NEW JERSEY TRANSPORTATION ASSET MANAGEMENT PLAN

Pavement Data Collection
Data Quality Management Program

Network-Level Quality Control and Quality Assurance Pavement Condition Data Collection

Pavement Data Quality Management Programs

In New Jersey, the National Highway System (NHS) Pavement data collections are been handled by three entities namely:

1. New Jersey Department of Transportation, Bureau of Pavement and Drainage Management and Technology- Collects all the NJDOT owned Roadways and some tolls roadways
2. New Department of Transportation – Highway Performance Monitoring System (HPMS) Unit (Consultant – Michael Baker International) – Collects all the Counties and Township roadways under NHS.
3. New Jersey Toll Authority – Collects all the New Jersey Turnpike and Garden State Parkway Roadways – NJTA/HNTB/AID

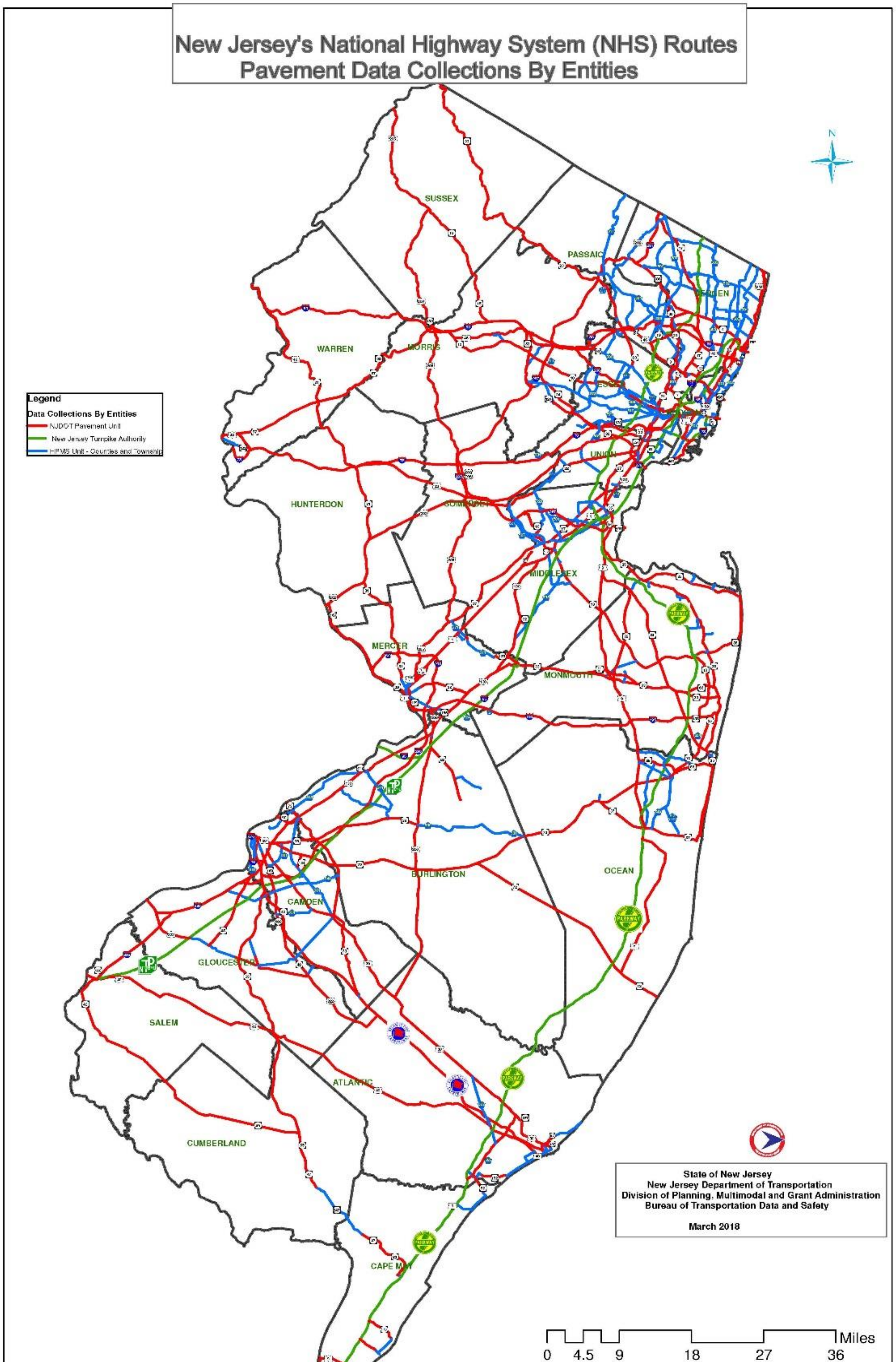
In developing the New Jersey State's Pavement Data Quality Management Programs, the three entities above enumerated their Data Quality Management Programs in compliance with the guideline on section 490.301 Federal Register/ Vol. 82 Rules and Regulations Performance Measures (PM2) as follows:

i. Data Collection equipment, calibration and certification
ii. Certification process for persons performing data collection
iii. Data quality control measures
iv. Data sampling, review and checking processes
v. Error resolution procedures

The reported Pavement Data Quality Management Programs are in accordance with American Association of State Highway Transportation Officials (AASHTO) Standards, Standard Specification for Transportation Materials and Methods of sampling and testing, Standard Equipment Specification for Inertia Profiler, Standard Practice for Certification of Inertial Profiling Systems. The reported IRI (International Roughness Index), Rutting, Faulting, and Cracking Percent are also computed in accordance with AASHTO Standard.

The New Jersey Department of Transportation in addition to collecting the State Highway System (SHS) will conduct reviews of consultants or other entities data as explained throughout this report with the explicit purpose of ensuing the alignment of reported metrics for data acceptance for NHS sections. Each consultant's Quality Management manual is appended for reference to exacting procedures followed for by that group.

Map showing each entity roadway locations



New Jersey Department of Transportation
Pavement Data Collection
Data Quality Management Manual

Network-Level Quality Control and Quality Assurance Pavement Condition Data Collection

Table of Contents

Section Number	Section Name	Section Description	Page Number
1	QM Overview	Quality Management overview to provide important information regarding the purpose of this report and implications of use.	2
2	Team Roles and Responsibilities	The quality-related responsibilities of the data collection team.	9
3	Pre-Collection: “Before” Phase - Preparation	Calibration and certification of measurement equipment, identification of verification sites, training and certification of personnel, and establishing pavement condition criteria.	10
4	Collection: “During” Phase	Activities include measurement equipment verification, testing of verification sites, real-time data checks, daily verification of pavement condition data completeness and reasonableness, periodic checks of processed pavement condition data (e.g., smoothness, rutting, and faulting), and distress ratings. The QC activities that monitor, provide feedback, and verify that the data collection data items meet the defined quality standards.	30
5	Post-Collection: “After” Phase - Deliverables, Protocols, and Quality Standards and Reviews	Data Review and Sampling -The data collection data items subject to quality review, protocols used to collect, and quality standards that are the measures used to determine a successful outcome for a deliverable. The criteria to describe when each deliverable is considered complete and correct are defined by the pavement management engineer. Data items are evaluated against these criteria before they are formally approved.	33
6	Acceptance: Quality Reporting and Error Resolution Plan	The documentation of all QM activities—including quality standards, QC, acceptance, and a process to address error resolution with corrective actions. This section also addresses the requirements of the final QM reporting criteria.	40

1. Introduction - NJDOT Quality Management Approach

Overview

Pavement management systems are more reliable, accurate, and complete when higher quality data is used. Substandard data can result in poor decisions, resulting in wasted money or a reduction in the viewed worthiness of a pavement management system.[1]

The purpose of this Quality Management (QM) Manual is to provide the tools, procedures, and practices required to ensure the highest level of pavement condition data for use in the Department's network-level Pavement Management System. The QM plan identifies key activities, processes, and procedures for ensuring quality of collected data to support the Pavement Management System. This manual outlines processes for systematically implementing QM practices and responsibilities throughout the data collection effort; before, during and after the pavement data collection activities.

Taking the time and effort to implement a quality management plan for pavement condition data collection to ensure data quality for the Pavement Management System has the following benefits:[2]

- Improved accuracy and consistency of data;
- Better credibility within the organization;
- Better compliance with external data requirements;
- Better integration with other internal agency data;
- Cost-savings from more appropriate treatment recommendations; and
- Improved decision support for managers.

Pavement behavior and performance is highly variable due to many factors, such as pavement structural design, age, climate, traffic levels, materials, subgrade, and construction quality. These factors contribute to changes in pavement performance that are reflected in the results of a pavement condition survey. Minimizing the impact of data variability on pavement condition data helps ensure that survey results reflect real

---

[1] Pierce, Linda M., 2014, **"***Quality Management for Pavement Condition Data Collection"***,** TRB**,** Washington, DC.
[2] Shekharan, R., D. Frith, T. Chowdhury, C. Larson, and D. Morian. 2006. "*The Effects of a Comprehensive QA/QC Plan on Pavement Management*." Transportation Research Record No. 1990. Transportation Research Board, Washington, DC.

changes in pavement performance rather than variations in data due to poor data quality and collection practices.[3]

Data for pavement condition assessment are combined and converted into condition indices to describe current pavement condition of the network. Large differences between the data collected and actual pavement condition may result in a completely different treatment recommendation, treatment timing and have a significant impact on the associated cost.

Pavement condition data quality supports a wide variety of decisions and has direct and indirect impacts on agency processes. Some of the major uses of pavement condition data include:[4]

- Characterizing current condition;
- Developing models of predicted pavement deterioration;
- Projecting future conditions;
- Developing treatment recommendations, timing, and cost;
- Preparing and prioritizing annual and multi-year work programs;
- Allocating resources between regions and/or assets;
- Analyzing the impacts of various budget and treatment scenarios; and
- Analyzing performance of different pavement designs and/or materials.

As with many fields of research, evolving data collection technology is one of the most rapidly changing areas of pavement management. The development and application of laser sensors and high-speed computer processing over the last 20 plus years have contributed greatly to the ability of agencies to collect large volumes of pavement condition data quickly and efficiently.

Data collection for NJDOT's SHS network condition assessment is fully automated. The Pathway Path Runner high speed profiler uses lasers and line and area scan digital video cameras to collect IRI, rut depth, cracking, slab cracking, and faulting data. Fully automated processing uses pattern recognition technology on the collected images to first detect pavement distresses from the pavement images and then classify those cracking distresses. While fully automated collection and processing reduces the labor required to conduct a network condition assessment, control mechanisms are necessary to ensure the best quality of data (accuracy, consistency, and completeness) is reported to FHWA and for use in pavement management forecasting and decision making processes.

---

3 Pierce, L. M., G. McGovern, and K. A. Zimmerman. 2013. *Practical Guide for Quality Management of Pavement Condition Data Collection.* Report No. FHWA-HIF-14-006, Federal Highway Administration, Washington, DC.

4 ibid

Data collection for NJDOT’s Non-SHS NHS sections is conducted separately by third-party consultants. Collection, verification, and acceptance criteria for consultant collected data for NHS network condition will be described as well. Each consultant also is required to have a QM plan for data collection that they are expected to follow. As part of each consultant’s QM plans, training, calibration, verification, accuracy and quality assurance is required to be conducted by the consultant. The department will conduct reviews of consultant data as explained throughout this report with the explicit purpose of ensuring the alignment of reported metrics for data acceptance for NHS sections. Each consultant’s QM manual is appended for reference to exacting procedures followed for by that group.

Definitions: Calibration / Certification / Verification

Calibration

Calibration is a set of operations which establishes, by reference to standards, the relationship which exists, under specified conditions, between an indication and a result of a measurement.

Note 1 – This term is based on the "uncertainty" approach.

Note 2 – The relationship between the indications and the results of measurement can be expressed, in principle, by a calibration diagram.

Note 3 – Calibration physically alters the base values that directly affects the output data.

Certification

Certification is a third-party attestation related to products, processes, systems or persons.

Note 1 - Certification is applicable to all objects of conformity assessment except for conformity assessment bodies themselves, to which accreditation is applicable.

Note 2 – Certification is a process that is used to ensure several components of a process are all in conformance with a set of established guidelines. The certification indicates that if the procedure is followed using the same equipment and personnel, reliable information will be collected.

Verification

Verification is a set of operations which is used to check whether the indications, under specified conditions, correspond with a given set of known measurands within the limits of a predetermined calibration diagram

Note 1 – This term is used in the "uncertainty" approach.

Note 2 – The known uncertainty of the measurand used for verification will generally be negligible with respect to the uncertainty assigned to the instrument in the calibration diagram.

Note 3 – Verification is a procedure used to check how close the reported data is to expected values by using the last calibration value. The calibration value is not altered; therefore, the base data is not altered. A correction offset may be applied to the data to make the reported data resemble the desired accuracy. Verification also ensures that the correct operation of equipment or a process is occurring according to its stated operating specifications.

Application of the Quality Management Plan

As documented in the National Cooperative Highway Research Program (NCHRP) Synthesis 401, Quality Management of Pavement Condition Data, Quality Control (QC) plans for pavement condition data are described in three phases:[5]

1. Pre-collection “Before” Phase — Calibration of measurement equipment, identification of verification sites, training of personnel, coordinating with Non-SHS NHS data collection consultants, and establishing pavement condition criteria.

2. Collection “During” Phase — Activities include measurement equipment verification, testing of verification sites, real-time data checks, daily verification of pavement condition data completeness and reasonableness, periodic checks of processed pavement condition data (e.g., smoothness, rutting, and faulting), and distress ratings.

3. Post-collection/Processing “After” Phase — Activities include processing, verification of the transferred pavement condition data, validation, acceptance, and reporting for NJDOT collected as well as consultant collected data (e.g., missing sections, out-of-range data, verification of distress ratings, creation of QM logs, and the fulfillment of compliance requirements).

Figure 1 below shows a flow diagram outlining the process to complete the annual QM Report.

---

[5] Haas, R., W.R. Hudson, and J.P. Zaniewski, “*Modern, Pavement Management*”, Krieger Publishing Company, Malabar, Fla., 1994.

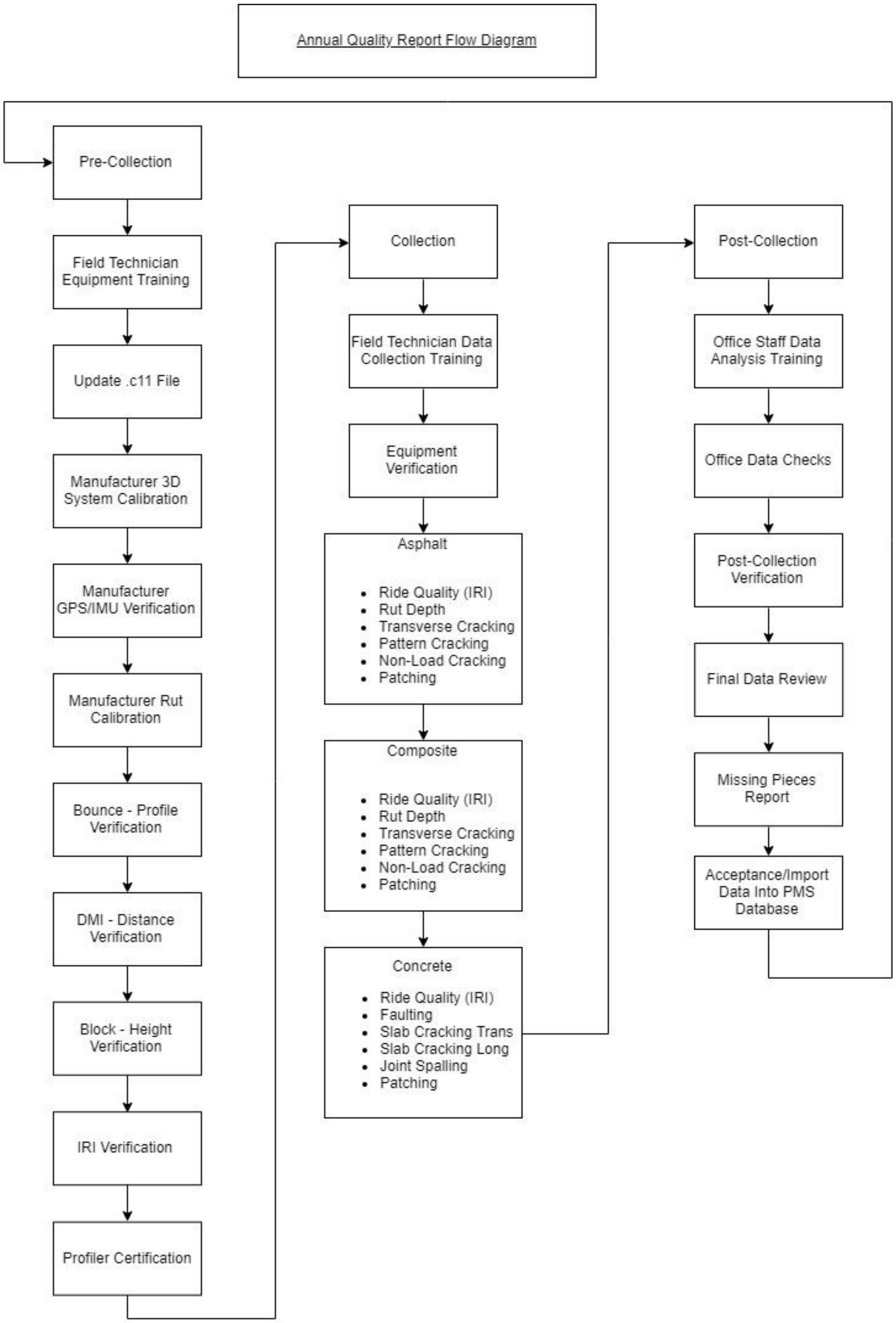


Figure 1. Flow diagram outlining NJDOT Quality Management Process

Implementation of the quality management procedures that include all three phases will assist in providing acceptable data quality criteria, acceptable levels of variability, and procedures that will help to minimize data variability. Table 1 provides a summary of the quality management plan activities for each of the three phases. Table 2 provides a list of recommended QM checks and frequencies.

Table 1. Pavement Condition Survey QM Plan Activities

Pre-Collection	Field Data Collection	Post-Collection/Processing
Quality control plan A. Equipment certification, calibration and verification B. Personnel training and certification C. Verification sites	Field collection: A. Equipment calibration checks B. Real-time monitoring C. End of day data checks	Office Data quality checks: A. Segmentation and location B. Format C. Completeness D. Consistency E. Time-series or other comparisons F. Distress rating
Data collection: A. Rating protocols B. Data items, data format, and schedule C. Data quality requirements and acceptance plan	Office Data checks: A. Sensor data and video images	Acceptance sampling: A. Sample size B. Compare sample and batch ratings
		Additional tools: A. Automated checks B. Data quality reports C. Data Backups

Table 2. Quality Management Activity Schedule

QC Activity	Frequency/Interval
Location of Section and Control Points	
Mileage review	Daily
SLD comparison	Weekly
Post collection final data review (before HPMS submission)	Annual
Initial comparison with master network definition file	Annual

Distress Ratings	
Data review (5% network review)	Weekly
Verification site testing	Monthly
Video reviewer training	Annual
IRI, Rut Depth, Faulting	
Equipment checks and monitor real-time	Daily
End of day data review	Daily
Inspect processed data	Daily
Inspect uploaded data samples	Daily
Verification site testing	Monthly
Verification of Image Quality - Right-of-Way and Pavement Downward Images	
Startup checks, real-time monitoring, and field review	Daily
Successful upload to workstation	Weekly
Data review (5% network review)	Weekly
Equipment Verifications, Calibrations, and Certifications	
Bounce Test - stability verification[6]	Monthly
DMI - distance verification[7]	Monthly
Block Test - height verification[8]	Monthly
Subsystem Check - IRI verification	Annual
Subsystem Check - Rut verification	Annual
Gyroscope calibration	Annual
Camera calibration	Annual
Profiler certification	Annual
Profiler Raw Data Backup	
Weekly review that backup has been completed	Weekly
Staff/Operator Training and Certification	
Staff training	Annual/5 years
Staff certification	Annual
Acceptance of Consultant Data	

[6] Refer to NJDOT Manual on Ride Quality Acceptance R-1 (Appendix A)
[7] ibid
[8] ibid

Verification of consultant/NJDOT data alignment	Annual
Acceptance of consultant data	Annual
* **Quality Expectations of each QC Activity are located in Table 5 & 6**	

Coordination with Data Collection Consultants

At the beginning of every calendar year the NJDOT HPMS group will provide all agencies and consultants responsible for network pavement distress collection a list of pavement sections that must be collected in that year. All agencies and consultants will provide their own data quality manual, equipment certification & calibration documents, and operator certification documents to NJDOT for review.

2. Roles and Responsibilities

NJDOT Pavement Management Unit (PMU) Team Responsibilities

This section describes the staff lead assignments associated with the aspects outlined in this QM manual. Four main roles have been identified and the description of responsibilities associated with each are shown in Table 3 below.

Table 3. Quality Management Staff Responsibilities

Team Role	QM Responsibilities
Pavement Management Engineer *(Sue Gresavage / Hermean Mathews)*	• Set quality standards, acceptance corrective actions. • Approve each deliverable per quality standards. • Approve resolution of quality issues. • Assess effectiveness of QM procedures. • Recommend improvements to quality processes.
Pavement Management Section Leader *(Sharad Rana / Haidy Abdu)*	• Communicate weekly with Field Crew Data Manager. • Monitor schedule adherence. • Supervise acceptance checks. • Assure data items meet broad set quality requirements. • Maintain records of equipment calibration and staff certification. • Prepare QM report.

Field Crew Data Manager *(Mark Kianka / Greg Walters)*	• Document operator training and ensure raters are adequately trained in protocols. • Observe and maintain records of equipment verification and data collection summary. • Maintain equipment systems verification log and submit exceptions to Pavement Management Section Leader.
Office Data Reduction Lead *(Haidy Abdu / Bella Kotwal)*	• Perform and document checks of total mileage, segment lengths, and comparison with master network definition file. • Perform data and video acceptance and document results. • Document SLD checks of segment location and completeness. • Document quality audits of uploaded and processed data. Report any problems using QC log.

3. Pre-Collection “Before” Phase

Data QC - Updates to the NJDOT .c11 File

A .c11 file is a proprietary file type used by the Pathway Pathview desktop software. This file relays important inventory information to the analysis software ensuring the correct routes are references with the correct pavement type. The .c11 file must be reviewed annually and compared to the current network definition as defined by the HPMS database and the NJDOT SLD. Any discrepancies should be verified and resolved with the Bureau of Data Development based on the best information. Where necessary, the .c11 file should be updated to ensure the validity and consistency of the following minimum criteria:

- Pavement type;
- Beginning and end mileposts;
- Section information (name and location);
- Direction (primary/secondary and cardinal).

Once the appropriate annual updates have been made, the .c11 file must be updated on any drives used in the testing vehicle and by the office data analysis staff.

Training

Field Technician Equipment and Network Data Collection Training

Operators of inertial profilers must pass a proficiency test and be certified to operate an inertial profiler. Field Technician Training and Certification include the following:

- NJDOT Ride Quality Specification (R-1);
- Understanding of the operation of inertial profilers; and
    - How to verify the distance measuring system (DMI Test);
    - How to verify the height sensor (Block Test);
    - How to verify the stability of the gyroscope (Bounce Test);
- Ability to collect profile and distress data;
- Understanding of how to evaluate data quality; of
    - Data collected;
    - IRI value calculated.

To qualify to be an operator, field technician's must complete a profile training course (e.g. NHI Course 131100) (every 5 years) and must have undergone NJDOT PMU training on the use of the specific inertial profiler they will be operating in the field.

Field Technicians must undergo both written and practical examinations to fulfill certification and must pass both portions of the test to be certified. The written exam is administered with the requisite profile training course described above. The practical exam is conducted as part of the annual profiler equipment certification.

Office Staff Data Analysis Training

Office Staff should be trained for both Pathway's processing and dTIMS processing. The NJDOT PMU utilizes in-house processing manuals for Pathway's Processing and dTIMS. While the manuals are comprehensive, training should be conducted annually to make sure all staff are aware of any updated procedures and at a minimum in the following areas:

- Pathway processing; for
    - Transferring and backing up data;
    - First/last image check;
    - Adjusting milepost extents;
    - Running autocrack;
    - Running autoclass;
    - Evaluating downward facing camera images;
    - Identifying pavement distress;
    - Evaluating profilograph;
    - Exporting data;
    - Accepting data.
- dTIMS processing; for
    - Updating the base;
    - Updating committed projects;

- Updating sectioning;
- Updating condition current;
- Processing analysis set;
- Reviewing and exporting budget analyses.

Consultant Verification Section Selection

As part of the pre-collection phase, NJDOT PMU will select the 10 mile verification site that will be utilized for the NHS data quality verification. The 10 mile section will be selected randomly within close proximity to the NJDOT headquarters to ensure the verification section can be collected early in the collection cycle. Once the 10 mile verification section has been selected, the extents will be shared with any NHS network level data consultants. All consultants, as well as the NJDOT Field Crew will be expected to collect measurements for the consultant verification section. This site is to verify that cracking parameters are similar for all network collected data and as such, is expected to be utilized in addition to the Surveyed Control Site. It is recommended to report 0.1 mile summary reports of distresses found on the verification sections to NJDOT's PMU prior to NHS distress collection to minimize any chance for recollection.

Verification/Certification Sites

Data verification should be conducted by testing a control site and by conducting data checks that are used for QC before and during production. Electronic data is compared to previously collected data to ensure data consistency and validity.

Establishing the Survey Control Site (Ground Truth)

The intention of the Surveyed Control Site is to provide a normalized location at which the data collection van and other profilers can conduct standard measurements to use as a verification that the equipment is functioning properly while in motion. The NJDOT PMU established the Surveyed Control Site (described below) in 2014. Annually, the minimum requirement of ground-truth data to verify the equipment verifications would include; the

- Reference longitudinal profiles (SurPRO walking profiler);
- Reference section for distance (Surveyed 528 ft)

Surveyed Control Site

The surveyed control site will be used for profiler certification as well as any additional verifications as specified in Table 2. The profile certification section shall be a straight roadway at least 528 feet in length. Measure the length of the section accurately to within 0.05 percent (3 inches) using a steel survey measurement tape. Clearly mark the starting and ending points of the test section with reflective tape. The NJDOT profile certification site is currently located at a decommissioned rest stop on 295 South, milepost 49.9. Figure 2 below shows a map of the location of New Jersey's Survey Control Site.

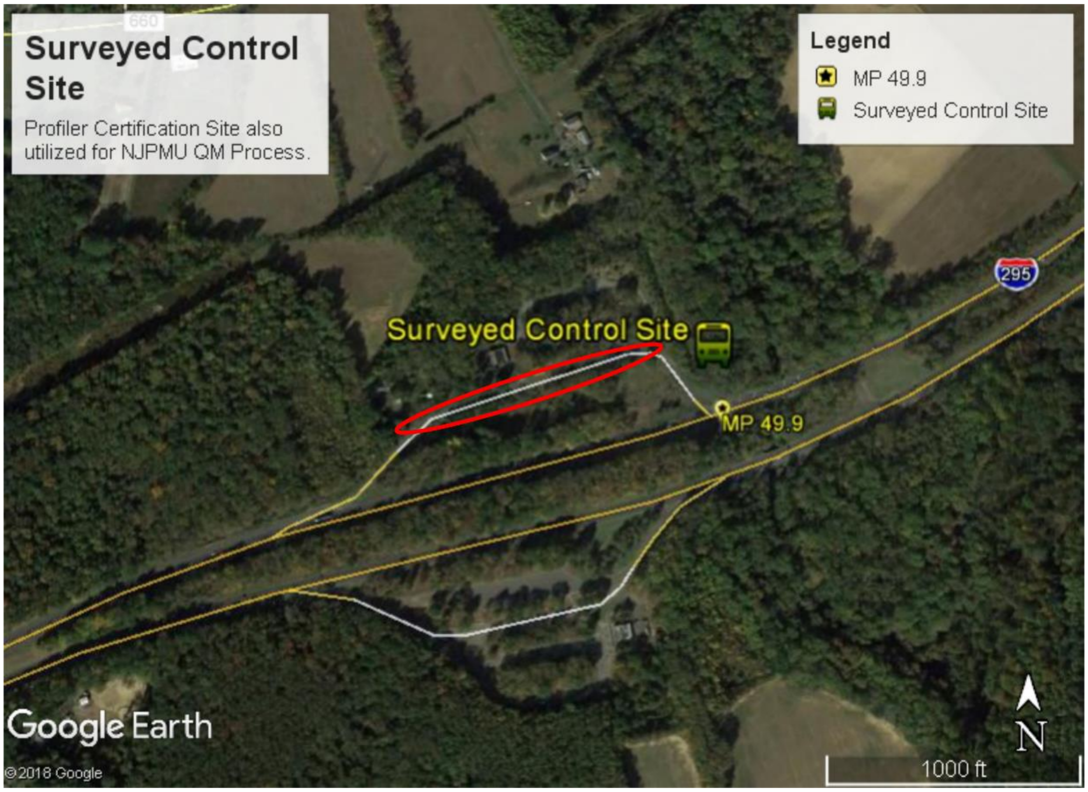


Figure 2. Survey Control Site, I-295_S MP 49.9

Consultant Data Verification Site

The consultant data verification site will be used as a referential comparison between any consultant data collected for NHS pavements in NJ. NJDOT PMU Pathway's Van will collect the baseline data for the annually selected 10 mile section. Any consultants that collect NHS data will also be required to collect data for that same location, and comparative analysis will determine how closely the data matches based on criteria mentioned throughout this manual.

The consultant verification site will be selected using data collected by NJDOT's data collection vehicle in the prior year's collection cycle. It is required to verify that the selected site has not undergone pavement maintenance or rehabilitation prior to the expected verification for the calendar year. The 10-mile site must include the following:

- Variety of pavement cracking (pattern, longitudinal, transverse, wheel path longitudinal, wheel path pattern)
- Measurable rutting

- Measureable faulting
- Area of cracked concrete slabs

The extent of pavement distress variability is to be determined by the NJDOT PMU Data Section Leader each year. The primary goal is to ensure that all agencies collecting data report similar percentages for all distress types that are found on the 10-mile verification site. The NJDOT PMU will be expected to preform 100% manual video review and adjustment to the data reported on the 10-mile control site to set the standard utilized to verify the consultant data.

Vehicle and Equipment Calibration/Verification/Certification

This section will describe the requirements and procedures employed to ensure that the subsystems of the network data collection van used to measure longitudinal surface profile and surface distresses are working satisfactorily.

Profiler and Distress Imaging Equipment Components:

The Pathway Path Runner is outfitted with the following sensors (Figures 3&4 below):

- Laser(s) (rut measurement);
- Laser(s) (macro-texture);
- Inertial Measurement Unit (IMU);
- Global Positioning Systems (GPS);
- Downward facing 3D camera (crack measurement);
- Forward facing HD Camera(s) (R.O.W. imaging);
- DMI (distance measuring device);
- Inertial Profiler (IRI measurements).

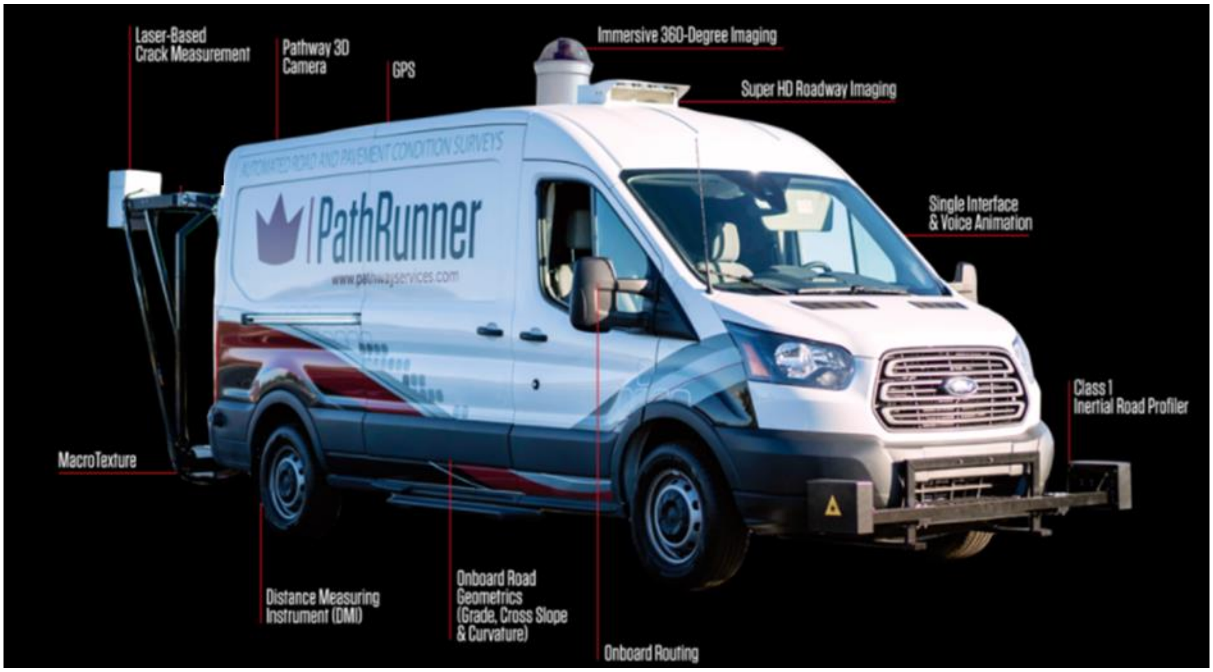


Figure 3. Pavement Profiler and Distress Imaging Subsystems

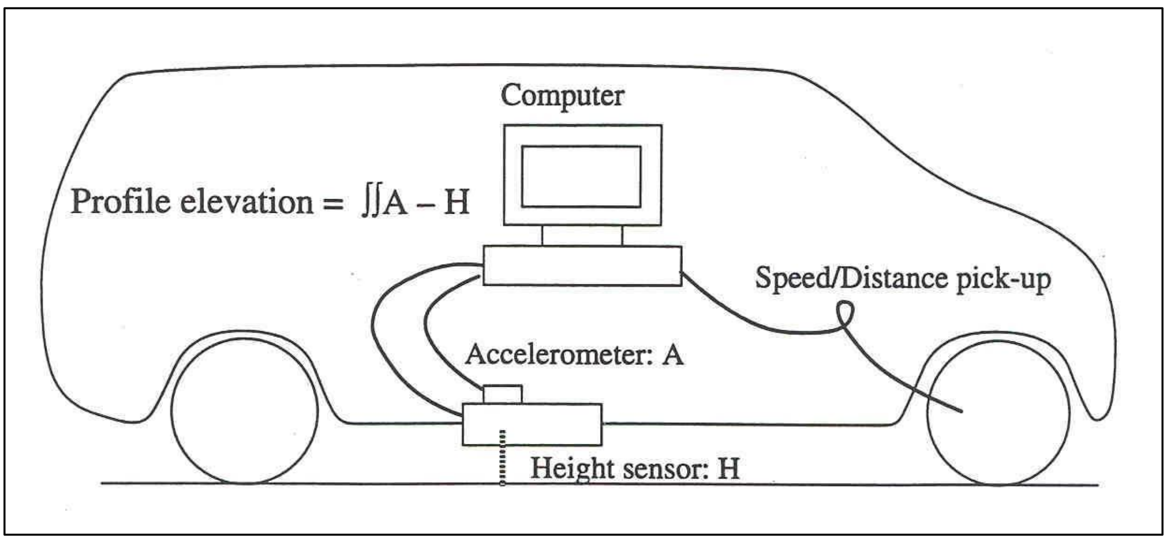


Figure 4: Diagram of Pavement Profiler Subsystems

Data Collection Vehicle Certification

The data collection vehicle certification process must be performed annually in accordance with NJDOT R-1 specification and test procedure (Appendix A), prior to the paving season and before network level data collection. It is highly recommended that manufacturer’s verification and/or calibration is conducted prior to data collection for subsystem verifications.

The vehicle certification is a combination of calibrations and verifications that are conducted partially by the equipment manufacturer and partially by the NJDOT PMU. This section will elaborate on the items required to fulfill the vehicle certification as well as the breakdown of responsibility.

Equipment Calibration/Verification by Manufacturer

All calibrations conducted on NJDOT PMU instrumentation is conducted by the manufacturer. The NJDOT PMU is responsible for the verification portion of the vehicle calibrations and verifications.

NJDOT's data collection vehicle undergoes profiler certification prior to acceptance of equipment from the manufacturer. A copy of this certification conducted by TTI is attached in the appendix.

In the pre-collection phase, the vehicle and its systems are tested and calibrated to be capable of collecting quality data. In house training and procedures are put in place to ensure that the vehicle remains in working condition throughout the data collection phase. Equipment calibration and verification is conducted before the initiation of the network data collection activities and periodically as identified in Table 2 to verify that the equipment is functioning according to expectations and that the collection and analysis methods are being followed.

After each separate piece of equipment is calibrated, before the actual data collection on the network pavements can proceed, the vehicle subsystems need to be verified. To verify the vehicle subsystems, rut data, pavement distress data, and ride quality data analysis needs to be compared to actual "known" measures by conducting a "ground truth." Annually, field data collection crews must be trained and/or refreshed to ensure that they are familiar with the operation of the equipment, the data collection plan, and the quality control tasks necessary to collect high quality data.

An annual report, provided by the manufacturer that summarizes the results of the calibrations is filed with the Pavement Management Section Leader as shown in Table 3, prior to beginning of the annual collection cycle. The report provided by the manufacturer shall include the minimum following information:

- Image subsystem;
    - Verification pass/fail;
    - Calibration pass/fail;
    - Calibration value before/after;
- GPS subsystem;
    - Verification pass/fail;
    - Calibration pass/fail;
    - Calibration value before/after;
- IMU Inertial Measurement Unit subsystem;

    - Verification pass/fail;
    - Calibration pass/fail;
    - Calibration value before/after;
- Rut subsystem;
    - Verification pass/fail;
    - Calibration pass/fail;
    - Calibration value before/after;
- 3D subsystem;
    - Verification pass/fail;
    - Calibration pass/fail;
    - Calibration value before/after.

Equipment Calibration/Verification by NJDOT PMU

Ride-Quality Verification

The NJDOT Ride Quality certification procedure is the process followed by all inertial profilers, which ensures the reported data aligns well from profiler to profiler. This procedure utilizes the Surveyed Control Site located at MP 49.9 on Rt. 295 South.

Inertial Profiler Certification Procedure

The inertial profiler must be verified annually through the NJDOT certification procedure. A minimum of 11 runs per lane must be collected and compared against a reference profile. New reference profiles are measured monthly by the accepted reference profiler of NJDOT. NJDOT utilizes a SurPRO walking profiler as the ground-truth reference values for longitudinal profile.

For all 11 collected profiles the IRI is first calculated. The average IRI and the standard deviation are calculated for each wheel path. Using the average reported IRI and the calculated standard deviation, the covariance can be calculated. The NJDOT procedure allows a covariance up to 3%. Next the absolute difference between the reference profile IRI and collected IRI values is determined. The average difference between IRI values is calculated. This average difference is used to determine the percent difference between reference profile and collected profile. The NJDOT procedure allows up to a 5% difference in reported IRI and reference IRI.

Inertial Profiler Verification Procedure

The inertial profiler must be verified monthly. A minimum of 5 runs per lane must be collected and compared against a reference profile.

For all 5 collected profiles the IRI is first calculated. The average IRI and the standard deviation are calculated for each wheel path. Using the average reported IRI and the calculated standard deviation, the covariance can be calculated. The NJDOT procedure allows a covariance up to 3%. Next the absolute difference between the reference profile IRI and collected IRI values is determined. The average difference between IRI values is calculated. This average difference is used to determine the percent difference between reference profile and collected profile. The NJDOT procedure allows up to a 5% difference in reported IRI and reference IRI.

Height Verification

The block test is used to verify that the height sensor is functioning properly.

The block test is performed after the profiler is turned on to warm up the equipment per the manufacturer's recommendations. This test is performed on each height-sensor in the profiler. Figure 5 shows the location of both height sensors that need to be verified annually, Figure 6 shows a close up of the height sensor mounted on the vehicle, and Figure 7 respectively shows a diagram of how the height sensor operates.

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 dimensions. During the test, the operator must not lean on the profiler or cause it to move in any way. Under windy conditions, it is best practice to perform this test indoors. The NJDOT field crew generally conducts the block test at the garage before going out in the field.

Figure 5. Height Sensor Measurement System Overview

Figure 6: Close up of Height Sensor

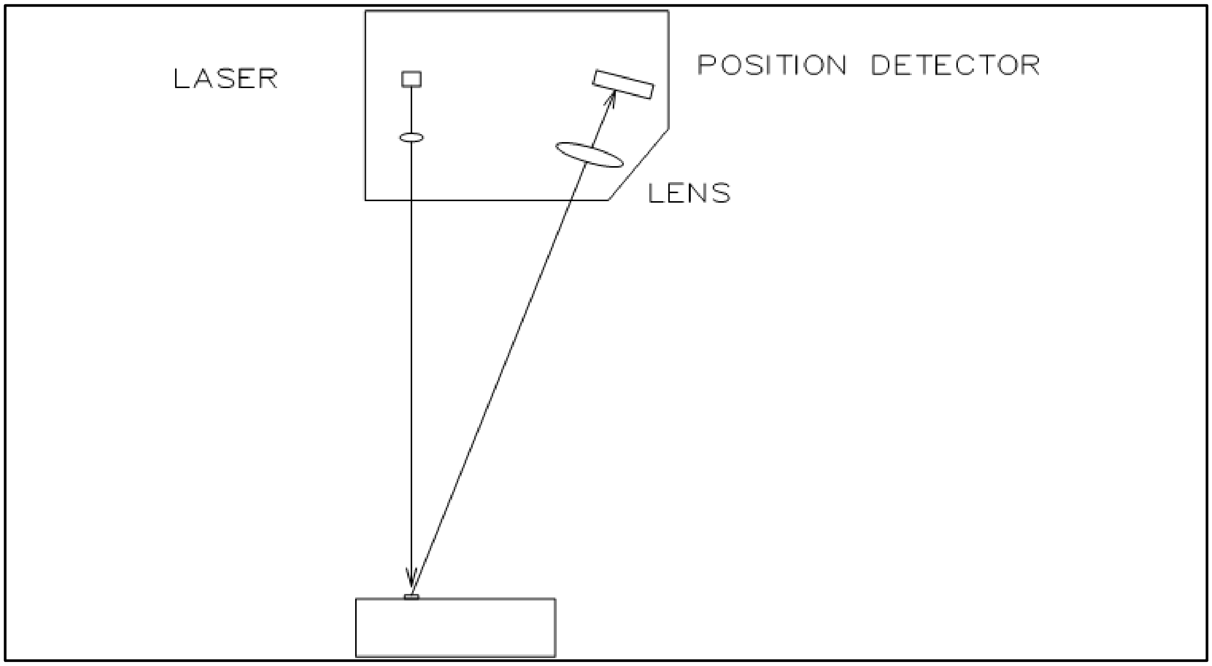


Figure 7: Diagram of Height Sensor

NJDOT PMU Block Test Procedure

1. Position a smooth base plate under the height sensor of the profiler and take ten height measurements.
2. Position a 0.25-in. block underneath the height sensor on top of the base plate and take ten height measurements.
3. 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.
4. Carefully replace the 0.50-in. block with a 1.00-in. block and take another set of ten height measurements.
5. Finally, carefully replace the 1.00-in. block with a 2.00-in. block and take the last set of ten height measurements.

Note 1 – 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 quarterly (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 test, the**

average of the absolute differences must be less than or equal to 0.01 inch for each gauge block.

Note 2 – Each NJDOT vehicle has a set of calibrated blocks that correspond to that particular vehicle. The block set for each respective vehicle should not be utilized to calibrate a different vehicle. The height of each block set should be calibrated annually.

Stability Verification

The bounce test is used to check system stability to ensure that the accelerometer 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. The bounce 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 simply verifies that they are functioning properly.

The bounce test is performed monthly 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 speed is simulated (50 mph). The equipment is placed on level, smooth pavement. Place a non-reflective surface on the pavement under each laser sensor so that the texture of the pavement will not affect the test. Figure 8 provides an illustration of the Bounce Test screen, while Figure 9 shows an example of error found in the bounce test.

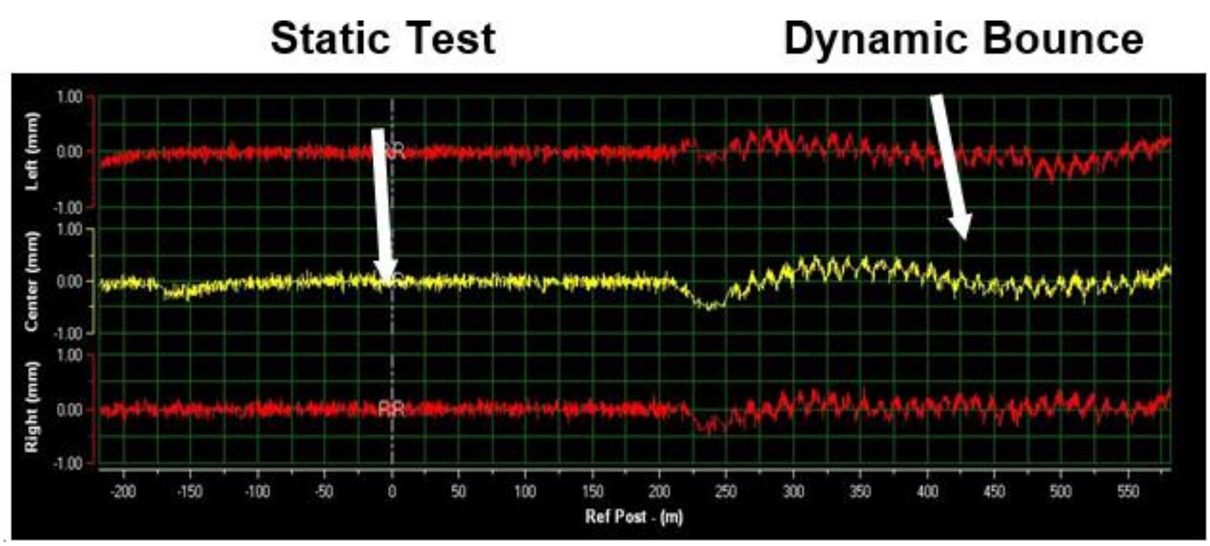


Figure 8: Example of the Bounce Test Screen

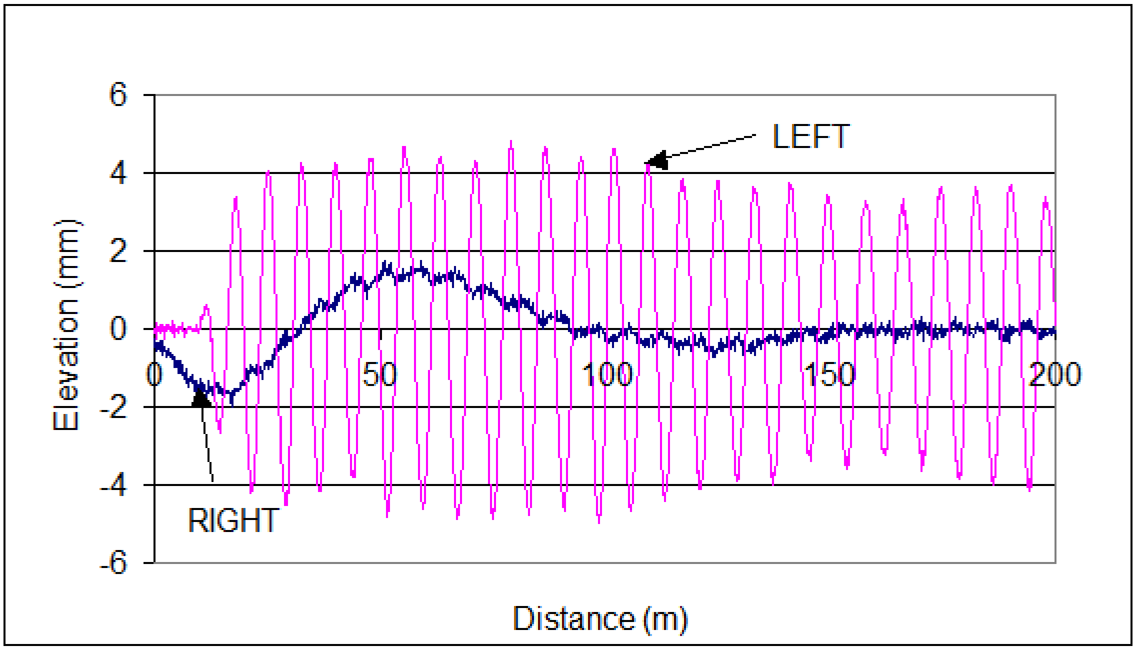


Figure 9: Error in the Left Accelerometer or Height Sensor

NJDOT PMU Bounce Test Procedure

1. The first step is to set the van's software to "time-series" setting.
2. Then collect IRI data with the vehicle as motionless as possible.
3. Simulate the IRI data collection for the time it takes to collect data on several 0.1-mile (528 feet) segments.
    a. The operator must be able to observe and maintain a consistent rocking motion exceeding two inches for the time required (minimum of 8 seconds) to simulate 528 feet of travel for a simulated speed of 50 mph.
    b. The software shall calculate IRI for 528 feet of simulated travel.
    c. The observed IRI value for a 528 feet long segment should be below 3 in. per mile.
4. Next, the sensor(s) should be moved vertically for a total displacement of approximately 2 inches (a yardstick may be helpful until the operator gets used to the procedure).
    a. The typical approach is to push the mounting system (bumper) at the center of the vehicle down approximately one inch or so and let the vehicle suspension rebound to create the total travel of 2 in.
    b. The operator must be able to observe and maintain a consistent rocking motion exceeding two inches for the time required (minimum of 8 seconds) to simulate 528 feet of travel for a simulated speed of 50 mph.
    c. The observed IRI values should be below 8 in. per mile for a 0.1-mile segment.
    d. The theoretical value for both phases of the "bounce test" is 0.

Length Verification

The DMI Test is used to verify that the distance measurement instrument (DMI) is recording distances accurately.

Adjust the cold tire pressure to the manufacturer's recommended value. Tire pressure increases as the air inside them warms up to operating temperature, so to prepare for distance calibration, the tire shall be pre-conditioned prior to testing. To compensate for the slight expansion in the tire diameter, drive around the test site for at least 5 miles to warm up the tires prior to collecting data for this test.

Note 1 - 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.

Note 2 - The DMI shall be verified monthly during the Network Pavement Management System (PMS) testing season.

NJDOT PMU DMI Verification Test Procedure:

1. Check the tire air pressure on the wheels of the housing vehicle and maintain according to the manufacturer's recommendations.
2. Allow electronic equipment to warm-up in accordance with the manufacturer's recommendations. Prior to running the test site, warm the tires by driving for 5 to 10 miles. Perform three runs over the test section. Initiate and terminate data collection at the test section using the auto-trigger. Reflective tape placed on the pavement surface shall be used to auto-trigger at the start and the end of the section. Run the profiler at a constant speed of 40 miles per hour. At the end of each run, the reading from the profiler's DMI is recorded.
3. 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. When utilizing a 528 feet test sections, the average of the three absolute differences must be less than or equal to 9.5 inches.
    a. 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 using the procedure provided by the manufacturer.
4. After entering the new calibration offset, the operator shall again make three runs over the delineated path and measure the distance with the profiler's DMI on each run.
    a. 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 9.5 inch for a 528 feet test section.

b. 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.

DMI Calibration Procedure:

1. Ensure the tires are properly pressurized and have been "warmed" by being driven at highway speeds for at least 20 minutes.
2. Ensure that reflective tape (or reflective markers provided by the manufacturer) is placed at the exact start and end of the surveyed DMI calibration site located on 295 South MP 49.9.
3. Launch the Profiler computer and data collection software. Ensure the DMI is "Run" mode. Choose "Calibrate" → "Arm Photocell". Verify the photocell is armed on the Profiler screen on line 5 of the collection software, the system should read "PhotoCell: Armed".
4. Approach the DMI calibration site and be prepared to maintain a steady speed through the entire process. Choose "Calibrate" → "Calibrate Distance". A text box will appear for the user to enter their name. Enter the user name and click "OK".
5. Another text box will appear for the user to enter the actual distance of the DMI Calibration site. Enter "528" ft and click "OK" for the surveyed DMI Calibration site located on 295 South MP 49.9.
6. A dialogue box will appear instructing the user to advance to the start location of the DMI Calibration site. Approach the start of the site maintaining a constant speed of 40 MPH using cruise control. Click "OK" once speed in maintained prior to reaching the start.
7. Once the Photocell is triggered at the start by the reflective marker an audible "START" will be alerted in the van.
8. After the Photocell is triggered at the end the new and old calibration numbers will be displayed. New Calibration values should be between 1.47 and 1.51. Click "OK" if new values are acceptable. Click "Cancel" if new values are not acceptable and repeat the calibration process.
9. After Calibration is performed verify the DMI is working accurately by performing DMI verification.

Distress Verification

The downward video review is used to verify the 3D camera system is working correctly identifying and classifying distresses on both asphalt and concrete pavement surfaces.

3D Camera Verification Procedure:

1. Ensure that data "sets" are ready for evaluation
   a. First-Last image check has already been completed
   b. Milepost adjustment has already been completed

    c. AutoCrack has already been completed
    d. AutoClass has already been completed
2. Open PathView program
3. Add current year’s data
    a. At minimum add Sets determined to be used for QA procedure
4. Apply current .C11 reporting file to data
    a. Distress → “Load Config”
6. Turn on distress pixels on 3D elevation plot
7. Turn on distress boxes on intensity plot
8. Check offset value for ROW image display is accurately portrayed
    a. This may be different for each rater based on personal comfort
    b. Average offset is -2
    c. To set offset, find easily distinguishable item (manhole, grate, prominent transverse crack) to align the ROW to the desired view
9. Open Excel Log and fill in appropriate metadata
    a. Date
    b. Name of person conducting review
    c. Set number and route being evaluated
    d. Milepost Start/From and To
    e. Direction (Cardinal as well as Increasing (I)/Decreasing (D))
10. Slowly tap spacebar to scroll forward through pavement distress images
    a. Checking 3D elevation plot to ensure that pixilated distress on 3D elevation plot is showing distresses where there appears to be distress
    b. Checking intensity plot to ensure that distress boxes match the type, severity, and extent of distress expected by the manual reviewer
11. Every 0.1 mile create record in log
    a. If no errors found, check good box
    b. If errors found, check bad box and document observed issues
        i. Errors will be recorded on a % acceptable basis (100% = Perfect, 0%=Completely Incorrect)
    c. If significant number of errors are observed, see Note 3
12. Once QA is completed for desired test set, conduct final Save and Close for excel log.
    a. Nothing has been changed in PathView at this point – normal Pathview shutdown without saving procedure is sufficient

Note 1: Data Reduction QA evaluation must be conducted by certified manual distress rater

Note 2: Be sure to save Excel log every 5-10 minutes to ensure no data loss

Note 3: If significant number of errors noticed, verify the correct .C11 file is loaded and that the data being evaluated has been processed for milepost verification, AutoCrack, and AutoClass. If any of these items have not been completed, the QA procedure cannot be completed on that dataset.

Note 4: Minimum number of miles to verify using this procedure (compared to the total collected network miles) must be equal or greater than 5%.

Rut Verification Procedure:

1. Ensure all personnel are wearing appropriate PPE including laser glasses. Also ensure that all personnel are aware that Rut Verification is in progress, that they should clear the area especially behind the van.
2. Position Pathways van on flat and clean ground.
3. Place Rut verification device behind pathways van and within the field of view of the laser system.
    a. The rut verification device must be positioned in the proper location from the back center of each of the two rear tires where the tire meets the ground.
    b. The rut verification device must be parallel to the rear line-laser profile.
    c. The rut verification device must be perpendicular (transverse) to the direction of travel.
4. Ensure van is set to "time-series" mode at a simulated speed of 40 mph.
5. Initialize Sensors in standard and appropriate order.
6. Once sensor systems are running, create new set file
    a. Sets in 400 series are reserved for calibration records
    b. Sets increase incrementally for each month's calibration records
    c. Same set can be used for DMI, Faulting, Rutting etc.
7. Start "time-series" mode but do not collect/save data yet
8. Verify lasers are sighted at Rut Verification Device
    a. See Note 2 about sighting tools
9. Using the computer in the data collection vehicle, ensure rutting profile is visible and looks like a rutted surface
    a. After sensors are all verified, begin collecting data and save data. A minimum of 1.0 mile of "time-series" mode data must be collected
10. Using Rutgers Rut Verification Device
    a. Stop testing and turn off rolling mode
    b. Turn off Lasers
    c. Spin Rut Verification Device 180°
    d. Go back and complete step 3-9 again
11. After testing with Pathway's van measure Rut on Side A and Side B of Rut Verification Device with Vernier Calipers to the 0.01".
    a. Record value for both on testing sheet that goes with SATA drives
12. Transfer data in drives to appropriate Data Reduction personnel
13. Once data is processed, evaluate rut and determine PASS/FAIL
    a. Average Rut must be within 5% of known value
    b. Average Rut must be within 10% of previous month's value (This is to check Rut Test Device has not gone out of compliance)

Note 1: If using the Rutgers Rut Tester, the van must be elevated using the Rutgers Ramps or equivalent height ramps. If using the Pathways Rut Tester, van must be left at ground level.

Note 2: A smartphone camera may be a sufficient tool to help sight the location of where the lasers are touching the ground. Not all cell phone cameras will work for this purpose.

Note 3: This testing can be accomplished in building 8.

Note 4: Laser safety glasses MUST be worn at all times for duration of Rut Verification testing

Note 5: The laser system has a safety motion detection device. If too much motion is detected, the laser system will be shut off. To rectify this, ALL of the subsystems must be restarted.

Note 6: When the pathways van is placed in ”time-series” mode, the laser system has an elapsed time shutoff of 300s (5 min). If the 300s mark occurs before testing is complete, all systems must be restarted.

Note 7: Rutting laser system has a red indicator light to show that lasers are ON and operating. If the red light is off, all subsystems must be reset. If resetting doesn't work to bring the lasers back on-line, all subsystems must be shut down and restarted.

Note 8: If rut profile is not showing for step 8 of the procedure, increase “time-series” test speed to 50 mph and try again.

Faulting Verification Procedure:

1. Ensure all personnel are wearing appropriate PPE including laser glasses. Also ensure that all personnel are aware that Rut Verification is in progress, that they should clear the area especially behind the van.
2. Position Pathways van on flat and clean ground.
3. Place Fault verification device behind pathways van and within the field of view of the laser system.
    a. The Fault verification device must be positioned from the back center of each of the two rear tires where the tire meets the ground.
    b. The Fault verification device must be parallel to the rear line-laser profile.
    c. The Fault verification device must be perpendicular (transverse) to the direction of travel.

4. Ensure van is set to “time-series” mode at a simulated speed of 40 mph
5. Initialize Sensors in standard and appropriate order.
6. Once sensor systems are running, create new set file

    a. Sets in 400 series are reserved for calibration records
    b. Sets increase incrementally for each month's calibration records
    c. Same set can be used for DMI, Faulting, Rutting etc.
7. Start "time-series" mode but do not collect/save data yet
8. Verify lasers are sighted at Fault Verification Device
    a. See Note 1 about sighting tools
    b. Using the computer in the data collection vehicle, ensure faulting is visible and looks like a faulted surface.
9. After sensors are all verified, begin collecting data and save data
    a. A minimum of 1 mile of "time-series" mode data must be collected
10. Using the Rutgers Fault Verification
    a. Stop testing and turn off rolling mode
    b. Turn off Lasers
    c. Spin Fault Verification Device 180°
    d. Go back and complete step 3-9 again
11. After testing with Pathway's van measure Fault Device from ground up to top with Vernier Calipers to the 0.01".
    a. Record value for both on testing sheet that goes with SATA drives
    b. Average Values to show Expected Fault Height
12. Transfer data in drives to appropriate Data Reduction personnel
13. Once data is processed, evaluate rut and determine PASS/FAIL
    a. Average Fault must be within 3% of known value
    b. Average Fault must be within 10% of previous month's value (This is to check Fault Test Device has not gone out of compliance) (IF USING WOOD DEVICE, CONCERNED WITH WARPING)

Note 1: A smartphone cell phone camera may be a sufficient tool to help sight the location of where the lasers are touching the ground. Not all cell phone cameras will work for this purpose.

Note 2: This testing can be accomplished in building 8.

Note 3: Laser safety glasses MUST be worn at all times for duration of Fault Verification testing

Note 4: The laser system has a safety motion detection device. If too much motion is detected, the laser system will be shut off. To rectify this, ALL of the subsystems must be restarted.

Note 5: When the pathways van is placed in rolling mode, the laser system has an elapsed time shutoff of 300s (5 min). If the 300s mark occurs before testing is complete, all systems must be restarted.

Note 6: Rutting laser system has a red indicator light to show that lasers are ON and operating. If the red light is off, all subsystems must be reset. If resetting doesn't work to bring the lasers back on-line, all subsystems must be shut down and restarted.

Note 7: If Fault is not showing for step 8 of the procedure, increase "time-series" mode test speed to 50 mph and try again.

Location Verification

The location verification procedure is used to verify the accuracy of the GPS based location system.

Export the driven path of the data collection vehicle as a shapefile and compare it against the official NJDOT dual-line shapefile. A buffer area of 50 feet is applied to the NJDOT shapefile. All areas where the data collection vehicle provides locations not within the buffer area are summed up and noted. No more than 1% (46 miles) annually can fall outside of the buffer area.

<u>GPS Verification Procedure:</u>

1. Open PathView program
2. Add data sets to be verified
3. Apply current .C11 reporting file to data
4. Navigate to menu item "GPS "Create Shapefile" option
    a. Export interval minimum 0.1 mi (528 ft)
    b. Save .txt file and export to appropriate log folder on the S: drive
    c. Create backup of .txt file
5. Convert Pathways .txt file to NJ State Plane ESRI .shp file
6. Open ArcMap
    a. Load NJDOT Base Map (see note 1) Layer
    b. Load Pathways .shp as layer
    c. Visually determine locations where GPS from Pathways is not similar to underlying Base layer and document in QA logs
    d. If using RU developed software, export report and save.
7. Determine length of GPS discrepancies
    a. In ArcMap click on the Geoprocessing menu and choose "buffer".
    b. Choose the official NJDOT shapefile under the dropdown box for "input features". Make sure to save the output file in the proper year's data quality log folders on the S: drive.
    c. Input a buffer of 50 linear feet.
    d. Choose "All" for the Dissolve Type and click OK. The buffered area will be added to the map.
    e. Open Arc Toolbox, expand Analysis Tools, expand Overlay, Choose "Erase".
    f. Choose the driven path of the data collection vehicle from the drop down box for "input features". Choose the buffered area from the drop down box for "clip features" then click OK.

g. Right click on the final layer created and open the attribute table. Find the field labeled “Shape_Length”, right click on the header and click on “Statistics…”. The total length outside of the buffered area will be summed in this window.

Note 1: Accurate Base map for each year must be obtained by PMU from SLD Group using the special rubber banding program. This base map must be dual line everywhere in the state (not single line as SLD). Base map must have GPS coordinates for roadway geometries at 0.01mi increment minimum.

Note 2: The GPS cannot be verified by the field Crew in Building 8, it must be conducted on collected data by Data Reduction Team

4. Collection “During” Phase

Data Items Required

Information collected as part of a network-level data collection effort includes ride quality (IRI), rutting, faulting, surface distress and right-of-way imagery. Table 4 provides a summary of the condition items collected:

Table 4. Network-Level Surface Data Items Collected by Pavement Type

Pavement Type	Network-Level Data Items
Asphalt	• Ride quality (IRI); • Rut depth; • Load-related (longitudinal, pattern) cracking; • Non-load related (longitudinal, pattern, transverse or construction joint) cracking.
Composite (asphalt over concrete)	• All distresses listed for asphalt pavements; plus • Reflective cracking.

Jointed Concrete	• Ride quality; • Faulting; • Slab cracking (transverse and/or longitudinal); • Joint spalling and/or pumping.

Equipment Verification

Although the equipment is calibrated annually, it should be verified periodically throughout the collection season to ensure the integrity of the subsystems. The Surveyed control site, (Rt. I-295 MP 49.9), as shown in Figure 2, will be run (three runs for repeatability and precision as described in the "Profiler Certification" section above) at a minimum of once per month. Additional control sites can be established at various locations in each region of the State to facilitate local field QC checks.

Field Data QC

- Surveyed Control Site (described in the "Surveyed Control Site" section) is recollected throughout the collection cycle on a monthly basis. Each segment should be collected three times each and data processed to ensure repeatability.
- Features like real-time graphs in the data collection vehicle allow the operator to make sure that the hardware is working correctly. The operator should follow the daily operation checklist as outlined in equipment manual to ensure proper data collection.
- Visual display of the images being collected allow the operator to make sure proper quality standards are met. All roadway images are fed both to the main data collection screen and to a dedicated full screen mode using the same front mounted monitor.
- The GPS mapping program allows for simultaneous playback for greater efficiency and accuracy. The onboard map also gives the operator the ability to ensure proper location by marking the expected beginning and ending points of a given section.
- The manufacturer recommends to begin collection on each collection set on a straight-away as often as possible. Starting the data collection in a curve leads to issues with processing at later steps in data processing.
- Voice animation alerts operator of any potential problems discovered by self-governing equipment and software.
- The data collection program continuously performs real-time data calculations and displays an alert any time that a sensor reading falls outside the valid ranges.

The key data items, protocols used for equipment verification, and associated quality standards are described in Table 5. Quality standards define the resolution, accuracy, and repeatability or other standards that will be used to determine the quality of each data item. If any subsystem fails verification twice concurrently, call the system manufacturer.

Table 5. Equipment Verification Quality Standards

Deliverable	Protocols	Resolution	Accuracy (compared to reference value)	Repeatability (for three repeat runs)	Reference Value
IRI (left, right, and average)	AASHTO R 57-14	1 in/mi	± 5 percent	± 3 percent	SurPRO IRI values
Rut depth (average and maximum)	AASHTO R 87-18*, R88-18* & PP69-14	0.01 in	± 0.06 in	± 0.06 in	Straight edge and caliper measurements
Faulting (average of faults over 0.2 in)	AASHTO R 36-13	0.01 in	± 0.06 in	± 0.06 in	Straight edge and caliper measurements
Pavement Distress	NJDOT procedure	0.1 mile	95%	NA	Manual video review
GPS location	NJDOT procedure	50 ft	99% of network	NA	NJDOT dual-line GIS layer

***AASHTO R48 has been discontinued. Users should refer to R87 and R88.**

Software Verification

As pavement data gets processed and checked for data quality standards updates to configuration files, processing metrics, and output reports may be produced. In an effort to maintain uniform standards for a data collection cycle, software logs must be kept showing what the current version of each software is, when it was updated, and what the purpose of the new software build or file is. The following are a list of files, databases, and software that should be tracked:

- dTIMS (Deighton)
- PathView (Pathway)

- AutoCrack (Pathway)
- .C11 (Pathway)
- INI file (Pathway)
- Yearly PMS database check log

All 0.1 mile summary data should be loaded into the PMS database once it is generated so standard database checks can be made for additional verification. These database checks at a minimum include the following:

- 30 < IRI > 400
- 0.1 mile locations with zero extent for all distresses
- IRI = 25 in/mile (This indicates a problem with the distance database)
- Duplicate records
- Asphalt distresses on concrete surfaces or concrete distresses on asphalt surfaces
- Consecutive 0.1 mile sections with identical extents for all distresses or IRI

Consultant Data Collection

All consultants will be expected to operate their equipment in a standard method in accordance with protocol discussed separately in each consultant's data quality management plan. If any changes to the method of data collection are made, the NJDOT PMU will be made aware of these changes so that they can be documented.

5. Processing "After" Phase

Post Collection Processing and Data Verification

In the post collection phase, the ability to correct faulty data can be challenging. Data collected in the field and transferred to the office undergoes post collection checks to quickly assess data completeness and accuracy. Office staff performs secondary quality reviews to verify the accuracy and completeness of the data. Three main groups of data reviews have been identified as Pavement Distress Data Review (5% of network), Location and Image Review (100% of network), and Final Data Review (100% of network).

The key data items, protocols used for network collection, and associated quality standards are described in Table 6. Quality standards define the resolution, accuracy, and repeatability or other standards that will be used to determine the quality of each data item.

All consultants are expected to follow all post collection processing and data verifications on their own data. NJDOT has procedures in place to accept or reject consultant data in Chapter 6 of this manual.

Table 6. Network Data Quality Standards

Deliverable	Protocols	Resolution	Accuracy (compared to reference value)	Repeatability (for three repeat runs)	Reference Value
Distress ratings	Agency distress rating manual	Varies	Varies	N/A	Downward Video Review
Location of segment	N/A	N/A	All segments in correct location	N/A	SLD
Segment begin point	N/A	0.01 mi (52.8ft)	± 0.05 mi (264ft)	N/A	SLD
Right-of-Way Images	N/A	N/A	Signs legible, proper exposure and color balance	N/A	N/A
Pavement downward images	N/A	N/A	1/8 in wide cracking visible	N/A	Downward Video Review

Pavement Distress Data Review

Pavement distress data (i.e. images and processed results) are provided to the office staff for review on a weekly basis. The office staff reviews 5 percent of the collected section length. Sampled section images are checked using the Pathway-supplied proprietary software and reviewed for such items as:

- Missing a high severity distress;
- Missing 5 or more instances of low/medium severity distress;
- Incorrect distress type or severity, or over-rating (indicating that a distress is present when actually there is no distress);

- Pavement surface and ROW images are reviewed weekly to prevent and minimize re-runs.

Location and Image Quality Review

Images should be checked for clarity and brightness using minimum established standards – e.g. the word “mile” on a milepost sign is legible. Systematic location offsets are investigated to determine whether the start and end points are incorrectly set, which can be corrected at this time.

All images should be clear and the distress type and severity be easily identifiable. The camera(s) should be able to quickly adjust to varying lighting conditions. For example, when the data collection vehicle is on an asphalt road and has crossed a concrete bridge, the camera(s) may “white out” from the higher degree of light reflection. Conversely, when the data collection vehicle exits a concrete bridge onto an asphalt pavement, the camera(s) may “black out.”

Pavement images should be synchronized with the R.O.W. images. The images should play in the correct order. The pavement type and texture should correspond to the pavement type and texture that is shown in the R.O.W. view. Custom ‘First and Last Image Check’ software scans digital images for completeness.

The following items are checked by the office staff to ensure that the collected ROW images have acceptable levels of clarity, brightness/darkness, and completeness:

- Image clarity — All images should be clear and highway signs easily read. Most highway distresses should be evident in all views. There should be minimal debris in the cameras’ viewing path.
- Image brightness/darkness — Images are not to be collected during hours when it is too dark (rule-of-thumb: if street lights or security lighting are lit, then it is too dark). It has been found that during poor lighting conditions, the images become very grainy and seem to be out of focus, or it results in a “black out,” In addition, if the data collection occurs just before a rain storm, the dark clouds may not allow the proper amount of light to enter the camera, and the subsequent image(s) will be of poor quality.
- Dry pavement — Testing lane should not have any standing water during testing; otherwise, the run will be rejected. Accordingly, data collection should be halted during and immediately after a rain storm. Water on the pavement invalidates collected data and rain drops accumulated on the protective glass of the ROW camera, will cause the images to be of poor quality due to the lack of clarity and sharpness.
- Image replay — Images should play sequentially and in the correct order. The data collection vehicle should give the impression that it is traveling in a forward direction.
- Missing images — There should be minimal or no missing images.

Final Data Review

The PMS database checks used include searches for missing data, out of tolerance data, and abrupt pavement condition changes when compared to data collected from previous years. Any pavement section discrepancies are further investigated for acceptance using the criteria in Table 7. These checks include the following sequential activities:

- Duplicate records — Duplicate records are noted for correction by the Office Data Reduction Lead and removed from the input file for processing of additional data checks. If a 1/10th mile section is listed multiple times with the same profiler date yet different distress values, then the equipment/software supplier must be notified of potential bugs. After the software bugs are addressed new output reports will need to be generated on all previously analyzed sets.
- Survey year — Survey year, month, and day are checked to verify dates of testing.
- Invalid key — Invalid key errors include: missing county number, invalid county number, missing state route and/or missing segment number, non-numeric data in a numeric field, invalid survey date, and invalid state route and/or segment number.
- Concrete sections – Zero slab/joint counts for concrete pavements.
- Missing segment — Confirms that there are no missing parent segments.
- High/Low limits for IRI – If below 30 in/mi. or above 400 in/mi.
- High/Low limits for rut – If below 0 in or above 0.5 in.
- High/Low limits for cracking % - If all distresses report 0% or if any distress is reported over 100%.
- Duplicate distress – More than 2 consecutive sections with the same distress density should be checked visually.
- Zero distresses – Any section with a distress density of zero for all distresses should be visually inspected by video review.
- Incorrect distresses for a surface type – No section should have distresses for a surface type that does not exist in that location.
- Duplicate IRI – More than 2 consecutive sections with the same IRI should be checked for errors
- IRI equal to 25 – This is typically due to a problem with the distance database that can be fixed
- Construction, lane deviation, and miscellaneous flags — Identifies if the proper coding has been applied to roadway segments that do not require condition assessment.
- Administrative data — Includes verifying that the state route data matches the data for turn-back and closed-to-traffic roadways.
- Surface type — Confirm that the surface type for the roadway segment is current.

Finally, the approved data is imported into the PMS database. The PMS database is used as the sole source of information provided by the PMS group for both internal uses including but not limited to pavement design, pavement condition forecasting, and future project selection, as well as being delivered to outside resources such as the HPMS federal data submission. Annually, the PMS Database is updated as required to insure consistency with the current network definition and other related characteristic information. These updates as a minimum include:

- SRI information for each road segment are accurate and include historical reference to road segments that have changed;
- Pavement type should be updated to match the most recent as-built data;
- Segment lengths should include full HPMS extent whether owned/maintained by NJDOT;
- Updates to NHS sections should be verified;
- Updates to jurisdiction should be verified;
- Updates to legislative district should be verified;
- Updates to lane counts should be verified;
- Lane mile check to match HPMS submission;
- Updates to skid values should be verified;
- Updates to speed limits should be verified;
- Updates to county codes should be verified;
- Updates to median Y/N should be verified;
- Updates to functional class codes should be verified.

Missing Data Report

As part of the PMS database review, a missing data report is generated. Missing data due to construction or some other major obstacle is commonplace when conducting a network pavement evaluation. The missing data report should include the following criteria:

- Reason for missing data;
- Location;
- Route name, direction, milepost;
- Segment number and segment start/end;
- Number of miles missing per section;
- Percent missing per section.

Viable reasons for missing data at the end of the year would include:

- Construction;
- Low bridge clearance;
- Road closed (permanently or semi-permanently);
- Lane departure.

HPMS standards allow a maximum of 5% missing sections on the National Highway System network. Significant runs of missing data, particularly on the NHS should be attempted to be re-collected, especially if the 5% threshold has been exceeded.

6. Acceptance

Acceptance Criteria and Corrective Actions

New Jersey Department of Transportation performs quality control of the data collected. The focus of acceptance is to validate that data meet the established quality standards. Table 7 provides a summary of the checks of the delivered condition data and corrective actions for items that fail to meet criteria.

Table 7. Data, Acceptance Level, Sample Size and Corrective Action

Deliverable	Acceptance (Percent Within Limits)	Acceptance Testing & Frequency	Action if Criteria Not Met / Error Resolution
IRI, rut depth, faulting	95 percent	Global database check for range, consistency, logic, and completeness. 5 percent sample inspection upon delivery.	Reject deliverable; data must be re-collected.
Distress Ratings	95 percent	Global database check for consistency, logic, completeness. Weekly inspection of all 3D image data, and 5 percent sample inspection upon delivery.	Reject deliverable; data must be re-collected.
Location of segment and segment begin point	100 percent	Weekly inspection of all segments locations against SLD.	Adjust to meet requirements.
Pavement downward images	98 percent of each section and not more than 5 consecutive images failing to meet criteria	Weekly inspection of 5 percent sample inspection upon delivery.	Reject deliverable; data must be re-collected.

Consultant Data	100 percent for logs; 10 percent of NJDOT reference values for verification site data	Global database check of certification, calibration, verification, and QA logs. Annual verification of metrics on verification site	Reject deliverable; data must be recollected

Acceptance of Consultant Data

Consultants will be required to submit all quality reporting items outlined in each individual consultants DQMP. In addition to reporting the distress data, the consultants must submit all certification, calibration, verification, and quality assurance logs. The NJDOT PMU will be responsible to conduct database checks to ensure that any consultant providing data has been reviewed in accordance with their respective DQMPs. The consultants will also be required to submit the 0.1 mile data including all metrics for the Consultant Verification site.

If the criteria for acceptance of verification data is met for the 0.1 mile data, the consultant data will be considered sufficient and will be accepted for reporting.

Quality Reporting Plan

The Pavement Management Section Leader monitors quality through QC activities and reports data quality exceptions as part of weekly status reporting, or more frequently, if conditions warrant. Quality is also monitored through acceptance reviews, and quality issues are reported to the data collection team as soon as issues are discovered.

No data will be loaded into the Pavement Management System database until the Pavement Management Section Leader certifies its integrity through the established QC and acceptance review procedures. Any data issues that are identified throughout the year are recorded. The QM report is used to modify the QM plan activities for the next year’s data collection with the aim of continuously improving the network pavement condition data quality.

7. Bibliography

1. Flintsch, G. and K. K. McGhee. 2009. "*Quality Management of Pavement Condition Data Collection"*. NCHRP Synthesis 401. Transportation Research Board, Washington DC.
2. Haas, R., W.R. Hudson, and J.P. Zaniewski, "*Modern Pavement Management"*, Krieger Publishing Company, Malabar, FL., 1994.
3. Pierce, L. M., G. McGovern, and K. A. Zimmerman. 2013. "*Practical Guide for Quality Management of Pavement Condition Data Collection".* Report No. FHWA-HIF-14-006, Federal Highway Administration, Washington, DC.
4. Pierce, Linda M., 2014, **"***Quality Management for Pavement Condition Data Collection"***,** TRB**,** Washington, DC.
5. Shekharan, R., D. Frith, T. Chowdhury, C. Larson, and D. Morian. 2006. *"The Effects of a Comprehensive QA/QC Plan on Pavement Management."* Transportation Research Record No. 1990. Transportation Research Board, Washington, DC.

Appendix A

NJDOT R-1

NJDOT R-1 – DETERMINING RIDE QUALITY OF PAVEMENT SURFACES

A. Scope. This test method is used to determine the ride quality of a pavement surface using a Class 1 Inertial Profiler System (IPS). If any part of this test procedure is in conflict with the referenced documents, such as ASTM or AASHTO standards, this test procedure takes precedence for its purpose.

B. Apparatus. Use the following apparatus:

1. Class 1 IPS that meets the requirements of ASTM E 950, Sections 4.0, 5.0 and 6.0 of AASHTO M 328, and the following:

   a. Valid certification approved by the Department.
   b. The data system provides the raw profile data in an ASCII format acceptable to the Department.
   c. Current version of *ROADRUF*, *ProVal*, or other Department approved pavement profile analysis software installed on the IPS computer to compute the IRI.

2. Base plate and gauge blocks, of 1 inch and 2 inch thickness, provided by the manufacturer to verify daily vertical calibration.
3. Retro-reflective traffic marking tape or other approved mechanism to automatically trigger the start and stop of profile measurements.

C. Procedure. Perform the following steps:

1. Turn on the inertial profiler and warm up all electronic equipment in accordance with the manufacturer recommendations in advance of testing.
2. Perform Block and Bounce tests each day prior to collecting data. Record the results in the calibration log. Ensure tolerances are within the certified limits.
3. Ensure retro-reflective traffic marking tape or other approved mechanism is placed at the beginning and end of each direction of travel lane.
4. Enter project information in the system.
5. Make provisions to start and stop recording profile at the beginning and end of testing. If automatic trigger mechanism is not install, make provision to initiate start and end data recording manually by pressing a specific key on the computer.
6. Ensure that the required speed is achieved and system is collecting profile data prior to recording profile.
7. For each test section, perform three test runs to collect data of both wheel paths of each lane in the longitudinal direction of travel. The wheel path is defined as being located approximately 3 feet on each side of the centerline of the lane and extending for the full length of the lane. Lanes are defined by striping.
8. Save data from each run separately prior to subsequent run or lane testing, clearly identifying each test section, lane identification, and run number.

D. Report. Generate an electronic report in excel format, compatible with the Department's version, of continuous IRI for each 0.01 mile lot after applying 300 feet high-pass filter. The report shall contain the following information:

1. Date of testing, IPS identification number used for testing, and name of operator.
2. Route, milepost location, direction, lane identification, run number, IRI of each wheel path, and average speed.

Appendix B

NJDOT TTI data collection vehicle certification

Texas Transportation Institute Profiler Certification Test Results

---

Profiler Operator	:	Jeremy Rockefeller
Wheelpath(s) Tested	:	LR
Profiler Tested	:	Pathway Model 3D1-110
Profiler Serial No.	:	110
Profiler VIN	:	1FTSE3ES9CDA42170
Test Date	:	07172012
Test Administered By	:	Emmanuel Fernando & Gerry Harrison
Filter Type	:	Pathway filter
Filter Program	:	PathwayFilterVer60.Exe
Version No	:	July 2, 2009

Overall Test Result: PASS

PROFILER REPEATABILITY AND ACCURACY (Medium Smooth Section)

Repeatability

Left Ave.STDV 11 Right Ave.STDV 10

Equipment Accuracy

Left u1 : -1.18	Right u1 : 0.37
Left u2 : 33.02	Right u2 : 26.12

IRI

Left STDV of IRI: .69 (PASS) Right STDV of IRI: .63 (PASS)

Average IRI (in/mile)

Wheel Path	Abs. Difference	
Left	.17	(PASS)
Right	.99	(PASS)

Emmanuel Fernando
7/17/2012

Texas Transportation Institute

Profiler Certification Test Results

Profiler Operator	:	Jeremy Rockefeller
Wheelpath(s) Tested	:	LR
Profiler Tested	:	Pathway Model 3D1-110
Profiler Serial No.	:	110
Profiler VIN	:	1FTSE3ES9CDA42170
Test Date	:	07172012
Test Administered By	:	Emmanuel Fernando & Gerry Harrison
Filter Type	:	Pathway filter
Filter Program	:	PathwayFilterVer60.Exe
Version No	:	July 2, 2009

Overall Test Result: PASS

PROFILER REPEATABILITY AND ACCURACY (Smooth Section)

Repeatability

Left Ave.STDV 10 Right Ave.STDV 9

Equipment Accuracy

Left u1 : -2.28	Right u1 : -1.35
Left u2 : 17.84	Right u2 : 14.26

IRI

Left STDV of IRI: 1.05 (PASS) Right STDV of IRI: .68 (PASS)

Average IRI (in/mile)

Wheel Path	Abs. Difference	
Left	1.98	(PASS)
Right	3.54	(PASS)

Emmanuel Fernando
7/17/2012

Michael Baker International

(Consultant)

County and Township Roadways Data Collection under National Highway System (NHS)

Pavement Data Collection
Data Quality Management Plan

Project Specific Plan for
New Jersey Department of Transportation

April 2018

Prepared By:

Michael Baker International
300 American Metro Blvd, Ste. 154
Hamilton, New Jersey 08619
(609) 807-9500

Contents

1. Introduction....2
2. Data Collection & Rating Protocols....3
2.1. Highway Performance Monitoring Field Manual....3
3. Data Collection Equipment & Calibration....5
3.1. Pavemetrics Laser Crack Measuring System (LCMS)....5
3.2. Surface Systems & Instruments, Inc (SSI) CS9300 Portable Profiler....7
3.3. Supporting Data Collection Systems....9
4. Data Quality Standards & Acceptance....10
5. Data Quality Control Measures....12
5.1. Pre-Production....12
5.2. During Production....15
5.3. Post Production....18
6. References....22

Document Change Control

Version Number	Author	Date	Description of Change
1.0	K. Contrisciane (Michael Baker)	April 2018	Original Draft

1. Introduction

This Pavement Data Collection Quality Management Plan documents the quality management practices and responsibilities that Michael Baker International, Inc. (Michael Baker) utilizes for pavement data collection provided for the New Jersey Department of Transportation (NJDOT). Through an existing data maintenance contract, Michael Baker performs pavement data collection in accordance with the HPMS Field Manual on Off-State NHS roadway sections across the state. This plan includes equipment calibration and certification measures, manual distress data collection, practices for pre-production through post-processing data quality control (QC) measures, data sampling/review practices, error resolution, and acceptance criteria. The QC activities documented will check that:

- *Data meets defined quality standards and requirements for acceptance;*
- *Data collection and processing are performed in a consistent and logical manner and;*
- *Data quality issues are identified and appropriate corrective actions are applied.*

With quality data, analyses from pavement management systems will provide more reliable results for decision-making processes. Standardized protocols will provide assurance that variability in pavement condition data between years reflect actual changes in pavement quality. This will allow for better compliance with data and reporting requirements, informed treatment plans and methods, reliable projections of future pavement conditions, work prioritization, resource allocation, and reliable decision support for managers.

The Michael Baker team has developed efficient pavement data collection and post-processing procedures to translate raw pavement data into highly-detailed useable pavement condition data and information products. The processes are performed on a network-level, providing reliable and consistent results that are configured based on specific project needs and local pavement conditions. Our experienced team has built, and continues to improve, a streamlined data processing and project delivery system with focus on innovation, efficiency and quality. The following document outlines those procedures, in accordance with 23 CFR 490.319(c)(1) requirements, which specifies:

(c) Each State DOT shall develop and utilize a Data Quality Management Program, approved by FHWA that addresses the quality of all data collected, regardless of the method of acquisition, to report the pavement condition metrics, discussed in § 490.311, and data elements discussed in § 490.309(c).
(1) In a Data Quality Management Programs, State DOTs shall include, at a minimum, methods and processes for:
(i) Data collection equipment calibration and certification;
(ii) Certification process for persons performing manual data collection;
(iii) Data quality control measures to be conducted before data collection begins and periodically during the data collection program;
(iv) Data sampling, review and checking processes; and
(v) Error resolution procedures and data acceptance criteria.

These requirements and topics are intertwined throughout this document. The table below provides a reference to these topics within the document.

Table 1. Document reference for FHWA Data QMP requirements.

Topic	Document Reference	Page
Data Collection Equipment Calibration	Data Collection Equipment & Calibration	5
Data Collection Certification	NCAT Certification Process	13
	Certification Documents	App. B
	ALDOT Certification Process	App. D
Data Quality Control Measures	Data Quality Control Measures	12
Data Sampling Review & Checking Processes	Data Quality Control Measures	12
Error Resolution Procedures & Data Acceptance	Data Quality Standards & Acceptance	10

The Michael Baker team will continue to update this document as new and innovative technologies emerge and data collection and processing procedures change.

2. Data Collection & Rating Protocols

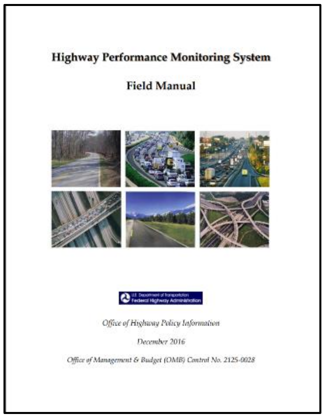
The New Jersey Department of Transportation (NJDOT) maintains approximately 2,300 centerlines miles of roads across the State. The state is also responsible for reporting HPMS-related data collection items on the NHS network that is not located on state-maintained roadways (Off-State NHS Network), which mainly consists of higher-order county and local jurisdiction routes. The Off-State NHS network consists of approximately 630 centerline miles of roadways. A full list of Off-State NHS routes can be found in Appendix A.

Figure 1. NJDOT Off-State NHS network.

2.1. Highway Performance Monitoring Field Manual

➢ ***Overview***

Highway Performance Monitoring System (HPMS) data is used for assessing highway system performance under the U.S. DOT and Federal Highway Administration's (FHWA) strategic planning and performance reporting process. The *HPMS Field Manual* provides a comprehensive overview of the HPMS program and describes in detail the data collection and reporting requirements for HPMS. Each State is required to prepare an annual submittal of HPMS data in accordance with the procedures, formats, and codes specified in this manual. According to the *HPMS Field Manual,* the data is used for the following purposes:



- To assess and report highway system performance under FHWA's strategic planning process.
- To form the basis of the analyses that support the *Conditions and Performance (C&P) Report* to Congress and is the source for a substantial portion of the information published in the annual *Highway Statistics* publication.
- To report metrics with respect to targets for established performance measures per 23 CFR 490.
- For use throughout the transportation community, including other governmental entities, business and industry, institutions of higher learning for transportation research purposes, and the general public.
- For performance measurement purposes in National, State and local transportation decision-making to analyze trade-offs among the different modes of transportation as part of the metropolitan and statewide transportation planning process.

The manual is updated on an as-needed basis and can be found online at:

https://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/page00.cfm

Distresses are reported according to surface type as detailed in Table 2, Data Item Requirements by Surface Type.

Table 2. Data Item Requirements by Surface Type

Surface Type	IRI	Rutting	Faulting	Cracking Percent
1 - Unpaved				
2 - Bituminous	in/mi	0.01"		Fatigue % area
3 - JPCP	in/mi		0.01"	% cracked slabs
4 - JRCP	in/mi		0.01"	% cracked slabs
5 - CRCP	in/mi			Punchout/long./patch % area
6 – Composite (AC / AC)	in/mi	0.01"		Fatigue % area
7 – Composite (AC / JCP)	in/mi	0.01"		Fatigue % area
8 – Composite (Bituminous / CRCP)	in/mi	0.01"		Fatigue % area
9 – Composite (Unbonded JC / PCC)	in/mi		0.01"	% cracked slabs
10 – Composite (Bonded JC / PCC)	in/mi		0.01"	% cracked slabs
11 – Other (e.g., brick)	in/mi			

Additionally, Michael Baker collects location data (GPS) in conjunction with pavement data for QA/QC purposes.

➢ *Data Collection Methodology*

Field Data Collection

Michael Baker performs pavement data collection for NJDOT in alignment with the *HPMS Field Manual* requirements through automated methods. A mobile-based data collection system (see Section 3) that includes a Laser Crack Measurement System (LCMS) and inertial profiler is used to capture raw field data. Pavement data collection is performed in both travel directions in the rightmost lane.

The table below shows the method of collection, capture and reporting resolution of each distress:

Table 3. Method of data capture and resolution.

Distress	System of Capture	Method of Capture	Reporting Unit	Reporting Resolution
IRI	Inertial Profiler	Automated	in. / mi.	1 in./ mi.
Rutting	LCMS	Automated	Inches	0.01 in.
Faulting	LCMS	Automated	Inches	0.01 in.
Cracking Percent	LCMS	Automated	Percent	1%

In 2016, data collection generally occured in the September/October timeframe. Data is submitted to NJDOT in Microsoft Office Excel format. All data records are broken down by the route ID (00000001__, 00000003__, 00000004__, etc.) and into 1/10th mile sections. Average distress values are reported for each section.

3. Data Collection Equipment & Calibration

Data collection is performed using two primary data collection systems, with several supporting systems:

Table 4. Mobile data collection system components & classification.

Primary Systems	Purpose	System Classification
Laser Crack Measurement System (LCMS)	Captures detailed surface distress information at highway speed including cracking, rutting and potholes.	Mission Critical
Inertial Profiler (IP)	Class 1 profiler used to capture IRI data.	Mission Critical
Supporting Systems	**Purpose**	**System Classification**
Distance Measuring Instrument (DMI)	Provides precise distance measurements to LCMS & IP systems.	Mission Critical
Applanix GPS with Inertial Measuring Unit (IMU)	A Position & Orientation System that provides stable GPS streams to the LCMS, IP and LiDAR systems.	Mission Critical
Mobile LiDAR with Ladybug Imagery	Provides panoramic ROW images.	Ancillary
Lane Departure Warning System	Warns driver of lane wandering.	Ancillary

The LCMS and inertial profiler along with the DMI and Applanix systems are classified as mission critical. This means if one mission critical system goes down or experiences technical difficulties during production data collection, the field crew must immediately stop data collection, document the problem and notify the Field Crew Coordinator. The Ladybug system is only considered mission critical when imagery is a deliverable as part of a scope of work. It is however a part of Michael Baker Standard Operating Procedures (SOP) to collect Ladybug imagery on all pavement data collection projects for QC purposes. If imagery is not scoped on a data collection project, classifying the Ladybug as a mission critical system component is at the discretion of Project Manager. Refer to 'Real-Time Data Checks' under Section 5.2 for stop and pause data collection conditions for each system.

3.1. Pavemetrics Laser Crack Measuring System (LCMS)

The Pavemetrics LCMS system is mobile-based automatic pavement distress detection system that consists of a double sensor laser array. This system is used to capture detailed surface cracking information, as well as rutting, potholes, patching, etc. The LCMS unit is integrated with an Inertial Measurement Unit (IMU), which also allows for the collection of slope, cross slope and International Roughness Index (IRI).

➢ ***LCMS Calibration & Verification***

Calibration is performed on various components of the LCMS by certified field technicians in accordance with ASSHTO R 57-14, *Standard Practice for Operating Inertial Profiling Systems*, that consist of:

- *Longitudinal (DMI) Calibration*
- *Height Calibration (Block Test)*
- *Block Test*

Longitudinal (DMI) Calibration

Longitudinal calibration involves calibration of the DMI unit so that the LCMS is correctly calculating measured distances. One DMI unit is integrated into both LCMS and inertial profiler system, so the longitudinal calibration of the inertial profiler system is done in conjunction with the LCMS. The method of calibrating distance on the inertial profiler system is a simpler and more accurate method to calibrate the DMI, so the SOP is to calibrate the DMI using the inertial profiler system. The longitudinal calibration of the LCMS is a configuration that consists of entering the number of DMI encoder pulses per meter. This configuration setting is changed based on the calibration of the inertial profiler, which is detailed in Section 3.2. This configuration setting is saved into raw data and loaded in the project database for tracking and quality assurance purposes.

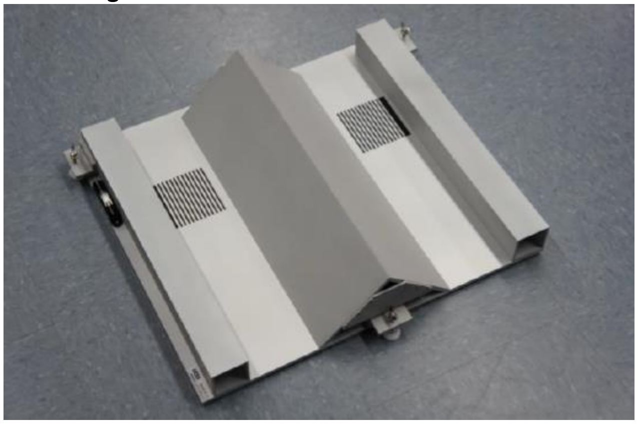
Longitudinal calibration of the LCMS is conducted monthly at minimum or when one of the following triggering events occur (whichever comes first):

- *When tire pressure is adjusted*
- *Before the onset of a new project*
- *After hardware maintenance of the laser sensors or DMI*
- *Whenever the profiler distance calibration is performed*

Height Verification (Block Test)

The block test involves verifying heights measured by the LCMS system. The block test of the LCMS is completed using a specialized calibration block manufactured by Pavemetrics as shown in the figure below:

Figure 2. Calibrated block for calibration.



A separate Validation Tool software module is used to calibrate both the height and width dimensions as well as focus test to assess the sensors optical quality and accuracy in regard to width and depth measurements. The LCMS block test is conducted monthly at minimum or when one of the following triggering events occur (whichever comes first):

- *Before the onset of a new project*
- *After hardware maintenance or removal\reattachment of the laser sensors*

Bounce Test

The bounce test is used to verify the operation of the accelerometer's ability to account for normal vehicle bounce while driving. Bounce testing is completed within accordance of ASSHTO R 57-14 and the manufacturer's recommendation. The LCMS bounce test is conducted daily before the start of data collection and after the vehicle sensors have warmed up.

- ***LCMS Annual Maintenance***

Michael Baker maintains an annual maintenance contract with Pavemetrics that includes laser sensor calibration and cleaning. This entails removing the laser sensors and sending them to the manufacturer for re-conditioning. This maintenance includes cleaning of the sensors, fine-tuning and re-calibrating and\or re-configuring the lasers as necessary, and updating firmware to make sure the system remains in a state of good repair. All calibration and verification steps are performed when the sensors are reattached to the mobile data collection vehicle.

The annual maintenance contract also includes periodic software updates to both the LCMS acquisition and processing software modules. These updates can include a combination of bug fixes, improvements to existing modules and/or new modules. As part of Michael Baker's SOP, no software updates are applied or adopted during the course a project, unless it includes a patch that fixes a major bug as classified by the manufacturer. All updates are tested in a test environment before production implementation. This methodology is executed in an effort to maintain data consistency and integrity through a data collection project.

3.2. Surface Systems & Instruments, Inc (SSI) CS9300 Portable Profiler

The SSI profiler is specifically used to capture high accuracy, repeatable measures of pavement roughness (IRI) and rutting information. When used in conjunction with the LCMS system, the data collection vehicle can capture detailed surface condition information, including roadway imagery with detailed surface distress information identified.

Figure 3. SSI profiling system.

- ***Profiler Calibration & Verification***

Similar to the LCMS, profiler calibration is performed by certified field technicians in accordance with ASSHTO R 57-14 that consist of:

- *Longitudinal (DMI) Calibration*
- *Height Calibration (Block Test)*
- *Block Test*

<u>Longitudinal (DMI) Calibration</u>

Longitudinal calibration is done within accordance of the ASSTHO R 57-15 and manufacturer's instructions using the SSI Profiler (v 3.2.7.26) *software. The following is Michael Baker's SOP relating to DMI calibration:*

- *Find a long, straight and flat safe track of road at least one-tenth of a mile (528') in length. Use a measuring wheel to measure exactly 528', referencing the beginning and ending measurements with a marking. Measure this distance at least two times with the measurement wheel to verify the distance. Measurements must be within 3 inches of each other.*

- *Place a traffic cone with DOT-C2 compatible reflective tape at the beginning and ending points of the measured track. It is important that two reflective tape stations are at accurate positions for calibration.*
- *Use the SSI Profiler software to initiate the calibration process using the Electric Eye (EE) functionality. To begin the calibration, follow the message prompts in the instruction window. Select "Next" and drive past the start position electric eye to begin the calibration. After the EE begins the calibration, an estimated distance will be shown. Near the final reflective tape location, arm the EE by selecting "Next" again. The calibration will finish when the EE is triggered. The user will then be prompted to enter the actual distance traveled.*

The SSI software reports the DMI calibration as the number of DMI encoder pulses over the 528' calibration distance. A conversion is done to calculate the DMI encoder pulses per meter, which is then used to configure the LCMS distance calibration. Below is an example of the conversion method:

SSI Encoder Counts (EC): 1,358,301
SSI Encoder Distance (ED): 528 ft.
Counts Per Foot: 2,572.5 (EC / ED)
Counts Per Meter (for LCMS): 8,440.1 -- > New LCMS Configuration

Longitudinal calibration of the profiler is conducted monthly at minimum or when one of the following triggering events occur (whichever comes first):

- *When tire pressure is adjusted*
- *Before the onset of a new project*
- *After hardware maintenance of the laser sensors or DMI*

Laser Height Verification (Block Test)

The block test involves verifying heights measured by each laser array of the profiler system. The SSI software provides a wizard-based calibration method that is easy to use. Calibration is performed by complete tests on 1", 2" and 3" calibration block heights using individually stacked 1" blocks as shown below:

Figure 4. SSI profiler block test.

The profiler block test is conducted monthly at minimum or when one of the following triggering events occur (whichever comes first):

- *Before the onset of a new project*
- *After hardware maintenance of the laser sensors*

Bounce Test

The bounce test is a diagnostic procedure used to determine if the system's accelerometers and height sensors are working in unison and calibrated correctly. The bounce test is not a calibration procedure, and its results are not used to reset or adjust the profiling system. Bounce testing is completed within accordance of ASSHTO R 57-14 and the manufacturer's recommendation. The profiler bounce test is conducted daily before the start of data collection after the vehicle sensors have warmed up.

3.3. Supporting Data Collection Systems

There are several other support systems that work in conjunction with the LCMS and inertial profiler systems:

- *Inertial Measuring Unit (IMU)*
- *Mobile LiDAR with integrated spherical camera system*
- *Lane Departure Warning System*

➢ ***Applanix POS LV GPS with integrated Inertial Measuring Unit (IMU)***

The Applanix POS LV is a high accuracy Position and Orientation System, utilizing integrated inertial technology to generate stable, reliable and repeatable positioning solutions for land-based vehicle applications. It includes two GPS antennas to determine position and orientation, and has an integrated IMU for positional correction when GPS signal is compromised. This system is integrated with both the LCMS and profiler systems to provide a single high-precision source for positional information.

➢ ***Optech SG1 Mobile LiDAR platform with integrated FLIR Ladybug5 spherical camera system***

While Light Detection and Range (LiDAR) data is not part of the pavement data collection process, its integrated spherical camera system collects right-of-way imagery that is a standard part of the pavement quality control process. This system combines five spherical cameras into a 360-degree view around the vehicle. This allows data collection processors and subject matter experts (SME) to confirm pavement conditions using an independent image collection system.

Figure 5. Mobile LiDAR system with spherical camera

➢ ***ADVENT LDWS100 Advanced Driving Assistance System***

The ADVENT LDWS100 is a lane departure warning system, that alerts the driver of vehicle wander. This system is used for both safety reasons and quality control, as significant vehicle wander outside of normal travel lanes and/or wheel paths can compromise the quality of data collected with the LCMS and IP.

4. Data Quality Standards & Acceptance

The key deliverables, protocols used for collection, and associated quality standards are described in the sections below. The resolution, accuracy, and repeatability measures are used to determine the quality standards for deliverables. Acceptance criteria uses these standards as the baseline to determine if the deliverable data is within acceptable limits.

➢ ***Data Quality Standards***

Table 5. Data Quality Standards.

Data Quality Standards				
Deliverable	**Protocols**	**Resolution**	**Accuracy** (compared to reference value)	**Repeatability** (for three repeat runs)
IRI (average)	ASSHTO	1 in/mi	± 10% of Class I profiler or within 10% of NJDOT value.	± 10% run to run for three runs
Rut Depth (average)	ASSHTO	0.01 in	± 0.08 in compared to manual survey	± 0.08 in run to run for three runs
Faulting (average)	ASSHTO	0.01 in	± 0.08 in compared to manual survey	± 0.08 in run to run for three runs
Cracking Percent	ASSHTO	1%	± 2% compared to manual survey	± 2% compared to manual survey

In addition to the above, no more than 5% of the total lane miles on highways can having missing, invalid or unresolved data in accordance with FHWA ruling § 490.313.

➢ ***Data Acceptance***

The focus of acceptance criteria is to validate that deliverables meet the established quality standards, as described above. The following describes acceptance testing, frequency, and corrective actions for data that fails to meet acceptable quality standards. A general guideline for error resolution is as follows:

- *Procedural Error – Adjust the procedure and reprocess data*
- *Processing Error – Reconfigure processing parameters and reprocess data*
- *Data Quality and Omission Errors – Reject the data and recollect*
- *Data Correctness Error – Reject the data and recollect*

Table 6. Data Acceptance Criteria & Error Resolution.

Acceptance Criteria				
Deliverable	**Acceptance** (% Within Limits)	**Acceptance Test**	**Frequency**	**Error Resolution** (Action if Criteria Not Met)
IRI, Faulting, Rutting & Cracking Percent	90%	Within 10% of NJDOT value	Before deliverable submission	Document discrepancies and verify with pavement imagery and construction schedule. Conduct repeatability test on sample section to verify data.
	90%	Within 20% of year-over-year (YoY) value	Before deliverable submission	Document discrepancies and verify with pavement imagery and construction schedule. Conduct repeatability test on sample section to verify data.
	95%	10% Repeatability on random samples	Weekly	Deliverables cannot be submitted. Recalibrate and reverify profiler and recollect.
	95%	Within 10% of blind control section sample	Weekly	Deliverables cannot be submitted. Recalibrate and reverify profiler and recollect.
GPS Coordinates	100%	Full GPS coverage on all inventoried segments	Daily	Recollect areas of missing GPS.
Location of Segment	100%	Correct location of conflated pavement data to segments	Daily	Reconfigure and reprocess GIS scripts or recollect.
Panoramic Images* LCMS Pavement Images*	98%	Legible signs, images in focus, clean lens (free of dirt, debris and water). No more than 5 missing consecutive images.	Before deliverable submission	Recollect areas with bad/missing images.

*Only when required as deliverable

5. Data Quality Control Measures

Effective data quality control measures are performed so that accurate and complete pavement data is collected and processed in a repeatable manner. Table 7 outlines Michael Baker's standard quality control measures that are in place for each pavement data collection project. Appendix C (*Data Quality Activities Roles & Responsibilities Matrix*) contains a detailed list of quality activities that each key member of a project performs that relate to each quality control measure shown below.

Table 7. Quality Control Measures.

Quality Control Measures		
Pre-Production	**During Production**	**Post-Production**
• *Personnel Training & Certification* • *Define Quality Standards & Acceptance Criteria* • *Equipment Configuration & Calibration* • *Project Database Setup & Application Configuration* • *Mission Planning* • *Pre-Collection Test Runs*	• *Daily Log Sheet* • *Weather, Equipment & Road Conditions Report* • *Real-Time Data Checks* • *Real-Time Vehicle Tracking* • *Field Data Checker* • *XML Data Loader* • *Distress Rater Consistency Checks*	• *Post-Data Collection Processing* • *Network Data Spatial Validation* • *Global Database Checks* • *GPS Verification* • *LCMS QA/QC Tool* • *Panoramic Image QA/QC* • *Quality Management Reporting*

5.1. Pre-Production

➢ ***Personnel Training and Certification***

A foundational component of Michael Baker's data collection process is the adequate and comprehensive training and certification of field technicians.

<u>Field Technician Training & Certification</u>

All LCMS field technicians are required to complete an extensive week-long training program. This training includes classroom-style instruction, equipment demonstrations, and first-hand LCMS data collection and equipment setup/shutdown procedures. Field technicians will receive a copy of the *Guide for LiDAR and LCMS Van Manual* which describes the items and procedures listed below in detail. These items are explained in detail during training.

Table 8. LCMS Field Technician training topics.

Guide for LiDAR and LCMS Van Manual – Training Topics	
Topic	**Sample Details**
1. *Required Equipment*	Laptop / Power Supply MiFi / Charger iPad / Charger Field Notes SSD Drives and Spare Drives External Hard Drive
2. *Procedure for Base Station Setup/Breakdown*	Connecting hemisphere, power cable, battery
3. *Van Startup Process*	Uncover, setup, and clean cameras Secure DMI cables Describes order that equipment must be turned on Describes order that software must be turned on Describes configuration of software settings Formatting disks to prepare for collection Setting up location to save collected data to Acquiring GPS Satellites

	Perform 3 test runs before collection
4. *Data Collection*	Monitoring of GAMS Solution (GPS) Monitoring of LCMS images in real-time Tracking Progress in Collector Application on iPad Vehicle and Passenger Safety Monitoring Disk Space Completing Field Notes
5. *Changing Drives During Collection*	Perform 3 test runs before continuing collection
6. *Van Shutdown Process*	Obtain Fixed Integer GAMS solution Transfer logging files Describes order to shutdown software programs Power down equipment Remove DMI Cover and close camera
7. *Data Extracting*	LiDAR, Ladybug, CORS, SBET, LCMS, Profiler data transfer
8. *Boresight Calibration*	Calculate heading, pitch, roll, and lever arm adjustments to each individual sensor
9. *Troubleshooting*	Describes procedures if cameras images do not display or LiDAR lasers do not fire

In addition to the above knowledge included in the *Guide for LiDAR and LCMS Van Manual*, field technicians will also learn techniques to verify if the equipment is calibrated:

- *Verification of DMI*
- *Accelerometer "bounce" test*
- *Sensor "block test"*

Field technicians are also instructed on factors that may affect data quality (environmental, GPS, calibration, etc.), so acceptable collection conditions can be attained.

At the end of the week-long training, all field technicians must pass an internal written test and a practical test demonstrating their ability to startup and configure the van for collection, follow LCMS data collection protocols, shutdown equipment and transfer data, and perform DMI, bounce, and block calibration tests on both the LCMS and inertial profiler systems. If the field technician passes both the written and practical exam, he/she will receive LCMS Data Collection Certification by Michael Baker.

National Center for Asphalt Technology (NCAT) Certification

In addition to receiving LCMS Data Collection Certification internally, data collectors are also required to obtain internal profiler certification through the National Center for Asphalt Technology (NCAT) at Auburn University. This certification program is compliant with *ASSHTO R 56-14 – Standard Practice for Certification of Inertial Profiling Systems* and is considered the ultimate test of pavement profiling equipment. Completing this certification prior to data collection so there is a high level of confidence that the data is collected accurately and represents real world conditions.

Operators are required to renew their certification status every three (3) years, while the SSI internal profiling system is re-certified on an annual-basis. As part of the NCAT certification process users are required to:

- *Partake in a pavement profiling training course;*
- *Pass a written exam;*
- *Successfully perform the block test, bounce test and DMI calibration and*
- *Operate the internal profiler on various test sections and achieve repeatability and accuracy scores of 92% and 90% respectively.*

The certification process is completed in accordance with the Alabama Department of Transportation procedures *ALDOT 448-12 – Evaluating Pavement Profiles,* which can be found in Appendix D. Major component repairs and/or replacement to the inertial profiler also warrant recertification. This includes repairs or replacement of:

- *The accelerometer and/or associated hardware*
- *Laser height sensor and/or associated hardware*
- *DMI*
- *Any circuit of the inertial profiler's CPU*
- *Modification of software parameters and scale factors as required by the manufacturer that are foundational to the certification process*

➢ *Define Quality Standards & Acceptance Criteria*

It is Michael Baker's SOP to have established Data Quality Standards and Acceptance Criteria before the start of data collection project. If an agency does not have standards or acceptance criteria in place, Michael Baker will work with the agency to establish them. See Section 4 on Data Quality Standards and Acceptance Criteria for the NJDOT data collection project.

➢ *Equipment Configuration & Calibration*

Equipment configuration and calibration is performed before the start of a project, and at regular intervals during the project based on the data collection system. See Section 3 for specifics on Michael Baker's equipment calibration protocols.

➢ *Project Database Setup & Application Configuration*

Michael Baker has built and continuously refines post-processing methods and applications to process and deliver high-quality pavement condition data in a variety of standardized formats. Central to the project delivery system is an enterprise project database which is established for each project. The Project Manager works with a Database Administrator to define project parameters during the database configuration process at the onset of each new project. An existing database schema that contains tables, views, procedures, users, roles, etc. has been developed and designed to work with data outputted from the mobile data collection equipment. This database schema is replicated on each new project database which allows for consistent project delivery every data collection cycle

In addition to the establishment of a project database, the following tools and applications are configured for each project:

- ***LCMS Field Data Checker*** *– Application used in the field after data collection to validate raw field data collected by the LCMS system.*
- ***LCMS XML Loader*** *– Used to load processed LCMS data (in XML format) into the project database.*
- ***LCMS QA/QC Tool*** *– Used to verify types and quantities of distresses automatically detected by the LCMS system*
- ***GPS Loader*** *– Loads post-processed GPS data from the Applanix system into the project database.*

➢ *Mission Planning*

An important step in the pre-production activities is the field inventory mission planning conducted by the Field Crew Coordinator in conjunction with the Project Manager and the agency. This involves clearly defining the location, names, mileages, and inventory direction of all routes scoped for data collection. GIS Technicians define the routes in ESRI's Collector application before data collection begins. Michael Baker will also work with the agency in the mission planning effort to best align the inventory schedule with other planned pavement maintenance activities.

During data collection, the ESRI Collector application tracks the van's position on the ESRI Open Street Map, thus verifying that the operator is driving the intended route. The map also provides the operator with the ability to see the exact starting and ending positions of each route. The application allows users to track progress by marking off collected/completed routes, thus minimizing accidental recollection and tracking progress and percent of total mileage complete.

➢ ***Pre-Collection Test Runs***

Once the LCMS system is running, field technicians are required to do a minimum of three (3) sample collections to verify that adequate GPS acquisition and to check that the LCMS images are displaying with acceptable clarity and exposure. Once test runs are completed and pre-production quality control measures are documented, data collection for production may begin.

5.2.During Production

➢ ***Daily Log Sheet***

A Daily Log Sheet is provided to field technicians which is completed during each day's collection. It includes the date, collection vehicle, van startup time, personnel names, routes collected in consecutive order, special notes/circumstances for each route, potential risks to data quality/corrective actions, and shutdown time. If issues arise in post-processing the data, the user can refer to these field notes for additional information or guidance and determine if reprocessing or recollection is necessary.

➢ ***Weather, Equipment & Road Conditions Report***

To effectively perform accurate data collection that is representative of true pavement conditions at the time of inventory, air temperatures must be above 35°F and the roadway surface must be dry and ideally be free of debris. Our team will work with an agency to schedule data collection when roads are clear and generally free of salt and sand that may have been applied as part of a winter weather treatment program.

Field technicians will observe if conditions are suitable for collection. The LCMS van cannot be operated in freezing temperatures as the accuracy of data collection may be compromised. A vehicle safety inspection is conducted to verify that equipment is secured within and outside the vehicle (DMI attached securely, monitors secured, etc.) and that tire pressure is at appropriate levels. Weather conditions and results of the vehicle safety inspection are documented in the report.

➢ ***Real-Time Data Checks***

During field data collection, the System Operator checks that data collection systems are continuously recording valid data streams.

Table 9. Real-Time system checks with stop\pause conditions.

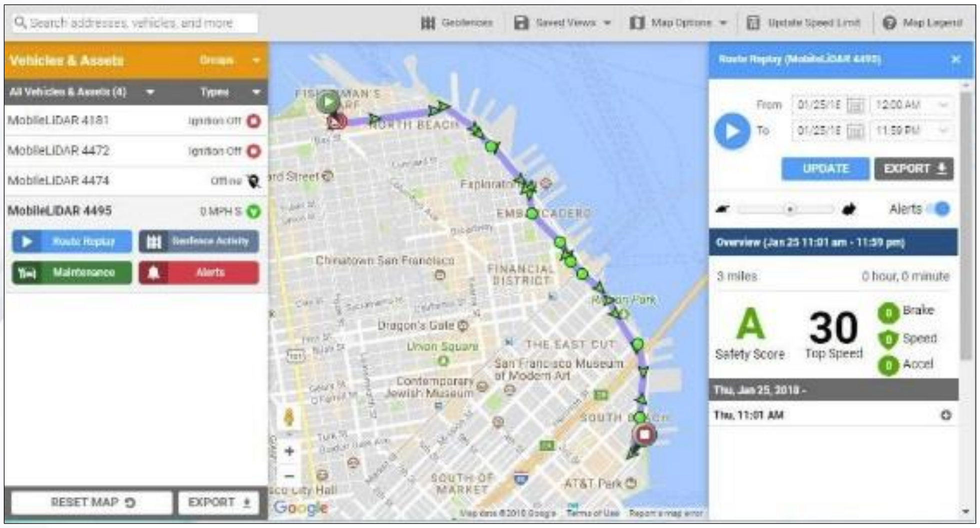
System	Checks	Stop \ Pause Collection Conditions
LCMS	• *Images are in focus, clear with minimal 'Out of Range' data.* • *Good GPS data stream*	• *> 30 second delay in images appearing on screen* • *5 consecutive bad images* • *GPS loss > 1 minute* • *Acquisition application or computer crash*
Profiler	• *Continuous live profiler data stream*	• *> 15 second delay of profiler data stream* • *Profiler application or computer crash*
Applanix	• *Good GPS data stream*	• *GPS signal loss > 1 minute* • *Applanix application or computer crash*
Imagery	• *Images are in focus, clear with good contrast and coloring*	• *> 30 second of bad image stream* • *Ladybug application or computer crash*

The Driver and System Operator should also monitor that the van is driven in the predefined lane of travel and make note of areas where construction, lane closures, or other interferences prevented collection in the selected lane. In addition, both field technicians are responsible for verifying that the van is driven as close to the center of the lane as possible to eliminate potential noise from rumble strips, debris on the side of the road, dropoffs, etc. These protocols help to obtain the most accurate and representative data is collected for the roadway section.

➢ *Real-Time Vehicle Tracking*

Michael Baker's designated field crew coordinator maintains daily contact with inventory crews to track progress and address issues that may arise. The mobile data collection vehicle is also equipped with tracking technology that allows the field coordinator to view the real-time location of crews and track route history which aides in monitoring productiveness.

Figure 6. Vehicle real-time tracking system.

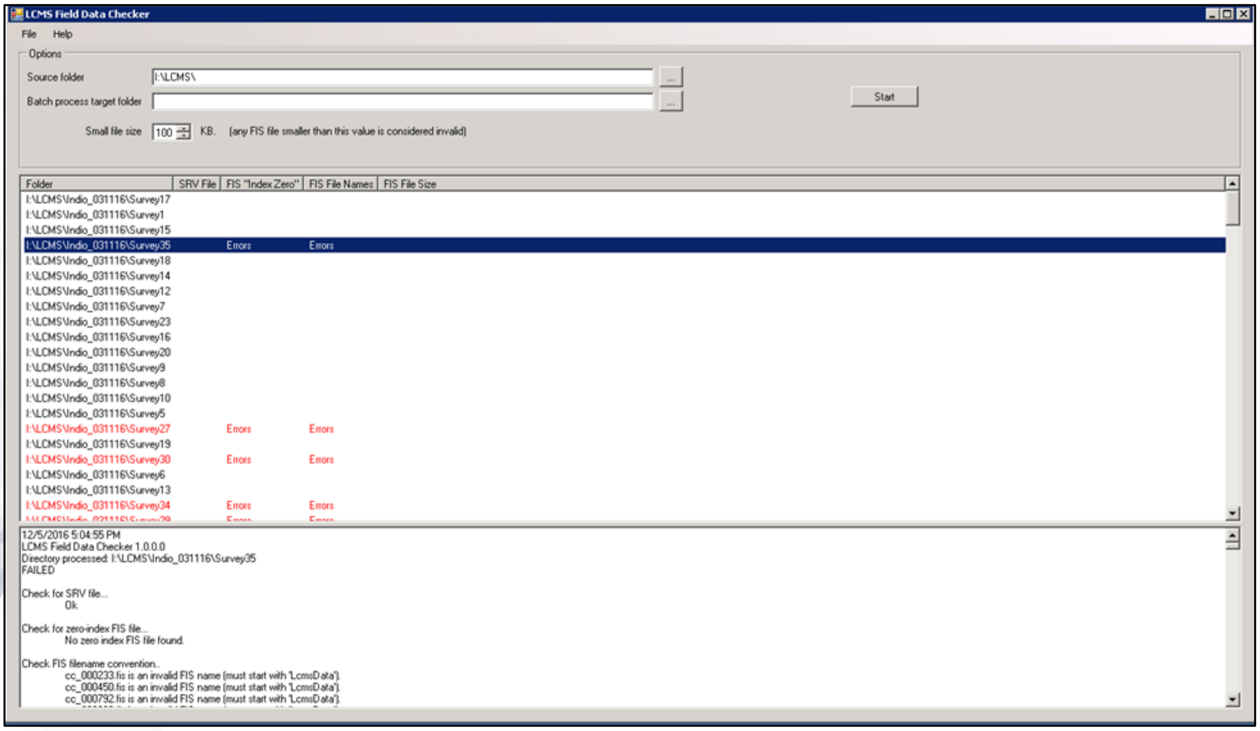


➢ *LCMS Field Data Checker*

After data collection is complete, field technicians run raw collected data through Michael Baker's custom-built LCMS Field Data Checker tool. This tool validates the integrity of the raw LCMS data and produces warnings and/or errors where discrepancies may exist. It should be noted that the Field Data Checker validates data conditions and not whether the data was collected acceptably or if the system operated correctly. However, data discrepancies can indicate that operational errors may have occurred and errors produced from this tool must be documented and evaluated. It is SOP that this tool be run after each day's collection before the system is shutdown. The LCMS Field Data Checker tool validates for the following:

- *Each folder must contain only 1 SRV file (more than 1 SRV file may indicate a collected data was overwritten)*
- *Correct FIS file naming convention - Prefix of "LcmsData_"*
- *Correct FIS file naming convention – Must have a 6-digit number following the prefix, such as "LcmsData_000123.fis"*
- *FIS files must be "zero-indexed." The first FIS file must be "LcmsData_000000.fis"*
- *FIS Files should be 3 – 5 MB in size and usually about 4 MB (FIS files significant less than this indicate possible drive-write errors and/or file corruption).*

Figure 7. LCMS Field Data Checker with error conditions in red.

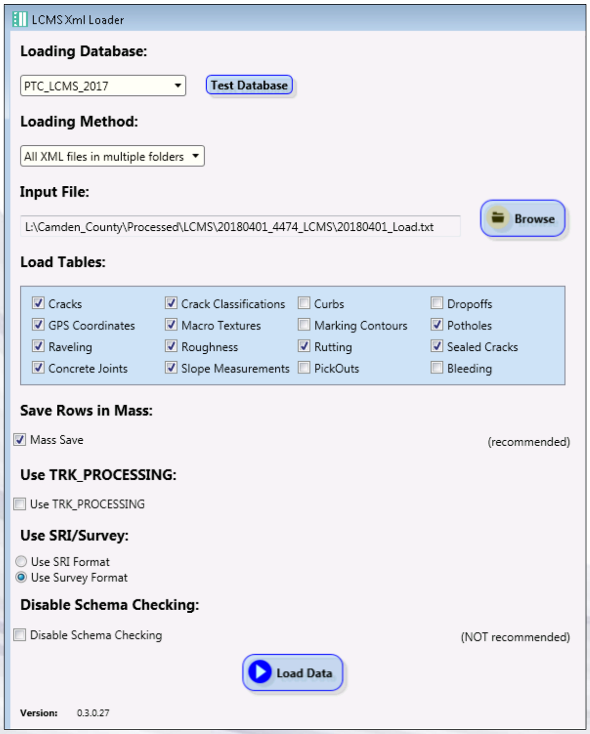


Field technicians complete and submit their Field Note logs to the Field Crew Coordinator at the end of each collection day and follow defined LCMS van shutdown protocol.

➢ ***LCMS XML Data Loader***

The LCMS XML Data Loader is another custom-built application that is used to load processed LCMS data (in XML format) to the enterprise project database. A key component of this application is the ability to check and verify the schema of the incoming processed data. Errors are triggered if the schema of the XML data does not match the defined schema of the target database.

Figure 8. LCMS XML Data Loader.



5.3. Post Production

- ***Post-Data Collection Processing***

After data collection is complete, field technicians upload raw field data to Michael Baker's secure data center daily or weekly, depending on the project scope. The data should be delivered and uploaded on schedule, so that if errors are identified, ample time exists to recollect and reprocess new data. Michael Baker's Pavement SME will process the collected data through proprietary LCMS RoadInspect software and apply the standard and appropriate configuration parameters. The Pavement SME may reprocess the data multiple times with different configurations to verify that distresses are correctly identified and classified. Once data processing is complete, the LCMS data is loaded through Michael Baker's custom-built XML Loader application to the project database.

- ***Network Data Spatial Validation***

Network-wide validation of the data is performed spatially with GIS, which is used to display GPS tracks that allows the reviewer to verify accurate and consistent spacing between FIS files (each FIS file represents one survey), verify lane location and drive path, identify FIS files with missing GPS information, identify routes not collected, and potentially locate other miscellaneous errors. Ground-truthing can also be performed by comparing markings/stripings in the aerial imagery with those displayed in the LCMS images, and it allows the reviewer to verify the reported pavement type matches the ground pavement type. This spatial review of the data helps verify that the GPS, DMI, and LCMS lasers functioned correctly, that the data matches real world conditions, and that the data collection crew drove the routes correctly.

- ***Global Database Checks***

A series of checks are completed on the compiled raw data in the project database. Within a Pavement Management Project Database, there are several key tables containing high-level data collection information, as well as detailed distress data. For the high-level data collection information, it is required that the LCMS Analysts run global database checks to verify formatting of key fields (date, time, file path, etc.), check for missing or null data in required fields (survey set, survey id, GPS, etc.), and verify that key fields have values within the expected ranges or domains.

Distress Specific Database Checks

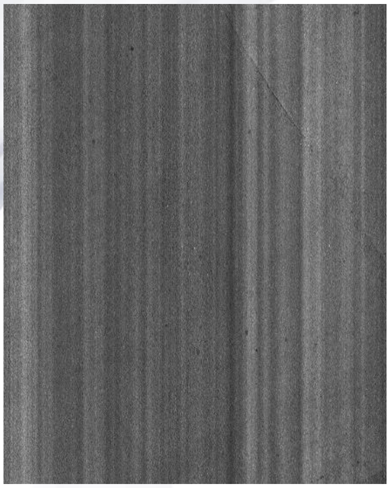
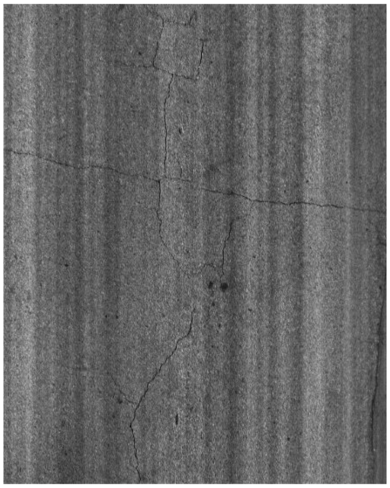
Review of the distress data (IRI, rutting, faulting, fatigue cracking, etc.) requires detailed analysis and section sampling. Due to the large quantity of raw distress data, this information is typically reviewed at an aggregate level by route and/or milepost sections (for example, tenth mile sections). The following measures are reviewed for each distress type through validation scripts:

- *Data exists for each road segment and milepost section*
    - *There should be ~20 FIS files for every 1/10th mile section*
- *Data is in the correct unit (mm, ft.) and rounded correctly*
- *Data is in the expected value range for the distress type*
    - *IRI should generally not have values of less than 30 or greater than 300*
    - *Distress rating for linear segments cannot be greater than segment length*
- *Null and negative distress values used appropriately*
- *Missing condition data*
- *Duplicate records*

- *Gaps in data*
- *Sudden changes in distress values, such as IRI or rutting values*
- *Distress type matches reported pavement type*

<u>Visual Verification of Distresses</u>

As standard protocol, the LCMS Analyst will select sample sections for each distress type and condition rating. They will verify that the data low points (good conditions), high points (poor conditions), and mid points (average conditions) correspond to the distresses displayed on the LCMS images. The LCMS Analyst will verify that the pavements sections marked as 'poor condition' visibly appear to be more deteriorated than those sections marked as in 'good condition.'


Low IRI *Medium IRI* *High IRI*

In addition, roadway sections containing distress values outside of the expected range require further analysis. For example, if a half mile section possesses an unusually high IRI compared to the adjacent sections, then further evaluation is required. The Pavement SME should query out the LCMS images for this section and review them to determine if the reported IRI values correspond with the assessed pavement quality. This assessment should be completed by the Pavement SME, as they will have the best judgement on whether distress values coincide with the LCMS image pavement quality. For example, the Pavement SME would verify that a high IRI value exists because the corresponding images show signs of deteriorated pavement. If no correlation is found between abnormal distress data values and the LCMS images, recollection or data reprocessing may be required. When necessary, Michael Baker will perform field verification of distress and condition ratings to verify the data is accurate.

<u>Compare Distress Values to Historical Data</u>

Distress data will be verified by comparing it with the previous year's data. The roadway names and sections can be joined to the previous year's collection data. The distress values can then be compared through a calculated percent change or difference and represented graphically comparing both years' data side by side. Sections where distress values have changed more than the defined threshold will be investigated. The reviewer will analyze the LCMS images, comparing both years, to determine if there are detectable pavement changes (resurfacing, new patching, etc.) that may contribute to changes in the reported distress values. If a significant data change cannot be explained, recollection or data reprocessing may be required.

The following table summarizes the quality control actions taken for major deliverables.

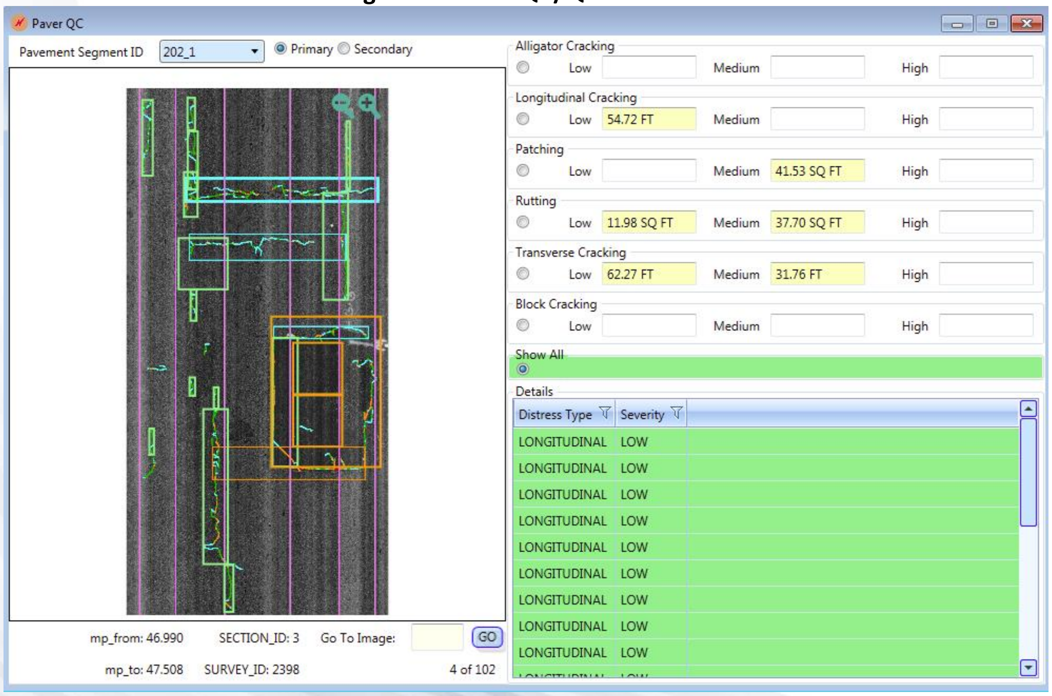
Table 20. Quality control activities.

Quality Control Activities			
Deliverable	**Quality Expectations**	**QC Activity**	**Frequency/Interval**
IRI Rut Depth Faulting Cracking Percent	95% Compliance with Standards	Initial equipment configuration, calibration, verification	Pre-collection
		Daily equipment checks and monitor real-time	Daily
		End of day data review and Field Data Checker	Daily
		Control, blind, or verification testing	Weekly
		Inspect uploaded data samples	Daily
		Inspect processed data	Daily
		Final data review	Prior to input into the PMS database

➢ ***LCMS QA/QC Tool***

The Michael Baker LCMS QA/QC Tool is used to verify the quantities and classification of distresses automatically detected by the LCMS RoadInspect software. The Quality Manager, Data Processing Manager and Pavement Engineer for the project work together to review a 2.5% sample of the network-level to verify that distress types, severities and extents are correctly being classified. If significant discrepancies are found, they can usually be corrected by adjusting LCMS RoadInspect application configuration parameters and reprocessing the raw field data.

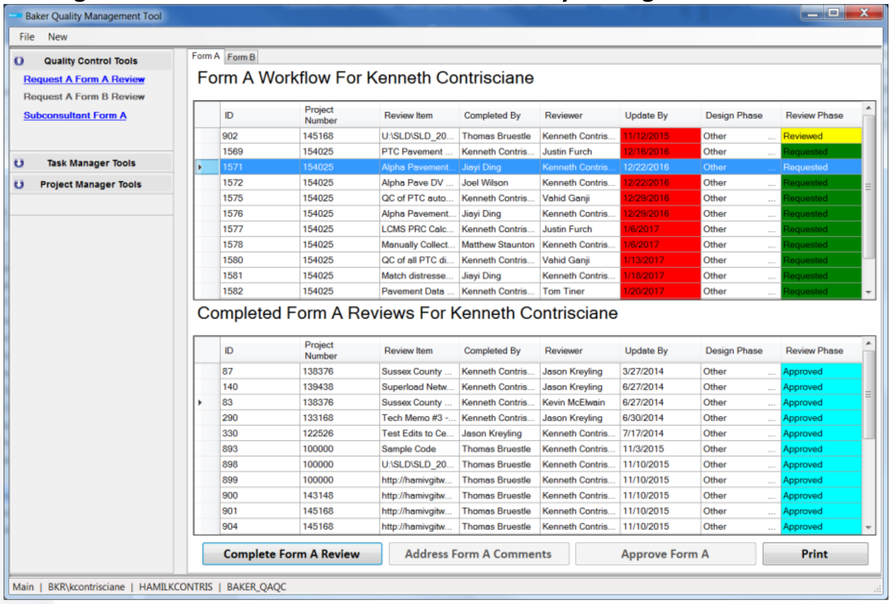
Figure 9. LCMS QA/QC Tool.



➢ *Quality Management Reporting*

Pavement quality control procedures in the LCMS data review will be documented as per Michael Baker International's regional Quality Assurance Plan (QAP). This office QAP describes office-wide planned processes and systematic actions, quality practices, and resources that are to be undertaken and which Michael Baker will follow to deliver quality data products. It requires that all client deliverables must be reviewed by the person executing the task, by a qualified colleague, the project manager, and all reviews must be documented in the office-wide Michael Baker Quality Management Application. Under this plan, a 'Form A' or 'Form B' must be completed to document that all required items were reviewed and corrective actions must be documented. This plan holds each party responsible for their part in quality control and serves as an archive of quality control measures completed for each project. These standard procedures are applied to all steps in the review of Pavement Management Projects.

Figure 10. Michael Baker International Quality Management Tool.



6. References

Pierce, L., McGovern, G., and Zimmerman, K. 2013. *Practical Guide for Quality Management of Pavement Condition Data Collection*. Report No. FHWA-HIF-14-006. Washington, D.C., U.S. Dept. of Transportation, Federal Highway Administration.

Alabama Department of Transportation (ALDOT), *ALDOT Procedures 448-12 Evaluating Pavement Profiles*. March 2015.

APPENDIX A
Off-State NHS Routes

Off-State NHS Routes			
Route	Start Milepost	End Milepost	Length
00000501__	0	3.36	3.36
00000501__	3.61	6.99	3.38
00000501__	23.73	37.21	13.48
00000501__	42.86	53.07	10.21
00000502__	7.23	23.79	16.56
00000503__	0	17.95	17.95
00000504__	8.96	15.83	6.87
00000505__	0.66	1.32	0.66
00000505__	1.93	20.64	18.71
00000506__	0	7.28	7.28
00000506S_	0	4.3	4.3
00000506SZ	0	0.29	0.29
00000507__	3.22	20.76	17.54
00000507__	21.35	28.34	6.99
00000508__	0	6.22	6.22
00000508__	6.58	11.53	4.95
00000508__	12.55	12.78	0.23
00000508S_	0	0.31	0.31
00000509__	0.21	0.25	0.04
00000509__	11.55	11.56	0.01
00000509__	22.35	25.78	3.43
00000509S_	0.93	2.98	2.05
00000509Z_	0	0.38	0.38
00000509Z_	2.61	2.87	0.26
00000510__	11.8	29.58	17.78
00000510Z_	0	1.21	1.21
00000511__	21.13	28.26	7.13
00000511A_	7.93	9.77	1.84
00000512__	31.34	32.96	1.62
00000513__	41.35	41.89	0.54
00000514__	24.35	24.59	0.24
00000514__	25.84	34.58	8.74
00000514__	34.67	34.91	0.24
00000516__	7.19	9.22	2.03
00000520__	14.86	16.81	1.95
00000524__	0	1.91	1.91
00000526__	31.73	35.56	3.83
00000527__	42.57	42.92	0.35
00000527__	47.08	51.58	4.5
00000527__	70.1	71.19	1.09
00000527__	76.48	78.17	1.69
00000527Z_	0	0.3	0.3
00000528__	30.25	34.94	4.69
00000529__	0.25	7.53	7.28
00000530__	0	14.28	14.28
00000531__	0.69	1.99	1.3
00000534__	0	0.4	0.4
00000534__	3.83	7.92	4.09
00000535__	14.96	25.84	10.88
00000536S_	0	1.54	1.54
00000537__	0.52	0.64	0.12
00000537__	27.46	28.44	0.98
00000537__	50.81	52.2	1.39

Off-State NHS Routes			
Route	Start Milepost	End Milepost	Length
00000537__	52.38	55.24	2.86
00000541__	16.34	23.84	7.5
00000543__	1.7	16.03	14.33
00000544__	0	1.84	1.84
00000544__	2.16	11.12	8.96
00000545__	6.59	6.94	0.35
00000545__	13.78	14.05	0.27
00000547__	0	0.81	0.81
00000547__	27.08	27.37	0.29
00000549__	1.19	12.35	11.16
00000549S2	1.45	4.09	2.64
00000551__	31.66	34.22	2.56
00000551__	34.22	34.57	0.35
00000553__	41.89	44.25	2.36
00000561__	36.33	43.28	6.95
00000561__	43.28	43.62	0.34
00000561__	43.62	44.9	1.28
00000561__	48.7	48.8	0.1
00000561__	50.42	50.95	0.53
00000563__	4.47	6.27	1.8
00000563__	7.14	13.74	6.6
00000571__	0	1.45	1.45
00000571__	36.51	40.87	4.36
00000571__	41.21	43.96	2.75
00000577__	0	1.43	1.43
00000577__	6.36	9.96	3.6
00000577Z_	0	0.37	0.37
00000585__	0	0.85	0.85
01000620__	0	0.21	0.21
01000629__	0	5.53	5.53
01000638__	0	3.91	3.91
01000692__	0	0.1	0.1
01000694__	0	0.09	0.09
01021017__	0.42	0.84	0.42
01021363__	0	0.12	0.12
01021364__	0.12	0.24	0.12
01021368__	0.12	1.12	1
01081204__	0	0.12	0.12
01151100__	5.51	7.45	1.94
01211145__	0	0.65	0.65
01221307__	0	1.63	1.63
02000039__	0.4	9.63	9.23
020000411_	5.86	6.05	0.19
02000049__	0	0.49	0.49
02000049__	4.06	4.64	0.58
02000049__	4.99	6.16	1.17
02000049__	6.27	7.54	1.27
02000049S_	0	0.3	0.3
02000059__	2	6.17	4.17
020000592_	0	0.51	0.51
02000068__	0	0.17	0.17
02000069__	0	0.3	0.3
02000070__	0	0.33	0.33

Off-State NHS Routes			
Route	Start Milepost	End Milepost	Length
02000070__	0.52	3.97	3.45
02000072__	0	2.05	2.05
02000077__	0	0.89	0.89
020000801_	0	1.69	1.69
020000801_	1.79	6.48	4.69
02000081__	5.01	5.1	0.09
02000081__	5.1	5.34	0.24
02000084__	2.48	2.84	0.36
02000084__	4.43	7.86	3.43
02000087__	4.05	7.27	3.22
02000087__	7.27	7.85	0.58
02000087S_	0	0.57	0.57
02000094__	0	2.44	2.44
02000096__	0	3.12	3.12
020001101_	3.83	4.68	0.85
020001242_	0.23	0.55	0.32
02000s68__	0	0.14	0.14
02000S81__	0	0.42	0.42
02000S89__	1	1.28	0.28
02031258__	2.54	2.55	0.01
02151042__	0	0.07	0.07
02151676__	0	0.18	0.18
02151677__	0.13	2.3	2.17
02191168__	0.39	0.47	0.08
02201305__	0	0.15	0.15
02321149__	0	1.61	1.61
02481229__	0	0.15	0.15
02521125__	0	0.07	0.07
02611255__	0	0.14	0.14
03000626__	1.83	9.01	7.18
03000632__	0	0.63	0.63
03000680__	0	2.51	2.51
04000603__	0	0.62	0.62
04000603__	2.3	2.41	0.11
04000605__	0	1.43	1.43
04000606__	0	0.18	0.18
04000611__	1.11	1.36	0.25
04000623__	0.32	0.55	0.23
04000631__	0	0.68	0.68
04000633__	0	0.85	0.85
04000635__	1.6	2.73	1.13
04000636__	0	2.83	2.83
04000644__	0	6.46	6.46
04000667__	1.2	1.56	0.36
04000670__	2.84	3.16	0.32
04000686__	0	0.54	0.54
04000689__	0	6.93	6.93
04081537__	0	0.21	0.21
04081551__	0.2	0.74	0.54
04081580__	0.09	0.71	0.62
04081585__	0.14	0.28	0.14
04081587__	0.51	0.57	0.06
04081630__	0	1.05	1.05

Off-State NHS Routes			
Route	Start Milepost	End Milepost	Length
05000601__	0	0.53	0.53
05000621__	5.3	7.79	2.49
05000623__	0.28	2.33	2.05
05081275__	0	2.67	2.67
05081277__	0	0.38	0.38
07000603__	0	3.72	3.72
07000609__	0	4.12	4.12
07000613__	2.64	6.06	3.42
07000630__	0	1.17	1.17
07000636__	1.86	4.88	3.02
07000638__	0	0.86	0.86
07000649__	0	5.3	5.3
07000658__	0	3.88	3.88
07000659__	0	0.7	0.7
07000660__	0	0.66	0.66
07000677__	0	1.02	1.02
07111073__	0.79	0.93	0.14
07111127__	0.35	0.54	0.19
07111787__	3.61	4.06	0.45
07111792__	0.58	0.86	0.28
07141814__	0	1.46	1.46
07141819__	0	1.34	1.34
07141820__	0.04	2.78	2.74
07141821__	0	0.6	0.6
07141822__	0	0.57	0.57
07141844__	0	2.13	2.13
07141846__	0	1.11	1.11
07141865__	0	2.38	2.38
07141867__	0	0.33	0.33
07141868__	0	1.98	1.98
07171203__	0	4.1	4.1
08000640__	0.45	1.24	0.79
08000689__	0	5.47	5.47
08221113__	0	2.51	2.51
09000653__	0	3.01	3.01
09000659__	0	1.82	1.82
09000678__	0.48	1.74	1.26
09000681__	0	0.48	0.48
09000681__	3.79	5.31	1.52
09000697__	0.12	0.91	0.79
09011547__	0	0.2	0.2
09061546__	0	0.95	0.95
09061561__	0.77	0.91	0.14
09061562__	0	0.2	0.2
09061564__	0	0.55	0.55
09061699__	1.08	1.58	0.5
09061706__	0.33	0.53	0.2
09061709__	0.44	0.6	0.16
09061722__	0.15	0.62	0.47
09061726__	0	0.44	0.44
09061728__	0.41	0.6	0.19
09111120__	0	0.42	0.42
09111121__	0.61	0.92	0.31

Off-State NHS Routes			
Route	Start Milepost	End Milepost	Length
09121076__	0	0.83	0.83
11000672__	1.97	2.17	0.2
11031969__	3.41	3.55	0.14
11111422__	0	0.09	0.09
11111526__	0	0.66	0.66
11131008__	0	0.21	0.21
11131424__	0.37	1.35	0.98
12000604__	1.81	3.74	1.93
12000604__	3.74	5.4	1.66
12000604__	5.44	6.32	0.88
12000607__	0	0.07	0.07
12000609__	0	0.8	0.8
12000609__	1.69	3.44	1.75
12000617__	0.22	6.58	6.36
12000622__	0	1.62	1.62
12000622__	1.87	6.97	5.1
12000622__	7.04	7.44	0.4
12000649__	0	0.53	0.53
120006573_	0.65	0.96	0.31
120006651_	0	1.32	1.32
12041282__	0.25	0.52	0.27
12101193__	0	0.18	0.18
12102054__	0.68	2.27	1.59
12141066__	0	0.47	0.47
12141070__	0	0.24	0.24
12141231__	0	0.1	0.1
12251948__	0	0.21	0.21
130000042_	7.4	8.03	0.63
13000008__	0	0.43	0.43
13000008__	2.91	3.25	0.34
13000013__	1.92	3.06	1.14
13000013A_	2.64	3.76	1.12
13000050__	6.27	6.79	0.52
13000055__	0	1.1	1.1
13041034__	0	0.24	0.24
13161208__	0	0.07	0.07
13161330__	1.31	1.63	0.32
13171049__	0.45	0.67	0.22
13312101__	0	0.59	0.59
13312101__	0.79	1.66	0.87
13312102__	1.87	2.23	0.36
13312102__	2.34	3.22	0.88
14000623__	0	2.34	2.34
14000630__	0	0.51	0.51
14000654__	0.62	0.66	0.04
14000665__	0	1.1	1.1
14000694__	0	0.22	0.22
14041173__	1.63	1.78	0.15
14171001__	0	0.09	0.09
14171002__	0.61	0.73	0.12
14171177__	0	0.11	0.11
14221332__	0.45	1.07	0.62
14241160__	0	0.33	0.33

Off-State NHS Routes			
Route	Start Milepost	End Milepost	Length
14241165__	0	0.31	0.31
15000623__	0	8.71	8.71
15000631__	3.12	3.51	0.39
15000632__	0	1.76	1.76
15000632__	2.52	3.5	0.98
15000635__	2.05	2.36	0.31
15062138__	0	0.37	0.37
15250010__	0.18	0.4	0.22
15250016__	0	1.03	1.03
16000601__	0.28	6.64	6.36
16000621__	0.99	3.49	2.5
16000640__	0.79	2.25	1.46
16000646__	1.46	4.18	2.72
16000649__	0	3.07	3.07
16000659__	0	2.62	2.62
16000673__	0	2.44	2.44
16000681__	0	3.22	3.22
16000689__	0	2	2
16000689__	2.79	3.85	1.06
16000697__	0	3.54	3.54
16000709__	0	0.26	0.26
16081233__	0	0.05	0.05
16081447__	0.24	2.12	1.88
16081455__	0	1.38	1.38
16081467__	0	0.09	0.09
16081508__	0	0.04	0.04
16141702__	0	1.25	1.25
18000617__	1.86	1.91	0.05
20000608__	0.53	1.29	0.76
20000613__	0	1.53	1.53
20000613__	1.57	1.9	0.33
20000613__	1.9	4.46	2.56
20000623__	0	1.4	1.4
20000624__	0.66	2.51	1.85
20000630__	0.17	0.72	0.55
20000638__	0.32	0.55	0.23
20000655__	3.42	4.82	1.4
20041015__	0	0.97	0.97
20041150__	0	0.09	0.09
200413861_	0.18	0.29	0.11
200413862_	1.73	2.06	0.33
200413892_	0	1.47	1.47
200413893_	0	0.55	0.55
20041394__	0	0.27	0.27
20041427__	0.09	0.16	0.07
21000678__	0	0.92	0.92
21191211__	0	0.64	0.64
		Total Mileage	**629.59**

APPENDIX B
NCAT Certification Documentation

Certificate of Completion

Vahid Ganji, Michael Baker International, Inc.

This is to certify that the person named above has successfully completed the

Operator Certification for Inertial Profilers

By NCAT at Auburn University

March 6, 2018

Profiler	Ames Engineering - Model 8300			
	Rough DGA	Medium-Smooth DGA	Smooth DGA	OGFC (≤5%)
Repeatability (≥92%)	99%	99%	99%	1%
Accuracy (≥90%)	97%	95%	96%	

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

Jason Nelson, Training Coordinator
National Center for Asphalt Technology

ALABAMA DEPARTMENT OF TRANSPORTATION

Certificate of Completion

Clark Jackson, Michael Baker International, Inc.

This is to certify that the person named above has successfully completed the

Operator Certification for Inertial Profilers

By NCAT at Auburn University

March 6, 2018

Profiler	Ames Engineering – Model 8300			
	Rough DGA	Medium-Smooth DGA	Smooth DGA	OGFC (≤5%)
Repeatability (≥92%)	99%	98%	99%	2%
Accuracy (≥90%)	96%	93%	93 %	

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

Jason Nelson, Training Coordinator
National Center for Asphalt Technology

ALABAMA DEPARTMENT OF TRANSPORTATION

Certificate of Completion

Jack King, Michael Baker International, Inc.

This is to certify that the person named above has successfully completed the

Operator Certification for Inertial Profilers

By NCAT at Auburn University

March 6, 2018

Profiler	Ames Engineering - Model 8300			
	Rough DGA	Medium-Smooth DGA	Smooth DGA	OGFC (≤5%)
Repeatability (≥92%)	99%	98%	99%	2%
Accuracy (≥90%)	96%	93%	93 %	

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

Jason Nelson, Training Coordinator
National Center for Asphalt Technology

ALABAMA Department of Transportation

Certificate of Completion

Kenneth Contrisciane, Michael Baker International, Inc.

This is to certify that the person named above has successfully completed the

Operator Certification for Inertial Profilers

By NCAT at Auburn University

March 6, 2018

Profiler	Ames Engineering - Model 8300			
	Rough DGA	Medium-Smooth DGA	Smooth DGA	OGFC (≤5%)
Repeatability (≥92%)	99%	99%	99%	1%
Accuracy (≥90%)	97%	95%	96%	

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

Jason Nelson, Training Coordinator
National Center for Asphalt Technology

ALABAMA DEPARTMENT OF TRANSPORTATION

APPENDIX C
Data Quality Activity Roles & Responsibilities Matrix

Data Quality Activity Roles & Responsibilities Matrix

Activity	Project Manager (PM)	Quality Manager (QM)	Field Crew Coordinator (FCC)	Fleet Manager (FM)	Field Crew (FC)	Data Processing Manager (DPM)	Pavement Engineer (PE)
General Roles & Responsibilities	• *Verify that scoped project work is complete on-time and on-budget.* • *Develop work plans for assigned tasks.* • *Client communication.*	• *Assist PM in assuring that all deliverables meet established data quality standards & acceptance criteria.*	• *Provide oversight and training of FC.* • *Monitor FC daily production and handle data collection issues.*	• *Provide oversight of all equipment and vehicle maintenance activities.* • *Verify that vehicle and equipment is maintained in a state of good repair.*	• *Perform field data collection.*	• *Provide oversight of incoming raw field data through processed final deliverables.*	• *Serve as Technical Advisor and SME through the project.*
Personnel Training & Certification	• *Verify that assigned staff & equipment have certification at project onset.*	• *Verify that assigned staff & equipment maintain certification throughout project.* • *Conduct Distress Rater certification program, training and testing & related documentation.*	• *FC training and documentation.*	• *Verify that assigned staff & equipment maintain certification throughout project.* • *Verify that profiler meets and maintains Class 1 status.*	• *Achieve and maintain NCAT certification status.*	• *Assist QM with Distress Rating training and certification.*	• *Assist QM with Distress Rating training and certification.*
Define Quality Standard & Acceptance Criteria	• *Verify that data quality standards & acceptance criteria are well defined & documented before project onset.*	• *Communicate data quality standards & acceptance criteria to staff.* • *Verify that quality standards and acceptance is achieved on all final deliverables.*	• *Awareness of data quality standards & acceptance criteria.*	• *Awareness of data quality standards & acceptance criteria.*	• *Awareness of data quality standards & acceptance criteria.*	• *Awareness of data quality standards & acceptance criteria.*	• *Awareness of data quality standards & acceptance criteria.*
Equipment Configuration & Calibration		• *Assuring equipment calibration process is documented.*	• *Training Field Crew on equipment calibration process*	• *Verify that equipment meets and maintains Class 1 status.*	• *Performing equipment calibration per documented standards.*		• *Aid in calibration training if necessary.*
Project Database Setup & Application Configuration	• *Work with DPM and PE to defined project parameters.*	• *Verify that project and application parameters have been documented.*				• *Establish project database & parameters with PM and PE in conjunction with a database administrator.*	• *Assist PM & DPM in establishing project parameters.*
Mission Planning	• *Work with FCC to develop mission plan.*	• *Verify mission plan is documented.*	• *Develop mission plan and engage FC.* • *Verify that mission plan is being carried out during production*	• *Awareness of mission plan.*	• *Execute mission plan and notify FCC of issues in field, data collection problems or deviations of mission plan*		

Data Quality Activity Roles & Responsibilities Matrix

Activity	Project Manager (PM)	Quality Manager (QM)	Field Crew Coordinator (FCC)	Fleet Manager (FM)	Field Crew (FC)	Data Processing Manager (DPM)	Pavement Engineer (PE)
Pre-Collection Test Runs	• *Verify that test run results meet project quality standards & acceptance criteria.*	• *Verify that test run results meet project quality standards & acceptance criteria.*	• *Work with FC to conduct test runs*		• *Perform test runs in field.*	• *Oversee processing of test run data.*	• *Aid in test runs if needed.*
Daily Log Sheet	• *Verify that Daily Log template is established for project.*	• *Perform periodic checks of Daily Logs for completeness*	• *Establish project Daily Log and Verify FC is submitting each inventory day.* • *Review Daily Log*		• *Complete Daily Log each day and submit to FCC.*	• *Review Daily Log as necessary as part of data review process.*	
Weather, Equipment & Road (WER) Conditions Report	• *Verify that WER report template is established for project.*	• *Perform periodic checks of WER report for completeness*	• *Establish WER report and Verify FC is submitting each inventory day.* • *Review WER report.*		• *Complete WER report each day and submit to FCC.*	• *Review WER report as necessary as part of data review process.*	
Real-Time Data Checks	• *Approve issue resolution resulting from real-time data check issues.*	• *Verify issues with real-time data checks are resolved.*	• *Keep daily communication with all FC. Report issues related to equipment immediately to PM, QC & FM.*	• *Resolve equipment problems in conjunction with FCC & FC.*	• *Perform real-time data checks and document & report issues immediately to FCC*		
Real-Time Vehicle Tracking			• *Utilize Real-Time Tracking software to keep track of crew location.*	• *Maintain Real-Time Tracking software & hardware.*			
Field Data Checker	• *Approve issue resolution resulting from Field Data Checker.*	• *Verify issues with Field Data Checker are resolved.*	• *Verify that crew is running Field Data Checker. Inform DPM of potential issues.*		• *Run Field Data Checker each inventory day and provide data logs to FCC.*	• *Oversee application design and updates.* • *Review Field Data Checker logs and identify recollect conditions.*	
XML Data Loader	• *Approve issue resolution resulting from XML Data Loader.*	• *Verify issues with XML Data Loader are resolved.*				• *Oversee application design and updates.* • *Run XML Data Loader and resolved issues. Log & report issues to QM.*	

Data Quality Activity Roles & Responsibilities Matrix

<u>Activity</u>	Project Manager (PM)	Quality Manager (QM)	Field Crew Coordinator (FCC)	Fleet Manager (FM)	Field Crew (FC)	Data Processing Manager (DPM)	Pavement Engineer (PE)
Distress Rater Consistency Checks	• *Approve issue resolution resulting from distress rater consistency check.*	• *Conduct distress rater consistency checks with PE.* • *Document consistency check and review with DR.*					• *Aid the QM with the distress rater consistency check.*
Post-Data Collection Processing	• *Approve issue resolution resulting from post-data collection processing.*	• *Verify issues with post-data collection processing are documented and resolved.*				• *Oversees all post-production activities.*	
Network Data Spatial Validation	• *Approve issue resolution resulting from network data spatial validation.*	• *Verify issues with network data spatial validation are resolved.*				• *Oversee network data spatial validation process*	
Global Data Checks	• *Approve issue resolution resulting from global data checks.*	• *Verify issues with global data checks are resolved.*				• *Oversee global data checking process*	
GPS Verification	• *Approve issue resolution resulting from GPS verification.*	• *Verify issues with GPS verification process are resolved.*				• *Oversee GPS verification process.*	
LCMS QA/QC Tool	• *Approve issues resolution resulting from LCMS QA/QC Tool process.*	• *Verify sampling, documentation and issues are resolved.*				• *Oversee LCMS QA/QC Tool checking.*	• *Support DPM in LCMS AQ/QC Tool checking process.*
Panoramic Image QA/QC	• *Approve issues resolution resulting from Panoramic Image QA/QC process.*	• *Verify sampling, documentation and issues are resolved.*				• *Oversee Panoramic Image QA/QC process.*	
Quality Management Reporting	• *Approve Quality Management Plan.* • *Project point person for Quality Audits conducted by third-party.*	• *Create Quality Management and share with project team upon PM approval.* • *Verify that all Quality Management activities*	• *Document all role appropriate project related QA/QC activities using Baker Quality Management Tool.*	• *Document all role appropriate project related QA/QC activities using Baker Quality Management Tool.*	• *Document all role appropriate project related QA/QC activities using Baker Quality Management Tool.*	• *Document all role appropriate project related QA/QC activities using Baker Quality Management Tool.*	• *Document all role appropriate project related QA/QC activities using Baker Quality Management Tool.*

Data Quality Activity Roles & Responsibilities Matrix

<u>Activity</u>	Project Manager (PM)	Quality Manager (QM)	Field Crew Coordinator (FCC)	Fleet Manager (FM)	Field Crew (FC)	Data Processing Manager (DPM)	Pavement Engineer (PE)
		have been conducted and documented. • *Support PM with Quality Audits.*					

APPENDIX D
ALDOT 448-12 – Evaluating Pavement Profiles

ALDOT-448-12
EVALUATING PAVEMENT PROFILES

1. Scope

1.1. This procedure covers the certification requirements and the use of a roadway surface inertial profiler for ride quality measurement for both quality control (QC) and quality assurance (QA) construction testing.

2. Referenced Documents

2.1. *AASHTO Standards*:

2.1.1. R 56, Standard Practice for Certification of Inertial Profiling Systems

3. Inertial Profiler

3.1. *Housing vehicle*, capable of traveling at consistent speeds while collecting pavement profile data.

3.2. *Distance measuring subsystem*, accurate to within 0.15 percent of the actual distance traveled.

3.3. *Inertial referencing subsystem*, capable of measuring the movement of the housing vehicle as it traverses the pavement under test.

3.4. *Non-contact height measurement subsystem*, capable of measuring the height from the mounted sensor face to the surface of the pavement under test.

3.5. Intergrated System

3.5.1. Shall include hardware and software capable of producing and storing inertial profiles by combining the data from the inertial referencing subsystem, the distance measurement subsystem, and height measurement subsystem.

3.5.2. Shall have the capability of measuring and storing profile elevations at intervals sufficiently frequent to meet the requirements of Section 4.

3.5.3. Shall have the capability of summarizing (computing) the profile elevation data into summary roughness statistics over a section length equal to 0.1 mile. The International Roughness Index (IRI) for each longitudinal path profiled is the summary roughness statistic prescribed in this procedure.

3.5.4. Shall have design to allow field verification for the distance measurement (longitudinal) subsystem and the height measurement (vertical) subsystem described in Section 6.

3.5.5. Shall be certified for use as described in Section 4.

3.5.6. Air pressure in the tires of the housing vehicle will fall within the vehicle manufacturer's recommendation. 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.

4. Inertial Profiler Certification

4.1. This section provides minimum certification requirements for inertial profilers used for quality control for acceptance testing of surface smoothness on Department paving projects where the profile-based smoothness specification is applicable.

4.2. The certification process covers test equipment that measures longitudinal surface profile based on an inertial reference system mounted on a housing vehicle. The intent of minimum requirements stipulated herein is to address the need for accurate, precise, uniform, and comparable profile measurements during construction.

4.3. Minimum Requirements:

4.3.1. Operating Parameters:

4.3.1.1. The inertial profiler shall be capable of reporting relative profile elevations less than or equal to 4 inches that have been filtered with an algorithm that uses a cutoff wavelength of no less than 200 ft and no more than 300 ft.

4.3.1.2. The inertial profiler shall also be able to calculate and report the IRI (in inches/mile) from the corresponding measured profile, where the operator is permitted to automatically trigger the start and stop of data collection at the designated locations. Measured profiles shall be provided in electronic text files suitable for importing into the latest version of Profile Viewing and Analysis (ProVAL) Software as described in Section 9.

4.3.1.3. The inertial profiler shall also be verifiable for measurements in height and distance as described herein.

4.3.2. Equipment Certification:

4.3.2.1. Equipment certification involves using the inertial profiler to collect profile data on test sections designated by the Department for this purpose at the NCAT Pavement Test Track. NCAT certification personnel will administer this program. Before equipment certification, as a recommendation, the inertial profiler owner should verify the longitudinal and vertical calibration of his or her equipment following manufacturer's recommendations. This recommended verification should be conducted at the owner's facility prior to the scheduled date of certification testing.

4.3.2.2. On an annual basis, the inertial profiler shall undergo certification tests at the NCAT Pavement Test Track to establish that it complies with the minimum requirements for accuracy and repeatability set forth in this test method. At that time, the proficiency of certified operators will also be demonstrated as required in Section 5. An inertial profiler shall also undergo certification testing after undergoing major component repairs or replacements as identified in Section 7.

4.3.2.3. For certification, the inertial profiler's distance measurement subsystem shall be accurate to within 0.15 percent of the actual distance traveled.

4.3.2.4. Certification tests will be run on the swept inside lane of the NCAT Pavement Test Track on designated dense mix test sections with smooth, medium-smooth, and rough surface profiles, and on a designated open-graded mix test section with a smooth surface profile. Each section will be 528 ft in length with 300 ft of lead-in distance. Ten repeat runs shall be made of the inertial profiler with data produced for both test wheel paths in the prescribed direction of measurement. Inertial profilers will be evaluated by comparing results to those generated by the reference SurPRO profiler. The inertial profiler owner shall provide data to NCAT certification personnel that is suitable for importing into the latest version of ProVAL.

4.3.2.5. NCAT certification personnel will use the latest version of ProVAL to evaluate the repeatability of the owner's data and compare the accuracy of results generated by the owner's data to results generated by the reference SurPRO profiler. Performance will be differentiated between dense and open graded mixes. In order to earn certification for dense graded mixes, ProVAL generated values for accuracy and repeatability cannot exceed those values specified in AASHTO R 56. In order to earn certification for open graded mixes, a profiler shall have passed certification for dense graded mixes and shall also produce average IRIs within 5% of the SurPRO average in each wheelpath on the smooth OGFC section.

4.3.2.6. NCAT will report the results of the certification tests to include the following information:

- Make and manufacturer of inertial profiler tested.
- Unique hardware serial number of inertial profiler tested.
- Version number of software used to generate ProVAL import file.
- Operator of the profiler tested.
- Names of the NCAT certification personnel responsible for the evaluation.
- Date of data collection.
- Overall outcome of the testing process (i.e., pass or fail). A separate certification will be provided for dense and open-graded pavement

surfaces. It will be possible to pass on dense surfaces but fail on open-graded surfaces.

- The ProVAL report that shows the accuracy and repeatability of the tested inertial profiler on each of the four certification pavement surfaces.

4.3.2.7. A decal will be placed on the inertial profiler by NCAT certification personnel following successful certification. Separate decals will be used to designate acceptability for use on dense and open-graded pavement surfaces. Each decal will show the month and year of certification and the month and year the certification expires.

5. Operator Certification

5.1. Operators of inertial profilers used for testing of pavement ride quality shall pass a proficiency test and be certified to operate an inertial profiler in Alabama. NCAT certification personnel at the NCAT Pavement Test Track will administer the test for the Department. The test for the applicants for certification will include knowledge of Department's smoothness specifications, this ALDOT Procedure, verification of inertial profiler calibration, and collection of certification profile data.

5.2. To qualify as a certified inertial profiler operator in Alabama, the applicant shall pass the written examination with a score of 70 percent or higher, pass the practical examination for verification of inertial profiler calibration, and pass the practical examination for profile measurements. All practical examinations shall be demonstrated using the inertial profiler provided by the applicant.

5.3. The applicant shall demonstrate that he/she can perform the longitudinal and vertical verifications described under Sections 6.2, 6.3 and 6.4. Additionally, the applicant shall perform profile measurements along a given route established by NCAT. The route will be at least 2,500 ft long, with designated 0.1 mile test sections and "leave-out" segment(s). The applicant shall profile the designated wheel paths of the test route in the specified direction following the procedures given in this test method. The applicant shall provide the test data in electronic files suitable for importing into the most recent version of ProVAL. For the practical examination, the applicant's performance is evaluated as passing or failing.

5.4. Upon passing the written examination and proficiency test, the NCAT certification personnel will give the successful applicant an identification card, which will verify the certification to operate an inertial profiler for testing on Department paving projects. The card will identify the specific types or brands of inertial profilers for which the operator certification is valid. This card will also specify the expiration date of the operator certification. The Department has the authority to revoke the card and operator certification at any time because of misuse.

5.5. Recertification of the operator will require successful completion of another proficiency test as described in this section for initial operator certification. Proficiency of certified operators shall be demonstrated at the time of each inertial profiler's annual recertification. A new written examination for certifying operators shall be required every three years.

6. Verifying Calibration and Consistency

6.1. A longitudinal and vertical verification procedure shall be performed at least once before an inertial profiler is used for either QA or QC testing on a project. Although the specific steps to complete the verifications will vary in accordance with the manufacturer's recommendations, the basic procedures will not change. The results of all longitudinal and vertical verification checks shall be documented in a profiler log. The profiler log shall be a collection of the required equipment and operator certifications and BMT forms (BMT 202 through 207) found in the ALDOT Testing Manual. The Engineer will review the profiler log prior to use on the project.

6.2. Longitudinal verification

6.2.1. The longitudinal verification standard will be a straight roadway test section at least 528 ft in length. This distance shall be measured accurately to within 0.15 percent using a steel measurement tape or electronic measuring device. An analog measuring wheel or roll-a-tape is not sufficient for accurate measurement and will not be allowed. The inertial profiler owner shall establish the longitudinal verification standard and notify the Engineer prior to the first time the longitudinal verification is performed.

6.2.2. Air pressure on the tires of the housing vehicle shall be checked and maintained according to the manufacturer's recommendations and documented in the profiler log.

6.2.3. Perform the longitudinal verification by navigating the inertial profiler over a measured test section at least 528 ft in length.

6.2.4. If the inertial profiler's distance measuring subsystem measures the length of the test section to within 0.15 percent of its actual length, no additional verification is necessary.

6.2.5. If the inertial profiler's distance measuring subsystem fails to measure the length of the test section to within 0.15 percent of its actual length, the calibration shall be adjusted according to the manufacturer's guidelines and the longitudinal verification repeated.

6.2.6. The results of the longitudinal verification shall be documented on BMT 203 "Inertial Profiler Calibration Log."

6.3. Vertical verification - Block Test

6.3.1. The vertical verification standard will be flat plates or blocks of known thicknesses and low thermal expansion. As a minimum, two uniform base plates and three 1-in. measurement plates will be needed. Alternatively, a precisely machined block that provides all the required heights is acceptable. The actual thickness of the three measurement plates shall be measured to within 0.001 in. All vertical calibration plates shall be provided and maintained by the inertial profiler owner. The thicknesses will be certified by the NCAT certification personnel at the time of annual certification.

6.3.2. The vertical verification shall be performed on a flat and level area using a base plate and three flat 1-in. measurement plates. It is acceptable to perform the test indoors, which may be necessary when windy conditions exist.

6.3.3. Place a uniform base plate under the inertial profiler’s non-contact height sensor. The inertial profiler’s height measurement subsystem shall use this as the reference height for the first set of measurements.

6.3.4. Place the first 1-in. measurement plate on top of the uniform base plate below the non-contact sensor. The inertial profiler’s height measurement subsystem shall measure this displacement to within 0.01 in. of the 1-in. plate’s actual measured thickness.

6.3.5. Place the second 1-in. measurement plate on top of the two existing plates below the non-contact sensor. The inertial profiler’s height measurement subsystem shall measure this displacement to within 0.01 in. of the 2-in. total thickness of the two measurement plates.

6.3.6. Place the third 1-in. measurement plate on top of the two existing plates below the non-contact sensor. The inertial profiler’s height measurement subsystem shall measure this displacement to within 0.01 in. of the 3-in. total measured thickness of the three measurement plates.

6.3.7. Remove the three measurement plates and verify that the inertial profiler’s height measurement subsystem returns to zero, within 0.01 in., on top of the base plate.

6.3.8. Vertical verification shall be performed for all non-contact height sensors.

6.3.9. The results of the Block Test shall be documented on BMT 203.

6.4. Vertical Verification – Bounce Test

6.4.1. With the base plates in position simultaneously under both wheel path sensors, place the vehicle in an operating mode that simulates longitudinal movement and initiate profile data collection. Data is collected with the vehicle as motionless as possible for the time required to travel 828 ft.

6.4.2. Without interrupting the data collection process, both sensors are repeatedly subjected to a vertical displacement of approximately 1 to 2 in. This bouncing motion shall be maintained and data collected for the time required to travel 528 ft.

6.4.3. Without interrupting the data collection process, continue to collect data with the vehicle as motionless as possible for the time required to travel 828 ft.

6.4.4. Measured profiles shall be saved and analyzed in ProVAL using the Ride Statistics Continuous analysis option with a 528 ft base length and 300 ft of lead in and lead out. Computed IRI values in the first and last (static) 528 ft segments shall not exceed 3 in. per mile, while the IRI for the middle (bouncing) segment shall not exceed 8 in. per mile. If the computed IRI values exceed 3 in. per mile for the static test and/or exceed 8 in. per mile for the bounce test, then the manufacturer's recommendations for performing sensor operational checks shall be followed. The static and bounce tests shall then be repeated. If the tests fail to meet these requirements, the inertial profiler will be deemed to be not certified and barred from use on ALDOT projects until it passes the certification program at NCAT.

6.4.5. The results of the Bounce Test shall be documented on BMT 203.

6.5. IRI consistency

6.5.1. The Department will designate at least one control section in each Division that will be used as a basis for consistency measurements the first time an inertial profiler is used on a given project. Control sections will be established by selecting 1000-foot sections with a maximum IRI of 120 inches per mile that will maintain a consistent ride profile over the time period when daily checks are needed. Information regarding the control section locations is available from the State Materials and Tests Engineer.

6.5.2. An inertial profiler certified within the past 90 days shall be used to determine the IRI of the section by making a series of at least five profile measurements. The average IRI of the measurements shall be used to establish the IRI of the control section; provided that the cross correlation of the measurements as determined using the latest version of ProVAL is at least 88 percent (dependent upon the filters used, spectral content of the measured surface, operator, etc.). Once established, this control section can be used to validate that an inertial profiler is operating properly at any time.

6.5.3. An inertial profiler is consistent when a single IRI determination does not vary more than 5 percent from the initial control section IRI established by the inertial profiler owner.

6.5.4. After an inertial profiler has been used for the first time on a project, it is acceptable to re-run 528 ft of pavement that was measured on the previous day for comparison purposes. An inertial profiler is verified to be consistent when the current day's value does not differ by more than 5 percent from the previous day's value.

6.5.5. If the contractor owns more than one certified inertial profiler, it is acceptable to compare separate runs made by the two devices. A certified inertial profiler is consistent when it does not differ from another certified inertial profiler by more than 10 percent.

6.5.6. The Department may also choose to run random consistency checks by bringing in a certified inertial profiler. A contractor's certified inertial profiler is consistent when it does not differ from the Department's certified inertial profiler by more than 10 percent. If the contractor's inertial profiler differs by more than 10 percent from the

Department's certified inertial profiler, then the contractor's inertial profiler will be deemed to be not certified and barred from use on Department projects until it passes the certification program at NCAT.

6.5.7. The results of the initial IRI consistency check shall be documented on BMT 207 "Control Site Target IRI Report."

6.6. Major component repairs of the type referenced in Section 7 may be needed when specified longitudinal or vertical verification tolerances are not met or consistency cannot be verified. Major component repairs shall require recertification as described in Section 4.

6.7. The profiler log shall be kept with the inertial profiler at all times that is subject to review by the Engineer. Verifications, calibrations, consistency checks, and certifications shall all be included in the profiler log.

7. Repair and Adjustment of Inertial Profilers

7.1. All repair and adjustment of inertial profilers shall be documented on BMT 204 "Inertial Profiler Maintenance Log."

7.2. Major component repairs or replacement to an inertial profiler require recertification of the equipment. These may include but are not limited to:

- Repair or replacement of the accelerometer and its associated hardware.
- Repair or replacement of the non-contact height sensor and its associated hardware.
- Repair or replacement of the distance measuring instrument.
- Repair or replacement of any printed circuit board necessary for the collection of raw sensor data or the processing of the inertial profiles and IRI.
- Modification of software parameters and scale factors as required by the manufacturer that are foundational to the certification process.

7.3. The operator of the inertial profiler may make minor adjustments to the equipment without having to complete the recertification process as long as the adjustments allow the equipment to fulfill the procedure in Section 5.

7.3.1. Inspecting, resoldering, or replacing connectors is considered a minor adjustment.

7.3.2. Cleaning components or normal adjustments to voltage levels as required by the manufacturer is considered a minor adjustment.

7.3.3. Setting software parameters and scale factors as required by the manufacturer is considered a minor adjustment as long as they are not foundational to the certification process.

8. Test Procedure

8.1. IRI measurements shall be in each wheel path, then averaged and summarized every 0.10 mile. Technically speaking, this average of the left IRI and right IRI is termed the Mean Roughness Index (MRI).

8.2. The Bounce Test, described under Section 6.4, and the IRI consistency check, described under Section 6.5, shall be performed daily before any data is collected. The results of the daily Bounce Tests and IRI consistency check will be documented by the Contractor and verified by the Project Engineer on BMT 202 “Daily Inertial Profiler Log.”

8.3. Locate and mark all sections that will not be included in the evaluation of pavement smoothness for payment of bonuses or penalties. Sections that will not be used include the first and last 25 ft of the paving project, 25 ft either side of bridge ends, and those areas as directed by the Engineer.

8.4. Contractor shall provide the distances and descriptions of features that may be subject to exclusion using BMT-206 “Project Feature Log.”

8.5. Clean the roadway path of all debris and other loose material before data is collected.

8.6. All data collected outside the certified speed range shall not be acceptable. Re-measure any pavement segment where the travel speed of the inertial profiler is less than or exceeds the manufacturer’s recommended operational speed at any point during data collection.

8.7. A pre-section length of roadway of up to 450 ft may be required to stabilize the inertial profiler’s filters and achieve the same accuracy in the first 0.1 mile 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 0.1 mile 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 may be used at the discretion of the Engineer when the physical constraints of the project require it and other project conditions make it acceptable.

8.8. Inertial profiler measurements shall be made in both wheel paths of the paved surface using sensor path spacing of between 65 and 71 inches.

8.9. Measurements shall be made in the direction of traffic.

8.10. Data collection for payment purposes is meant to be performed at the end of the paving operation or staged as prescribed by the Department.

8.11. The contractor shall submit to the Engineer a table that identifies the lanes, wheel paths, and distance locations tested for each file created during profile testing on BMT-202 “Daily Inertial Profiler Log.” Profile elevation data shall be presented to the Engineer in an electronic format on a USB flash drive with a file format as described in Section 9. The Engineer will use the latest version of ProVAL to calculate the IRI values and applicable tables to determine associated pay factors.

8.12. The Engineer will:

8.12.1. Determine all features that will be excluded from the pay computations.

8.12.2. Calculate and record the IRI from each longitudinal line profiled for a pavement travel lane (The payment schedule will be based on the MRI calculated from both wheel paths in a travel lane.).

8.13. The Engineer will use the latest version of ProVAL to calculate the pay adjustment for segment lengths no more than 0.1 mile long.

9. Test Data Description and Format

9.1. Report test data in .ERD format that can be read directly into the latest version of ProVAL. This will permit the Department to directly input profile data, collected with any inertial profiler, into its data reduction program for QA testing.

10. References

10.1 AASHTO Standards

- M 328, Standard Specification for Inertial Profiler
- R 54, Standard Practice for Accepting Pavement Ride Quality When Measured Using Inertial Profiling Systems
- R 57, Standard Practice for Operating Inertial Profiling Systems
- R 43M/R 43, Quantifying Roughness of Pavements

10.2 ASTM Standards

- E 867, Standard Terminology Relating to Vehicle Pavement Systems
- E 950, Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference

New Jersey Toll Authority (NJTA)

HNTB/AID (Consultants) Data Collection under New Jersey Turnpike and Garden State Parkway Roadways

Advanced Infrastructure Design, Inc.

QUALITY MANAGEMENT SUPPORTING DOCUMENTS (DATA COLLECTION & ANALYSIS) Year 2018

Annual Pavement Condition Assessment (APCA) and Ride Quality and Monitoring Program (2018)

NJTA - A3584, General Consulting Engineering Services

HNTB

May 15, 2018

Advanced Infrastructure Design, Inc.

Todd Rothermel,
VP, Technology Practice Leader
HNTB Corporation
9 Entin Road- Suite 202
Parsippany, NJ 07054

Re: NJTA Order for Professional Services No. A3584: General Consulting Engineering Services
HNTB Number: 61402-OM-030, Task Order No. CS3-1

Quality Management Supporting Documents: Year 2018

Dear Mr. Rothermel:

Enclosed please find the supporting documents for the Quality Management Processes that will be implemented on Task A (Data Collection), Task B (Image Processing) and Task C (Data Computation and Compilation) of the Data Collection on Year 2018.

Please refer to the summary tables presented on this document that describe Data Collection Equipment, Data Collection Calibration and Certification, Certification process for persons performing manual data collection, Data Quality Control Measures Before and During Data Collection, Data Sampling, Review and Checking Process, Data Quality Standards and Acceptance Procedures.

If you have any questions or require any additional information, please do not hesitate to contact me via phone or email.

Sincerely,

Kaz Tabrizi

Kaz Tabrizi, PhD, PE
Executive Vice President and Quality Manager

Introduction

New Jersey Turnpike Authority (NJTA) owns and operates both the New Jersey Turnpike (hereafter referred to as Turnpike) and the Garden State Parkway (hereafter referred to as Parkway), two of the busiest toll roads in America. In most areas, each toll roadway comprises of four lanes for its full length. In the widest areas, the Turnpike and Parkway have up to 14 lanes and 12 lanes, respectively. The total travel lane mileage of each road is approximately 1,200 miles, not including ramps, shoulders, and access roads.

On this project (total duration of five years), Advanced Infrastructure Design, Inc. (AID) will conduct a comprehensive study of the road condition of both the Turnpike and Parkway in 2018. This will include the collection, processing, and quality control of geo-referenced pavement condition data with AID's testing vehicle at typical highway speeds. During a previously completed Term Agreement (New Jersey Turnpike Authority Order for Professional Services No. A3352, total duration of three years), all travel lanes of both toll roads were investigated in 2013 and the most travelled lane was investigated in 2014 and 2015. The analyzed data was presented in a series of summary reports. Analyzed data was also provided in a form suitable for integration into the Pavement Management System (PMS) to be developed and used by the Authority. The above-mentioned PMS Term Agreement was extended in the form of a new Agreement (New Jersey Turnpike Authority Order for Professional Services No. A3584, total duration of five years), and the most travelled lane was again investigated in 2016 and 2017.

Data collection in 2018 will include pavement ride quality (based on the IRI, rut depth, surface condition (SDI as established by New Jersey Department of Transportation, NJDOT), and high-resolution video logging. IRI and rut depth were measured with an inertial profiling system, while SDI will be determined through a visual survey of the pavement surface condition. High-resolution video logging will include collecting center, left and right images of the measured lanes. These images will be taken at 20 ft. intervals and synchronized with the center image. The left, center, and right images will be stitched together to form a panoramic view (approximately 120° field of view). These images will be submitted electronically, along with summary spreadsheets that include image names, milepost, GPS coordinates (Latitude and Longitude), vehicle speed, and date and time of testing for every image recorded.

In addition, the deliverable from this work will also include the average IRI, rut depth, and SDI values for every 0.1 mile of lanes investigated on the Turnpike and Parkway, referenced in terms of both a linear referencing system and GPS coordinates. Overall results will be submitted electronically in a series of spreadsheets.

Project Details

The New Jersey Turnpike and Parkway will be tested with AID's "integrated testing vehicle" (ITV). The total mileage of the network to be collected in 2018 is 2,200 lane miles, divided into twenty-nine (29) segments on the Turnpike and eight (8) segments on the Parkway, respectively.

The Turnpike spans from Milepost (MP) 0 (Broadway Avenue, after the Delaware Memorial Bridge) to MP 122.00 (Fletcher Avenue, before the George Washington Bridge). Over this length, the number of lanes per direction varies from two to seven. The Parkway spans from MP 0 (State Highway 109) to MP 172.40 (New York State Line). Over this length, the number of lanes per direction varies from two to eight. The overall view of both toll roads is shown in Figure 1. The Route ID, description, total mileage and start milepost and end milepost are summarized in Table 1 for easy reference.

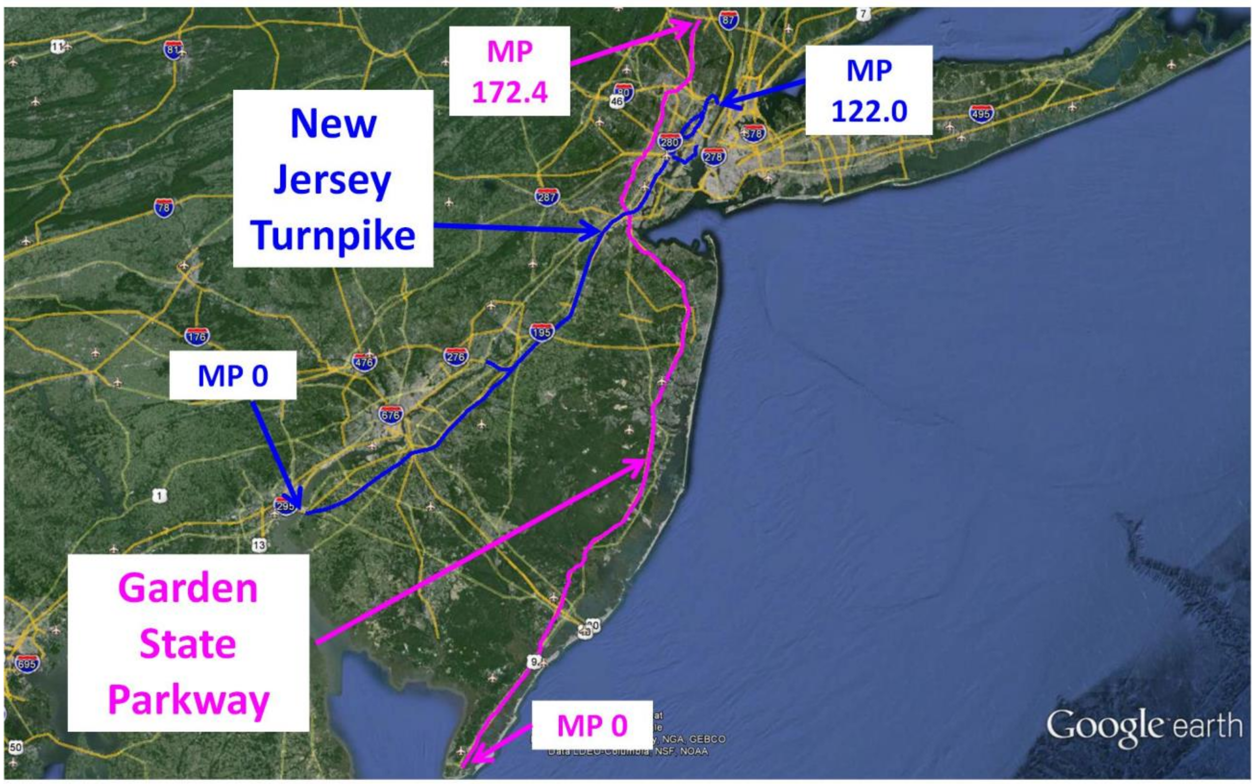


Figure 1. Overall View of the Project Limits

Table 1. Turnpike and Parkway Road Classification and Segmentation.

Roadway	Route ID	Description	Miles	From	To
New Jersey Turnpike (NJTPK)	SN	From South to North	49.07	0.00	48.80
	NS	From North to South	48.83	48.70	0.00
	SNI	From South to North on Inner	56.65	48.80	105.50
	NSO	From North to South on Outer	56.91	105.60	48.70
	SNO	From South to North on Outer	56.85	48.80	105.70
	NSI	From North to South on Inner	57.05	105.80	48.70
	SNE	From South to North on Easterly	10.82	106.40	117.20
	SNIE	From South to North on Inner to Easterly Roadway	0.88	105.50	106.40
	SNIW	From South to North on Inner to Westerly Roadway	0.55	105.50	106.10
	SNOE	From South to North on Outer to Easterly Roadway	0.72	105.70	106.40
	SNOW	From South to North on Outer to Westerly Roadway	0.37	105.70	106.10
	SNW	From South to North on Westerly	10.77	106.10	117.20
	NSE	From North to South on Easterly	10.50	117.10	106.60
	NSEI	From North to South on Easterly to Inner Roadway	0.80	106.60	105.80
	NSEO	From North to South on Easterly to Outer Roadway	0.92	106.60	105.60
	NSW	From North to South on Westerly	10.44	117.10	106.30
	NSWI	From North to South on Westerly to Inner Roadway	0.46	106.20	105.80
	NSWO	From North to South on Westerly to Outer Roadway	0.59	106.20	105.60
	SN95X	From South to North on I-95 Express	5.28	117.20	122.00
	NS95	From North to South on I-95	2.02	119.10	117.10
	NS95L	From North to South on I-95 Local	3.28	122.00	119.10
	NS95X	From North to South on I-95 Express	3.95	122.00	119.10
	NS80	From North to South from Interstate 80	2.11	118.90	116.70
	SN80	From South to North on Interstate 80	2.44	116.10	118.90
	SN95L	From South to North on Route 95 Local	3.97	118.40	122.00
	PEW	From East to West on the PHMTE	6.41	6.40	0.00
	PWE	From West to East on the PHMTE	6.72	0.00	6.70
	HEW	From East to West on the NBHCE	8.26	8.20	0.00
	HWE	From West to East on the NBHCE	8.08	0.00	8.20
Garden State Parkway (GSP)	NB	North Bound	151.87	0.00	172.40
	SB	South Bound	152.28	172.40	0.00
	NBI	North Bound Inner	21.89	103.60	125.60
	NBO	North Bound Outer	21.44	103.60	125.60
	SBI	South Bound Inner	21.42	125.30	103.80
	SBO	South Bound Outer	21.40	125.30	103.80

Data Collection Equipment

The ITV vehicle, shown below, integrates linear distance measurement (DMI) and GPS, a wide-angle high-resolution video camera, a Laser Crack Measurement System (LCMS), and Ground Penetrating Radar (GPR) antennas (not used on this project). The AID Team intends on utilizing this vehicle to collect LCMS (including distresses, IRI, and rutting) and video data.

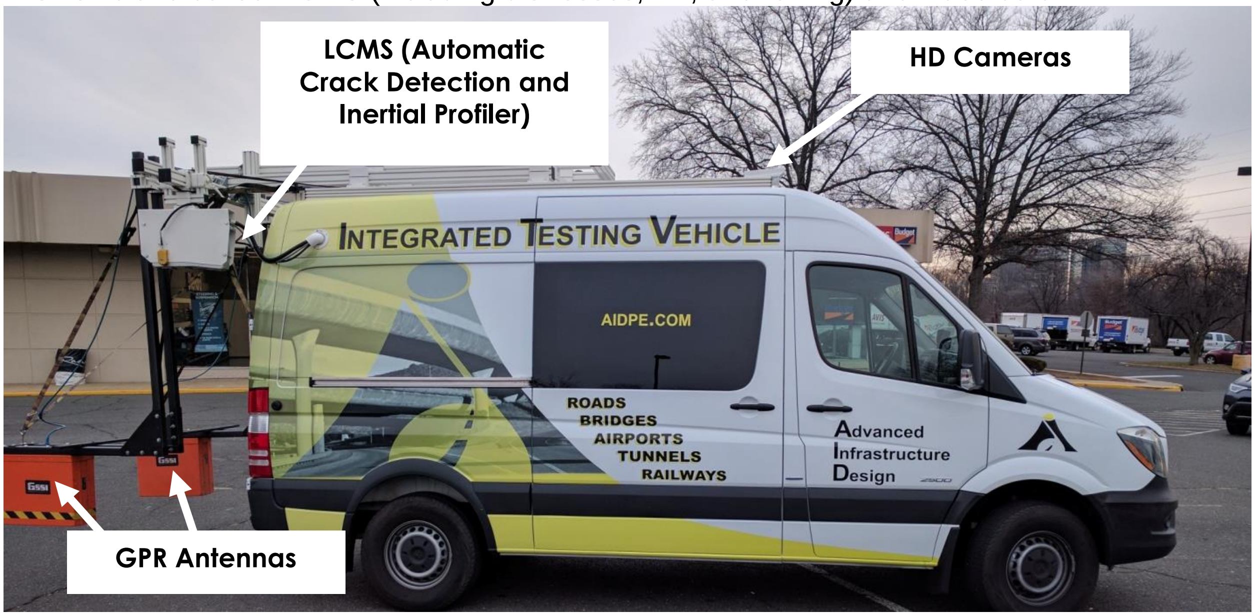
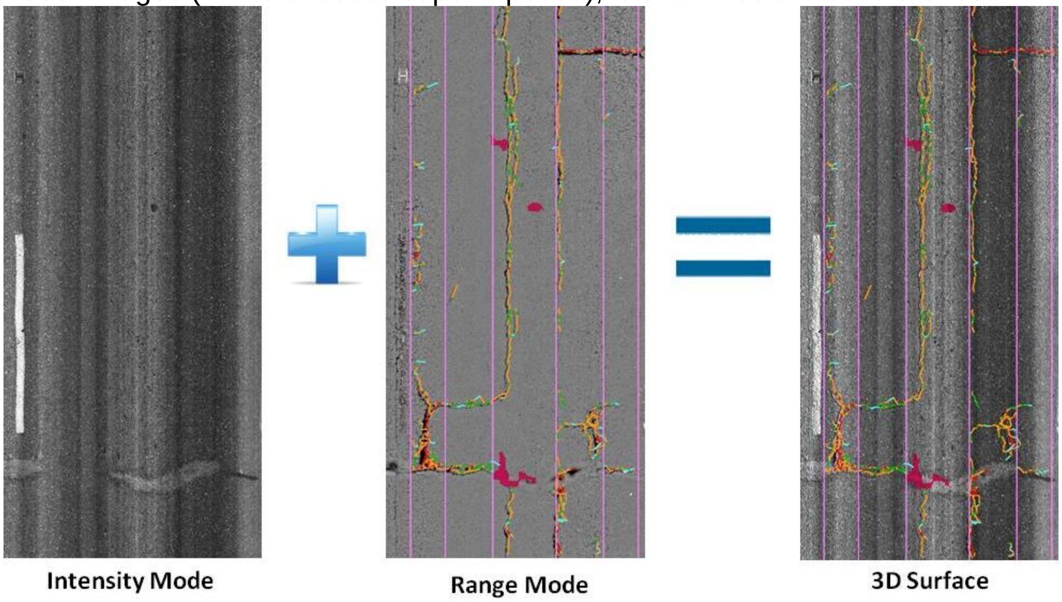


Figure 2. AID's Integrated Testing Vehicle (ITV)

AID's LCMS system (manufactured by Pavemetrics) scans the pavement surface using transverse profiles collected at every 5 mm intervals. Every individual transverse profile is composed of 4,160 data points. The surface profile can be analyzed to generate the longitudinal profiles for measuring roughness (IRI) and transverse profiles for assessing rut depth. Additionally, the LCMS system allows collecting surface distress data (Cracking Percentage) via automated crack detection algorithms. In addition to IRI, rut depth, and surface distress information, LCMS can provide texture evaluation by estimating the Mean Texture Depth (MTD). Typical visual output from the LCMS system, showing the Intensity, Range, and Combined 3D Surface laser images (with distresses superimposed), is shown below for reference.



Please note that even though LCMS is capable of collecting surface distress data (Cracking Percentage), surface condition for this project will be estimated through windshield reviews and the surface distress index (SDI as established by NJDOT) will be determined. An in-house developed hardware and software system by AID will be used to collect the SDI distresses. This is accomplished based on windshield surveys conducted by a rater in AID's ITV. The NJDOT protocols for *Pavement Condition Indices and Analysis* (Bertucci, 2012) will be used for collecting and classifying the SDI data. To obtain SDI, a specialized keyboard is used with all distresses and severities identified by NJDOT as part of the SDI calculation. This keyboard collects DMI and the rater toggles "on" and "off" distresses when they are first perceived and when they are not observed anymore. Inputs from the rater are recorded electronically in a table with the corresponding DMI, time from beginning of the survey, and start and end distance of each distress identified from the beginning of the survey.

In addition, a three camera high definition (HD) video system installed on the roof of the vehicle is capable of collecting HD jpeg images every 20 ft. High-resolution video logging includes collecting center, left and right images of the measured lanes. These images will be taken at 20 ft. intervals and synchronized with the center image. The left, center, and right images will be stitched together to form a panoramic view (approximately 120° field of view). For every image (see sample image below), linear distance, GPS coordinates (Latitude and Longitude), vehicle speed, and time of testing will be recorded. The linear distance will be later converted to milepost and all parameters will be included into summary spreadsheets for easy reference. These spreadsheets along with the stitched images will be submitted electronically.

Figure 3. Panoramic (Stitched) Sample Image

All systems in AID's ITV are fully integrated in terms of distance measuring system and GPS coordinates. A differential GPS unit capable of collecting sub-meter coordinates in real-time is also incorporated. All systems will be used to collect data on the Turnpike and Parkway while the ITV will usually travel at speeds of about 55 mph, thus not requiring the need of any traffic control.

Data Collection Equipment Calibration and Certification

LCMS Block Calibration

The LCMSValidationTool module uses a calibrated pyramidal object to validate the calibration of a LCMS sensor. This optional module includes the validation object (see Figure 4) and the validation software (LcmsValidationTool). This calibration is conducted before the beginning of the project and every three months after.

The validation steps are divided in two parts. The first part (Range Validation) verifies the sensor alignment in order to make sure that calibration tables (.ltx and .ltz files) are still valid. The second part (Focus Validation) assesses the sensors optical quality. Different portions of the reference object are used depending on which test is performed. These two steps must be performed for three positions (left/center/right) in the field of view of each sensor.

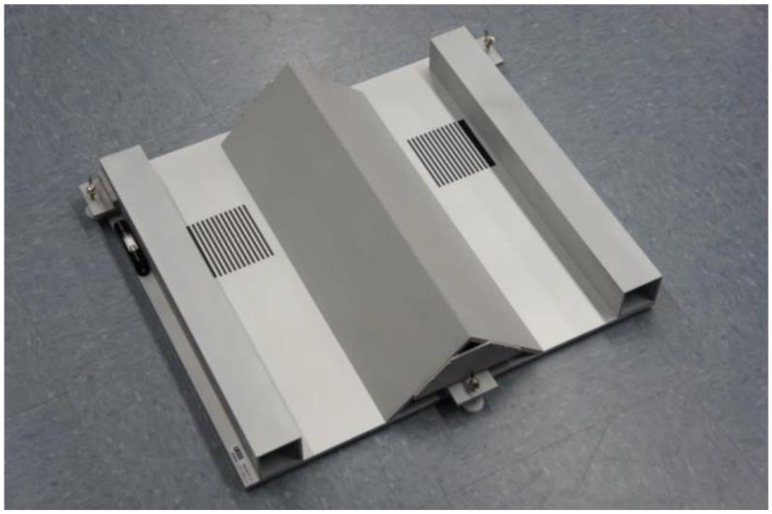


Figure 4. Calibrated pyramidal object for validation

Several indicators defined by the manufacturer (named Accuracies X1, X2, Z1 and Z2, Noise Levels Z1 and Z2 and Focus Quality) are measured. Table 1 provides the thresholds between the numerical values for each indicator and the sensor status.

Table 1. LCMS Sensor Status Thresholds

Indicator	Fail	Good	Excellent
Accuracy X 1	> 3.5	3.0 to 3.5	< 3.0
Accuracy X 2	> 3.5	3.0 to 3.5	< 3.0
Accuracy Z 1	> 1.2	1.1 to 1.2	< 1.1
Accuracy Z 2	> 1.2	1.1 to 1.2	< 1.1
Noise Level Z 1	> 1.2	1.0 to 1.2	< 1.0
Noise Level Z 2	> 1.0	0.5 to 1.0	< 0.5
Focus Quality	< 0.4	0.4 to 0.5	> 0.5

Profiler

AID's LCMS unit meets and exceeds *ASTM E 950* Class I profiler requirements and AASHTO Standards M328-14, R43-14, R56-14 and R57-14 for pavement roughness (IRI) data collection and analysis. The LCMS enables collecting IRI data within a speed range of 15-60 mph. AID will follow AASHTO standards in collecting IRI data for this project. AID's LCMS has also been tested and verified by the Maryland State Highway Administration (MDSHA) and selected field engineers have also been certified as profiler operators by the West Virginia Division of

Highways. The verification with MDSHA is conducted on a yearly basis and the WVDOT has been recently obtained (February 2018-2022) by two (2) AID engineers. Moreover, the LCMS' 3-D imaging system is recognized under Code 1 for IRI equipment type by FHWA's *HPMS Field Manual (Dec. 2016)*.

Along with this report a letter from the LCMS manufacturer (Pavemetrics) is included. This letter describes the precision and bias of the equipment that meets ASTM E-950 and AASHTO requirements. In addition, the most recent certification of the LCMS profiler from Maryland State Highway Administration is also included separately for reference.

Moreover, AID conducts a quarterly calibration of the LCMS Profiler on two (2) different sections of the Turnpike:

- Outer roadway, Southbound direction, Milepost 60 to 54
- Inner roadway, Northbound direction, Milepost 54 to 60

During these periodic calibrations, at least one pass with AID's ITV is collected and the IRI results are compared. IRI values are calculated for every tenth of a mile segments within the test limits. If results are within ±5% of previously obtained results, the LCMS Profiler is considered to provide accurate results.

Distance Measurement Instrument (DMI)

The DMI installed in AID's ITV is also calibrated before the start of the project and every three (3) months thereafter. A straight section that is 1,026 ft. long (or two tenths of a mile) is tested three (3) times quarterly to calibrate and validate the distance measured by the DMI. The beginning and end of the section had been previously established with a measuring wheel and pavement marks were laid on the pavement surface for easy identification.
On every pass, the beginning and end of the calibration section are extracted from the LCMS 3D surface images and distance between the beginning and end of the section is measured. In order to determine that the DMI is within calibration, measurements must be within 4 inches of each other.

Figure 5. AID's DMI

Certification Process for Manual Data Collection

AID conducts in-house training of technicians/engineers that will be participating on data collection tasks. The training is conducted by senior engineers at least once a year and the following processes are reviewed.

Data Collection Equipment
On this part of the training, the different hardware components are reviewed:

- Vehicle startup sequence
- Electric supply system
- Video Collection System (cameras and computer)
- LCMS Cameras, Data Collection System and Computer
- SDI hardware (laptop and especially designed keyboard) and components (cables, miscellaneous)
- DMI hardware (encoder) and components (cables, miscellaneous)
- GPS hardware (GPS antennas and receiver) and components (cables, miscellaneous)

Distresses
The Distress Identification Manual for the Long-Term Pavement Performance Program (FHWA, Fourth Revised edition, 2003) is discussed in detail. The type of distresses that are listed by NJDOT as part of the SDI calculation (windshield review) are reviewed and discussed:

- Multiple Cracking,
- Transverse Cracking,
- Longitudinal Cracking,
- Load Related Multiple Cracking,
- Load Related Longitudinal Cracking and
- Patching

In addition, the severity of each distress is reviewed and discussed:

- Low Severity
- Moderate Severity
- High Severity

Moreover, AID's in-house hardware and software system specifically developed for this task is reviewed during the certification process. As part of this process, the specialized keyboard used to record surface distresses is described. On that keyboard (see image below for reference), a key is assigned to every type and severity of distresses listed as part of the SDI calculation. When the rater toggles "on" the distress selected the pressed key lights up for easy reference and stays lit until the rater toggles "of" the distress selected. Since travelled distance from the DMI is recorded for every time a key is pressed, the start, end and severity of every distress can be properly recorded. This information is later analyzed in the office to assign a percentage to every distress type and severity for every tenth of a mile of roadway.

Figure 6. Specialized Keyboard to Conduct Surface Distress Surveys

After all distresses used for SDI calculations and AID's hardware and software are thoroughly explained, AID engineers conduct condition surveys on a roadway with known distress ratings. Through an iterative process of rating and discussing results, AID engineers learn to calibrate their distress rating skills on pavements with different types of distresses. Engineers are approved to conduct windshield distress surveys after demonstrating overall understanding of the visual rating process, distress identification (type and severity of distresses) and ability to handle and operate the specialized keyboard. Each engineer and the instructor participating on the training sign the attendance sheet which is documented and stored for the record.

<u>Data Collection Troubleshooting</u>
Field technicians/engineers are also trained to verify the equipment is calibrated, to conduct troubleshooting and resolve issues during data collection. As part of the real-time data collection check, the following topics are discussed:

- Monitoring of GPS solution (real-time accuracy and GPS data quality, i.e., number of satellites received)
- Monitoring of LCMS data collection (LCMS files recorded real-time)
- Monitoring of Video data collection (jpeg images recorded real-time)
- Monitoring of distance measured by DMI
- Verification of distance traveled on each pass (both LCMS, Video and SDI systems)

The training lasts for half a day at AID's offices and warehouse and at the end of the day the technicians/engineers are approved for data collection purposes. As previously indicated, the in house certification program is conducted at least once a year, and an attendance sheet is keep for recordkeeping.

<u>Quality Control Measures Before Data Collection</u>
Before data collection, the following control processes are conducted:

- AID's ITV
    - Ensure tire pressure on all wheels is adequate and verify that DMI, LCMS and video cameras are secured.
    - Verify that all external cables are connected.

- Video Data Collection System
  - Ensure cameras are clean and all cables are connected.
  - Validate number of files and distance travelled equals to a 20 ft. spacing between images.
- LCMS System
  - Verify laser cameras are clean and all cables are connected.
- GPS System
  - Verify that antenna is securely attached to the roof of the vehicle and all cables are connected.
- SDI Data Collection System
  - Ensure AID's in-house developed hardware system (i.e., laptop and especially designed keyboard) is properly connected.

<u>Quality Control Measures During Data Collection</u>

During data collection, the following control processes are conducted:

- Video Data Collection
  - Ensure images are clear, color balanced, with proper exposure and in focus.
  - Ensure files saved are complete, not corrupted.
  - Validate number of files and distance travelled equals to a 20 ft. spacing between images.
- Profiler Data Collection
  - Verify distance recorded from profiler matches distance measured by the DMI from video system.
- GPS Data Collection
  - Cross-check time of start and time of end on GPS file matches time recorded by video system.
- SDI Data Collection
  - Ensure distance recorded from SDI computer matches distance by DMI from video system.

<u>Data Sampling, Review and Checking Processes</u>

After data collection, the following activities and quality control processes are completed during Task B of this project (Image Processing):

- Panoramic Images Generation (Synchronize and stitch left, center, and right images and Convert DMI to approximate milepost):
  - Ensure left, center and right images are synchronized.
  - Ensure number of files generated matches the number of files from center camera.
  - Cross-check file naming convention (milepost) with image view at randomly selected mileposts (10%).
- Excel File Generation (Prepare spreadsheets with Panoramic image name, Milepost, GPS coordinates, Vehicle speed, Date and time of data collection):
  - Ensure data included in all columns (image name, GPS, speed, time and date) is complete.
  - Verify number of images generated vs. number of rows within the spreadsheet coincide.
- File Share through an external USB Hard Drive
  - Verify files were uploaded on the hard drive.
  - Download sample files (10%) to ensure files are not corrupted.
  - Verify hard drive arrived to destination.

After data collection, the following activities and quality control processes are completed during Task C of this project (Data Computation and Compilation):

- Video Ties Preparation (correlation between DMI from video computer system and mile markers from recoded images):
    - Randomly select milepost from recorded images
    - Display GPS coordinates at the same location
    - Cross check with mile markers
- Sectioning every 1/10 mile segments (Assign control points and determine 1/10 break-downs):
    - Randomly select milepost from summary spreadsheets
    - Verify recorded images with corresponding mile markers.
- Data Computation (Integrate and combine IRI, GPS and SDI results):
    - Randomly select milepost from analyzed data
    - Verify GPS coordinates with corresponding mile markers
- Excel File Generation (Summary Excel spreadsheets with mileposts, GPS coordinates, IRI, SDI and rutting)
    - Ensure data included in all columns is complete.
    - Validate SDI by reviewing image files.
    - Adjust distress percentages if necessary
- File Upload into HNTB ProjectWise system
    - Verify files were uploaded.
    - Download sample files (10%) to ensure files are not corrupted.

Data Quality Standards and Data Acceptance Criteria

As defined by the FHWA Practical Guide for Quality Management of Pavement Condition Data Collection (2013), the key deliverables, protocols used for collection, and associated quality standards are described below. Quality standards define, when applicable, the resolution, accuracy, and repeatability or other standards that will be used to determine the quality of each deliverable.

Table 2. Data Quality Standards

Deliverable	Protocols	Resolution	Accuracy (compared to reference value)	Repeatability (for three repeat runs)
IRI (left, right, and average)	AASHTO	1 in/mi	± 5 percent	± 5 percent
Rut depth (average and maximum)	AASHTO	0.01 in	± 0.06 in	± 0.06 in
GPS (latitude and longitude)	N/A	0.00001 degree	± 0.00005 degree	± 0.00005 degree
Distress ratings	NJDOT SDI distress rating manual	Varies	± 10 percent	N/A
Location of segment	N/A	N/A	All assigned segments surveyed & assigned correct location	N/A
Segment begin point	N/A	0.01 mi	± 0.05 mi	N/A
Panoramic images	N/A	N/A	Signs legible, proper exposure and color balance	N/A

The focus of acceptance is to validate that deliverables meet the established quality standards. Following is a description of acceptance testing, the frequency to be performed, and corrective actions for items that fail to meet criteria

Table 3. Data Acceptance Criteria

Deliverable	Acceptance (Percent Within Limits)	Acceptance Testing & Frequency	Action if Criteria Not Met
IRI, rut depth, faulting	95 percent	Weekly control, verification, and blind site testing. Global database check for range, consistency, logic, and completeness and inspection of all suspect data. 5 to 10 percent sample inspection upon delivery. Use of GIS for further inspection.	Reject deliverable; data must be re-collected.
Distress ratings	95 percent	Global database check for consistency, logic, completeness. 5 to 10 percent sample inspection upon delivery.	Return deliverable for correction
GPS coordinates	100 percent	Weekly control, verification, and blind site testing. Plot on base map using GIS upon delivery.	Return deliverable for correction
Location of segment and segment begin point	100 percent	Plot on base map using GIS. Global database check of accuracy and completeness.	Return deliverable for correction
Panoramic images	98 percent of each control section and not more than 5 consecutive images failing to meet criteria	Weekly inspection of control, blind, or verification site video. 5 to 10 percent sample inspection upon delivery.	Reject deliverable; images must be re-collected.

Dear Sir/Madam,

Pavemetrics Systems Inc. is a company that specializes in sensor and algorithm development for the automated inspection of transportation infrastructure including roads, runways, railways and tunnels. In the United States Roughly 80% of State Departments of Transportation get pavement condition data from Pavemetrics sensors on an annual basis.

Pavemetrics' Laser Crack Measurement System (LCMS) is a sensor and software package that is capable of measuring a wide variety of pavement surface properties at highway speeds day or night.

Reporting Roughness

When equipped with Pavemetrics' Inertial Measurement Units (IMUs) and specialised reporting software, the LCMS is capable of measuring longitudinal profile and reporting the International Roughness Index.

The LCMS can meet the sampling interval (every 25mm or less) as well as precision (0.38mm) and bias (1.25mm) requirements for reported profiles of an ASTM E-950 Class 1 profiler. This status can be validated using ProVAL as is presented in Figures 1 and 2.

File	Basis	Sample Interval (mm)
gauche_hp	Yes	300.000000
LcmsLongProfile_3060145744_B360m_L620m_s300mm_L	No	300.000000
LcmsLongProfile_3060147689_B360m_L620m_s300mm_L	No	300.000000
LcmsLongProfile_3060148201_B360m_L620m_s300mm_L	No	300.000000
LcmsLongProfile_3060149107_B360m_L620m_s300mm_L	No	300.000000
LcmsLongProfile_3060151110_B360m_L620m_s300mm_L	No	300.000000
LcmsLongProfile_3060151580_B360m_L620m_s300mm_L	No	300.000000
LcmsLongProfile_3060152646_B360m_L620m_s300mm_L	No	300.000000
LcmsLongProfile_3060155670_B360m_L620m_s300mm_L	No	300.000000
LcmsLongProfile_3060156161_B360m_L620m_s300mm_L	No	300.000000
LcmsLongProfile_3060152050_B360m_L620m_s300mm_L	No	300.000000

Result	Value
Bias (mm)	0.677
Precision (mm)	0.313
Bias Classification	1
Precision Classification	1

Figure 1: ProVAL Certification for Left Wheelpath

File	Basis	Sample Interval (mm)
LcmsLongProfile_3060145744_B360m_L620m_s300mm_R	No	300.000000
LcmsLongProfile_3060147689_B360m_L620m_s300mm_R	No	300.000000
LcmsLongProfile_3060148201_B360m_L620m_s300mm_R	No	300.000000
LcmsLongProfile_3060149107_B360m_L620m_s300mm_R	No	300.000000
LcmsLongProfile_3060151110_B360m_L620m_s300mm_R	No	300.000000
LcmsLongProfile_3060151580_B360m_L620m_s300mm_R	No	300.000000
LcmsLongProfile_3060155670_B360m_L620m_s300mm_R	No	300.000000
LcmsLongProfile_3060156161_B360m_L620m_s300mm_R	No	300.000000
LcmsLongProfile_3060152646_B360m_L620m_s300mm_R	No	300.000000
droite_hp	Yes	300.000000
LcmsLongProfile_3060152050_B360m_L620m_s300mm_R	No	300.000000

Result	Value
Bias (mm)	0.703
Precision (mm)	0.368
Bias Classification	1
Precision Classification	1

Figure 2: ProVAL Certification for Right Wheelpath

The LCMS is also compliant with the following AASHTO standards:

Standard	Requirement
M328-14: Standard Specification for Inertial Profiler	In order to be compliant measuring systems must include height sensors, accelerometers and a distance sensor. An Integrated LCMS is compliant with this standard as it includes lasers for height measurement, accelerometers (included in Pavemetrics IMUs) and a DMI for distance measurement.
R43-14: Standard Practice for Quantifying Roughness of Pavements	In order to be compliant devices must utilize a method for IRI calculation that is equivalent to the one detailed in the standard. The LCMS IRI calculation method is compliant with this standard.
R56-14: Standard Practice for Certification of an Inertial Profiling System	In order to be compliant, measuring systems must meet all the requirements and specifications of M328. In addition, relative elevation measurements must be made every 2 inches (or more frequently) and high-pass filters applied according to the included specification. The standard also includes a certification process which requires 0.01 inch precision for height measurements, 90% accuracy compared to ground-truth, and a 92% run-to-run repeatability.

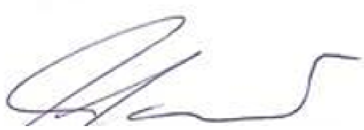
	The LCMS complies with these requirements and has successfully passed R56 certification at the NCAT facility.

Rutting Measurement

Regarding the measurement of rutting, the LCMS is compliant with the following AASHTO standards:

Standard	Requirement
R48-10: Standard Specification for Determining Rut Depth in Pavements	In order to be compliant with this standard, rutting calculations require at least five (5) measurement points across the lane and a profile spacing of no more than 10m. Rut depth calculations must also be made using the included equation and have a resolution of 3 mm and an accuracy of ±3 mm at a 95% confidence level. The LCMS is compliant with this requirement.
PP70-14: Standard Practice for Collecting the Transverse Pavement Profile	In order to be compliant with this standard, measuring systems must report collected transverse profiles every 3.0m for network-level work and every 0.5m for project-level work. Additionally, profile width must be 4.0m or larger and spacing between transverse measurement points must be 10mm or smaller. Vertical resolution must be 1mm or better and the accuracy of each measurement point must be at least 3mm relative to the average elevation of the same profile. Accuracy of measurements to a true horizontal reference must be at least 5mm. Lastly the measured profile must be along a line that is no more than 10 degrees in rotation from the lane centerline. The LCMS is compliant with these requirements.
PP69-14: Standard Practice for Determining Pavement Deformation Parameters and Cross Slope from Collected Transverse Profiles	In order to be compliant with this standard, devices must determine the cross-slope of the road and the percent deformation using the stipulated method. Additionally, devices must be able to define five (5) road zones and use average elevations to define a point for each zone before calculating rutting using the prescribed method. The LCMS is compliant with these requirements.

With Best Regards,



John Laurent
Chief Technical Officer
Pavemetrics Systems Inc.
150, Boulevard Rene-Levesque Est., Suite 1820
Quebec City, QC G1R 5B1
+1 418 262 8707
jlaurent@pavemetrics.com

MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

Larry Hogan
Governor
Boyd K. Rutherford
Lt. Governor
Pete K. Rahn
Secretary
Gregory Slater
Administrator

December 5, 2017

Hadi Rashidi, PhD, PE, Senior Engineer
Advanced Infrastructure Design, Inc.
1 Crossroads Drive, Hamilton, NJ 08691

This letter verifies that the inertial profilers, listed below, belonging to Advanced Infrastructure Design, Inc. meet the requirements for use in measuring pavement smoothness for the State of Maryland Ride Specification.

- Ford E-350 (ITV#1) vin 1FTSE34L74HB31806 (ICC Profiler)
- Mercedes Sprinter (ITV#2) vin WD3PE7CD8GP186289 (LCMS)

All profilers accepted for use in Maryland are re-verified yearly.

Sincerely,

Bonnie A. Johnson

Bonnie A. Johnson
Ride Specification Program Manager
Asphalt Technology Division