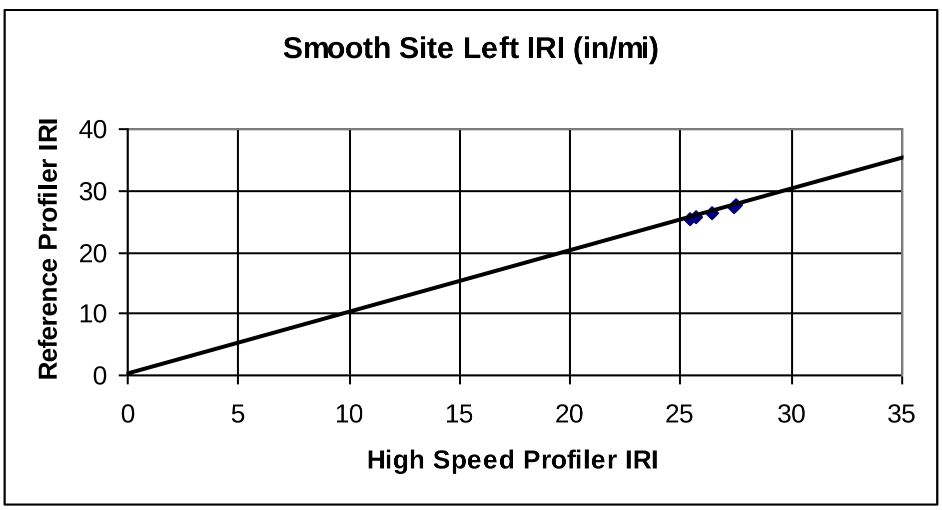


	Site Smooth						
	Ref Prof				HS Prof		
	RIRI (in/mi)	LIRI (in/mi)	MRI (in/mi)		RIRI (in/mi)	LIRI (in/mi)	MRI (in/mi)
Run01	27.4	26.4	26.9		27.4	26.4	32
Run02	30.5	38.1	34.3		30.5	38.1	34.3
Run03	31.2	36.6	33.9		31.2	36.6	37.8
Run04	31.3	40.2	35.7		31.3	40.2	40
Run05	31.1	37.8	34.5		31.1	37.8	34.5
Run06	31.6	38.6	35.1		31.6	38.6	35.1
Run07	27.4	27.4	27.4		27.4	27.4	36.3
Run08	27	25.4	26.2		27	25.4	39
Run09	27.6	27.5	27.6		27.6	27.5	37
Run10	26.2	25.7	25.9		26.2	25.7	34
Average	29.13	32.37	30.75		29.13	32.37	36
	Site Moderate						
	Ref Prof				HS Prof		
	RIRI (in/mi)	LIRI (in/mi)	MRI (in/mi)		RIRI (in/mi)	LIRI (in/mi)	MRI (in/mi)
	Site Rough						
	Ref Prof				HS Prof		
	RIRI (in/mi)	LIRI (in/mi)	MRI (in/mi)		RIRI (in/mi)	LIRI (in/mi)	MRI (in/mi)
			Avg MRI				Avg MRI
			Ref Profiler				HSP
Smooth site			30.75				36

Moderate site			107				101
Rough site			168				165

Plot the average MRI for the Reference Profile and high speed profile for the three test sites. Apply a linear trend line to the plot for visual comparison. **The correlation can not be used to adjust the values in the database or adjust the payment values**.


Smooth Site Right IRI (in/mi)
Reference Profiler IRI
40
30
20
10
0
0
5
10
15
20
25
30
35
High Speed Profiler IRI


Smooth Site Left IRI (in/mi)
Reference Profiler IRI
40
30
20
10
0
0
5
10
15
20
25
30
35
High Speed Profiler IRI

TEST RESULTS—
THE RESULTS OF THE CERTIFICATION TESTS SHALL BE DOCUMENTED BY THE TESTING AGENCY. THE DISTRIBUTION OF THE RESULTS OF THE CERTIFICATION SHALL BE DETERMINED BY THE TESTING AGENCY. RESULTS OF CERTIFICATION SHALL INCLUDE THE FOLLOWING INFORMATION:

- identification of the profiler tested (i.e., make, model serial number, software version, owner, etc.);
- date of last certification;
- operator of the profiler;
- name of the individual from the testing agency who conducted the test;
- date of test;
- number of paths the profiler can measure in the same run;
- filter type, name of the filter program, and the applicable program version number used to evaluate the profiler accuracy;
- overall determination from the test: Pass or Fail;
- known longitudinal distance of the DMI test section; and
- average absolute difference between the DMI readings and the known distance, expressed in distance unit and as a percentage of the known longitudinal distance.

The following information is to be provided for each profile trace:

- overall repeatability score;
- overall accuracy score;
- coefficient of variation of the IRIs computed from the profiles; and

- average of the IRIs determined from the profiler test data, the IRI determined from the unfiltered reference profile, and the absolute percentage difference between the two averages.

The report will also label each test result with a Pass or Fail depending on whether the given test value meets or fails to meet the prescribed criterion. The profiler must pass all tests to be certified. A decal or other approved marking shall be placed on the profiler as evidence of certification. This decal shall show the expiration date (month and year) of the certification.

PROFILER OPERATIONAL PROCEDURE

Periodic Verification of the Height Sensor

On a monthly basis during the construction or Network PMS testing season perform a height sensor check as described in the previous section. At a minimum perform the test using the 1-in and 2-in blocks. If the equipment fails the minimum test, then perform the full range of block tests (using 0.25, 0.50 1.00 and 2.00 in blocks) to determine system linearity problems or complete system failure. The operator of the profiler should tabulate the measurements and record them in the calibration log.

Daily Verification of the Height Sensor

Perform block test using the 1-inch block prior to performing data collection everyday. Obtain one measurement on the base plate, and then place the 1-inch block on the base plate and obtain a reading. Compute the difference between these two readings to obtain the measured height of the block. Compute the difference between the measured height of the block and the actual height of the block to see if the difference is within 0.01 inches. If this requirement is met, the profiler has successfully passed the daily height-sensor verification. If this requirement is not met, repeat the test. If this requirement cannot be still met a more extensive block test using repeat measurements and other block heights may be needed to verify that the height sensors are functioning properly.

(COMMENT: If only a monthly check is required, and a problem is detected, all data collected during the previous month will be suspect.)

Accelerometer Calibration

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Calibrate the accelerometer(s) in the profiler at intervals recommended by the manufacturer or whenever problems are suspect. Perform a bounce test daily prior to performing data collection.

Monthly Verification of Distance Measuring System:

This test is used to verify the calibration of the distance measuring instrument system in the profiler by comparing the distance measured by the DMI in the vehicle to that established by a steel surveying tape.

Adjust the cold tire pressure to the manufacturer's recommended value. Because tire pressures increase as the air inside them warms up to operating temperature causing the tire diameter to expand, drive around the site for at least 5 miles to warm up the tires prior to collecting data for this test.

(Comment: The manufacturers recommended tire pressure will vary with type of vehicle. Hence, it is not appropriate to specify a tire pressure. The best procedure to calibrate the DMI is to first check the cold tire pressure, warm the tire and then calibrate the DMI. This calibration factor will be valid for the hot tire pressure at the time of calibration. Thereafter, when you make measurements, if you check the cold tire pressure and warm the tires the tire pressure should be at the hot tire pressure that correspond to the value when the DMI was calibrated.)

The DMI shall be calibrated monthly during the construction or Network PMS testing season.

Daily Measurement Control—

An Owner-Agency should select a reasonable method to verify daily that the inertial profiling system utilized can produce consistent results under normal operating conditions on pavements typically encountered during data collection. Options include:

- Using a Control Section;
- Checks using previous day's data; or

- NJDOT Verification testing.

Control Sections can be established by selecting one or more 0.1-mile sections with a maximum IRI of 120 in. per mile that will maintain a consistent ride profile over the period of time needed for verification testing. A recently certified profiler is determined to be operating within acceptable operational limits by performing the calibration verification testing noted above. A series of at least five profile measurements is then performed on the selected control section and the coefficient of variation must be 3 percent or less. The average IRI of the control runs shall be used as the Control Section IRI. Once established, this Control Section can be used to validate on a daily basis that the inertial profiler is operating properly. A Control Chart should be established and maintained by plotting daily runs to determine profile drift as the section ages. Typically, no single IRI determination should vary more than 5 percent from the original control section IRI.

Previous day's data When data is being collected on a fairly continuous basis such as on a construction project or during annual network-level analyses, it is possible to re-run short sections of pavement that were collected on the previous day and compare to data currently collected for the same section. The current day's value should not differ by more than 6 percent of the previous day's value.

NJDOT Verification testing If the NJDOT has access to more than one certified inertial profiler, then verification checks can be made randomly. When the IRI from the two certified systems differ by more than 10 percent, a resolution should be determined. This may require re-certification.

Calibration Verification Log—

Maintain a log to be kept with the inertial profiler to provide a verification of calibration history.

QA TEST PROCEDURE

TABLE 1 OUTLINES THE STEPS FOR MEASURING THE PAVEMENT PROFILE USING AN INERTIAL PROFILER.

Table 1—Measuring Pavement Profile for QA Purposes

Step	Action
1	Clean the roadway path to be measured of all debris and other loose material.
2	When measuring the pavement profile, operate the inertial profiler at a constant speed within the certified range. All data collected above or below the certified speed range will not be accepted. Re-measure any pavement segment that has an average operational speed of less than the certified speed.
3	A pre-section length of roadway of up to 500 ft may be required to “settle” the inertial profiler’s filters and achieve the same accuracy in the first 528 ft that is achieved through the rest of the job. The pre-section length is dependent on the filter type, the grade change on entering the test segment, and the accuracy required of the first 528 ft of measured pavement. Typically, this pre-section shall be at least 300 ft in length and located immediately before the section of pavement to be tested. Shorter sections have been used when the physical constraints of the project required it and the other project conditions made it acceptable. Take the inertial profiler measurements two longitudinal profile traces using the sensor path spacing between 65 and 71 in.
4	Collect measurements in the direction of traffic. Make 3 runs in each wheel path starting at the same location using the auto triggering mechanism.
5	Data Collection (QA data collection is meant to be performed at the end of the paving operation or staged as prescribed by the NJDOT). Submit a table to the NJDOT that identifies the lane(s), trace(s), and distance location(s) tested for each file created during the QA testing.
6	Present the profile elevation data to the NJDOT in an electronic file format readable by ProVAL.

7 Compute a IRI at interval and a continuous IRI summary roughness statistic for each profile trace.

Note—ProVAL is a computer software program developed under the auspices of FHWA and is available for use to calculate and compare profiles and their indices (i.e., IRI, RN, PSD, etc.). The software also has the ability to calculate the continuous IRI histogram.

REFERENCED DOCUMENTS

AASHTO STANDARDS:

- MP 11, Inertial Profiler
- PP 49, Certification of Inertial Profiling System
- PP 50, Operating Inertial Profilers and Evaluating Pavement Profiles
- R 40, Measuring Pavement Profile Using a Rod and Level
- R 43M/R 43, Quantifying Roughness of Pavements

Karamihas, Steven M., **Development of Cross Correlation for Objective Comparison of** Profiles, University of Michigan Transportation Research Institute, 2002