Pennsylvania Department of Transportation

Data Quality Management Program

May 17, 2018

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PennDOT is pleased to present its Pavement Performance Measure Data Quality Management Program as required through the Federal Highway Administration final rule, 23 CFR Part 490, of the Moving Ahead for Progress in the 21st Century (MAP-21) legislation. The final rule established measures through which State departments of transportation (State DOT's) can be assessed on the performance of pavements on the Interstate and Non-Interstate National Highway System (NHS).

The National Highway Performance Program (NHPP) is a Federal highway program through which aid is provided to State DOT's for maintaining the condition of the NHS as well as building new facilities on the NHS. The performance measures, as defined in MAP-21, will be used to determine good stewardship of the Federal aid by the State DOT's. To that end, State DOT's will report on pavement conditions that are used in project decision making. The State DOT's must first prove the data are accurate by providing a Data Quality Management Program (DQMP).

PennDOT respectfully submits the DQMP for the collection and reporting of the required pavement conditions. The DQMP provides detail on the calibration and certification of data collection equipment used in Pennsylvania, the data collection procedure, data definitions, data rater certification, data quality control, data review, and data error processing. PennDOT has had a comprehensive quality program in place since 2008. We believe our program provides the means for verifying the accuracy and completeness of the pavement condition data, and the process to make timely corrections when needed, thus ensuring quality pavement condition data is reported and used in decision making.

Sincerely,

J. Michael Long, P.E.
Chief, Asset Management Division
Bureau of Maintenance and Operations

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Pennsylvania Department of Transportation
MAP-21 Data Quality Management Program
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Pennsylvania Department of Transportation
MAP-21 Data Quality Management Program (DQMP)
May 2018

1) Data Collection Process

The Pennsylvania Department of Transportation (PennDOT) contracts out the network pavement condition data collection, including roughness, rutting, cracking, and faulting. Data collection consists of a 100% survey on over 28,000 miles of state-owned roadway in addition to approximately 2000 miles of Local Federal Aid roadways every year. One hundred percent of Interstate and Non-Interstate NHS is collected every year; the remaining networks are collected on a two-year cycle.

The use of "Vendor" throughout this DQMP refers to the contractor collecting, analyzing, and reporting the pavement condition data required through 23 CFR Part 490 of MAP-21.

a. Data Collection Equipment

The Vendor's data collection equipment conforms to Class 1 profiling equipment requirements, as specified in ASTM E950/E950M.

i. Equipment Calibration – All of the Vendor's equipment undergoes an extensive Quality Control (QC) procedure that includes block calibration and test, roughness calibration and bounce test, Distance Measuring Instrument (DMI) calibration, Laser Crack Measuring System (LCMS) testing and calibration, and video and pavement image alignment and quality testing. See Appendix A for the complete QC Acceptance Report and detail on all calibration and testing performed.

The Vendor's data collection equipment is calibrated according to the manufacturer's recommendations before beginning any data collection. The Vendor also routinely performs calibration of the data collection equipment as shown in Table 1, taken from the Vendor Quality Assurance Plan (QAP) (see Appendix B).

The Vendor's Inertial Profiler equipment meets AASHTO Standard M328-14. Additionally, the Vendor's Inertial Profiler equipment meets the requirements of AASHTO R56-14 Section 5 (Equipment), and follows Section 6 of this Standard for Equipment Calibration Verification, including the bounce and block tests. See Appendix C for the block test log and the bounce test procedure followed. An example of the Vendor's equipment certification record is available on page 7 of their QAP (Appendix B).

Table 1. Vendor Equipment Calibration Schedule

Equipment	Calibration Interval	Process
Cameras	At start of project; a change in mechanical components; becomes necessary as a result of our Corrective Action process.	Realign cameras to match original alignment, both for left/right and pavement/sky ratios. Images are measured to determine the ratios are correct.
Laser SDP	At start of project; change in mechanical components; becomes necessary as a result of our Corrective Action process.	Perform block and bounce tests to verify static function of the equipment. If passed, collect control sites for comparison to benchmark data.
Pave3D	At start of project; change in mechanical components; becomes necessary as a result of our Corrective Action process.	Collect data on control sites to validate pavement imagery quality and alignment between left and right lasers.
DMI	At start of project; every 28 days; change in mechanical components; becomes necessary as a result of our Corrective Action process.	Collect along a marked route of known, measured length to confirm accuracy of the system.
GPS	At start of project; change in mechanical components; becomes necessary as a result of our Corrective Action process.	Perform stationary signal acquisition and ensure real-time corrections are active. Collect control sites to validate against known-good data.

ii. Equipment Certification – PennDOT maintains two roughness verification sites; one site is bituminous with a reference roughness, International Roughness Index (IRI), in each wheelpath ranging from 40 to 55 in/mi; the second site is jointed concrete pavement with a reference roughness ranging from 70 to 85 in/mi. Each roughness verification site is 528 feet long with 1,056 feet lead in and lead out sections. The Vendor runs these sites prior to the start of, and throughout, network data collection.

Roughness - PennDOT annually tests the roughness verification sites with a SurPRO 3500 Walking Profiler to obtain the reference roughness values. The SurPRO, an inclinometer-based walking profiler which meets AASHTO Standard R56.14, has a sample rate of 1000 samples per second and can collect samples every 1.0 inches. The following procedures are used to determine the “reference” roughness values for each verification site.

Concrete Verification Site:

1. PennDOT makes eight passes with the SurPRO 3500 in each wheelpath.
2. If the standard deviation of the IRI values of the five most repeatable runs for each wheelpath is determined to be within ± 3% of the mean, then PennDOT will make five passes with an inertial profiler.
3. If the standard deviation of the five IRI values collected with the inertial profiler in each wheelpath is within ± 3% of the mean, and the inertial profiler mean is within ± 3% of the SurPRO 3500 mean IRI value for each wheelpath, then the SurPRO 3500 mean for each wheelpath will be established as the reference roughness value.

Bituminous Verification Site – a different procedure is used to determine the reference roughness on the bituminous verification site because the geometry of that test site presents challenges for the SurPRO 3500.

1. Four PennDOT Inertial Profilers utilizing five pairs of roughness sensors make 10 passes on the verification site. The values from each pass are averaged together for each wheelpath for each of the five pairs of sensors.
2. If the standard deviation of the roughness values of the five sensors is within ± 3% of the mean of the roughness values of the five sensors, the mean of the five sensors for each wheelpath is used as the reference roughness.

PennDOT's Inertial Profiler equipment meets AASHTO Standard M328-14, the requirements of AASHTO R56-14 Section 5 (Equipment), and follows Section 6 of AASHTO 56-14 for Equipment Calibration Verification, including bounce and block tests.

The Vendor makes a minimum of five repeat runs on the roughness verification sites prior to the start of network data collection. Since the roughness verification sites are open to traffic, the Vendor runs the sites at 40mph, PennDOT's required test speed for safety. The Vendor submits the five runs, or the five best runs if more were collected, to PennDOT for analysis of repeatability and accuracy. PennDOT uses ProVAL software to examine the profile runs if necessary and process the IRI data.

PennDOT uses a calculation developed in MS Excel to evaluate the repeatability and accuracy of the Vendor test runs. PennDOT's criteria requires a minimum of five test runs be within 3% of the reference roughness value and within 7% for run to run repeatability. Both exceed the AASHTO R56-14 and ProVAL default accuracy and repeatability requirements.

Pavement Data – The Vendor uses PennDOT's six distress calibration sites to calibrate their distress rating equipment and process, and establish precision and bias. The Vendor runs the distress calibration sites three to five times prior to starting network data collection for calibration, and monthly throughout the network data collection for correlation testing. Electronic sensor data, and full Right-of-Way (ROW) and pavement images are collected on all distress calibration sites following standard procedures used for the network data collection. See the Vendor's QAP in Appendix B for more detail.

If any data type fails both the percentage and absolute value thresholds as defined in Table 2, the test vehicle fails certification.

Once the failing issue(s) is resolved, the test vehicle must go through the pre-survey distress calibration procedure again. This process is followed until the test vehicle passes certification.

Table 2. Vendor Equipment Data Controls

Data Type	Percentage	Absolute Value	Unit
IRI	5%	1.000	Inch per mile
Rutting	5%	0.050	Inches
Macro Texture MPD	10%	0.080	Inches
Macro Texture RMS	10%	0.050	Inches
Cross Fall	5%	0.500	Percent Slope
Roll	5%	0.500	Percent Slope
Grade	5%	1.000	Percent Slope
Pitch	5%	1.000	Percent Slope
Fault Height	5%	0.039	Inches

PennDOT certifies the Vendor's pavement data collection equipment and rating procedure through the collection and processing of the distress data of the same six distress calibration sites, from each data collection vehicle to be used for network testing. The Vendor's processed condition data are compared to PennDOT's average pavement condition data for rutting, cracking, and faulting (see Section 3)a. for more detail). The Vendor's data must meet the accuracy and repeatability for each distress as defined in Table 3 before PennDOT will certify the equipment for data collection and the rating procedure for data reporting.

Distance Measuring Instrument (DMI) - PennDOT maintains a Distance calibration site that the Vendor runs prior to the start of network data collection, every 28 days throughout network data collection, and if there is a change in mechanical components or if required because of a Corrective Action.

PennDOT maintains a log of the results of the equipment calibration verification. See Appendix D.

Table 3. Expected Accuracy of Data Collection Elements

Element	Accuracy	Repeatability
Roughness (IRI)	± 10% compared to ARRB Walking Profiler	± 5% run to run for three repeat runs
Wheelpath Rut Depth	± 10% compared to PennDOT's survey of each Wheelpath	± 5% run to run for three repeat runs
JCP Faulted Joints	± 10% compared to PennDOT's survey	± 5% run to run for three repeat runs
JCP Broken Slab	± 10% compared to PennDOT's survey	± 5% run to run for three repeat runs
JCP Transverse Joint Spall	± 10% compared to PennDOT's survey	± 5% run to run for three repeat runs
JCP Transverse Cracking	± 10% compared to PennDOT's survey	± 5% run to run for three repeat runs
JCP Bituminous Patching	± 10% compared to PennDOT's survey	± 5% run to run for three repeat runs
Bituminous Fatigue Cracking	± 10% compared to PennDOT's survey	± 5% run to run for three repeat runs
Bituminous Transverse Cracking	± 10% compared to PennDOT's survey	± 5% run to run for three repeat runs
Bituminous Miscellaneous Cracking	± 10% compared to PennDOT's survey	± 5% run to run for three repeat runs
Bituminous Edge Deterioration	± 10% compared to PennDOT's survey	± 5% run to run for three repeat runs
Bituminous Left Edge Joint	± 10% compared to PennDOT's survey	± 5% run to run for three repeat runs
Bituminous Patching	± 10% compared to PennDOT's survey	± 5% run to run for three repeat runs

iii. Repair and Adjustment of Equipment – PennDOT requires recertification of the inertial profiler(s) if any major component repairs or replacement occur, including the following:
    1. The accelerometer and its associated hardware
    2. The non-contact height sensor and its associated hardware
    3. The distance measuring instrument
    4. Any printed circuit board necessary for collection and processing of raw sensor data

    The Vendor meets these requirements for the inertial profiler as shown in the Equipment Calibration Schedule in Table 1. Table 1 also shows that all components of the data collection equipment go through a recalibration if there is a repair or any adjustment is made to the equipment.

b. Data Collection Procedure
   Pavement condition data, including roughness, rutting, cracking, and faulting, are collected every year on 100% of the State-owned Interstate and Non-Interstate NHS routes, and on a two-

year cycle for Local Federal Aid routes. Data are collected in one direction on undivided roads and both directions on divided roads. The pavement condition data are collected on State-owned roads according to PennDOT's Location Referencing System; on Municipally owned federally-aided roads, or Local Federal Aid roads, according to that Location Reference System.

i. Location Referencing System
   1. State-Owned Roads – are segmented according to PennDOT's Location Referencing System (LRS). This is a linear reference system that is used to index and designate the State-owned roadway network; to define roadway lengths, locations and route connectivity. All sections of State-owned roadways are assigned a unique identifier to which roadway features, including pavement type and conditions, are assigned.

      Each State-owned roadway in the 67 Pennsylvania Counties is given a route number (State Route – SR). Each SR, identified by a four-digit number, is subdivided into approximate one-half mile "Segments," also identified with four-digit numbers. Finally, each Segment is further sub-divided into one-foot "Offsets."

   2. Local Federal Aid (LFA) Roads - are segmented according to the local road LRS. This is a linear reference system that is used to index and designate the LFA network, similar to the PennDOT State Highway system; to define roadway lengths, locations and route connectivity. All sections of LFA highways are assigned a unique identifier to which roadway features, including pavement type and conditions, are assigned.

      Each LFA roadway is given a unique route. Each route, identified by a four-digit number or alpha-numeric value, is subdivided into "Segments" identified with four-digit numbers. The segmentation of the LFA routes is based on intersecting roadways, resulting in varying segment lengths.

   The pavement condition data for State-owned and LFA routes are collected within their respective linear referencing systems. The pavement conditions required through this MAP-21 regulation will be summarized and reported at 0.10 mile increments within each LRS. Each Segment will be divided into 0.10-mile increments until the last increment before a pavement type change, a bridge deck, or the end of a Segment. If the last increment before any of these physical features is equal to or less than 52.8 feet, that short length will be added to the previous full 0.10-mile increment so no increment is over 0.11 mile. If the last increment is greater than 52.8 feet, it will be a separate increment that is less than 0.10 mile. The full 0.10-mile increment will reset to begin again with the new pavement type, on the leave side of the bridge, or with the next Segment on the route, and so on through the end of the route.

ii. Vendor Data Collection Procedure – The Vendor's data collection routing is prepared prior to commencing any data collection. Pre-data collection vehicle calibration certification takes place so only those vehicles that pass the certification are authorized to collect data. The actual field work begins with testing the roughness verification and distress calibration sites. Network data collection can begin once the data from these control sites have been collected.

However, network pavement condition rating does not begin until PennDOT approves the results of the control sites. See the Vendor's Project Collection Protocol in Appendix E.

The Protocol includes instruction for running the control sites monthly, the DMI calibration, routing, network data collection, data shipment, and downtime. The Field Operations Data Collection Standard Procedure document (also in Appendix E) provides further instruction on specific procedures such as daily vehicle inspection, operating subsystems, and video (image) collection. The Project Set-up section provides detail on the testing equipment, daily reports, camera visibility, weather, real-time data quality checks, and data storage.

iii. Weather Limitations – PennDOT requires data collection occur only when the temperature and weather conditions are within the operating range recommended by the manufacturer of the data collection equipment. Additionally, data cannot be collected during precipitation, or when standing water is present on the pavement. Data collection is not to begin when, and must end before, the sun is low enough on the horizon to cause a glare on the panoramic images.

2) Data Processing
   a. Data Definitions
   The Vendor reports pavement condition data as defined in PennDOT's Publication 336, Automated Pavement Condition Survey Field Manual (see Appendix F). Most conditions are reported at the extent of three severity levels. The extents are in longitudinal feet or area for bituminous pavement conditions, and either the number of joints or slabs for jointed concrete pavement conditions. PennDOT will report the four conditions required for this MAP-21 regulation as follows (see additional detail in Appendix G)

i. Cracking – Collected in accordance with AASTO Standard PP68-14 and quantified according to AASHTO Standards R55-10 and PP67-16.
   1. Bituminous – Fatigue cracking is reported to PennDOT as the length of cracking in each 39-inch-wide wheel path at each of three severity levels. The length of cracking in the three severity levels from each wheel path is added together and multiplied by the wheel path width in feet (3.25 feet), resulting in a square foot area of cracking for each 0.10-mile increment. The area of cracking is divided by the area of the 0.10-mile-long increment. The percent area of cracking for each 0.10-mile increment will be reported to the nearest one percent (1%).
   2. Jointed Concrete – The number of cracked slabs in each of three severity levels are reported to PennDOT. For MAP-21 reporting the total number of cracked slabs in each 0.10-mile increment is divided by the total number of slabs in the 0.10-mile increment, to report the percent of cracked slabs to the nearest one percent (1%) for each 0.10-mile increment.

ii. Faulting – Collected in the right wheel path and reported according to AASHTO Standards R36-13 and R57-14. The number of faulted transverse joints at each of two severity levels (medium and high) has historically been reported to PennDOT. For MAP-21 reporting, all faulting is used, not just that at PennDOT's medium and high severities; the average faulting depth, in absolute values, to the nearest 0.01 inches for each 0.10-mile increment will be reported.

iii. Rutting – Collected in both wheel paths according to AASHTO Standards R48-10 and PP70-14. The length of rutting at three severity levels for each wheel path has historically been reported to PennDOT. For MAP-21, the average of all rutting of both the left and right wheel paths will be reported to the nearest 0.01 inch in 0.10 mile increments.

iv. Roughness – Collected by the Vendor using Class 1 profiling equipment meeting ASTM E950/E950M and operated in accordance with AASHTO Standards M328-14, R43-13, R56-14, and R57-14. Roughness data is collected in both wheel paths, which are 39 inches wide, according to AASHTO Standard R57-14. IRI (in/mile) will be reported according to AASHTO Standard R43-13, as the average of left and right wheel paths in 0.10 mile increments.

b. Certification of Raters

The Vendor trains all Data Rating Technicians to use data reduction software and applications, to verify data resulting from these applications, and ensure the data meets PennDOT requirements. The training is tracked in a training matrix available in Appendix H. See the Data Processing section of the Vendor's QAP in Appendix B for more detail.

PennDOT uses six distress calibration sites to verify the Vendor's training of their Data Rating Technicians. The Vendor's data for these sites, as rated by the project lead or QC delegate, must meet accuracy and repeatability requirements set by PennDOT prior to network data reporting. These requirements are discussed in more detail in Section 3 of this DQMP. Once the Vendor's calibration site data has passed the quality check, the Vendor uses these ratings as the benchmark that all raters must meet in order to proceed with network data processing. The Vendor maintains a log of the control site comparison of all raters. See Appendix I.

c. Operator Certification

The Vendor certifies the operators of their data collection vans through training and practical testing administered by the Field Operation Training Supervisor, including static training/testing and simulated live data collection. Ongoing feedback is provided by the project Field Supervisor and Senior Field Operators. The Vendor maintains a Matrix of Tasks each Field Operations Technician must meet; see Appendix J.

d. Data Format

The pavement condition data will be delivered in 0.10 mile increments. Rutting, cracking and faulting will be reported at the same 0.10-mile increment as the roughness data. The 0.10 mile increments will start at the beginning of an SR/Segment and reset at the beginning of every Segment along the SR (see Section 1)b.i. Location Reference System). The final increment in each Segment will be no longer than 0.11 mile: if the final increment is equal to or less than 52.8 feet, that short increment will be added to the previous full 0.10-mile increment; if the final increment is greater than 52.8 feet (but less than 0.10 mile), it will be considered a separate increment. The full 0.10-mile increment will reset with the beginning of the new Segment. A similar situation will occur at bridge decks and pavement type changes; the last increment prior to the bridge or pavement change may be less than a full 0.10-mile increment but will not be longer than 0.11 mile. The full 0.10-mile increment will reset with the pavement on the leave side of the bridge and with the new pavement type.

3) Data Quality Control

PennDOT has had a three-tier data quality control process in place since 2008. The three data quality checks are:

1. Distress Calibration/Roughness Verification Sites
2. Blind Verification Sites
3. Random 2.5% Selection (Data Acceptance)

Quality Control is also performed on data location and image quality.

a. Distress Calibration/Roughness Verification Sites

PennDOT requires the Vendor to test six pavement distress calibration sites, four bituminous and two jointed concrete, plus two additional sites for roughness verification, all prior to commencing network data collection. The Vendor must collect and submit panoramic images and pavement condition data including roughness on the six distress calibration sites. The Vendor also collects and submits roughness data on the two roughness verification sites. These eight sites are used to evaluate the repeatability and accuracy of the Vendor collected data.

The distress calibration sites are selected to represent the range of conditions and severity levels encountered on the Pennsylvania roadway network. The roughness sites are also selected to represent a range of roughness; between 40 IRI and 85 IRI.

PennDOT tests each of the six distress calibration sites prior to the Vendor testing the sites. A minimum of three PennDOT raters perform at least two ratings of the six sites to determine the reference data.

i. Cracking - The minimum of six ratings on each site are averaged for each distress and severity combination, including fatigue cracking on bituminous sites and transverse cracking on jointed concrete sites.

ii. Faulting - PennDOT processes the collected longitudinal profile to identify the number of joints per Distress Calibration site and the location of each detected fault. The location list is checked against the pavement images to verify the fault occurs at a joint, and then it is assigned a severity.

iii. Rutting - PennDOT uses a combination of string-line and data collection equipment to determine reference rutting data. Rutting data is collected manually every other year using a string-line and measuring the maximum rutting in each wheelpath to the nearest 1/8th inch every 10 feet over the entire length of each site (PennDOT collects rutting on jointed concrete pavements for internal use). PennDOT uses data collection equipment outfitted with a Laser Crack Measurement System (LCMS) to capture rutting in the years between manual data collection.

iv. Roughness - PennDOT maintains two roughness verification sites; one site is bituminous with a reference roughness in each wheelpath ranging from 40 to 55 in/mi; the second site is jointed concrete pavement with a reference roughness in each wheelpath ranging from 70 to 85 in/mi. Each roughness verification site is 528 feet long with 1,056 feet lead in and lead out sections.

    PennDOT annually tests the bituminous pavement roughness verification sites with four inertial profilers (see Section 1)a.ii.) that conform to Class 1 profiling equipment as specified in ASTM E950/E950M. PennDOT annually tests the jointed concrete pavement roughness verification sites with a SurPRO 3500 Walking Profiler to obtain the reference roughness values. The SurPRO, which meets AASHTO Standard R56.14, has a sample rate of 1000 samples per second and can collect samples every 1.0 inches.

v. Accuracy and Repeatability – The Vendor begins annual data collection by testing the six distress calibration sites and two roughness verification sites with each testing van used for network data collection. The Vendor's reported pavement condition site data are compared to PennDOT's average surface conditions, manually collected or automated rutting, automated faulting, and reference roughness data. Table 3 shows the required accuracy and repeatability of the Vendor's data. Each condition and severity combination is evaluated. When any one condition does not meet the required accuracy or repeatability, the Vendor must re-evaluate that condition and resubmit the results. This process is repeated until the requirements in Table 3 are met. Then, and only then, the Vendor is permitted to begin network data reduction.

    The Vendor is required to collect and report roughness on the two roughness verification sites monthly throughout network data collection. PennDOT compares the monthly data to the reference IRI to verify the accuracy of delivered network roughness data. PennDOT works with the Vendor to identify why the data does not meet requirements anytime the roughness data is out of tolerance. This includes reviewing and comparing PennDOT and Vendor data. If it is determined that the Vendor data is incorrect, the Vendor is required to make the necessary corrections and re-run the verification sites. PennDOT also reserves the right to request the ERD files to spot check any submitted network data, and complete comparison test runs with PennDOT profilers. If PennDOT determines that network data has been negatively impacted the Vendor must re-collect those routes impacted.

b. Blind Verification Sites
PennDOT selects 125 Segments prior to the start of every testing season to use as Blind Verification sites. The Segments selected are distributed statewide to represent the full range of conditions, and are not disclosed to the Vendor. PennDOT evaluates these images using the same procedure as for the distress calibration sites: a minimum of three raters perform at least two ratings of each site.

    The Vendor submits a Tested Segment Summary report of batches of Segments collected and to be delivered to PennDOT at least monthly throughout the network data collection. Based on that report, PennDOT requests the Vendor submit the images, roughness, and distress ratings of those segments that are included in the Blind Verification sites, up to 100 Segments. The Vendor has five working days to submit the requested pavement and panoramic images and pavement condition data.

The accuracy of the Vendor's Blind Verification Site data shall be within ± 10% of the average PennDOT ratings. Locations flagged for review are sent to the Vendor immediately for verification and resubmission.

The Vendor's Blind Verification Site data is also compared to data from the previous two years. Unexplained differences (i.e., when no maintenance or construction work was done on the Segment) of more than ± 10% for distress ratings and more than ± 50 in/mi for IRI are flagged for review. These Segments are sent to the Vendor for verification and resubmission.

c. Random 2.5% Selection (Data Acceptance)
PennDOT uses the Vendor's Segment Summary report, discussed in Section 3)b. Blind Verification Sites, to randomly select 2.5% of each "batch" of data the Vendor delivers for acceptance of that data batch. Bituminous and jointed concrete pavement Segments are selected separately. PennDOT notifies the Vendor of the selected Segments at which time the Vendor is required to deliver pavement images and pavement condition data including roughness within two weeks.

PennDOT uses the Vendor images to rate each Segment included in the Random Sample in a single pass by one rater. The comparison of PennDOT rating to Vendor data is used to accept, or reject and require corrective action of, the batch delivery using the criteria in Table 4.

Table 4. Batch Data Acceptance Criteria

Reported Value	Initial Criteria	% Within Limits	Action if Criteria Not Met
IRI	±25%	95	Reject deliverable
Individual Distress Severity Combination	±30%	90	Feedback on potential bias or drift in ratings. Retrain of definitions.
Total Fatigue Cracking	±20%	90	Reject deliverable
Total Non-Fatigue Cracking	±20%	90	Reject deliverable
Total Joint Spalling	±20%	90	Reject deliverable
Transverse Cracking, JCP	±20%	90	Reject deliverable
Location - Segment/Offset	Correct Segment Surveyed	100	Return deliverable for correction.
Location – Section Begin	±40 feet	95	Return deliverable for correction and system check.
Panoramic Images	Legible Signs	80	Report problem – reject subsequent deliverable.

An additional evaluation of batch data for acceptance includes an analysis of historical data. PennDOT plots three years of conditions, summed and normalized for all Segments in the batch by pavement type, in a bar chart. Differences between the three years are checked and the need to send the batch to the Vendor for review and resubmission is determined if a difference between years is caused by the current year's data.

d. Image and Location QC
PennDOT reviews all Interstate images and the images of four or five routes from each County in a batch delivery. The review includes:

i. Image Quality – Check image brightness, and clarity and focus; the cleanliness of lens; the image banner information; and the playback of images.

ii. Location Quality – Compare image location to the location on a GIS map; supplement with comparison to Straight Line Diagram (SLD) for correct segment, and start and stop points.

e. Vendor QC Plan
The Vendor has a detailed QC Plan specific to Pennsylvania: PennDOT Quality Assurance Plan (QAP) in Appendix B. The QAP includes, but is not limited to, the following:

i. Testing Vehicle Certification – Certification must be completed for each testing vehicle to begin data collection. The certification is performed by the Vendor. The Vendor keeps certification records for each vehicle; an example is in the QAP (Appendix B, page 7).

ii. Data Collection – Field Operations Technicians are trained to use and troubleshoot onboard computer systems, video equipment, and automotive systems. Field Operations Technicians are also trained to find inconsistencies and errors in the collected data and images. A training checklist for different Field Operations Technician positions is in Appendix J.

iii. Data Processing – Data Processing Technicians are trained to use data processing applications, and perform checks and identify errors to ensure data meets PennDOT requirements. Training is tracked in a log in Appendix H.

iv. Data Rating – Distress Rating Technicians are trained in the PennDOT distress protocol. Each Distress Rating Technician must be familiar with this protocol before beginning distress rating. Each Distress Rating Technician rates each of the PennDOT Distress Calibration Sites. These ratings are compared to the benchmark ratings approved by PennDOT. Each rater must pass all the distress calibration sites consistently before beginning network data rating. All Distress Rating Technicians must also rate the Distress Calibration sites mid-way through the network data collection. These interim results are compared to the benchmark data to ensure rating consistency throughout the project. A log of the Distress Rating Technicians' Control Site Comparison is in Appendix I.

v. Data Analysis – The Vendor applies quality checks on the final data to be delivered including, but not limited to: Completeness; Location Information; Section Length; Linear Reference; Roughness; Faulting; and Rutting.

vi. Corrective Action – The Vendor has developed a corrective action plan for data that fails internal quality reviews, or when PennDOT identifies an error in delivered data (see page 28 of the QAP in Appendix B). In both cases, the cause of the error is determined; random or systematic. Random errors require correction to that specific section with the error; systematic errors require correction to the data in the batch with the error and possibly previous batches. Additional training and clarification will be provided to the Distress Rating Technicians as necessary.

4) Data Sampling, Review, and Checking Process

a. Data Sampling

PennDOT selects, through random sampling, 2.5% of each Vendor data delivery batch for Data Acceptance. See Section 3)c. Random 2.5% Selection for detail on this tier of PennDOT's three tier Data Quality Control.

b. Data Review

PennDOT has two data review processes as part of the Data Quality Control.

i. For the Distress Calibration Sites (Section 3)a.) and Blind Verification Sites (Section 3)b.), a minimum of three PennDOT raters perform at least two ratings of the sites involved in each data review process. The average of the six minimum ratings, for each distress and severity on each site, are used to evaluate the Vendor's data on these sites.

ii. PennDOT uses the Vendor's pavement images to rate the Random 2.5% Selection sites (Section 3)c.). One PennDOT rater makes a single pass through the images to evaluate the distresses. The Vendor data are compared to the PennDOT ratings to accept or reject the "batch" of data delivered with which the 2.5% sample is associated.

c. Data Checking Process

PennDOT has three data checking processes.

i. Distress Calibration/Verification Sites – The Vendor data are compared to PennDOT's reference data for accuracy and repeatability. See the requirements in Table 2.

ii. Blind Verification Sites – The Vendor data are compared to PennDOT's reference data. Vendor data must be within ± 10% for distress ratings and ± 50 in/mi for IRI.

iii. Random 2.5% Selection – The Vendor data are compared to PennDOT's reference data derived from the Vendor's pavement images. Acceptance or rejection of the Vendor's batch data is based on the criteria in Table 3.

iv. Additionally, PennDOT checks the location of the reported data by verifying the location of the images delivered for all Interstates, and four or five routes from each County in a batch delivery.

5) Error Processing Procedures

a. Data Acceptance Criteria

PennDOT evaluates 2.5% of the Vendor data for acceptance or rejection, based on the following:

i. Comparison of Vendor's data to PennDOT's reference data. PennDOT uses the Vendor's images to rate each Segment, by one rater in a single pass, to determine the reference data for each Segment in the 2.5% random sample. Acceptance criteria are in Table 3.

ii. The Vendor's current condition data are compared to two previous years' data, the conditions summed and normalized for all Segments in the batch by pavement type. The data are presented in bar charts to check for differences between the three years. A difference in the current year data will flag that condition; the batch will be returned to the Vendor for review and resubmission.

b. Data Upload Edit Checks

Once PennDOT has released the Vendor data for upload to PennDOT's roadway data warehouse, the Roadway Management System (RMS), the data goes through a sequence of front end error processing steps. The data are checked for errors such as survey date, invalid LRS key, pavement surface type, Segment length, and condition data length. If the data passes all edits it is loaded to RMS. If the data has an error in any one of the edit checks, the record is flagged and is sent back to the Vendor for review and resubmission.

i. Pavement History – Segment Surface Type check

PennDOT maintains a database of pavement history for all Segments that includes maintenance and construction work since the road was built. The pavement surface type is used to determine the pavement condition data that will be accepted. If the pavement history and Vendor delivered surface types do not match, the Vendor data is rejected and sent back to the Vendor for review and resubmission. Or if the Vendor pavement surface type is correct, PennDOT updates the pavement history and re-submits the Vendor data for upload.

c. Error Resolution Process

PennDOT accepts the Vendor data for upload to the RMS after the data has passed the Random 2.5% Selection process. During upload, the data are run through a series of edit checks. Records that fail the edit checks are summarized in an error report; depending on the error type, the record might go back to the Vendor for review and resubmittal. Those edit checks include: the partial survey length exceeds the Segment length; the extent of the condition reported exceeds the Segment length; the number of joints or slabs is not reported; predominate pavement type is incorrect. Should the predominate pavement type delivered by the Vendor prove to be correct, then the error goes to the corresponding District to correct in the database, after which time the condition data will load to the RMS.

NOTE: The Pennsylvania Turnpike Commission (PTC) is operated separately from PennDOT. The PTC handles their own pavement data collection and provides that data to PennDOT for reporting. See Appendix K for the PTC's Data Quality Management Program.

APPENDIX A

ARAN9000 QC Acceptance Report

Test Done in Richmond, VA, USA

@Persons Responsible for verifying all the ARAN Data and Video are ready for collection of a project.

Aran # 52	Signatures	Signatures Date
Data Processing Specialist David Hunter		
Distress Supervisor Donna Daniels		
Surveyor Supervisor Geoff Dew		
Data Services Manager Matthew Connelly-Taylor		
Fleet CS Supervisor Derek Pescod		
Director of operations Denis Charland		
Quality Manager DJ Swan		

List of Documents to Review

ARAN9000 QC Acceptance Report – Real Time

ARAN9000 QC Acceptance Report - Post Processed

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APPENDIX A

1. Scope

This document details the procedures and reporting forms for conducting ARAN9000 factory Acceptance Tests during production of the ARAN.

ARAN9000 Acceptance Tests are designed to test the hardware and software of this specific ARAN. These tests are not intended to fully exercise a new design. New designs are tested under more extensive Design Qualification Tests.

ARAN9000 Acceptance Tests are designed to supplement the preventive maintenance checks. It is assumed that basic hardware functionality and preventative maintenance checks have been completed prior to acceptance testing.

Each ATP must be completed and processed before proceeding to the next ATP.
The ARAN Crew must complete the End Of Day Procedures every day (this includes the End Of Day Reports). Mark the collected sections with an “X” that are not being used, and with a “C” for used sections.

2. Applicable Supporting Documents and Files

Aran 9000 user manual on the ACS

https://www.dropbox.com/sh/n5qup4hbd0tst9d/AAAlo1wU6fzSN2x0XWPRonAXa?dl=0

This link contains the following

- VA routing and template
- Vertical Verification Bounce Test.docx
- Lever Arms Master.pdf
- Richmond Aran Certification Log.xlsx

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3. ARAN Configurations

3.1 Hardware Configuration

The tested ARAN consisted of the subsystems listed below:

SUBSYSTEM	YES / NO	NOTES
Chassis	Yes	Sprinter
Roughness System and Faulting	Yes	Crio
Roughness Laser Type	Yes	GoCator 5 k
Laser Texture	Yes	Quantity: 1
Server Computer	Yes	
Row Computer	Yes	
Pavement Computer	Yes	
Frankie Computer	Yes	
Row Cameras	Yes	Quantity: 1 Type:320
Pavement Type	Yes	Type: LCMs
POS LV Version	Yes	Ver 5 SN 7067

3.2 Software Configuration

Software Program	VERSION	NOTES
Aran Collection Suites (ACS) 9000	2.2.4.94	
Server Computer OS	Windows 7	
Row Computer OS	Windows 7	
Pavement Computer OS	Windows 7	
Frankie Computer OS	Windows 7	
Microsoft Office	2010	
Microsoft SQL	2005SE	

3.3 Vehicle Weight

Complete with all Equipment.

Front Axle	3320 Lbs.
Rear Axle	3880 Lbs.
Total Weight	7200 Lbs.

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3.4 ARAN Setup

We are using the settings from VA.

AS-0000000050 VA Settings Non LCMS

AS-0000000054 VA Settings LCMS

With the following changes to Texture if applicable

Texture	Enabled
Texture RMS and MPD	Enabled
Texture in Right Wheel Path	Enabled
High-Pass Filter Length	1.97 in
Low-Pass Filter Length	0.04 in
RMS length	1 mmil
Measurement Interval	1 mmil

Set up for VA	**Completion Date**
Aran set up for VA	**20150822**
Project Setting XML was compared with a VA Aran	**42**
Done By:	**DW**

4. Static Calibrations and Verifications

4.1 Block Calibration and Test

Purpose: To verify that the lasers height readings and calibrate the accelerometer of the Roughness system.

Procedure: Calibrate the laser height using the ACS Roughness calibration process. (CRIO Systems Only)

Results:

Type of Roughness System	**CRIO**

Block Height	**Left Laser Value**	**Right Laser Value**	**Left Laser Difference**	**Right Laser Difference**	**Pass / Fail**
.5 inch	**0.502**	**0.489**	**0.002**	**0.011**	**Pass**
1 inch	**1**	**0.996**	**0.000**	**-0.004**	**Pass**
2 inches	**2.001**	**1.992**	**0.001**	**-0.008**	**Pass**
Date Done	**20150504**	**20150504**	**20150504**	**20150504**	
Done By	**DP**	**DP**	**DP**	**DP**	

Acceptance: Values within 0.04 of an inch of the block size

4.2 Roughness Calibration and Bounce Test

Purpose: To verify the accelerometer and lasers are in sync and there is not excessive noise in the Roughness system.

Procedure: Read and complete the testing in the document Vertical Verification Bounce Test Ver 2. Complete the test 3 times and export ERD files as well as the CSVs. Record values below. Create and save the Project settings XML file to be added to data for verification.

Results:

Calibrations	Left Gain Results	Right Gain Results
Calibration 1	-0.070	-0.070
Calibration 2	-0.070	-0.070
Calibration 3	-0.0705701	-0.0719602
Pass/ Fail	**Pass**	**Pass**
Date Done	**Aug 7**	
Done By	**DP**	

Acceptance: Compact Rio Gain values 0.07 and Non Compact RIO between 470 and 480

Bounce test Results

Section ID	Session ID	Left Static Max	Right Static Max	Left Bounce Max	Right Bounce Max
Bounce1		3.2	3.2	9.5	7.5
Bounce2		3.2	3.2	8.5	10.0
Bounce3		3.2	3.2	9.5	9.0
Average					
Pass/Fail			**Fail do to Gocators**		
Date Done			**2015 0729**		
Done By			**Milo S**		

Acceptance: Roline with a CRIO system should have static values no more than 3 inches per mile and Bounce values of no more than 8 inches a mile. Spot and Non CRIO systems will fail, so please mark them as a FAIL.

4.3 Texture Calibration

Purpose: To calibrate the texture and ensure it is working in the full range of the laser.

Procedure: *Follow the ACS texture calibration process. (Non CRIO only)*

Results:

Completion Date	**Software would not do calibration**
Done By	**DP**
Results	**Fail**

4.4 Verify all lever arms and offsets

Purpose: Verify that the numbers in the ACS and PCS are correct.

Procedure: *Complete the Lever Arms Master.pdf manually with the laser and measuring devices and compare them to the ACS settings.*

Results

The values in ACS and PCS are correct	**Yes**
Done by	**DP**

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4.5 GPS Static

Purpose: *Verify that the Lever Arm and OmniSTAR corrections are coming in correctly.*

Procedure: Start services using the ACS launcher and start the ACS software. Align the ARAN to the designated positions (50, 51, 56 and 108) and collect a full PCS file in both directions (away from gate/towards gate).

Results:

Section ID	Session ID	PCS File	Latitude	Longitude	Elevations	Error
Reference	Spot 50		37.605270238652295	-77.49164123337962	62.83372752	
Spot50D1	20150821.103815	LV201508210904.02	37.60527151	-77.49164266	?	0.1897
Spot50D2	20150821.113544	LV201508211116.005	37.60526807	-77.49164332	?	0.3000
Reference	Spot 51		37.605297139533675	-77.49169317254491	62.85741932	
Spot51D1	20150821.122212	LV201508211116.015	37.60529198	-77.49169537	?	0.600
Spot51D2	20150821.121252	LV201508211116.013	37.60529279	-77.49169543	?	0.5109
Reference	Point 56		37.605260691756385	-77.49167298388811	62.84215737	
Spot56D1	20150821.115010	LV201508211116.007	37.60525711	-77.49167437	?	0.4242
Spot56D2	20150821.120508	LV201508211116.010	37.60525652	-77.49167558	?	0.5196
Reference	Point 108		37.60523187775430	-77.49164634013390	62.76924229	
Spot108D1	20150821.133254	LV201508211316.004	37.60523211	-77.49164975	?	0.284
Spot108D2	20150821.134120	LV201508211316.006	37.60522938	-77.49164862	?	0.328

Acceptance: Data collected with real time correction Below **1.25 meters with VBS corrections.**

Calculate the distance between the reference and collected measurements for each point. A quick tool can be found here: **http://www.csgnetwork.com/gpsdistcalc.html**

Pass/Fail	**Pass**
Date Done	**20150821**
Done By	**Derek Pescod**

4.6 Reverse Runs

Purpose: *To reset the IMU data Roll and Pitch on the vehicle back to zero.*

Procedure: Complete the document Frame Angle Calculation.xlsx and fill in the chart below with your verification runs.

Results:

Section ID	Session ID	Roll Values	Pitch Values
Run 1 Direction 1		-1.674463688	-0.583412426
Run 1 Direction 2		1.779171729	0.54017893
Run 2 Direction 1		-1.807067597	-0.564598394
Run 2 Direction 2		1.759161531	0.568662533
Run 3 Direction 1		-1.809248837	-0.523491701
Run 3 Direction 2		1.785404746	0.627917704
Run 4 Direction 1		-1.773205569	-0.552085613
Run 4 Direction 2		1.77228382	0.588883824
Run 5 Direction 1		-1.811439159	-0.539028756
Run 5 Direction 2		1.759766277	0.597792463
Average of all Verification runs		-1.674463688	-0.583412426

Pass/Fail	**Pass**
Date Done	**20150804**
Done By	**Allan V**

Acceptance: Roll and Pitch +/- 0.1.

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5. Distance Measurement Instrument

5.1 DMI Repeatability Road Test

Purpose: To test normal chainage operation function, specifically the shaft encoder assembly.

Procedure: Complete a DMI calibration based on current Fields operations Dmi calibration procedures remember to *complete the Sales Force DMI record log.*

Results:

Run	Calibration Number (pulses/m)
1	**852.29**
2	**852.22**
3	**852.18**
4	**852.17**
5	**852.29**
Average Calibration Number	**852.215**
Standard Deviation	**0.054467**
Ambient Temperature	**24 degrees C**

Acceptance: Average Calibration Number must be between 850 and 858. The Standard Deviation must be less than 0.3

5.2 DMI Card Diagnostic Verification

Server DMI Max Count	**602110**
Row DMI Max Count	**602110**
Row B DMI Max Count	**NA**
LCMS DMI Max Count	**602110**

Acceptance: All numbers should be the within +/- 2.

Distance Measurement Instrument - Signoff:

Date Done	**20150814**
Done By	**VB**
Results Pass/Fail	**Pass**

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5.3 LCMS Standing Starts and Stop on DMI Site

Purpose: To provide an onsite reviewable control for testing and calibrating LCMS

Procedure: From a complete stop on the begin point of the DMI site, select Start and without moving select Begin and driving in a smooth and controlled fashion, collect the length of the DMI site. Come to a complete stop at the end point of the DMI site. Select End and then Stop. Export the csv results of this run using the tool in Review Data. This will be reviewed by CS to confirm the system status and what actions may be necessary.

Results:

Section	Session ID	Average Left Rut	Average Right Rut	Profile Matches Road
Run 1	**NA**	**NA**	**NA**	**NA**
Run 2	**NA**	**NA**	**NA**	**NA**
Run 3	**NA**	**NA**	**NA**	**NA**
Pass/Fail				
Date Done				
Done By				

Acceptance: Profile matches road conditions and average rutting values are within **%5** of historical data.

5.4 GPS and Geometrics - QC Testing

Purpose: To exercises the GPS, geometrics, and digital video storage on a hilly and curved road and verify repeatability.

Procedure: Collect the designated Geometrics loop 3 times. Starts are important ensure you are starting in the correct location. Graph the results of the following values Pitch, Roll, Heading.

Report Subsection

Pitch Results

Session ID	Section ID	Average Pitch
20150824.100458	**Geometrics1**	**0.023633928**
20150824.101728	**Geometrics2**	**0.065642336**
20150824.103125	**Geometrics3**	**0.096494725**
	Average	**0.061923663**
	STDEV	**0.036572467**

Acceptance:

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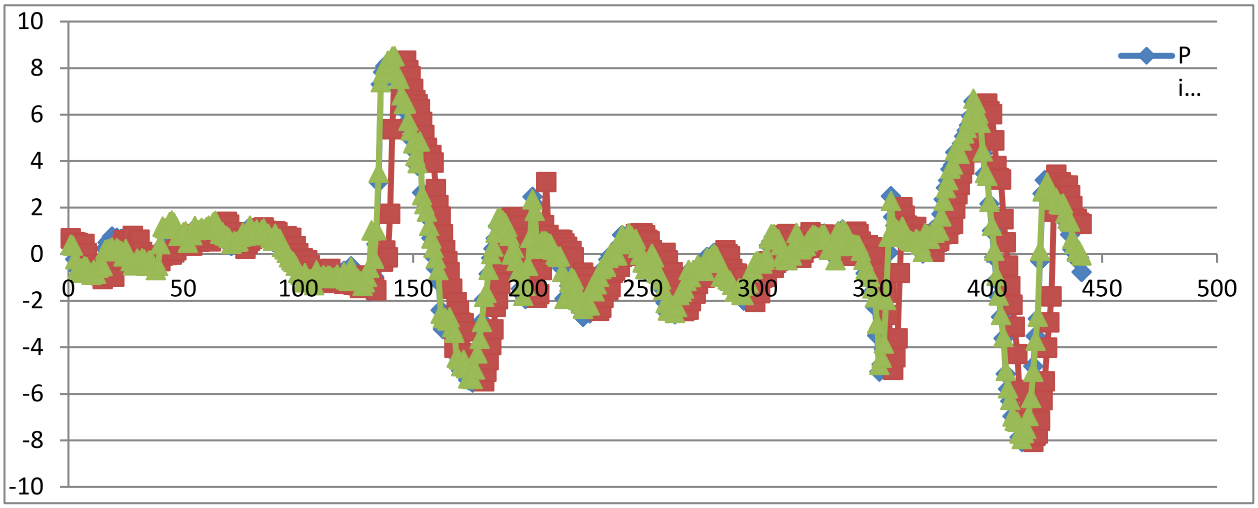
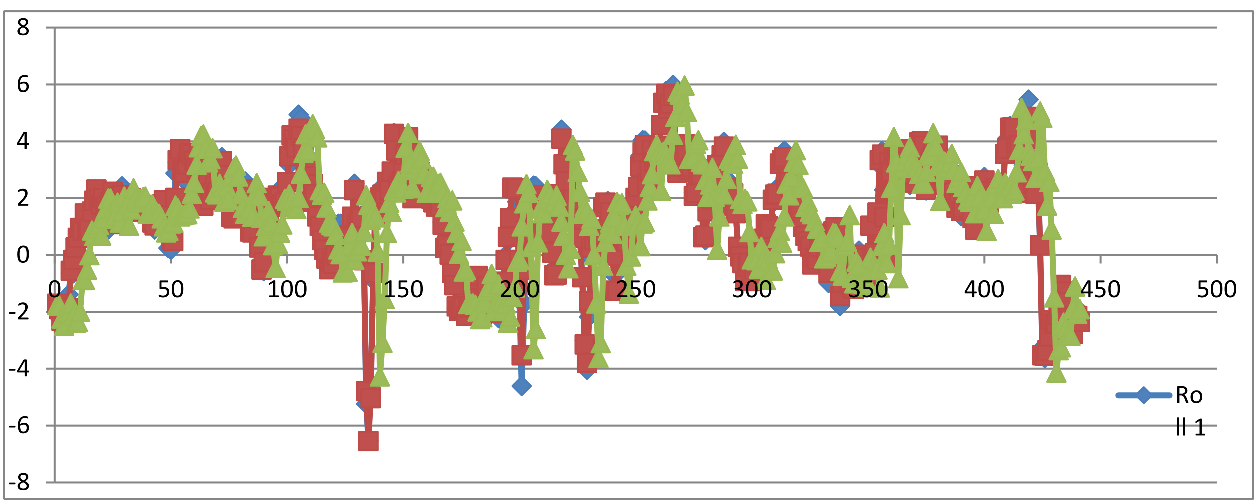


Roll Results

Section ID	Roll Average
Geometrics1	1.357102991
Geometrics2	1.340527298
Geometrics3	1.366249456
Average	1.354626582
STDEV	0.013038666

Acceptance:

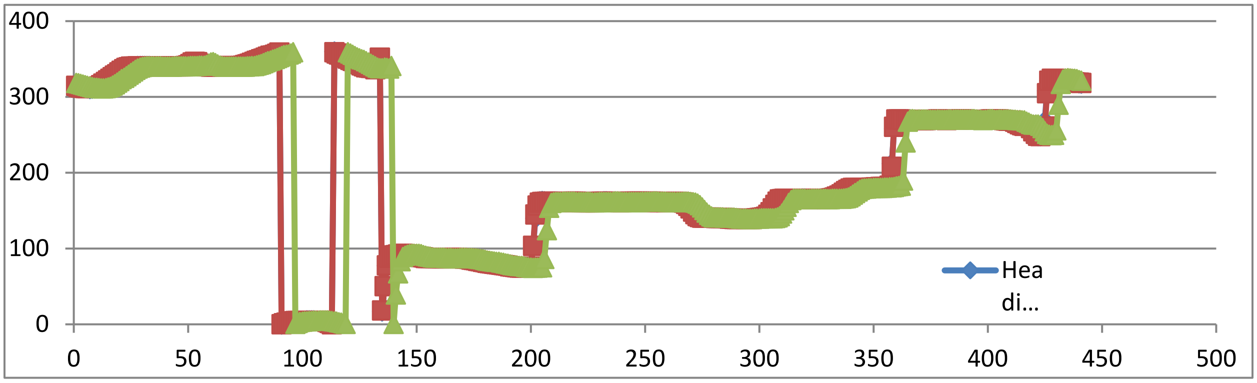


Heading Results

Section ID	Heading Average
Geometrics1	207.6769177
Geometrics2	207.6134703

Geometrics3	**207.2717183**
Average	**207.5207021**
STDEV	**0.217947507**

Acceptance:



6. Video and Pavement Alignment and Surveyor

6.1 Video and Pavement Alignment and Quality

Purpose: To verify that Video and Pavement quality and alignment as well as verify settings for the rest of the testing.

Procedure: *Focus the ROW camera and set it up with the VA alignment.*

Verify that the Pavement is aligned and quality is up to Roadware standards.

Obtain camera alignment sign off from office.

You will need to collect 2 full sign offs and a one meter test.

1st file is our regular(asphalt) 200 Milli-Mile sign off file.

2nd file is a concrete(Dumbarton) 200 Milli-Mile sign off file.

3rd file is drive over the 1 meter circle at approximately 25 mph.

Upload those files and create a sign off file under XXXXX and submit the files for sign off.

Date Done	**20150824**
Done By	**DW**

6.2 Surveyor Loop and Static Calibration

Purpose: To test the timing and accuracy of the surveyor system

Procedure: Run the Surveyor Loop 5 times and do a Static Calibration. Upload the Surveyor loop and Static to the FTP and email #Fleet_cs and #Survyor with the link to the data.

Date Done	**20150823**
Done By	**DW**

7. Extended Section Road Test

Purpose: Test extended operation and functionality on long test section (55 miles an hour).

Procedure: Collect 4 - 25 mile long files at highway speeds while checking that systems are working correctly and do an end of day to ensure everything is collecting properly.

Section ID	Session ID	Errors or Issues
ExtendedRuns1	20150815.110420	No Issues
ExtendedRuns2	20150815.113629	No Issues
ExtendedRuns3	20150815.121029	No Issues
ExtendedRuns4	20150815.123917	No Issues
Date Done		**20150815**
Done By		**DW**

Results: Review all the data of the End of Day Report check for missing images and review all CSVs.

7.1 Sales Force, Safety and Spare Parts

Items	Yes/No notes	Check by
Spill Kit	Yes	VBaptista
Safety Vest	Yes	VBaptista
Safety Flares	Yes	VBaptista

Safety Kit	Yes	VBaptista
Safety Glasses	Yes	VBaptista
First Aid Kit	Yes	VBaptista
CO2 Detector	Yes	VBaptista
Laser Safety Goggles	Yes	VBaptista
Spare Parts	Yes. New spare parts to include and the old spare parts to remove. Sayed Notified by email.	VBaptista
Aran on Sales Force	Yes. But It still in ATP. No project assigned.	VBaptista
Aran Dailies on Sales Force	Yes	VBaptista
Aran Spare Parts in Sales Force	Yes	VBaptista
Aran Assets in Sales Force	Yes.	VBaptista
Air Con system works	Roof Top AC unit not Cooling. Truck AC Cooling but not enough.	VBaptista
Power system works	Yes.	VBaptista
Vehicle Manual	Yes.	VBaptista
Garmin on Aran	Yes.	VBaptista
Printer	Yes.	VBaptista
Garmin	Yes.	VBaptista
Cell Phone	Yes. It does not receive company emails .	VBaptista

8. VA Controls

Confirm setup for VA before running controls. Site 5, 6, 7, 8

IRI in inches Ruts in inches, X-Fall in %Slope, Roll and Pitch in degrees, MPD and RMS in millimetres.

8.1 Site 5
8.2 Site 6
8.3 Site 7
8.4 Site 8

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APPENDIX B - PennDOT Quality Assurance Plan

This Quality Assurance Plan is intended to be a living document which will be mutually approved by PennDOT and Fugro and updated and improved through the life of the project.

Fugro Roadware

July 2017

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Document Change Control

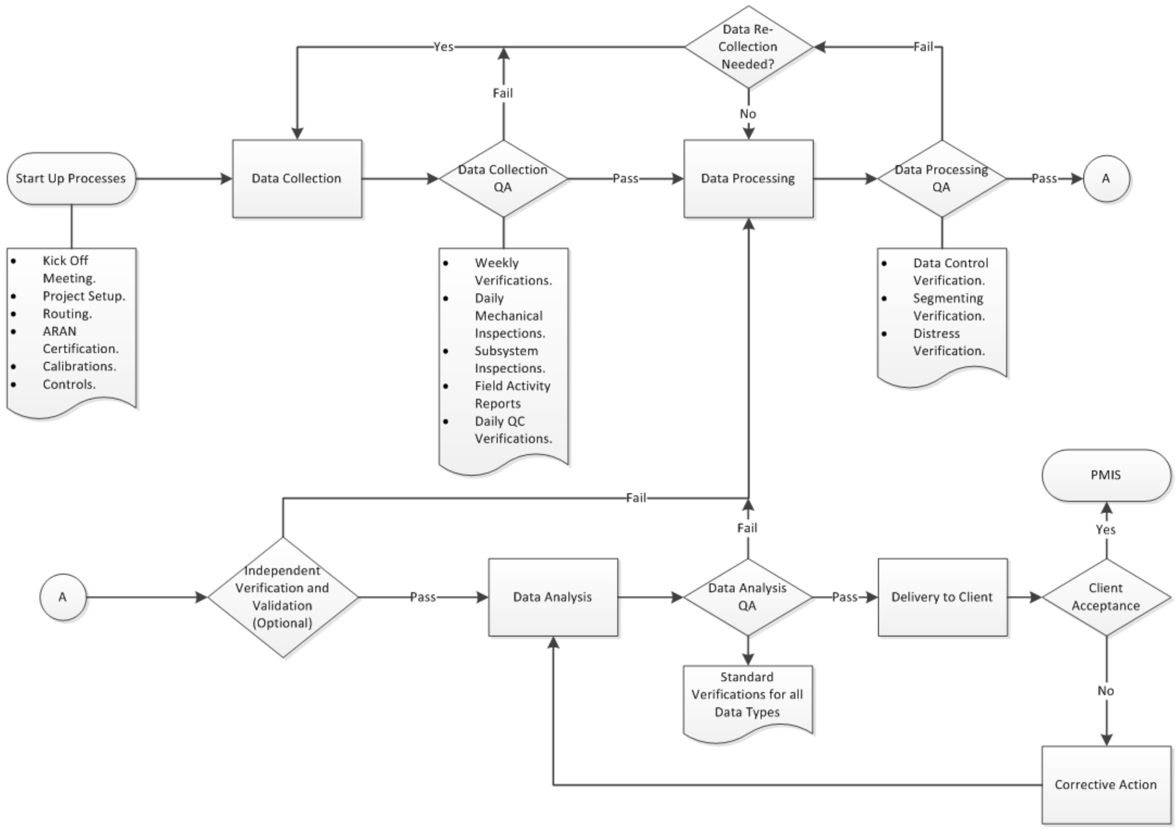
The following is the document control for revisions to this document.

Version Number	Date of Issue	Authors	Brief Description of Change
DRAFT	July 4,2017 July 18,2017	Monty Cliff Cory Hackbart	Draft QAQC Plan created Added Title page, Table of Contents
Final	Sept 19,2017	Cory Hackbart	PENNDOT 2017 Quality Assurance Plan - Sept 19 2017.doc

Introduction

Fugro Roadware is committed to delivering road condition and asset data to the highest level of quality, while maintaining data value through quick, efficient delivery. This requires quality control to be incorporated into every process, ensuring that any exceptions are caught as early as possible and handled according to pre-defined rules and is showed in the following figure:

Figure 1 Process Flow



As an integral part of our registration with ISO 9001:2008 Quality Management System (QMS) these principles are built into our day to day procedures, using a combination of standard and project-specific quality assurance processes. Fugro Roadware has a comprehensive set of standard operating procedures (SOPs) for controlling quality both in the field and in our offices. These SOPs ensure that each task is performed with consistency and discipline. Numerous checkpoints throughout the data life cycle ensure we identify and re-survey, as early as possible, any roadway segments that do not meet specified quality standards. Our consistency and discipline ensure data accuracy and repeatability.

Our quality management system (QMS) and our standard operating procedures (SOPs) link to Fugro Roadware's Continuous Improvement and Customer Satisfaction processes and extend to all programs, suppliers, and activities that affect the quality of our services. This will effectively reduce the time needed for PennDOT to monitor the data as it is being collected and processed.

This quality assurance plan is intended to be a living document which will be mutually approved by PennDOT and Fugro and updated and improved through the life of the project. The processes outlined in this plan have been created from valuable lessons learned on previous PennDOT projects which include having a set of mutually agreed upon control sites with adequate benchmarks and a clear communication process between PennDOT and Fugro for any clarification of requirements.

Fugro has adopted a Red Flag Program which automatically identifies any situation that commonly leads to collection, processing or delivery errors. These identifications are automatically sent to appropriate party members which may include the Senior Management of Fugro. For example, an ARAN which has not been certified to collect, and begins data collection, would be Red Flagged.

Start Up Processes

Project Management

The dedicated Fugro project manager ensures that all key internal stakeholders provide their respective expertise to plan out the path to a successful project completion, prior to submitting a formal response to an RFP.

Upon the award of the contract, the project manager will create a detailed project plan which will ensure that throughout the duration of the project, the technical project team is fully informed of all project requirements at all times.

Through life the project, the Fugro project manager will be PennDOT's single point of contact and they will be dedicated to ensuring the project is delivered properly and on time.

Internal Project Setup

In preparation for the PennDOT kickoff meeting, the project manager will hold an internal project setup meeting to finalize the project plan, clarify the scope to the technical project team, and gather any questions or clarifications from the internal project team. The first draft of the ARAN configuration, data dictionary, and the processing plan will be established during this meeting to ensure that we have a common understanding of the data deliverables and format required, and the steps required to create those deliverables.

PennDOT Kickoff Meeting

An in-person kickoff meeting with PennDOT will ensure that all internal and external project stakeholders have a clear and thorough understanding of the project requirements, and acceptance criteria prior to the commencement of any data collection or data processing. During this meeting, all of the following items will be discussed:

- All deliverables are defined and clarified.
- Any questions from the Internal Project Setup process are discussed.
- Schedules for all tasks and deliverables are presented, clarified and agreed to.
- Control site schedule, locations and benchmarks.

Final Project Setup

During the final project setup phase, the software configurations and project protocols will be finalized for every department involved in the collection or processing of data. This includes ARAN sub-system settings, project protocols, the internal processing plan and the quality plan. At this time project network directories, databases, and documentation repositories will be created following standard structures and formats to ensure that data and information is well organized and easily accessible by all parties.

Routing

Upon receipt of the PennDOT road network definition, an experienced GIS analyst will review the PennDOT network attributes such as the expected number of miles, functional class, number and order of road segments, polyline topology, beginning/end descriptions, GPS and direction of travel to ensure that the data is collected completely in the proper direction, to the desired limits and in the correct lane.

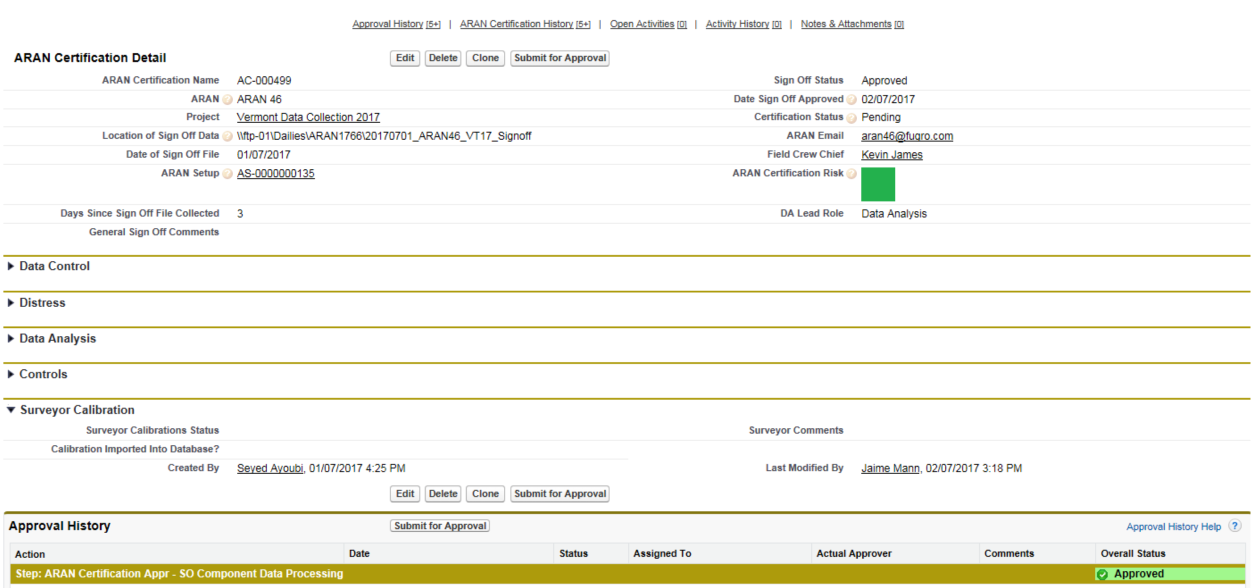
The Routing department will then prepare a collection package for the ARAN including all necessary entry, exit and monthly control sites. Once this package is completed, and before sending to the ARAN for collection, a series of standard queries are performed that ensure the road network elements such as road description, GPS, length, one way roads, lane designation and direction are logical, correct and in a proper order to ensure the correct and timely collection of these sections.

The master routed table produced by the routing department will be used by downstream quality control and quality assurance procedures in both the data collection and also the data processing departments, to ensure full coverage of the PennDOT network.

ARAN Certification

The ARAN certification process ensures that only quality data is collected. The ARAN certification is required to be completed prior to the ARAN being authorized to commence collection within a project.

Figure 2 is an example of one of these ARAN Certification records.



The ARAN certification is composed of several distinct validation processes:

Definition of ARAN Configuration

Part of our quality management system includes an ARAN setup phase to determine the ARAN configuration that is required to collect the data elements defined by the project scope and is performed by the Project Manager in conjunction with our technical experts.
The configuration requirements are documented via the pre-defined ARAN Setup record (Figure 3). This guarantees consistency and ensures that every ARAN entering a specific project uses an identical configuration.

Figure 3 ARAN Setup Record

Notes & Attachments [1] | ARAN Certifications [1] | ARAN Setup History [5+]

ARAN Setup Detail Edit Delete Clone

ARAN Setup Name	AS-0000000135	Comments	
Project	Vermont Data Collection 2017		
Location of Routing Importer xml	\\VIDEO-12\Operations\Projects\		
Location of Events xml	\\VIDEO-12\Operations\Projects\		
Location of Project Settings File	\\VIDEO-12\Operations\Projects\		
Location of Project Collection Rules	\\ftp-01\Deliveries\Vermont\Vermont2017\Protocals\Data_Collection\		
Location of Control Tracker Template	\\ftp-01\Deliveries\Vermont\Vermont2016 \Controls\ARAN_33_2016_07_20_July-20_ExitControls\		

Special Data Requirements

Special Data Requirements	Control sites - 4 sites Entry - 10 runs each site Monthly - 5 runs each site Exit - 10 runs each site Weekly Verifs - 3 runs, one site each week DMI - Monthly with Controls Surveyor Calibration/Loop - Richmond VA site - Entry and Exit Video Quality - High Dailies to client on ftp site

DMI

DMI	Enabled	DMI Distance Units	Miles

Event Configuration

Events	Enabled	Events Autostart Installed	✓
Enable Event Definition	✓	Point Event Detail	✓

Export/Backup Configuration

Station Interval	5 mmil/8.04672m

Faulting Configuration

Faulting	Enabled	Faulting in Right Wheelpath	✓
Faulting in Left Wheelpath	✓	Faulting Confidence Threshold	18
Faulting Filter Length	24	Faulting Detection Threshold	0.2 in/0.00508m
Faulting is Deliverable?	Yes		

Grade Configuration

Laser XVP Configuration

LCMS Configuration

LCMS	Enabled
LCMS Road Section Length	5 mmil / 8.04672 m

POS LV Configuration

POS LV	Enabled	POS LV Raw Data	✓
POS LV Max Raw Data File Size	8		

Roughness - Laser SDP Configuration

Laser SDP	Enabled	IRI	✓
Laser SDP Type	Roline	Laser SDP in Left Wheelpath	✓
Ride Number	☐	HIRI	☐
Laser SDP in Right Wheelpath	✓	MRI	☐
Laser SDP Profile	✓	Laser SDP Summary Interval	5 mmil/8.04672m
Laser SDP Raw Data	✓	Laser SDP Raw Data Storage Interval	1 in \ 0.0254 m
Laser SDP Profile Storage Interval	1 in / 0.0254 m		
Roughness is Deliverable?	Yes		

Texture Configuration

Texture	Not Enabled	Texture RMS and MPD	☐
Texture in Left Wheelpath	☐	Texture in Right Wheelpath	☐
Texture in Centre Wheelpath	☐	Texture Measurement Interval	
RMS Length			
Texture is Deliverable?	No		

Verification of ARAN Configuration and Sign Off

The first step for an individual ARAN certification is for the field crew to configure the ARAN in accordance with the ARAN Setup record (Figure 3) created in the Definition of ARAN Configuration stage. Once this is complete, the field crew collects a 'sign off' file, which will then be used to validate that the ARAN settings are identical to those defined in the ARAN setup record. The sign off file data is uploaded for independent verification by the ARAN Fleet Support and Data Processing teams.

ARAN Calibration and Control Sites

All equipment shall be calibrated according to the manufacturer's recommendations before the initiation of the data collection activities.

This equipment calibration and check will ensure that the equipment remains within acceptable precision and bias limits, and that the data is being collected and stored properly by the onboard computer system.

Equipment Calibration Schedule:

Equipment	Calibration Interval
Cameras	At start of project, there is a change in mechanical components or if it has become necessary as a result of our Corrective Action process.
Laser SDP	At start of project, there is a change in mechanical components or if it has become necessary as a result of our Corrective Action process.
Pave3D	At start of project, there is a change in mechanical components or if it has become necessary as a result of our Corrective Action process.
DMI	At start of project, every 28 days, or if there is a change in mechanical components or if it has become necessary as a result of our Corrective Action process.
GPS	At start of project, there is a change in mechanical components or if it has become necessary as a result of our Corrective Action process.

Control sites

Control sites are established for two specific purposes: to calibrate the distress rating process and to establish the precision and bias for the roughness and rutting information. For this project, control testing will consist of pre-survey calibration testing, as well as scheduled correlation testing throughout the project.

The calibration sites shall be collected three to five times each at the beginning of the project, and again five times each every month. As well as electronic sensor data, full Right-Of-Way (ROW) as well as pavement images will be collected on all calibration site runs. Standard procedures will be followed as for regular production data collection and processing.

An experienced member of the Data Processing team assigned to the project will then review the control site data to ensure that the data collected is comparable to known benchmarks for those sites, and is repeatable across multiple passes of the same site.

If any data type fails both the percentage and absolute value thresholds, the ARAN will fail its certification.

Data Type	**Percentage**	**Absolute Value**	
IRI	5%	1.000	Inch per mile
Rutting	5%	0.050	Inches
Macro Texture MPD	10%	0.080	Inches
Macro Texture RMS	10%	0.050	Inches
CrossFall	5%	0.500	Percent Slope
Roll	5%	0.500	Percent Slope
Grade	5%	1.000	Percent Slope
Pitch	5%	1.000	Percent Slope
Fault Height	5%	0.039	Inches

Any failing ARAN will be assessed by our technical experts to ensure the issue causing the failing data is resolved, and the ARAN will then restart the Controls process. Depending on the nature of the issue, any data collected by that ARAN since the last successful verification run could be slated for recollection and the suspect data discarded. The ARAN cannot pass its certification until all data types pass the Controls process. Once completed the ARAN is fully certified to collect the project.

As this contract could cover up to 6 collection cycles over 6 years, there may be a need to adjust the control site benchmark values due to regular deterioration or maintenance work being performed on those sections. In each case, Fugro Roadware will work with the PennDOT to either adjust the benchmark values or choose a new calibration sites and establish benchmark values for those new sites.

DMI Calibration

DMI is a critical component of the ARAN’s Linear References system. A calibrated DMI is necessary to ensure that all collected data is correctly correlated. As such we have developed a DMI Calibration Process that is performed during the initial certification process as well as every 28 days, or if the mechanical attributes of the ARAN change e.g. tires, by the ARAN’s Field Technicians. It is necessary to have five repeat runs within +/- 0.5% variance in order to pass.

Figure 4 below is an example of one of these records

DMI Calibration Detail (Edit | Delete | Clone)

DMI Calibration Name	DMI-0000000795	Project	New York 2015 - 2016 Pavement Condition Data Collection Services
ARAN	ARAN 44	Date of Calibration	17/08/2016
		DMI Calibration Result	Pass
		DMI Calibration Reviewed Result	Accepted

Pulse Counts

DMI Count - Server	203,667
DMI Count - Pavement	203,667
DMI Count - ROW	203,667
DMI Count - ROW-B	
DMI Count - ROW-C	

Tire Verification

Tire Pressure Driver Front	60	Tire Pressure Driver Front Result	Pass
Tire Pressure Passenger Front	60	Tire Pressure Passenger Front Result	Pass
Tire Pressure Driver Rear	71	Tire Pressure Driver Rear Result	Pass
Tire Pressure Passenger Rear	71	Tire Pressure Passenger Rear Result	Pass
Tread Depth Driver Front	0.314		
Tread Depth Passenger Front	0.314		
Tread Depth Driver Rear	0.275		
Tread Depth Passenger Rear	0.275		
Tire Width			
Tire Aspect Ratio			
Tire Wheel Diameter			

DMI Calibration

Previous Calibration Value	851.050	Calibration Length	450.000
Calibration Length Units	Milli-Miles		
1st Accepted Value	851.910	1st Accepted Value Result	Pass
1st Verif Value	852.090	1st Verif Value Result	Pass
2nd Verif Value	852.070	2nd Verif Value Result	Pass
3rd Verif Value	851.990	3rd Verif Value Result	Pass
4th Verif Value	852.180	4th Verif Value Result	Pass
Created By	Fredy Reyes, 17/08/2016 11:49 AM	Last Modified By	Fredy Reyes, 17/08/2016 11:49 AM

Data Collection

During collection, real time monitoring systems are employed to ensure data quality. These include:

Data Collection Personnel Certification Programs

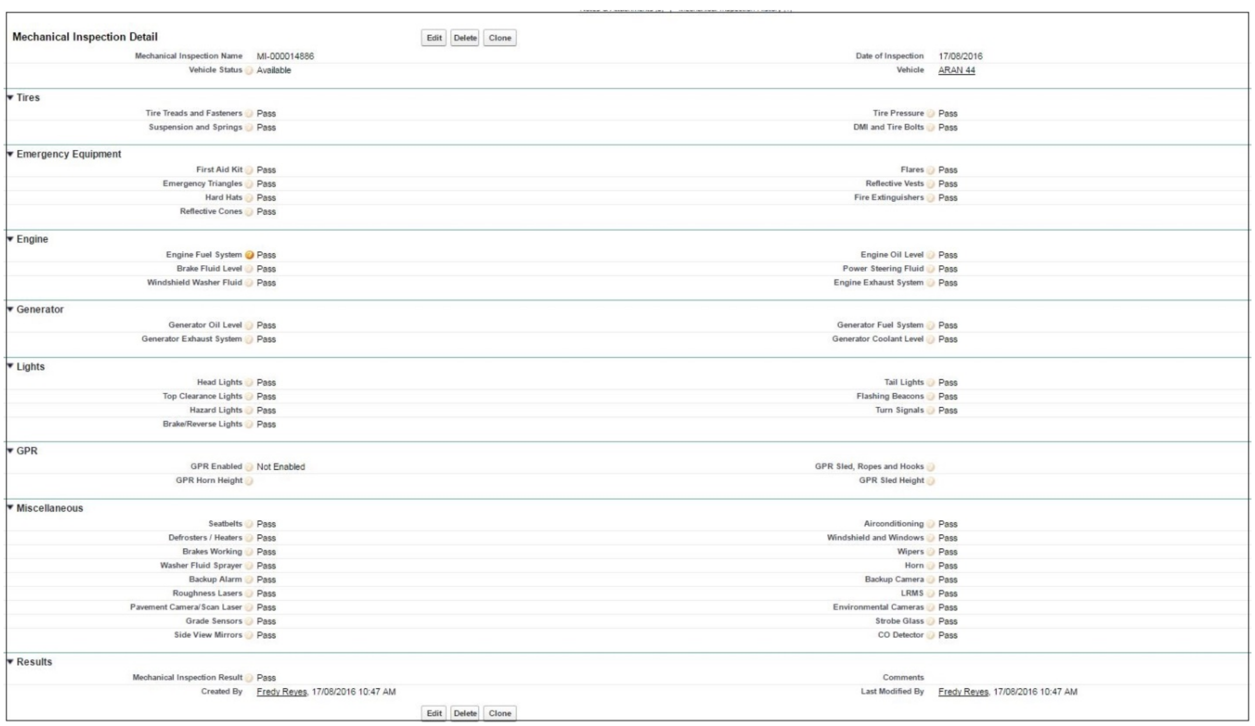
One of the key QC activities is training the personnel that will be collecting the data. Field Technicians must learn how to operate and troubleshoot complex computer hardware/software, video, and automotive systems. Their training includes calibrating the equipment, monitoring the data and video systems in real time, and understanding the multitude of factors that can affect data quality during the collection process.

Field Technicians are trained to review data in the field to look for inconsistencies and to check error logs. This allows the crews to spot problems, take corrective actions, and re-collect the segments before leaving the area.

Daily Mechanical Inspection

Prior to each collection day the ARAN technicians will perform a 50 point mechanical inspection that will ensure the safe operation of the ARAN, as well as a verification of the mechanical equipment which could impact the validity of the data collected (e.g. Tire Pressures, Suspension, etc.). Any mechanical anomalies are rectified immediately or if minor are noted on the Mechanical Inspection checklist and then rectified at the earliest convenience.

Figure 5 is an example of one of these records that shows the 50 points being inspected



Mechanical Inspection Detail

Edit | Delete | Clone

Mechanical Inspection Name	MI-000014886	Date of Inspection	17/08/2016
Vehicle Status	Available	Vehicle	ARAN 44
Tires			
Tire Treads and Fasteners	Pass	Tire Pressure	Pass
Suspension and Springs	Pass	DMI and Tire Bolts	Pass
Emergency Equipment			
First Aid Kit	Pass	Flares	Pass
Emergency Triangles	Pass	Reflective Vests	Pass
Hard Hats	Pass	Fire Extinguishers	Pass
Reflective Cones	Pass		
Engine			
Engine Fuel System	Pass	Engine Oil Level	Pass
Brake Fluid Level	Pass	Power Steering Fluid	Pass
Windshield Washer Fluid	Pass	Engine Exhaust System	Pass
Generator			
Generator Oil Level	Pass	Generator Fuel System	Pass
Generator Exhaust System	Pass	Generator Coolant Level	Pass
Lights			
Head Lights	Pass	Tail Lights	Pass
Top Clearance Lights	Pass	Flashing Beacons	Pass
Hazard Lights	Pass	Turn Signals	Pass
Brake/Reverse Lights	Pass		
GPR			
GPR Enabled	Not Enabled	GPR Sled, Ropes and Hooks	
GPR Horn Height		GPR Sled Height	
Miscellaneous			
Seatbelts	Pass	Airconditioning	Pass
Defrosters / Heaters	Pass	Windshield and Windows	Pass
Brakes Working	Pass	Wipers	Pass
Washer Fluid Sprayer	Pass	Horn	Pass
Backup Alarm	Pass	Backup Camera	Pass
Roughness Lasers	Pass	LRMS	Pass
Pavement Camera/Scan Laser	Pass	Environmental Cameras	Pass
Grade Sensors	Pass	Strobe Glass	Pass
Side View Mirrors	Pass	CO Detector	Pass
Results			
Mechanical Inspection Result	Pass	Comments	
Created By	Fredy Reyes, 17/08/2016 10:47 AM	Last Modified By	Fredy Reyes, 17/08/2016 10:47 AM

Edit | Delete | Clone

Daily Subsystem Check

Prior to commencing the collection of data on behalf of the PennDOT, the ARAN Field Technicians will clean lens covers of all sensors, check mounting and wiring connection, and verify that test signals are received by the on-board computer. Output from the computer will be verified. Sensors will be physically checked by interfering with the laser beam and observing the corresponding response. Signal output and computer generated data will be verified to ensure that all components are working properly. This procedure is to ensure that all of the ARAN Systems (including both the software and the associated hardware) are functioning correctly and that all of the Data collected is validated, accurate and of the highest quality possible.

Real-time Quality Monitoring on the ARAN

Quality control subsystems are built into each ARAN. Each ARAN is equipped with ergonomic, front-mounted computer controls and a High Definition screen that enable the Technician to actively monitor all images, all data streams and confirming stored data. Onboard software monitors the individual data collection subsystems in real-time and alerts the operator when data is out of range or if an equipment malfunction has occurred. If a sensor is recording out-of-range (IRI, rutting, grade, GPS), or does not register a change for a predetermined length of time, the system uses audio and text alerts to notify the operator of the potential malfunction.
Any collection section in which the real-time quality monitoring identifies an issue that will result in data that does not meet our strict quality standards will be rejected by the Field Technician in the ACS, and will be recollected. These rejected collections are excluded from the data processing steps.

Field Activity Report and End of Day Verification

A Field Report is created each day when collection has finished. This includes names of each ARAN operator, number of miles collected in each functional class, start and end times of collection, number of collected PennDOT network sections, and comments pertaining to issues encountered during collection.

Data integrity log files are generated by the ARAN Collection Software (ACS) which contain the following information:

1. Current ARAN configuration settings.
2. A list of collected sections with a summarized data value from each sub-system collected, rejection status, and any comments pertaining to any anomalies of the collection to communicate to Data Processing staff.
3. PennDOT network sections still requiring collection.
4. Locations of any images not recorded.
5. References of all GPS files collected.

In addition to the log files, sample images are automatically selected from each camera system as follows:

1. 3 images from the start of the collection day
2. 3 images from the middle of the collection day
3. 3 images from the end of the collection day
4. 3 images randomly selected by the ACS

The Field Technicians review the content of the data integrity log files and the sample images from that day, and will reject any collection where the log data or image data shows it does not meet the quality standards. Additional comments pertaining to any anomalies of the collection are added at this point for use by Data Processing staff.

Daily Quality Control Verifications

Following the Field Technician review, the data integrity log files, the sample images and comments are uploaded for secondary verification by Data Processing staff. The Data Processing technician assigned to the ARAN will review the data integrity log files and sample images following a 15 point checklist:

1. Camera Alignment conforms to project requirements
2. Missing images are few enough to conform to our quality standards
3. ARAN configuration settings conforms to the project requirements
4. Format of summarized data report meets quality standard
5. Chainage flow is consistent with project requirements and quality standards
6. Summarized data values are within standard tolerances and are reasonable
7. Summarized data values are populated for each enabled sub-system
8. GPS files collected conform to our quality standards
9. Any project specific data requirements have been met
10. ROW images conform to our quality standards

11. Environmental images conform to our quality standards
12. Pavement images conform to our quality standards
13. Pavement image Width conforms to project requirements
14. Pavement image Length conforms to project requirements

The status of the checks is entered into a DS Daily Verification record. If the daily quality control checks are approved, then the DS Daily Verification record is set to “Pass”. If the daily quality control checks fail, then the DS Daily Verification record is set to “Fail”, an automatic notification of the failure is delivered to the Project Manager, Field Technicians, Field Supervisors, Fleet Support, Technical Manager, and Director of Operations, root cause analysis is completed, and corrective actions are initiated. The suggested corrective action, which may include recollection of data, is submitted for review, and must receive approval of both Fleet Support and our technical manager before any further acceptance of collected data.

Figure 6 below is an example of one of the DS Daily Verification records.

DS Daily Verification Detail [Edit] [Clone] [Submit for Approval] [View ARAN Setup]

DS Daily Verification ID	DV-0000016360	DS Daily Verification Unique Name	ARAN 332016-07-15
ARAN Daily Report	ADR-000028238		
ARAN Status 1	Collection (Full Day)		
ARAN Status 2			
Complete	Yes		
Created By	JD Muir, 18/07/2016 9:55 AM	Last Modified By	JD Muir, 18/07/2016 9:55 AM

▼ **ARAN Daily Report Information**

Project	Vermont Data Collection 2016		
ARAN	ARAN 33		
Date of Collection	15/07/2016		
Total Collection	89.015		
Days Since Waiting on ARAN Data	0		

▼ **Data Control**

Data Control Status	Pass		
Camera Alignment	Pass		
QC_Video_.CSV	Pass		
QC_Data_Files_.CSV	ARAN 9000		
Data Control Comments			
Data Control Actions			

▼ **Data Analysis (all settings must match ARAN Setup record)**

Data Analysis Status	Pass		
1M0 File Name	N/A	Daily CSV Format	Pass
XML/1M0 Comparison	Pass	Daily CSV Chainage	Pass
Datachek Log	ARAN 9000	Daily CSV Sensor Data	Pass
PCS Data	Pass	Daily CSV GPS Data	Pass
Export Log CSV	Pass	Controls Validation	
GPR Data	N/A	Controls Comments	
Special Data Requirements	N/A	Controls Tracker Location	
Data Analysis Comments			
Data Analysis Actions			

▼ **Distress**

Distress Status	Pass	Pavement Images	Pass
ROW Images	Pass	Pavement Image Width	
Environmental Images	N/A	Pavement Image Length	
Distress Comments			
Distress Actions			

▼ **Fleet Support**

Fleet Support Review and Fixes		Failure Resolution	

Preventative Maintenance Program

To ensure that the uptime of our ARAN collection fleet is at its highest possible, we have implemented a robust and automated Preventative Maintenance Program. Automated Work Orders are issued based on meter readings from the ARAN such as the odometer or generator hour's meter. There are five different types of preventative maintenance performed on the ARANs. They are a 10K (miles), 20K, 80K, 120K and Generator 250 hour preventative maintenances.

Figure 7 below is an example of a 20K preventative maintenance schedule

PM Schedule Detail [Edit] [Delete] [Generate PM WO]

PM Schedule #	PM-000623	PM Status	Active
Model Work Order	WO-0004060	Asset Tag	ARAN 44
Model WO Description	20 K Service Interval	Asset Description	ARAN 44
PM Due Date	25/09/2016		

▼ **PM Scheduling - Calendar Based**

Schedule by Calendar	☐	Calendar Based Due Date	
Calendar Interval	1	Floating Interval	☐
Calendar Interval UOM	Days	Auto Release	✓

▼ **PM Scheduling - Meter Based**

Schedule by Meter	✓	Last Meter Reading Date	16/08/2016
Meter ID	M-000033	Last Meter Reading Value	290,848.00
Meter Schedule Interval	40,000.00	Last Meter Read Value Cumulative	290,848.00
Meter UOM	Miles	Meter Interval % Complete	77.12%
		PM Due Meter Reading Value	300,000.00
Initial Meter Reading Due Value	300,000.00	PM Due Cumulative Meter Value	300,000.00
Initial Meter Interval % Remaining	22.88%	Meter Based Projected Due Date	25/09/2016

▼ **Last & Current PM Work Orders**

Last WO Completed	WO-0008146	Current Work Order	WO-0008146
Last WO Completion Date	02/04/2016	Current WO Status	Closed
Meter Reading at WO Completion	260,000.00	Current WO Due Date	28/03/2016
Cumulative Meter Reading at WO Comp	260,000.00		
Created By	Derek Pescod, 13/04/2014 6:20 PM	Last Modified By	Robert Nickelson, 15/06/2016 2:50 PM

Data Processing

There are many quality control and quality assurance processes that occur during the data processing phase of a project. At each process, if data does not meet quality standards, or PennDOT specifications, that data is recorded on the project non-conformance report. All non-conformances are reviewed by the Project Manager in conjunction with the project team in order to determine if the data will be recollected, reprocessed as part of an exceptions batch, or is suitable to be delivered to the PennDOT with a documented exception.

Data Processing Personnel Certification Programs

Data Processing Technicians will be trained on how to use all applications and tools and how to perform analytical checks to verify data meets requirements. Their training includes identifying common place errors, such as image brightness issues, out of range sensor readings or incorrectly detected pavement distress. All training is tracked in our training matrix to ensure that staff do not begin work until they have the necessary skills to do so.

Data Control

Data Control Technicians in our offices receive the shipments of collected data and begin the data processing effort by uploading the data to our data storage servers and importing the data into our production databases. All data is then backed up to tape which is stored in a secure, climate controlled facility, to ensure that a copy of the data is available if a major incident were to impact our primary data storage (See Business Continuity and Disaster Recovery Plan).
As a part of the setup phase of the project, the necessary project network directories and databases into which this data is to be stored were created in accordance with our standards for data locations and structures. Due to these standard locations and structures all staff are able to find the information they require with minimal effort. Templates are created that govern the behavior of the tools used to upload, import and backup the data and effectively automate the majority of the Data Control process, reducing downtime between processing steps and eliminating manual error. Recollection of a road or part of a road shall be deemed necessary when either five or more consecutive images, or 5% or greater are found to be “defective images”; where either the images are not present or have outlying histogram values as identified by Fugro Roadware’s initial video checks.

Sections containing questionable images could be submitted to PennDOT for review and a course of action shall be agreed upon by Fugro Roadware’s Project Manager and PennDOT. The resulting action could include acceptance of the images, batched or individual photo manipulation, or full recollection of the suspect data. Fugro Roadware will then use the input from PennDOT during final quality checks, recollection, and re-deliveries.

The following checks are completed to ensure data quality at this stage:

1. Data Shipment Work Order information is compared to the data on the physical media and to the Field Daily Reports for the relevant date range. If any data is found missing

from the physical media, the ARAN operators are contacted in order to ship the remaining data.
2. Data transferred to our servers is compared to the data on the original physical media. If discrepancies are identified, corrective actions will be taken by the Data Control Technician, including rerunning the automated processes or manually uploading the data to ensure a complete copy of the collected data exists on our storage servers.
3. The images on our storage servers are compared to the images expected based on the data collected and stored in our production databases. Any discrepancies between the expected images and the images on the storage servers are logged as an exception in our production database. Any collection session that does not meet our quality standards will be rejected.
4. Each image on our storage servers is run through multiple automated algorithms to check them for common image issues such as brightness, contrast, and clarity. Any image that does not meet our quality standards will logged as an exception in our production database. Any collection session that does not meet our quality standards will be rejected.
5. The playback sequence of the images is checked and any incorrect sequencing is reprocessed to resolve the issue.
6. A detailed comparison is conducted of the data integrity log files created by the Field Technicians for each day of collection, to the comments contained within the production database. Any changes or updates to the comments on each collected session from the Field Technician responsible for the collection can be incorporated at this stage to provide the most complete annotation of the collection. If a collected data file is identified as not meeting quality standards, these comments are used to exclude that data from any further processing. The comments are also available in the production database throughout the processing effort to provide On-the-Ground insight about the collected session so that Data Processing staff can make the most informed decisions when processing the data.
7. Data is automatically verified to ensure that there is no duplicate data imported into the production database.

Segmenting

Segmenting is the method of trimming and creating the best fit for the ARAN data to the PennDOT network definition. This is primarily achieved by comparing that the GPS collected by the ARANs matches the expected coordinate definition for the beginning and end of each PennDOT segment. Where GPS is unable to provide a suitable solution, further refinement is achieved using a combination of the description for the start and end of segment, imagery collected by the ARAN, and mapping tools. The Vision software suite synchronizes all data streams to allow our technicians to make the best possible informed decisions to produce the most accurate results. Any discrepancies will be verified with PennDOT. During the segmenting process the data undergoes the following quality control checks:

1. The overall position of the collection in regard to the PennDOT network is checked during the segmentation process. Files that are collected and associated to one routed section but belong entirely to another routed section will be transferred to the relevant routed section if required. If this leaves a gap in collection for the initial routed section,

this routed section will be added to the non-conformance list for review by the Project Manager to schedule recollection of the section. This applies to collection in a different district, county, route, lane, direction or mile point.

2. Once segmentation is complete the image exceptions recorded during the Data Control processes will be reviewed to determine if segmented data meets our standards. Any data that does not meet our quality standards will be rejected and added to the non-conformance list for review by the Project Manager to schedule recollection of the section.
3. The PennDOT segments expected to be covered by the collected data are compared to the actual segments covered by the collected data after the segmentation process is completed for a specified data set. This identifies any collected session that has been missed in the segmentation process, so that they can be corrected.
4. The chainage of all segments is checked to ensure no matches begin before the expected linear reference, resulting in a negative chainage value. If any cases are identified, the Data Processing Technician will investigate and correct.
5. The segmented length of each segment is checked to ensure no negative lengths exist. If any cases are identified, the Data Processing Technician will investigate and correct.
6. In the case where data was collected for one routed section but a portion of the collected session belongs to a separate routed section, the portion is transferred to the correct routed section. All transfers are reviewed to ensure they are correct and intentional.
7. Segments that have had their length and position changed during the segmentation process are reviewed when the level of change exceeds the project tolerance. If any cases are identified, the Data Processing Technician will investigate to ensure the best solution has been identified. If necessary the segment will be escalated to the project manager to discuss with PennDOT.
8. Segments that have had the length of the collected data compressed or stretched to match the definition of the segment during the segmentation process are reviewed when the level of change exceeds the project tolerance. If any cases are identified, the Data Processing Technician will investigate to ensure the best solution has been identified. If necessary the segment will be escalated to the project manager to discuss with PennDOT.
9. Segments with a length less than the defined tolerance. If any cases are identified, the Data Processing Technician will investigate to ensure the best solution has been identified.
10. If any anomalies are identified during the segmentation process that do not result in failure of our quality standards but could assist with later processing stages, the Data Processing Technician will add the comments to the production database so that they are visible to other Data Processing staff.

Distress

As a part of the setup phase of the project, the PennDOT distress protocol is translated into Fugro's standard distress protocol format, which is a familiar format to all of our Distress Rating Technicians, contains photo examples of distress types and examples and ensures that the protocol is well understood and not misinterpreted. The protocol document is provided to all Distress Rating Technicians before the project starts so that any clarifications required can be added. New distress rating scenarios may be identified during the course of the project, at which point scenario will be reviewed by the Senior Distress Lead, in conjunction with the Project Manager and PennDOT as appropriate, in order to identify the best possible approach. The protocol will be updated to include the new information, and a new version released to all parties.

A Distress Schema that corresponds to the distress protocol is embedded in the production database for the Project. This Distress Schema contains only the specific distress types and a severity required for the specific project, and ensures that only those distresses can be rated. The distress classification and rating settings are also defined in the Distress Schema, ensuring consistency across the entire project.

Distress control sites

Prior to starting network production a set of distress controls sites are chosen. The control site process ensures inter-rater consistency and compliance to the distress protocols as defined in the project setup phase. These sites will be used to 1) Set the reference or benchmark standard for the project and 2) Calibrate the rating team. Using the distress identification criteria outlined in the Distress Protocol, the project lead or QC delegate will rate each of the control sites which then become the benchmark to be submitted to the PennDOT for approval. Once the benchmark has been approved, all other members of the distress rating team for the project must rate each of the control sites. The results will be compared against the project lead or QC delegate, for rating technician calibration purposes. Before any technician will be allowed to proceed with production work on the project, he/she must pass all the verification sites consistently. This process will ensure that every technician is producing the same results, within acceptable limits, prior to beginning production.

Distress Review

Upon completion of a batch of data, standard queries on the distress data are run by a separate team of independent distress raters/QC to ensure that they meet project requirements. Based on the results, the technician(s) will be instructed to either redo the file, entire day or entire batch of data.

To ensure consistency among technicians, the rating team will rate the distress verification sites at the mid-point of the project. Results will be compared to the reference standard to ensure that each operator remains consistent and accurate.

This combination of benchmarking, standard queries, and inter-operator consistency will assure the overall consistency and validity of the distress ratings.

Each set of data will also be validated with the following quality control measures to ensure all data delivered is of the best possible quality:

1. Collected sessions in which no distress has been rated are reviewed to identify missed ratings or to confirm a valid reason such as being under construction or new pavement.
2. Automated distress that has not been classified is reviewed and classified in a separate review.
3. Any portion of a collected session that does not have a pavement type rating or a number of lanes rating is reviewed and re-rated to ensure the data is complete.

4. Any portion of a collected session that has more than one rating of pavement type or number of lanes is reviewed and re-rated to ensure the rating is accurate.
5. All occurrences of a milled pavement rating where construction is not rated are reviewed for accuracy and consistency.
6. Lane width ratings less than the defined minimum threshold will be reviewed and edited to ensure accurate measurements.
7. Locations where only one of Construction or Lane Deviation rating occurs are reviewed to ensure these ratings are accurate.
8. All locations where a specific distress occurs on an incompatible pavement type are reviewed edited to ensure pavement types and distresses are correlated correctly.
9. Any portion of a collected session that does not have a Shoulder type rating is reviewed and re-rated.
10. Any portion of a collected session that has more than one Shoulder type rating is reviewed and re-rated.
11. Any portion of a collected session where density or length of cracking exceeds the defined threshold is reviewed for accuracy.

Distress Year to Year Comparison

To ensure consistency over many cycles of data collection, historic information is compared to current information at the same geographic location. If this is available from PennDOT for year one it will be performed otherwise it will be performed in all subsequent years. This will allow the identification of any unanticipated changes in roadway performance. This process often identifies sections that have been rehabilitated or have deteriorated drastically. For the purposes of quality control, the amount of each distress type is compared between consecutive years and a section that has improved by 5% without rehabilitation or that has decreased in condition by more than 15% is manually reviewed to ensure accuracy in the current data.

Analysis of Results

A full analysis of the distress rater verification results will be completed and included in the control site analysis. All values will be highlighted according to their relative tolerance checks and any abnormal values will be explained.

Further to this, a full analysis of all distress results will be performed and reported; highlighting the results and offering analysis of any anomalies or trends that would be of interest to the PennDOT. This analysis will be performed and reported for the Full Network as well as by Distress Type.

Data Analysis

During the Data Analysis phase the outputs of all previous steps are combined to achieve a holistic view of the data. Once processing of the profile data is complete, quality checks are implemented at this stage to ensure that all delivered data is logical, GPS and linear reference flow properly, and proper format and units are used. The results are combined and completeness checks are performed to ensure that the results meet PennDOT needs.

For initial quality checks, sensor deliveries are put together which include segmented data, roughness, rutting, and faulting sensor data. An iVision instance will be setup containing both sensor and right of way imagery to facilitate viewing and initial QC by PennDOT personnel. Although no edits will be performed on the data prior to these initial preliminary deliveries, the overall quality of the images can be checked easily and early by the PennDOT at this stage.

The work conducted during the segmenting and distress rating steps is reviewed again to ensure the linear referencing, and reported distresses are logical and reasonable. These additional checks can identify anomalies that were not apparent without the holistic view of all data streams, and ensure that our data deliveries are of the highest possible standard and include:

- Checking the quantity of data before and after segmentation to ensure that no data is missing.
- Identifying and correcting any errors resulting from segmentation.
- A preliminary comparison between the segmented data and the master routed table, checking for section length discrepancies, section start and end discrepancies, partial collections, and missing sections without a valid explanation.
- Checking that pavement specific distresses are only being rated on the appropriate pavement types.
- Checking that distresses and pavement types have been rated properly, as outlined by PennDOT approved Distress Protocol.
- Checking that distress ratings meet minimum requirements and do not exceed maximum thresholds as defined industry and PennDOT standards.
- Checking that rated pavement types align with PennDOT expectations and providing sound reasoning if there is a valid discrepancy.
- Checking to make sure that rated lane widths and pavement widths are present and accurate.

Once the data has been verified that it meets project requirements with the segmentation and distress rating data, algorithms are applied to the longitudinal and transverse profile data in order to extract roughness, cross fall, and rutting measurements. Algorithms are also applied to the vehicle position and orientation data in order to calculate the geometric attributes of the roadway. The settings to be used in each of these algorithms are defined during the project setup phase based on the requirements of the project, and are then stored in template files that are used each time the algorithms are run on that project. This greatly reduces the risk of suboptimal settings being used during the project, and ensures consistency between data sets.
PennDOT locations, distress, pavement events, and sensor data, are then reviewed at the micro level and, if applicable, against previous years data.

Standard completeness quality control includes:

- Total length of delivery matches expected length.
- Total number of sections matches expected number of sections.
- No data in delivery has been previously rejected.
- No section in delivery has been delivered previously without valid exception.
- Sections shorter than expected length have valid exception e.g. road turns to gravel.

- Any sections not delivered have valid exception e.g. road closed.

Standard locator information quality control includes:

- No blank or NULL values.
- All locator values match PennDOT specified locator values.
- All combined locator values are the sum of their component reported parts.
- All hierarchical relationships between locators are maintained.

Standard length quality control includes:

- All rubberbanded segments will match the expected length.
- All rubberbanded segments with an adjustment of +/- 20% will be validated.
- All rechained segmented with an adjustment of +/- 5% will be validated.
- No segments with a 0 length.
- No segments with negative lengths.
- Segment lengths that differ from historical length by 5% or more will be validated (applicable in subsequent years).
- For fixed interval reporting, the interval length will match PennDOT specification except at homogenous section break, or collection session break.

Standard linear reference quality control includes:

- No blank or NULL values.
- Direction and chainage flow relationship matches PennDOT specification.
- Direction values meet PennDOT specification.
- Chainage flows within contiguous sections.
- No overlapping chainage.
- No duplicate mile points within locator definition.

Standard GPS quality control includes:

- No blank or NULL values.
- Confirming percentage of post-processed GPS coverage is within tolerance.
- Reported latitude and longitude values plot within expected boundaries.
- Reported elevation values are within expected boundaries.
- Segment elevation within +/-6 inches from historical data.
- Segment latitude and longitude within +/-1 meter from historical data.
- Segment latitude and longitude within +/-1 meter from PennDOT location definition.

Standard speed quality control includes:

- No blank or NULL values.
- No negative speed values.
- No 0 speed values.
- For any section requiring pavement images speed will be less than 55mph.

Standard date field quality control includes:

- No blank or NULL values.
- Date format will match specification.
- Date of collection is within data collection period.

Standard roughness quality control includes:

- No negative values, except for -1 where used as invalidation identifier.
- No blank or NULL values.
- IRI values correlate with the functional class of the road, other reported pavement condition data, and reported events such as speed bumps, railroad crossing, cattle guards, round-abouts, or stop-and-go traffic.
- Summarized maximum, minimum, or average reported values will be validated against the reported data before summarization.
- Large discrepancies between left and right IRI values will be validated.
- Conducting a visual investigation using the ROW and pavement images and charted IRI data to determine the causes of these irregular values.
- Review sections which show more than 5% improvement in values without reported rehabilitation, and sections which show more than 15% deterioration in values, per year compared to historical data.

Standard faulting quality control includes:

- Checking that the number of faults is not greater than the number of number of rated joints.
- Checking that faulting is not occurring on non-jointed pavements unless requested specifically by PennDOT.
- Summarized maximum, minimum, or average reported values will be validated against the reported data before summarization.
- Conduct a visual investigation using images to determine the causes of any fault values which are outside of the expected range.
- Review sections which show more than 5% improvement in values without reported rehabilitation, and sections which show more than 15% deterioration in values, per year compared to historical data.

Standard rutting quality control includes:

- Ensure % of valid transverse profiles is sufficient to provide rutting values that are representative of the section.
- No negative values, except for -1 where used as invalidation identifier.
- No blank or NULL values.
- Conduct a visual investigation images and Transverse Profile rut values which are outside of the expected range, or which contain large discrepancies between left and right wheelpaths.

- Summarized maximum, minimum, or average reported values will be validated against the reported data before summarization.
- Review sections which show more than 5% improvement in values without reported rehabilitation, and sections which show more than 15% deterioration in values, per year compared to historical data.
- Review to ensure that shallow, deep, severe and failure ruts are correctly allocated and add to a total of 100%.

Standard road geometry quality control includes:

- No blank or NULL values.
- All values outside of typical design tolerances will be validated.
- Conducting a visual inspection of the route using ROW images, a GIS map, and our Curve Fit Module to ensure algorithms are detecting features optimally.
- Reprocessing of exception data commonly caused by vehicle deviation from collection path or required lane changes.
- Comparison of geometric features detected in the opposing directions and reprocessing if applicable to ensure optimal curve representation in both directions.

All of these checks during the Data Analysis stage are done to ensure high accuracy is met on Rutting, Faulting Height and Number, MPD, IRI and GPS. These checks are performed to ensure the data meets ASTM E950, ASTM E1845-09, AASHTO M328-14, AASHTO R36-13, AASHTO R43-13, AASHTO R48-10, AASHTO R55-10, AASHTO R56-14, AASHTO R57-14, AASHTO PP67-16, AASHTO PP68-14, AASHTO PP69-14, AASHTO PP70-14, TEX-1001S and those of stringent projects we have done for Model Inventory of Roadway Elements (MIRE) and Strategic Highway Research Program (SHRP) 2.

Project Reporting and Aggregation

Once the micro level quality control is complete, the final delivery report is generated with data aggregated to PennDOT specifications. This report undergoes further quality control and assurance processes, much like the micro level processes to ensure that the aggregation step has not introduced any errors, and that the data in its aggregated form is logical and reasonable. The aggregated report is checked to make sure that all expected data is present and that it meets all linear reference requirements, distress and sensor data requirements, and additionally all final delivery format requirements, so that the data will smoothly integrate with the PennDOT pavement management system.

Along with the final delivery report, a delivery summary report will be produced that lists any data exceptions that occurred which may cause some anomalies in the delivered data. Each summary report will list items such as collection over or under runs, where the collected data length is different than that routed length by over 20%, sections with construction or lane deviations, uncollectable sections, and locations with sensor data exceptions. Each exception will be listed with the PennDOT locators and mile points along with a brief comment when applicable.

iVision

Once the reported data has passed all quality control steps previously documented, the data is published to iVision for online review purposes. Additional quality control steps are completed on the iVision instance including:

- User list matches PennDOT user expectations and internal standards.
- Validation of image links.
- Validation of playback synchronization.
- Length data published matches delivery.
- Number of segment records published matches delivery.

Final Quality Assurance

When data has passed all quality control steps and has been published to iVision, a final quality assurance step is completed in which a second suitably qualified Data Analyst will review the reported data to ensure it complies with our internal standards and the project data dictionary. Any anomalies found at this stage must be validated or reprocessed to remove the anomaly.

Image Deliveries

During the project setup phase, a sample image banner is created based on PennDOT requirements, and this banner is adjusted until PennDOT is satisfied with the results. Once the sample banner has been approved the settings used to create the banner are stored in a template file that is used by our Vision software to create every banner on every image for the remainder of the project. This minimizes the opportunities for manual error, and ensures that the banner on each delivered image meets PennDOT specifications. At the same time any specifications for image renaming or folder structure are recorded in the project template file.
During the project the following standard quality control measures are completed on each image delivery:

- List of collected sessions to be included in the image delivery is created and confirmed by the Data Analyst to ensure it matches the corresponding data delivery.
- Files are processed to add the banner, and update metadata as per the project template file. During this process an exception log is automatically created which records any issues encountered. Any exceptions created during this process are investigated and reprocessed after correcting the source data, or by applying a custom template for the exception files only.
- Once the banner processing is complete, sample images from 10% of collected sessions are manually reviewed to ensure the banner information is correct in terms of formatting and the data displayed.
- An algorithm is run on the delivery images to compare the images in the delivery folder to the expected images based on our production database. Any exceptions will be reprocessed using a custom template for the exception images only.

- An algorithm is used to compare the folder structure and image names of the delivery images to the project template file to ensure that they match PennDOT specifications.
- Once all quality controls steps have passed and the Data Technician responsible for completing the image delivery is satisfied with the quality, a final Quality Assurance step is completed with a second suitably experienced Data Technician completing the same quality control steps to ensure nothing has been overlooked.
- Once the quality assurance steps have passed for the image delivery it is copied to our storage servers, removable media for delivery to PennDOT, and backed up to tape. This ensures that a copy of the data is available if a major incident were to impact our primary data storage, or the PennDOT data storage.
- When the images have been backed up the removable media will be shipped to PennDOT, and the shipment tracking number communicated to the Project Manager to ensure the PennDOT is aware of the impending delivery.

Pilot Test Delivery

To ensure that Fugro Roadware is meeting PennDOT requirements, we process and deliver a pilot data set as soon as a representative sample of the network (usually between 250 and 500 miles) has been collected.
The pilot gives both PennDOT and Fugro Roadware the opportunity to follow their typical end to end process using real data, ensure that all procedures, software, and configurations, are working as designed, evaluate the final reports, and if necessary to make changes to any step of the process. If any rework is required this same Pilot Data set shall be reworked as a priority and resubmitted to the PennDOT for acceptance before any further data deliveries are made.

Resource Planning and Forecasting

On a weekly basis the Project Manager and Director of Operations meet to review the project forecast and resource needs to ensure that this project has the staff it needs to ensure the on time delivery of the data.

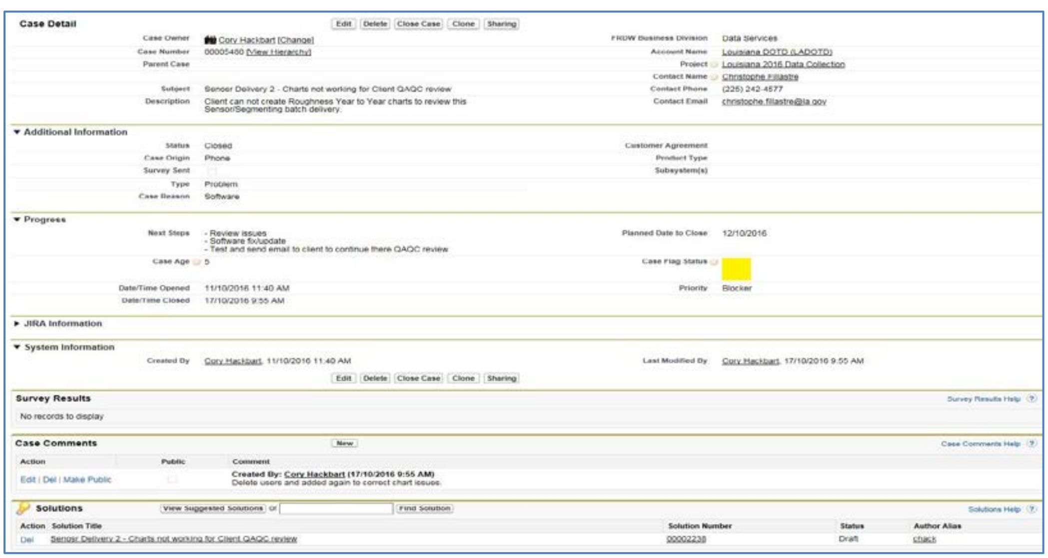
PennDOT Identified Issues and Corrective Action

PennDOT Identified Data Issues

Fugro Roadware proposes that concerns be communicated according to the following Policy. If for any reason, the integrity of data delivered to PennDOT by Fugro Roadware is found to be questionable or unsatisfactory, the following steps will be performed:

1. An email sent to the Fugro Project Manager by PennDOT
    - A clear description of the problem(s)
    - PennDOT's network locators e.g. Roadcode, Roadname etc.
    - File Name (if possible)
    - Chainage
    - Direction
    - Length
2. Creation of a case (Figure 8) for PennDOT tracking by the Fugro Project Manager.
3. Activation of the Corrective Action process if necessary by the Quality Manager.
4. Verification of the problem by the Fugro Project Manager and Processing Team.
5. Appropriate corrective action employed by Fugro.

Figure 8 example of a submitted case



Corrective Action

When the QC or QA process reveals errors in the data, the data must be appropriately reprocessed and a Corrective Action (CAPA) record created (Figure 9). Errors can either be discovered by Fugro during the QC process or by PennDOT during the QA process. In addition, PennDOT staff may also identify problems prior to accepting the final deliverables. The steps for correcting the errors identified at each stage of the process are described below.

Figure 9 example of a corrective action report

CAPA Detail Edit Delete Clone

Owner	Denis Charland [Change]	Impact	3
CAPA Number	CAPA-0522	Probability	2
Status	Implemented	Risk	
Nature of Non-Conformity	Per the linked customer survey result by Daniel Sokolnicki, Segmented Delivery 13 was missing ARAN 34 data for the Michigan 2016 project.	Age	0
Scheduled Date		Days Since Last Action	0
Root Cause(s) of Non-Conformity	The project number on the data shipement was mis-labled to VA16 instead of MI16 by an employee cross-training in the data control.	Red Flag	No Flag
Action to Prevent Recurrence	The employee in question was reminded of the importance of ensuring that the Fedex shipments are properly labeled.	Audit Record	
Date of Implementation	03/08/2016	OFI	
Date of Verification		Related CAPA	
Record Type	Corrective [Change]	Case	
		Survey Result	SR-0000000926
Created By	Brock Newitt, 03/08/2016 7:50 AM		

All sections failing Fugro internal quality review will be corrected prior to forwarding the deliverable to PennDOT. Fugro will provide documentation of these checks, identifying any management sections which required re-rating and identifying the potential source of the original errors. If the errors are identified as systematic, then all similar roadways rated by the individual identified as being in error will be reviewed and corrected as appropriate. This includes data from previous deliverables as well. Upon identification of errors, additional clarification or training will be provided, as needed.

As the QA review identifies differences between Fugro's ratings and PennDOT's ground truth ratings, these differences will be scrutinized to determine the magnitude and the cause of the errors. When errors are discovered in 10% or less of the deliverable checked, the entire deliverable will be accepted. However, if more than 10% of the data checked during QA falls outside of the allowable limits, then the entire deliverable will be returned to Fugro for correction.

If a deliverable is returned to Fugro, each difference is noted as whether PennDOT believes the difference to be caused by a random or systematic error. Random errors require that the specific pavement section be corrected. Systematic errors require an entire data set to be corrected.

Final acceptance activities are performed by PennDOT to determine if deliverables have met the established acceptance criteria. Should the PennDOT acceptance review find the data unacceptable for a given deliverable, the deliverable will be returned to Fugro for correction. In such cases, it is critical that both Fugro and PennDOT understand the reasons for deliverable rejection and work together to ensure the current deliverable is corrected and also to determine the impact on other deliverables. Data will be accepted as PennDOT year-to year comparisons are completed.

Warranty

Fugro warrants the quality of the data shall meet the needs of PennDOT and will make remedy to the data if any errors are discovered by either party within a mutually agreed timeframe.

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APPENDIX C
BLOCK TEST LOG

Aran Number XX
Person Performing the tests
Date

All blocks should be within 0.001 inch or 0.0254 mm of the designated height of the block.
The block sizes for a new build should be as follows 0.25 inch, 0.5 inch, 1 inch and 2 inch.
Weekly or daily verifications should be done with a 1 inch and 2 inch block.

Standard Inches

Right Laser	0.25 inch block	0.5 inch Block	1 inch block	2 inch block	3 inch block
Actual Block Height	0.25	0.5	1	2	3
Height Reading with Base Plate					
Height Reading with Base Plate and Block					
Difference Pass or Fail	0	0	0	0	0

Left Laser	0.25 inch block	0.5 inch Block	1 inch block	2 inch block	3 inch block
Actual Block Height	0.25	0.5	1	2	3
Height Reading with Base Plate					
Height Reading with Base Plate and Block					
Difference Pass or Fail	0	0	0	0	0

Metric millimeters

Right laser	6 mm	13 mm	25 mm	50 mm	75 mm
Actual Block Height	6	13	25	50	75
Height Reading with Base Plate					
Height Reading with Base Plate and Block					
Difference Pass or Fail	0	0	0	0	0

Left laser	6 mm	13 mm	25 mm	50 mm	75 mm
Actual Block Height	6	13	25	50	75
Height Reading with Base Plate					
Height Reading with Base Plate and Block					
Difference Pass or Fail	0	0	0	0	0

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APPENDIX C
VERTICAL VERIFICATION BOUNCE TEST

Vertical Verification – Bounce Test **Jan 28 2015**

This test is for Arans with Compact RIO with Roline and or Go-cator style Roughness lasers.

The bounce test must be done on a flat, smooth level piece of ground. Make sure the lasers are not on bumps or cracks and for best results tape a white piece of paper on the ground so that it does not blow away and ensure the paper is flat to the ground. Verify that while the Aran is bouncing the lasers both left and right stay on the flat smooth surface of the paper and or smooth concrete.

The Roughness Settings
You should have both right and left wheel path enabled and installed.
Raw Data Storage 1 inch or 0.0254 m (Raw Data Storage affects the IRI numbers)
Profile Length 12 inch or 0.3 m (Profile length affects the ERD files)

The DMI Settings
Put the Aran in DMI simulation 40 mph or 60 km.

Collect a Segment
Collect a segment totaling at least 900 milli-mile or 900 m.
Chainage 0-300 the segment will be collected with no movement.
Chainage 300 – 600 the Segment will be collected with a vertical movement of about 1-2 inches.
Chainage 600 – 900 the segment will be collected with no movement.

Do not worry if the collected segment is long and or if the chainage of the vertical movement and no movement are not exactly at the correct chainage. It is important that you do the minimum chainage for each of the three stages.

Checking your Data in ProVal

The no movement sections should have an amplitude of less than 3 inches or 0.05m.

The no movement sections should have amplitude any more than 8 inches or 0.14 cm.

Under Review Data in the ACS software you will find ERD Report, click on ERD Report. There are four things you need to know when exporting ERD files. What file you are exporting, where you are exporting the file, Lead In and Section Length.

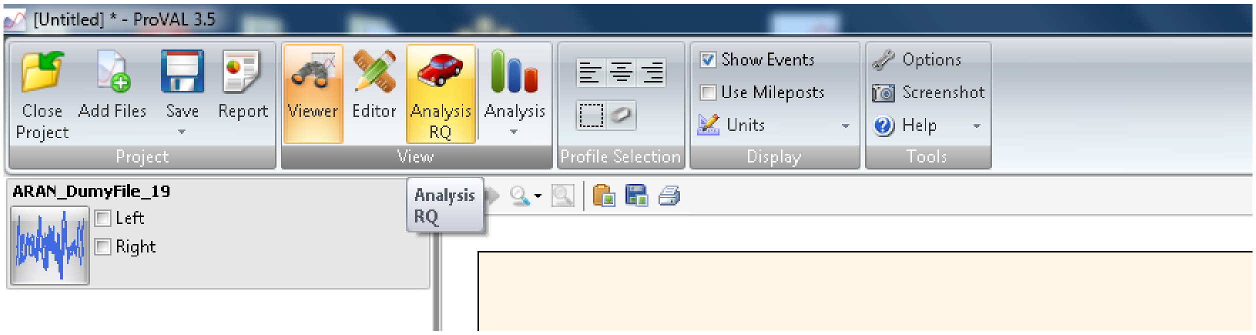
Lead In is the distance in feet where you want the ERD file to start. Example is if you collected 900 feet of data but only need the data from 600 to 900 feet totaling 300 feet. You would set your lead In to 600 feet so that you do not export the first 600 feet of data in your ERD file and your Section length is the distance from the lead do you want your ERD file to be. So in this example your Section length would be 300 feet.

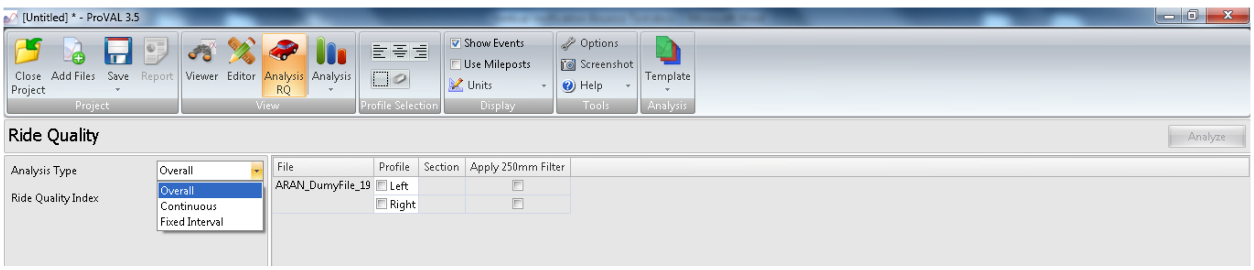
For the bounce test export the Segment with the following settings Lead In = 0 Section length = 9999.

APPENDIX C
VERTICAL VERIFICATION BOUNCE TEST

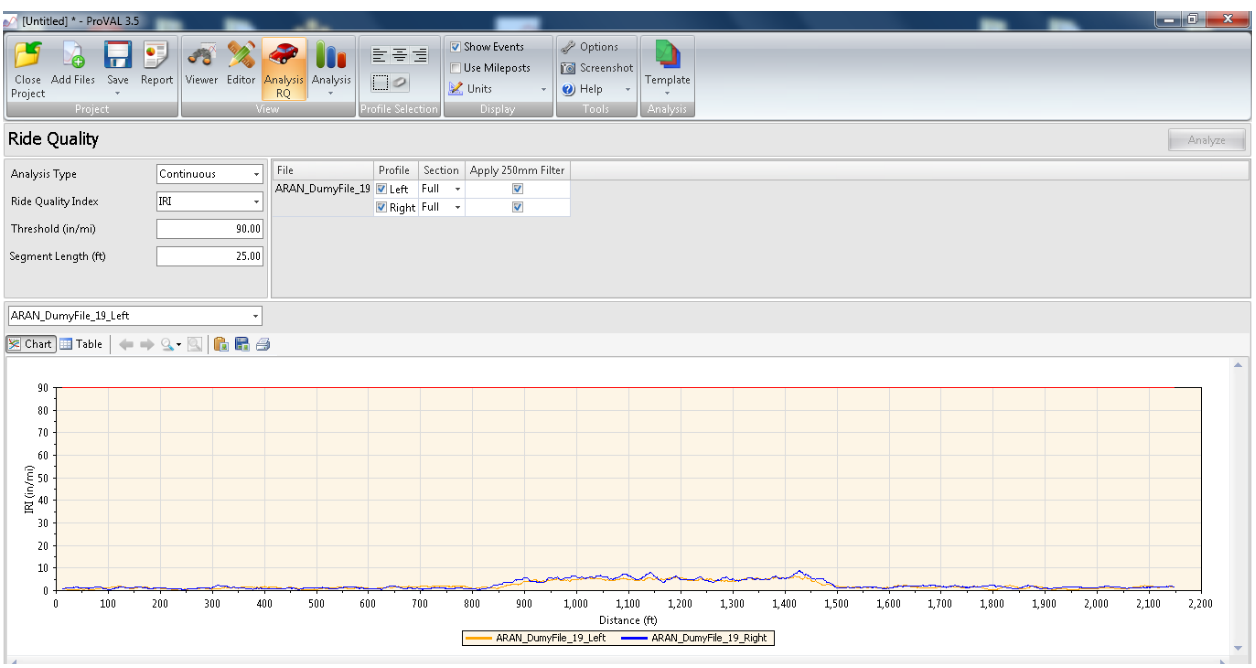
Open ProVal (3.5 is the demonstrated version).

Drag and drop the ERD file you just exported into the ProVal window and you should see the file in the left hand window. Click the Red Car Icon Analysis RQ (Road Quality)



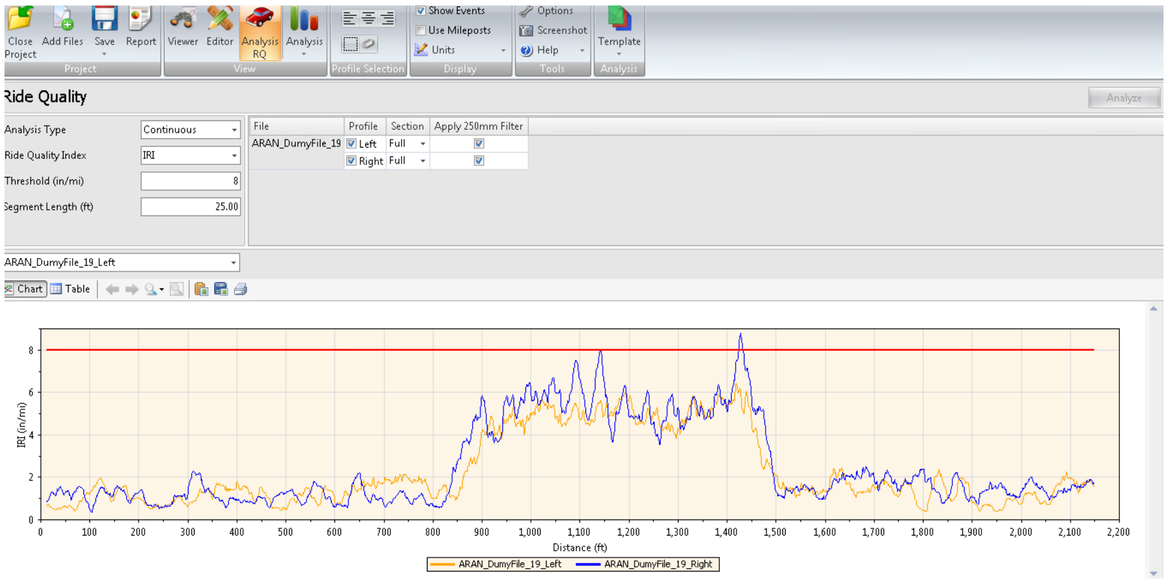


Change the Analysis Type to **Continuous**. Then check the Profile Left and Right so that they both have check marks beside them. Now chick Analyze to see the results.



APPENDIX C
VERTICAL VERIFICATION BOUNCE TEST

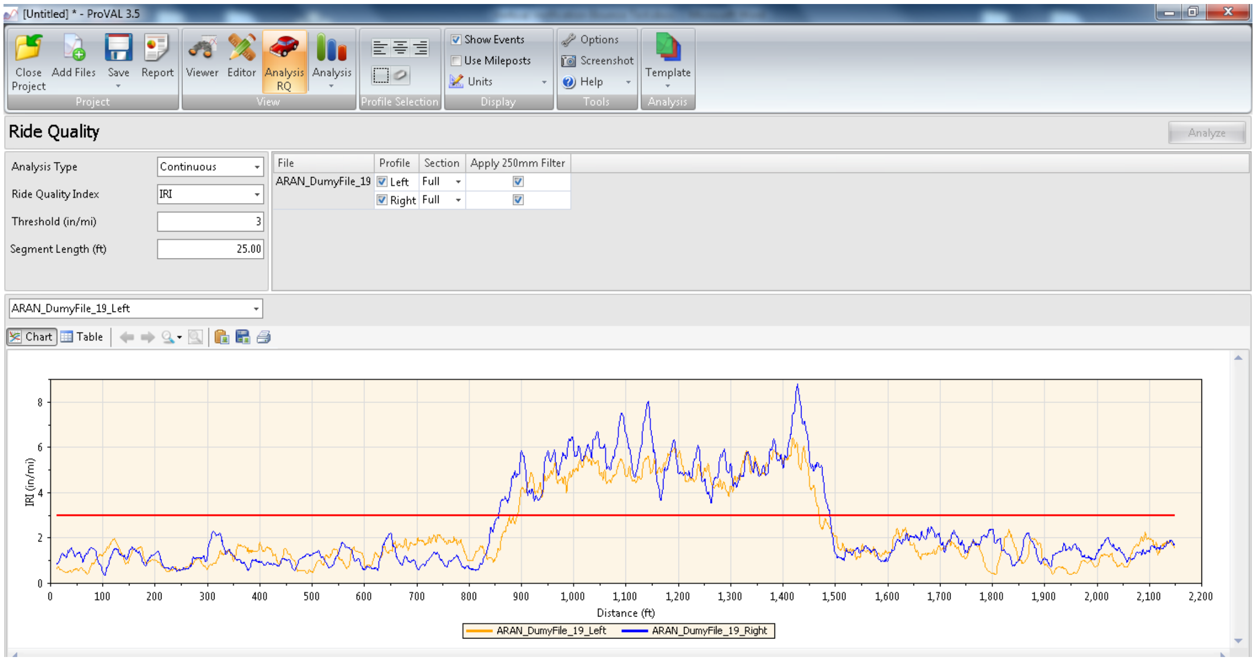
You will notice the scale is off and hard to see your values. Now to change that set the Threshold (In\Mi) to 8 and click Analyzes again, the scale will change so that you can see if any of your values are larger than 8 inches over a mile.



You can see in this example that the end of the vertical movement section of this file is just out of range and should be retested. I would think from reviewing this file this Aran should pass the Bounce test. When bouncing you should move the Lasers about 1 to 2 inches vertically in a smooth motion. Rough and or fast movements will produce a spike like you are seeing around 1500 feet in this example. This file was collect or exported a little short. 900 meter is 2952.76feet.

Now to change that set the Threshold (In\Mi) to 3 and click Analyzes again to see your no movement sections are less than 3 inches over a mile.

APPENDIX C
VERTICAL VERIFICATION BOUNCE TEST



You can see in the above image that both no vertical movement sections are below the red line and the noise level on the accelerometers is passing.

Trouble shooting **(All steps should be verified but they are broken up for understanding)**

If you are passing the no motion sections but failing the movement section of the test, check the following possible issues listed below.

- Verify that the Lasers and Accelerometers are on the correct sides.
- Recalibrate your Roughness.
- Verify your paper or ground is flat and without cracks or ripples.
- Watch you Roughness Diagnostics to see if there are inconsistencies with the values.
- Block tests for Right and Left lasers should be done.

If you are passing the vertical movement sections but failing the no movements section of the test, check the possible issues listed below.

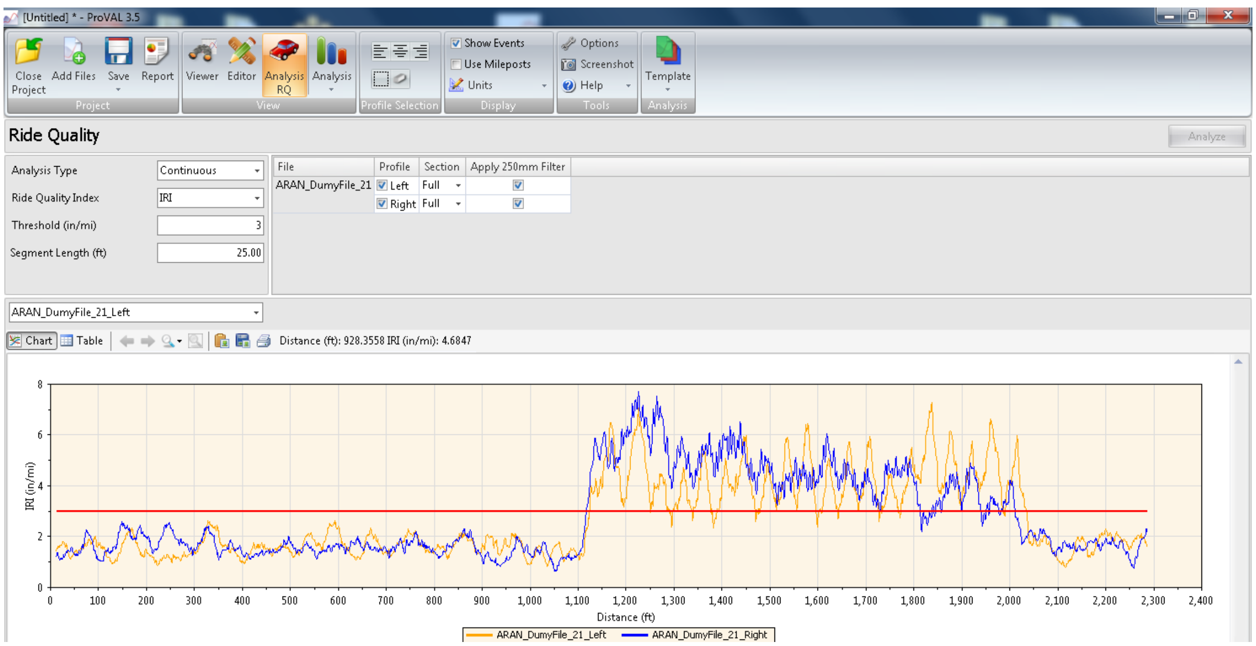
- Turn off the Aran engine (The vibrations maybe showing up in your accelerometer)
- Recalibrate your Roughness. Gains should be around (-0.7XXXXXXXXX)
- Watch you Roughness Diagnostics to see if there are inconsistencies with the values.
- Windy days may be rocking the Aran and give you higher values.

APPENDIX C
VERTICAL VERIFICATION BOUNCE TEST

If you are failing all sections parts of the test, check the possible issues listed below.

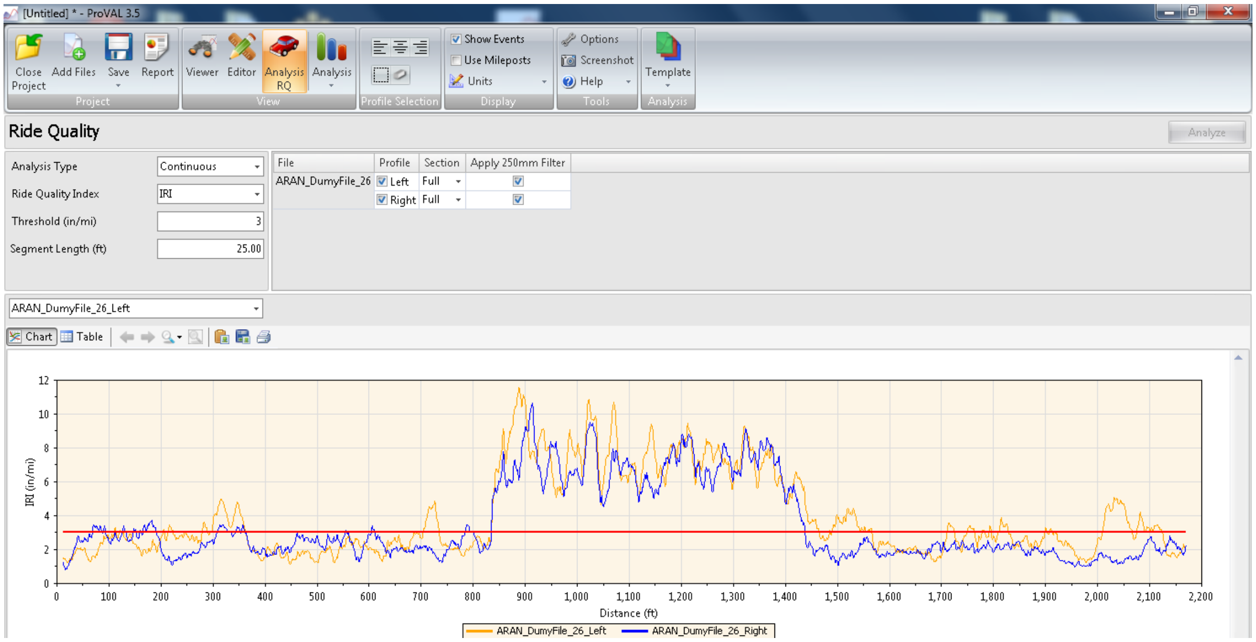
- Verify that you have the correct settings and have Roline or Go-cator lasers.
- Recalibrate your Roughness. Gains should be around (-0.7XXXXXXXXX)
- Watch you Roughness Diagnostics to see if there are inconsistencies with the values.
- Review your Review data to see that the values look close to your ERD values.
- Verify that the units be checked in the ProVal software.
- Do all steps listed in the Trouble Shooting part of this manual.
- Call Fleet CS.

A look at some bounce test.

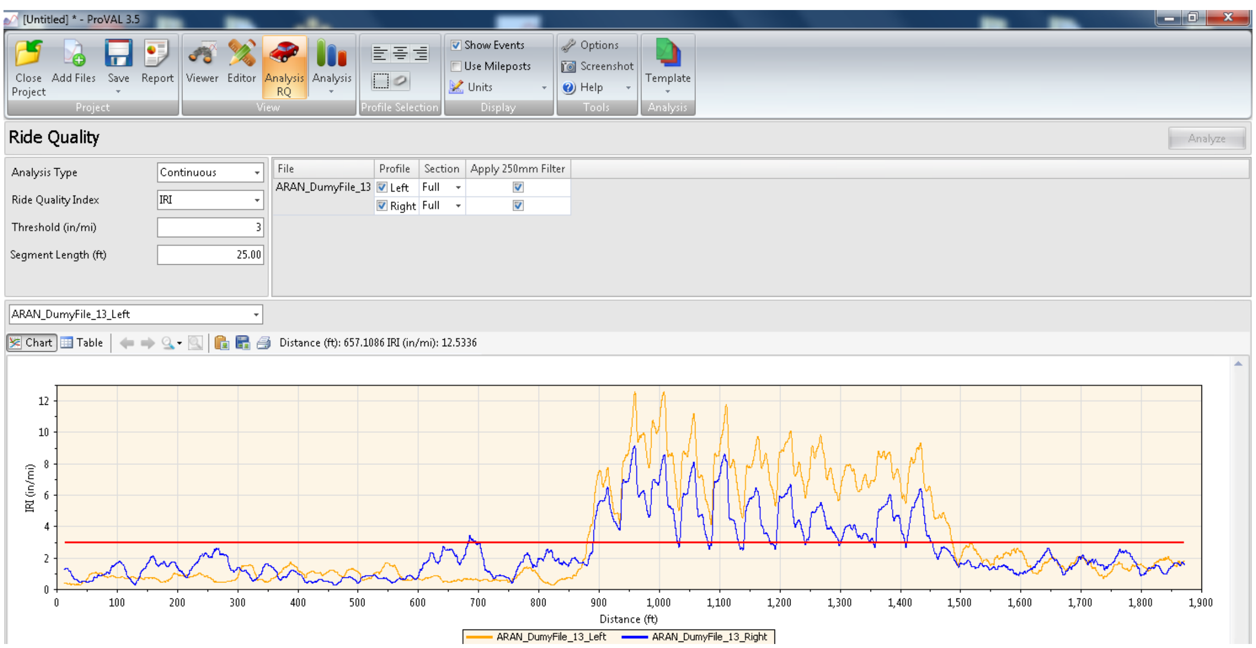


This image shows a bounce test that passes the amplitude test. No vertical movement sections of this file are blow 3 inches per mile and the vertical movement section is below 8 inches over a mile but it is too short and I am sure if the test was rerun it would pass.

APPENDIX C
VERTICAL VERIFICATION BOUNCE TEST



The file above was collected while the Aran engine was running and you can see the no vertical movement sections are about 3 inch over a mile and the movement section is above 8 inches over a mile. This file failed in every aspect. Turning off the engine and recollect the file proved to be the issue.



This file was collected with the Left and Right accelerometer plugged in backwards. The no vertical movement section almost passed but the bouncing section did not at all. Changing the accelerometers connections back to the correct side fixed this issue.

APPENDIX D

PennDOT High Speed Profiler Verification and Operator Precision

			Bitum LWP = 43 - 50 RWP = 43 - 49										Concrete LWP = 70 - 80 RWP = 71 - 82									
Date Printed:	4/6/18		**169-9026**				**170-9026**				**180-9028 Single Point**				**180-9028 Wide Spot**				**188-9021**			
			SITE 1		SITE 2		SITE 1		SITE 2		SITE 1		SITE 2		SITE 1		SITE 2		SITE 1		SITE 2	
Date of Test:	1/4/17		Air Temp		Surf Temp		Air Temp		Surf Temp		Air Temp		Surf Temp		Air Temp		Surf Temp		Air Temp		Surf Temp	
			00°		**00°**		**00°**		**00°**		**00°**		**00°**		**00°**		**00°**		**00°**		**00°**	
		Pass	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT
Company Name:	BOMO	1	0	0	0	0	0	0	0	0	48	44	76	75	45	39	79	76	0	0	0	0
		2	0	0	0	0	0	0	0	0	45	41	74	76	44	39	73	76	0	0	0	0
Device Type:	HIGH SPEED	3	0	0	0	0	0	0	0	0	48	41	72	75	45	40	72	76	0	0	0	0
		4	0	0	0	0	0	0	0	0	45	43	71	73	44	42	73	74	0	0	0	0
Software Version:	Various	5	0	0	0	0	0	0	0	0	46	41	72	74	45	42	72	75	0	0	0	0
		6																				
Number of Sensors:	3	7																				
		8																				
Operator Name	Various	Mean	-	-	-	-	-	-	-	-	46	42	73	75	45	40	74	75	-	-	-	-
		Std.Dev.	-	-	-	-	-	-	-	-	2	1	2	1	1	2	3	1	-	-	-	-
Precision analysis by site (information only):			-	-	-	-	-	-	-	-	NO	NO	YES	YES	YES	NO	NO	YES	-	-	-	-
Bias analysis by site (information only):			-	-	-	-	-	-	-	-	YES	NO	YES	YES	YES	NO	YES	YES	-	-	-	-
Bias analysis by pass (information only):		1	-	-	-	-	-	-	-	-	YES	YES	YES	YES	YES	NO	YES	YES	-	-	-	-
		2	-	-	-	-	-	-	-	-	YES	NO	YES	YES	YES	NO	YES	YES	-	-	-	-
		3	-	-	-	-	-	-	-	-	YES	NO	YES	YES	YES	NO	YES	YES	-	-	-	-
		4	-	-	-	-	-	-	-	-	YES	YES	YES	YES	YES	NO	YES	YES	-	-	-	-
		5	-	-	-	-	-	-	-	-	YES	NO	YES	YES	YES	NO	YES	YES	-	-	-	-
		6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX D
Vendor High Speed Profiler Verification and Operator Precision

Unit	**39**
Date of Tests	Various
Date Printed:	4/6/2018
Company Name:	ROADWARE
Device Type:	HIGH SPEED
System Software Version:	-
Number of Sensors:	2
Operator Name	Various

	Bitum LWP = 43 - 50 RWP = 43 = 49								Concrete LWP = 70 - 80 RWP = 71 = 82							
	39				**39**				**39**				**39**			
	4/6/16				**5/5/16**				**6/13/16**				**7/5/16**			
	SITE 1		SITE 2		SITE 1		SITE 2		SITE 1		SITE 2		SITE 1		SITE 2	
Pass	LT	RT	LT	RT	DT	RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT
1	45.59	41.51	73.44	75.24	44.6	41.59	72.28	72.55	45.87	43.23	72.36	74.35	45.27	44.27	73.59	77.12
2	44.45	42.21	74.81	75.17	45.03	41.61	73.22	74.26	44.27	43.18	72.5	74.87	45.14	44.01	73.38	74.95
3	45.72	41.68	71.96	75.33	45.1	42.18	73.24	73.87	45.6	42.18	72.7	73.35	45.29	43.64	75.7	77.32
4	45.57	41.64	73.93	74.49	45.22	41.37	72.15	74.08	44.92	43.41	72.78	75.84	45.9	42.84	73.38	76.57
5	44.47	41.61	72.66	75.71	45.34	43.11	73.34	73.53	45.47	42.1	72.33	73.82	44.22	44.09	74.11	76.39
6																
7																
8																
Mean	45.16	41.73	73.36	75.19	45.06	41.97	72.85	73.66	45.23	42.82	72.53	74.45	45.16	43.77	74.03	76.47
Std.Dev.	0.64	0.28	1.10	0.44	0.28	0.70	0.58	0.68	0.64	0.63	0.20	0.97	0.60	0.57	0.98	0.93
Precision analysis by site (information only):	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Bias analysis by site (information only):	YES	NO	YES	YES	YES	NO	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES
Bias analysis by pass (information only): 1	YES	NO	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
2	YES	NO	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
3	YES	NO	YES	YES	YES	NO	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES
4	YES	NO	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES
5	YES	NO	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E

Hi Team,

Welcome to Pennsylvania. Before you start collection in Pennsylvania you must carefully read and acknowledge the Pennsylvania Project Requirements. You have also to acknowledge that you have printed this document and keep it handy on ARAN all the time you are collecting in the state of Pennsylvania.

Project Requirements

I. Entry and Exit Controls

a) All sites must be collected 5 times (passing). Data, Control Tracker and ERD (good and bad runs) to be uploaded on ftp under

/Dailies/ARAN17XX/YYYYMMDD_ctrls

Note: First two ARANs needs to run Control site # 12 ten times for benchmarks

b) Control sites 1 & 2

Control sites 1 and 2 must be collected within one day using auto-start sensor.

Sites must be collected within one day. For each run on site 1 and 2 you have to generate ERD report. Under ERD report, lead-in should be set as a 0; length of the sections should be set as 2112 ft. Please separate data for good runs from data for bad runs (CSVs and ERDs). To determinate correlations repeatability for site 1 and 2 please use ProVAL. For information how to install and use ProVAL call project supervisor (ProVal application will be uploaded in your Project folder)

c) Control sites 10, 11, 12 and 13

Regardless if site is segmented or not all sites needs to be collected as a one long segment (from the start through the end). Data should be imported into control tracker to ensure that you have passed each site. If data averages fail please generate ERD to evaluate correlation repeatability; otherwise you do not need to generate ERD for these four sites.

d) Each ARAN crew is responsible for maintaining and updating the Control Tracker through-out the project. Each submission should include all previous control sites.

e). Control Tracker for Entry /Exit is uploaded in your daily folder under

/Dailies/ARAN17XX/Projects/85101PA17/Controls/

APPENDIX E

f). Data and video should be shipped to office as soon as you have Entry controls completed. Please use your USB 3.0 jump drive to ship data as soon as you can.

II. Monthly Controls

a) Control tracker for monthly controls are uploaded in your Project folder under

/Dailies/ARAN17xx/Projects/85101PA17/Controls/Monthly Controls

b) Control sites 1 and 2 must be collected five (5) times within one day using auto-start sensor.

For each run on site 1 and 2 you have to generate ERD report. Under ERD report, lead-in should be set as a 0; length of the sections should be set as 2112 ft. Please separate data for good runs from data for bad runs (CSVs and ERDs). To determinate correlations repeatability for site 1 and 2 please use ProVAL. For information how to install and use ProVAL call project supervisor (ProVal application will be uploaded in your Project folder

c) Sites 7 and 8 must be collected three times (passing). If you have good results you do not need to generate ERD report for these four sites.

III. DMI CALIBRATION

a). The DMI calibration must be performed monthly as a part of Monthly controls and/or if there is any changes in DMI configuration, if you have tire replaced, if there is consistent discrepancy between collected and routed segments or as per PM/CS/Project Supervisor request. DMI calibration site is located on US-22 East (please see attached map). Please make sure that calibration has been indicated in daily report and submitted on Sales Force as well. To remind you, for your safety and to increase accuracy it is Project requirement to have DMI calibration performed by using WEB cam. For more information about that please contact your Project Supervisor.

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IV. Routing Packages

a). Assigned routing package(s) will be uploaded in your daily folder under

/Dailies/ARAN17XX/Projects/85101PA17/Routing

A day or two before you have completed assigned routing package you should informs Field Supervisor about that to verify if all requested sections were collected. In a case that your ARAN has to leave unfinished assigned map (routing package) you are responsible to upload updated map in your daily folder to make sure that collection could be continued smooth and without doubling. In a case that you are not using Street and Trips please upload list of the not collected sections as a relevant document. To verify that you have valid updated list of the not collected sections please contact your Project Supervisor. For additional questions or concerns please call me any time.

b). In a case that you are going to leave assigned DS before you have finish requested routed sections, crew is responsible to upload last updated map (e.g. 20150325_Working_ s26a85032000.est) or list of not collected sections validated by Project Supervisor in routing folder with explanation and / or special instruction for the crew who will continue collection.

V. Regular Collection

a). Pavement Video - Must not have more than 10% with wet/damp conditions.

b). ROW and Pavement video must not have dropped more than 5 consecutive images.

c). All routed events should be accepted or skipped. In a case that you have to split file up, please return back at least 2 segments to make particular segment current and start collection again. Verify that you have enough room to continue collection smooth and with no errors.

d). Gravel sections: Penn DOT indicated that there will be numerous of sections which may start as gravel but turn to pavement later. As per client's requirements we need to collect all gravel routes for video logging only. Of course, standard collections rules apply; If you are certain that particular road is not safe to be driven on or equipment could be damage or destroyed, you have right to refuse to collect. In that case please make a few images under particular section header; under the comment please explain what would be the reason of not collecting particular section.

APPENDIX E

e). Most of the client's complaints are related to poor ROW video quality. According the Contract we must provide as best as possible ROW video quality. To verify that video has been collected as per Fugro-Roadware standards Daily attachment must contain three additional sets of three consecutive ROW and pavement images. First set should be taken from the first file collected, second set between 12 and 1 PM and third set from the last collected file. Total of 9 images should be attached for each day of collection until further notice. (Please see attached folder structure). Make sure that Images for this purpose are chosen *manually*. Please do not use EOD application to generate images, EOD application will pick images randomly rather than from requested part of the day. Uploaded image must retain the original number (name).

f). Request for removable hard drives should be emailed (Work order) to DC two weeks in advance. Hard drives inventory should be updated upon every change (data shipment, shipment from office, after drives are released from office e.t.c). Minimum number of available drives should not be less than 20.

g). To collect routed sections shorter than a 0.1 MI please collect section longer and indicate it under your comment (bridges). Such short section has to be collected longer to provide acceptable IRI reading.

h). Sections start/end from dead end should be collected as per instructions from CS and commented properly. If you are not sure how to do that please contact your Project Supervisor.

i) Sections collected with some irregularities (longer or shorter than routed, opposite direction, quality not as per Fugro-Roadware standards e.t.c) must be properly commented. According our policy operator is responsible to use list of the standard comments (attached).

VI. Weekly Data shipment

Data shipment has to be send to office as per weekly schedule. To skip data shipment you have to inform Project manager, Field Supervisor and Data controls supervisor in advance and request approval to skip/ postpone data shipment. Crew is responsible to ship data every week as per attached schedule (please see attached document).

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VII. Down time

a). In a case of technical difficulties when you cannot troubleshoot an issue within an hour please call CS for assistance. CS /Project Supervisor must be informed if status has been change during the day.

b). Please try to schedule chassis maintenance on rainy day; if it is not possible please inform Field Supervisor and / or CS about that (Mr. Seyed Ayoubi). For any unscheduled mechanical and generator's maintenance crew is responsible to immediately inform Mr. Seyed Ayoubi (CS) and Project Supervisor.

VIII. Project Contract and client's contacts phone number

a) As an integral part of this Welcome package here is Project Contract (attached).
b) Client's contact's names (attached)

Project Contract and Client's contact's names must be printed and kept handy all the time while collection in Pennsylvania. These documents could be used only as proof that we are contracted by PENDOT to do work in Commonwealth of Pennsylvania. This documents shell be presented if requested by Police or Military authority in a case we need to access some restricted zones or in a case if we are using emergency turnarounds on Interstates and State highways in Commonwealth of Pennsylvania. It is strongly prohibited to use Document for any other purpose without Department Manager, Project Manager's or Project Supervisor's authorization. If using the Document please immediately inform Department Manager and Project Supervisor.

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Repair Services

Mercedes Dealer, Sunmotors

6677 Carlisle Pike, Mechanicsburg, PA 17050, United States

Phone; 1 717-691-3333

Onan Generator repair service

4499 Lewis Road

Harrisburg, PA 17111-2541

Phone Numbers

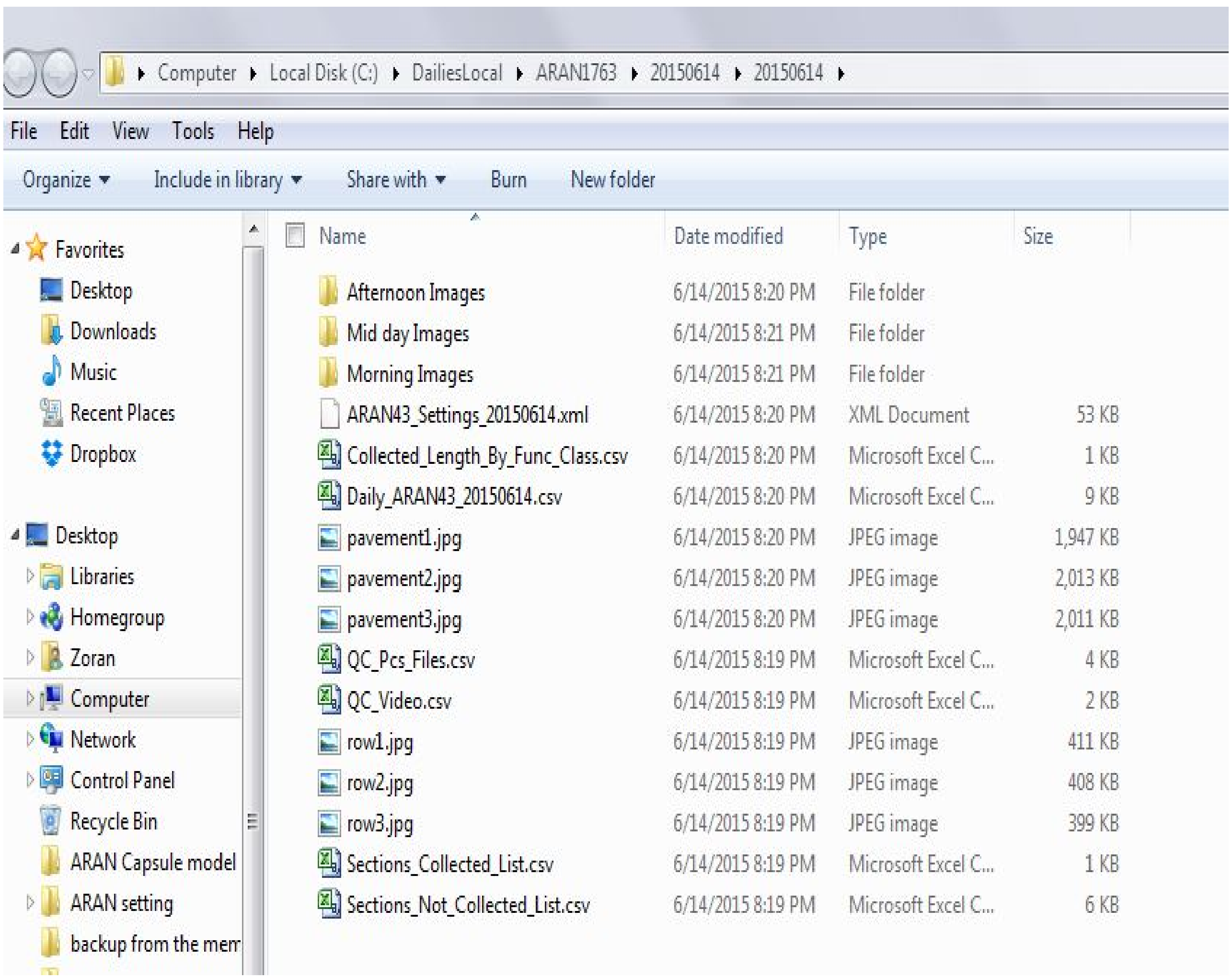
Local: 717-564-1344

Toll Free: 800-841-1344

APPENDIX E

ATTACHMENTS

Daily attachment folder structure



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85101PA17 Data shipment schedule

ARAN	**Project**	**Day ARAN Ships**	**Day Office Receives**
ARAN 39	PA17	Monday	Tuesday
ARAN 40	PA17	Tuesday	Wednesday
ARAN 41	PA17	Wednesday	Thursday
ARAN 43	PA17	Thursday	Friday

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Standard Comments

	Comment
Operator Standard Comment List	Section Collected Short - [enter reason why]
	Section Collected Long - [enter reason why]
	Section Split - [enter reason why] - Restarted at [enter street name/ segment/ place]
	One Way Road - Collected in the opposite direction than routed
	Road Closed - [enter reason why]
	Section Closed For Construction Indefinitely - [enter other necessary information]
	Section Not Safe For Collection - [enter reason why]
	Section Not Collectable - [enter reason why]
	Dead End Start
	Dead End End
	Private Road - [enter necessary information]
	Delete File - [enter reason why]
	Dummy File
	No IRI Recorded - [enter reason why]
	GPS Mode In Single Ended 3D - [enter reason why]
	Other - [enter reason]

APPENDIX E

Your safety is our priority- A good safety culture is built over the period of time. It is never given. Think about that!

Think safe and stay safe!

Daily Collection Revised 12/01/17

1. **PURPOSE and SCOPE**

To provide general instruction on all facets of data collection as it pertains to the ARAN, the ARAN Crew, their responsibilities and work instructions.

Field Operations within the scope of this document:

- Senior Field Operations Technician 1, 2 & 3
- Field Operations Technician 1, 2 & 3

1. **PROCEDURES**

2.1. Vehicle Inspection

The crew, with the use of the Mechanical Inspections and Sub System Inspections checklists found under Maintenance Assets In SalesForce , will inspect and check off each item on the lists. Also during the visual walk-around make note of any damage to the ARAN, especially to the front or rear instrument enclosure and rear pavement cameras or LCMS/LRMS lasers. Also pay close attention to tire wear, suspension and steering problems.

2.2. Subsystems

2.2.1. Once all the subsystems have booted up properly, a dummy file must be collected. During collection ensure all subsystems are collecting properly and all video quality matches project specifications. Once you have finished collecting your dummy file, run the end of day report in the ACS. Open the Daily_ARANxx_20xxxxxx.csv and make sure your dummy file has been recorded. Open the QC_Pcs_Files.csv and make sure you have begun to save posdata. Open the QC_Video.csv and make sure you have not dropped any images. Open all images and make sure that the quality matches project specifications. Open the Project Settings Compare Program and compare the ARANxx_Settings_20xxxxxx.xml that has just been created against the .xml file used at project signoff. If there are any discrepancies the project supervisor must be contacted and problem resolved before data collection can begin.

2.2.2. At times, data may be collected by certain systems even though it is not specifically deliverable. In the event that there are problems with a non-deliverable system, the project manager will be contacted for permission to disable the offending system and collect without it.

1.1. Video Collection Procedures

Video lighting guidelines are discussed and agreed upon during the project setup meeting. Before collection can begin a sign off file must be uploaded to the FTP site. The operator is responsible for creating an ARAN certification in SalesForce under their corresponding project page. Once this has been completed data control will review all images. Throughout the project, data control will QC the video daily and any concerns will be relayed to the project supervisor and C.S. immediately.

1.1.1. Ensure that there is adequate ambient light for ROW images to maintain all video detail. This means street signs must be clearly legible in all ROW images.

1.1.2. Continually review ROW and pavement images to ensure all images meet project requirements. This includes potential lighting and technical issues. Several times a day an end of day report should be run. Both the QC_Pcs_Files.csv and the QC_Video.csv must be opened in Microsoft Excel, each time the end of day reports are run, to make sure PCS is being collected and no images from the ROW camera(s) have dropped any images.

1.1.3. Always remember to start sections (files) early and end sections late, this will ensure that the entire section of the file has been collected entirely.

1.1.4. Always remember to start the data collection at the proper GPS "accept" point on the collection map.

1.2. **PROJECT SETUP**

Camera setup and alignment procedures as well as ARAN 9000 settings are discussed and agreed upon during the project setup meeting. Before an ARAN can begin collection in a project, camera setup and alignment and ACS settings must be done by C.S. or under supervision by C.S. Once a sign off file has been collected, the data will be uploaded to the FTP site. The crew is then responsible for creating an ARAN certification in SalesForce under their corresponding project's page. The location of the signoff must be noted in the certification and submitted before data services will begin to review the data and images. Controls can begin at risk if approved by the project manager, and the sign off status in SalesForce is changed to 'Authorized To Proceed At Risk'. Once controls have been completed, the crew must update their ARAN certification with the dates on when controls began and finished. All .csv files and control tracker and end of day reports must be uploaded to the FTP. Also the location of the control tracker that contains all of the controls sites ran must be noted. This will prompt the DA department to review the data.

Collection can only begin at this time if approved by the project manager and the sign off status in SalesForce is changed to ‘Authorized To Proceed At Risk’. Once the controls have been collected, the video and data will be shipped to the Project Manager for QC and acceptance. Throughout the project the video alignment QC will be monitored and any concerns will be relayed to the project supervisor immediately.

1.1.1. ARAN 9000 setup includes camera alignment and making sure all setting match the project setup sheet. When this has been concluded, a 200 mmi sign off file will be collected. Make sure the road chosen is ACP and has enough distress so the pavement camera/LCMS alignment can be verified. Simultaneously the ARAN crew will create an ARAN certification in SalesForce under their corresponding project’s page. The location of the sign off file must be noted in the certification and submitted before data services will begin to review the data and images. During collection runs, continuously check the pavement view. Watch for excessive hot spots, which are caused by the strobes washing out the image. Also watch for shadows when checking pavement view. Shadows should be eliminated or at worst, very faint. Heavy shadows in the image can indicate improperly firing strobes.

1.1.2. Surveyor Calibration and controls are run after the sign off has been approved. Controls can begin before approval if the project manager gives the go ahead. The surveyor calibration can only started after the camera alignment has been approved and signed off by the project manager. Once controls have been completed, the ARAN certification page in SalesForce must be updated with the control start and end dates. Also the location of the control tracker used must be noted by the ARAN crew. This acts as a signal to the DA department and they will begin to review the control data. Continuously check for strobe bulb failures. If one side of the pavement video flickers or blacks out, you may have a bad bulb. Both bulbs must be replaced at the same time, regardless of whether or not one is still working properly.

End of day reports

When the collection day has finished, end of day reports have to be created and uploaded to the FTP site for review by data control during the next business day. Run [end of day reports] under [data verification] in the ACS.

1.2. Digital Video

Each DVS computer must be checked regularly to ensure that video is of good quality and is being stored properly.

1.2.1. Open the collection video, make sure the video image is being updated regularly.

1.2.2. Ensure that you are double clicking on the ROW and Pavement camera videos to get the entire picture of ROW and Pavement videos approximately every mile of collection. This will guarantee that you are collecting accurate video images on the ROW and Pavement cameras.

1.2.3. Ensure that the frame numbers are incrementing appropriately.

1.1.1. Watch for error messages in the ACS.

1.1.2. Watch to ensure that video files are being created and stored to the appropriate folders on the appropriate hard drives.

1.2. 3D-DGPS

Ensure that there is a 3D-DGPS fix at the start of each section. Move the systems start point for the run back, if necessary, hit Start at the point where a 3D-DGPS fix is attainable. Once a fix is possible, hit ‘Begin Segment’ at the start of the actual section. Make good csv comments so Data Reduction can repair the GPS and deliver the appropriate data to the customer. Ideally, you want a 3D-DGPS fix at the end of each section as well.

1.3. Maintaining Visibility

Prior to start of section, ensure that all camera lens covers and enclosure windshields are clear. Also make sure that visibility is unobstructed. If debris appears on the camera lens or windshield during collection, stop the ARAN and clean immediately, as is safe to do so, or restart the section as appropriate. Any obstructions can be readily seen by carefully monitoring the camera view during collection. It is up to the operator to determine when sufficient time exists between rating and monitoring the collection screen to check the video of all cameras.

1.4. Weather Effects

When collecting pavement video, never collect on days where the pavement is obscured or non-representative of actual conditions due to road debris, severe dampness, etc. The ARAN should not be moved during weather that may present a hazard to the crew or vehicle, such as extreme high winds, slippery or blizzard-like conditions, etc.

1.5. LRMS/LCMS Lasers

1.5.1. During the morning setup the LCMS/LRMS glass must be cleaned. The settings in the ACS must reflect the project setup sheet and must not be changed unless there is approval from the Project Manager and done under supervision of C.S. or the project supervisor. The settings can be found in the ACS under configuration Laser XVP for the LRMS and configuration LCMS for the LCMS.

1.1.1. Safety is the utmost priority. Collection concerns should never jeopardize the safety of the crew, the ARAN, or the public.

1.2. Real Time Data Quality Checks

All Operators must know acceptable ranges for ‘good’ data and ‘good’ daily averages for the types of road surfaces they are collecting.

1.3. Collection Stoppage

Any type of error message that is fatal (will be highlighted in red in the error message box in ACS) MEANS collection must cease and the section re-collected. At times a problem will need to be evaluated and corrected, if critical errors and/or multiple minor errors continually occur during collection. Contact the fleet C.S. department first then your project supervisor whenever a problem that needs to be evaluated occurs. Also an email with your current status must be sent to #fleetcs and #fieldsupervisors and updated with any changes including when collection is resumed.

1.4. Section Approach

The approach methods are agreed upon between the Project Manager and the project supervisor prior to start of the project.

- Always try to attain the desired test speed before the start of the section.
- Try to maintain as constant a speed as possible throughout the section.
- Try to avoid accelerating when hitting the start of a section, or decelerating at the end.
- Always drive within the confines of the law.
- Try not to rock the subsystems too much as you enter into a file, so as to avoid generating POS/LV errors.

1.5. Checking Data

For the following, the Operator is alerted through real-time visual monitoring of the data readouts during collection. The data being collected should be referenced to the expected ranges for the type of road surface being collected. The end of day reports should be run throughout the day to make sure there are no dropped ROW or Pavement images and PCS is being recorded (see 2.2.1, 2.3.2). Using the review

data tab in the ACS the operator should continually review that the video images as well as data are being recorded.

1.1.1. Rutting: Ensure that both LRMS/LCMS lasers are working properly and ensure reasonable rut depths are being recorded.

1.1.2. POS/LV: Units may be on or off during transits.

1.1.3. GPS: Using the POSLV software, make sure you are in full Nav. Also make sure the status in in DGPS or Omnistar VBS. Your DMI cannot be offline. Next, your accuracy must be under 0.03. GAMS must be online only for collecting the surveyor loop. Ensure that GPS is achieving a 3D-DGPS fix at the start of each section and throughout most of the section length. Move the systems start point for the run back if necessary. Make a note of any section where a 3D-DGPS fix was not obtainable at the start of the section. In certain projects, it is necessary to monitor the accuracy drifting in POSView. In these scenarios, make sure that the accuracy readings remain below 1 meter. Momentary lapses may occur due to passing under bridges, heavy tree canopy, etc. but ensure that the accuracy comes back down to acceptable readings quickly.

1.1.4. Grade: Ensure that grade numbers are reasonable. Steeper uphill grades produce a positive grade. Steeper downhill grades produce a negative grade.

1.1.5. Cross-fall: Ensure that cross-fall numbers are reasonable. As the truck is tilted towards the driver, the cross-fall becomes more negative. As the truck tips towards the passenger, the cross-fall becomes more positive due to the camber of the road.

1.1.6. Roughness: Ensure that IRI numbers are reasonable for the pavement type being collected. Ensure that the ratio of left to right IRI is reasonable.

1.1.7. Faulting: Ensure that faulting numbers are reasonable.

1.1.8. Chainage: Check that chainage values and speed are present and consistent. Compare the speed reported on the collect data screen to the truck speedometer and the GPS (Garmin). If the truck speedometer is off by more than 5 mph, there may be a problem with the DMI calibration.

1.1. Data Quality Verification (Post-collection)

1.1.1. All deleted files must be marked with an ‘X’ in your daily .csv and commented ‘delete file’ in the comment column.

1.1.2. Make sure that all sections that are collected too long or too short have a comment in the daily .csv. Also any other relevant information must be noted in the comments section of your daily .csv. These can be recorded throughout the day in your end of day reports tab in the ACS.

1.2. Removable Hard Drives

1.2.1. Make sure to use 1TB or larger hard drives if available in the pavement computer.

1.2.2. Before removing drives from removable bays, the computer power must be completely shut off, then the drives can be removed.

1.2.3. Removable drives must be formatted before use. Brand new hard drives must be formatted using the ‘Full Format’ option. The ‘Quick Format’ can only be used if a full format has been performed previously. A full format is a good option on a used hard drive but should only be done when collection time will not be impacted.

1.2.4. Removable drives should be stored in bubble wrap or pink foam containers, provided by data control, and placed in a crush-resistant storage bin. The storage bin should be stored away from heat, wetness and magnetism.

1.2.5. Removable hard drives should be shipped in a pink foam container provided by data control and placed in a large FedEx box. If one is not available, each drive must wrapped in bubble wrap and placed in an appropriate size box with packing peanuts. UDMAs will be shipped in a static bag and individually enclosed in a crush-resistant container. This will be surrounded by bubble-wrap or Styrofoam peanuts to ensure that drives within the master package cannot collide.

1. definitions

DVS Digital Video Storage Computers

LRMS Lasers Laser Rut Measurement System, used to measure the transverse profile of the road.

LCMS Lasers Laser Crack Measurement System, they also measure transverse profile of the road.

1. references

Form 121/03 Maintenance Tracking Form

Form 123/03 Job Specification Checklist

Form 154/03 Subsystem Checklists

1. responsibility

ARAN Crew is responsible for:

- Perform all major vehicle maintenance before the start of any new project.
- Perform a physical and visual inspection of the ARAN each morning prior to the start of the day's data collection

Addendum: How to Record "Could Not Collect Sections"

The ARAN Operator should take pictures through the ROW camera on sections that are capable of being collected. These images should be placed in a folder for the dailie and noted in the CSV under Standard Operator's Comments.

Addendum: How to Collect One Way Roads Routed in the Wrong Direction

HOW TO COLLECT ONE WAY ROADS ROUTED IN THE WRONG DIRECTION

One way roads routed in wrong direction

Description

In situations where the ARAN encounters a one way road that runs in the opposite direction of the routing, it would be beneficial if it became standard operating practice for the ARANs to collect the road anyway even if it is in the opposing direction and apply a comment.

This way, if it is later decided that the routing can be flipped or modified, it just becomes a quick and simple in-office fix with no wait time for the truck to go back to the same location to recollect. Since they are already there, it doesn't hurt to collect the road as is and let data processing handle it.

Some ARANS already do this to some extent, but it could save time and money particularly with LA Locals where there are so many small and sometimes one way roads.

Always notify the DA's and Routing Dept. in the office of the discrepancy immediately.

Update

Should clarify that this would only be relevant and necessary when both directions aren't already routed. If both directions are routed, it would be collected going the other direction anyway.

Intentionally Blank

APPENDIX F

pennsylvania
DEPARTMENT OF TRANSPORTATION

AUTOMATED PAVEMENT CONDITION SURVEY FIELD MANUAL PUBLICATION 336

APRIL 2018

PREPARED BY:
BUREAU OF MAINTENANCE AND OPERATIONS
ASSET MANAGEMENT DIVISION
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COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

AUTOMATED PAVEMENT CONDITION SURVEY FIELD MANUAL

APRIL 2018

PUBLICATION 336

TABLE OF CONTENTS

Introduction

This manual is for use with the Pennsylvania Department of Transportation's Pavement Condition Survey. The Pavement Condition Survey is a distress survey, with the purpose of providing quantified, location-specific condition data on Pennsylvania's network of about 40,000 centerline miles of state highways.

The data collected is used for the following purposes:

1. To provide a uniform statewide condition evaluation that would improve decision making.

2. To provide management with the information and tools to monitor condition of the network, assess future needs, establish county condition rankings and optimize investments.

3. To provide condition information to fulfill the requirements of Act 68 (1980) which requires the allocating of maintenance funds to the individual counties based on needs.

4. To provide information for monitoring the performance of various pavement designs, rehabilitation and maintenance techniques.

5. To provide information for identifying candidate projects for maintenance and betterment programs.

Pennsylvania Location Reference System

Introduction:

The Location Reference System (LRS) is designed to bring Pennsylvania’s roadway designations into a verifiable, flexible, and constant Engineering standard. It is the key to the collection, storage, and integration of roadway information within the Department.

CO/SR/SEG/OFFSET is the KEY series of numbers given to the location of a point or feature on a state route. This fourteen digit number (CO/SR/SEG/OFFSET) is an integral part of the computerized Roadway Management System (RMS) where key roadway data are stored.

Pennsylvania is divided into 67 counties. Each county (CO) has a number which represents the first two digits of the LRS number. In each county there are state routes. The State Route (SR) is subdivided into approximate one-half mile segments (SEG). Finally, the OFFSET is an even smaller subdivision of the segment. The offset is the distance to a particular roadway feature from the beginning of the segment.

The Location Reference System is not complicated and anyone can easily take advantage of the benefits it has to offer. It adds permanence, accuracy, and stability to our marker system. It is easy to understand, costs less to maintain, and generates a computerized representation of the state highway network.

The following material will provide some insight into how the LRS was developed and the type of information that can be inferred utilizing the 14 digit KEY.

County (CO):

A. County Names, Numbers, and Maintenance District No.:

County Name	County No. (CO)	Maint. Dist. No.
Adams	1	8-1
Allegheny	2	11-1
Armstrong	3	10-1
Beaver	4	11-2
Bedford	5	9-1
Berks	6	5-1
Blair	7	9-2
Bradford	8	3-9
Bucks	9	6-1
Butler	10	10-2
Cambria	11	9-3
Cameron	12	2-4
Carbon	13	5-2
Centre	14	2-1
Chester	15	6-2
Clarion	16	10-3
Clearfield	17	2-2
Clinton	18	2-3
Columbia	19	3-1
Crawford	20	1-1
Cumberland	21	8-2
Dauphin	22	8-5
Delaware	23	6-3
Elk	24	2-8
Erie	25	1-2
Fayette	26	12-1
Forest	27	1-3
Franklin	28	8-3
Fulton	29	9-4
Greene	30	12-2
Huntingdon	31	9-5

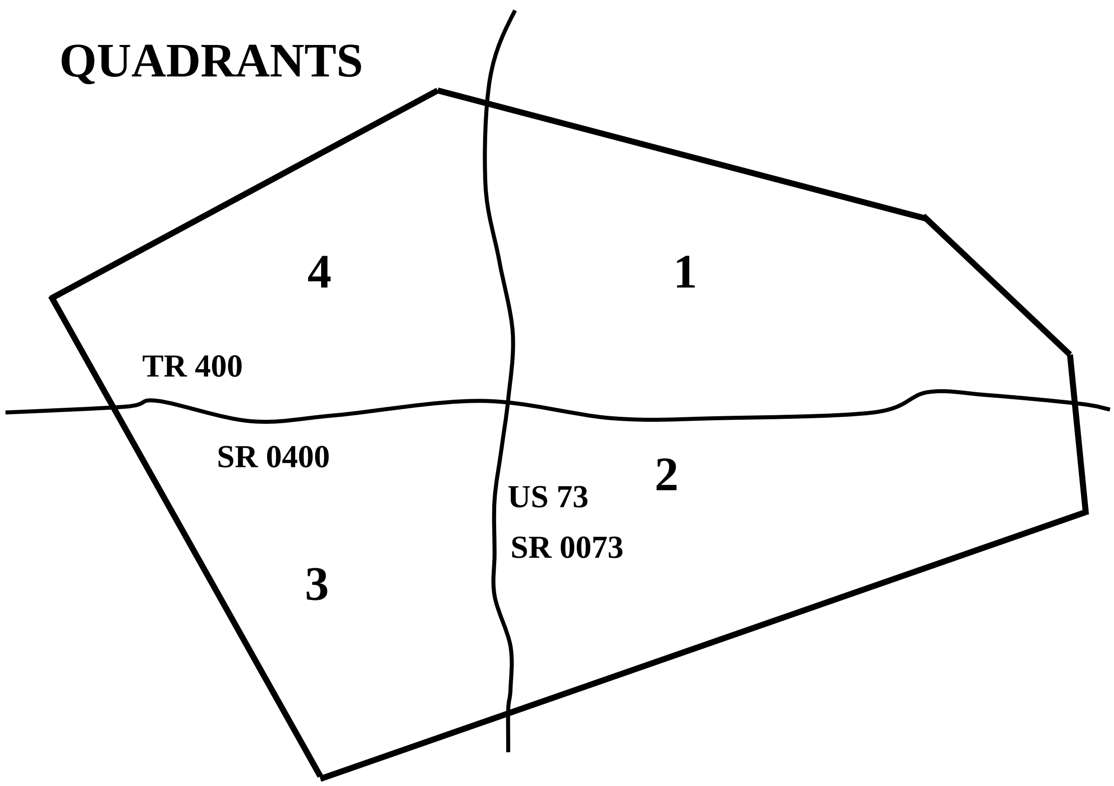
County Name	County No. (CO)	Maint. Dist. No.
Indiana	32	10-4
Jefferson	33	10-5
Juniata	34	2-9
Lackawanna	35	4-2
Lancaster	36	8-7
Lawrence	37	11-4
Lebanon	38	8-8
Lehigh	39	5-3
Luzerne	40	4-3
Lycoming	41	3-2
McKean	42	2-5
Mercer	43	1-4
Mifflin	44	2-7
Monroe	45	5-4
Montgomery	46	6-4
Montour	47	3-3
Northampton	48	5-5
Northumberland	49	3-4
Perry	50	8-9
Pike	51	4-4
Potter	52	2-6
Schuylkill	53	5-6
Snyder	54	3-5
Somerset	55	9-7
Sullivan	56	3-6
Susquehanna	57	4-5
Tioga	58	3-7
Union	59	3-8
Venango	60	1-5
Warren	61	1-6
Washington	62	12-4
Wayne	63	4-6
Westmoreland	64	12-5
Wyoming	65	4-7
York	66	8-4
Philadelphia	67	6-5

State Routes (SR):

A. SR Numbering Convention:

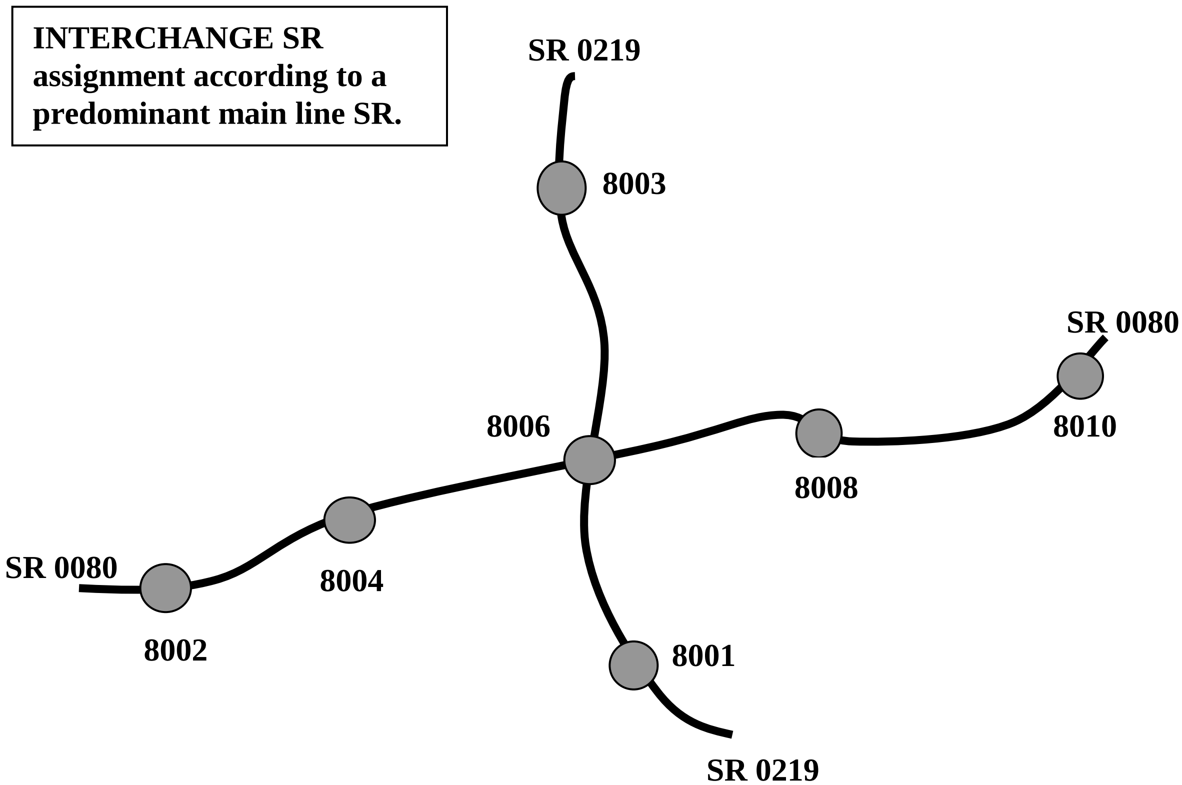
	SR Value
1. Interstates, US Routes, and PA Routes..........................	0001-0999
2. Quadrant Routes..	1000-4999

Note: By quadrants 1, 2, 3, or 4



3. Non-Toll PA Turnpike Routes...	5000-5999
4. Relocated Traffic Routes..	6000-6999

5. Interchanges...8000-8999



6. WYEs..9100-9199

7. Rest Areas..9200-9299

8. Truck Escape Ramps...9300-9399

9. Others..9400-9499

B. Odd/Even Convention:

1. Odd numbered SRs are assigned to north/south direction.

2. Even numbered SRs are assigned to east/west direction.

3. The Odd/Even convention MAY NOT apply to PA or US traffic routes.

C. Traffic Routes - Routes which have been assigned an Interstate, U.S., or PA traffic route designation.

D. Quadrant Routes (Non-traffic routes)

1. Four Quadrants
   - refer to quadrant diagram
   - refer to SR numbering convention

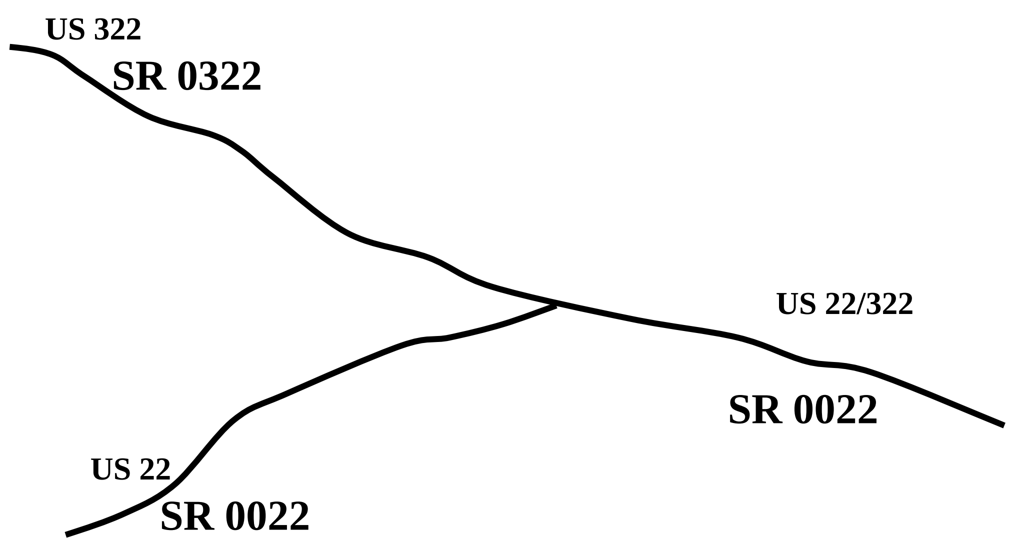
2. Directional Convention:
   - Odd number State Routes are N/S direction
   - Even number State Routes are E/W direction

E. Hierarchy -
If 2 or more traffic routes occupy the same section of roadway, the following hierarchy applies.

1. Interstate
2. U.S. Routes
3. PA Routes
4. Quadrant Routes

If the traffic routes are the same hierarchy class, then the SR number is assigned the lower numbered traffic route.

SR DESIGNATION OF SHARED ROADWAY



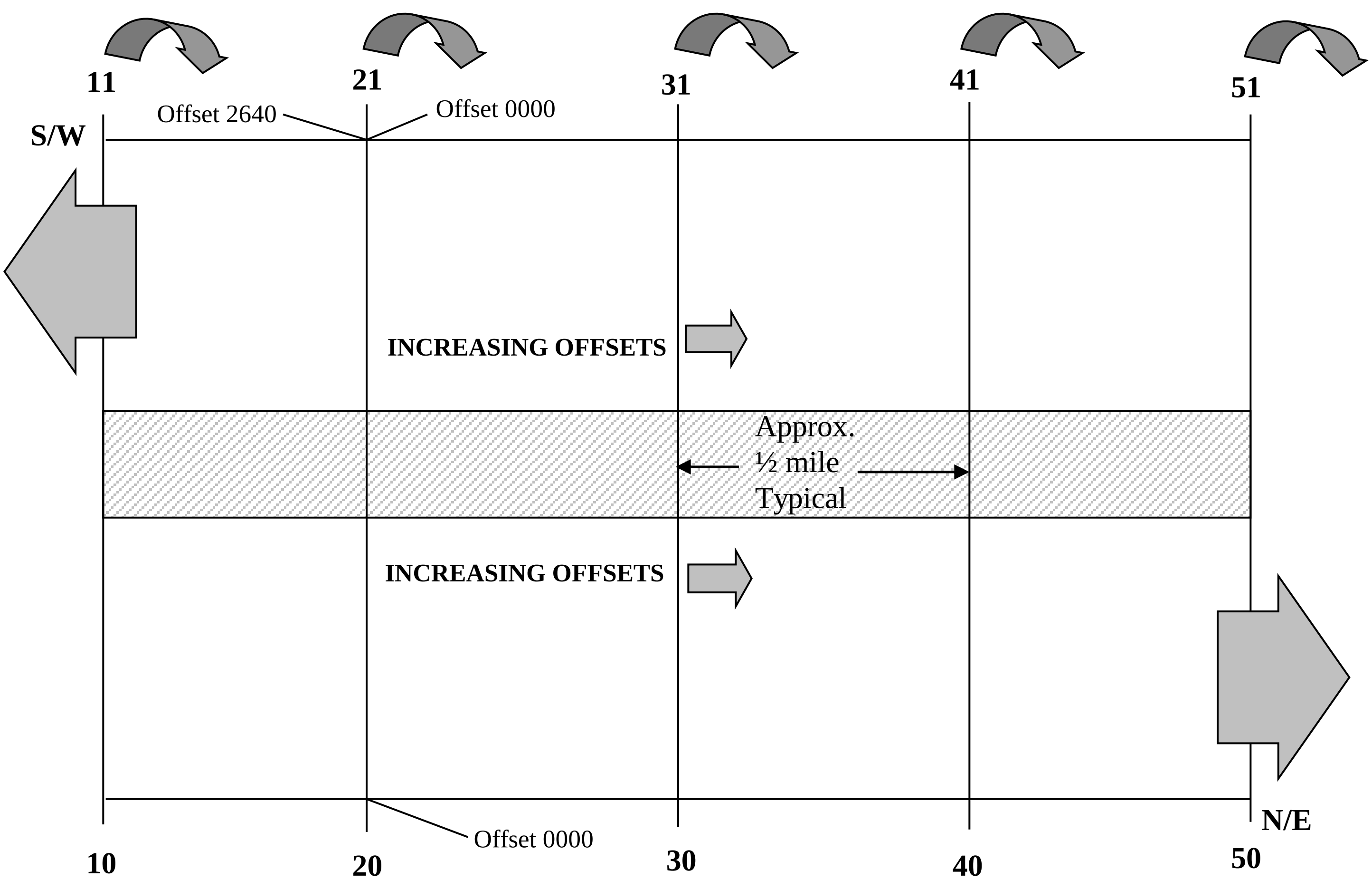
<u>Segments (SEG)</u>

A. Segment = approximately one-half mile sections of SR's that are usually numbered by 10's.

B. The beginning and ending points of Segments are placed at physical features where possible.

C. Direction
Divided roads have directional segments
- North or East are even numbers
- South or West are odd numbers

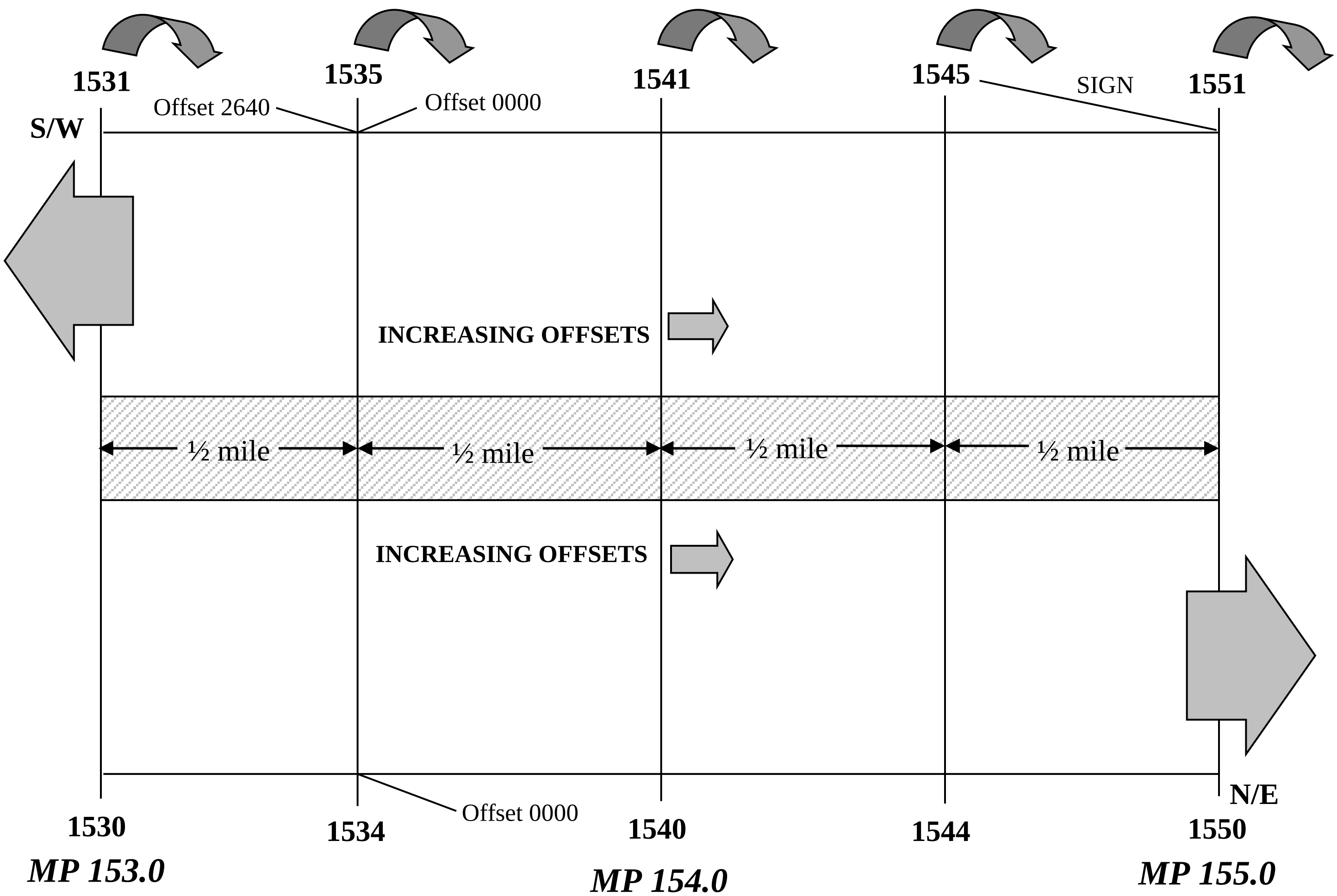
DIRECTIONAL SEGMENTING ON DIVIDED HIGHWAYS



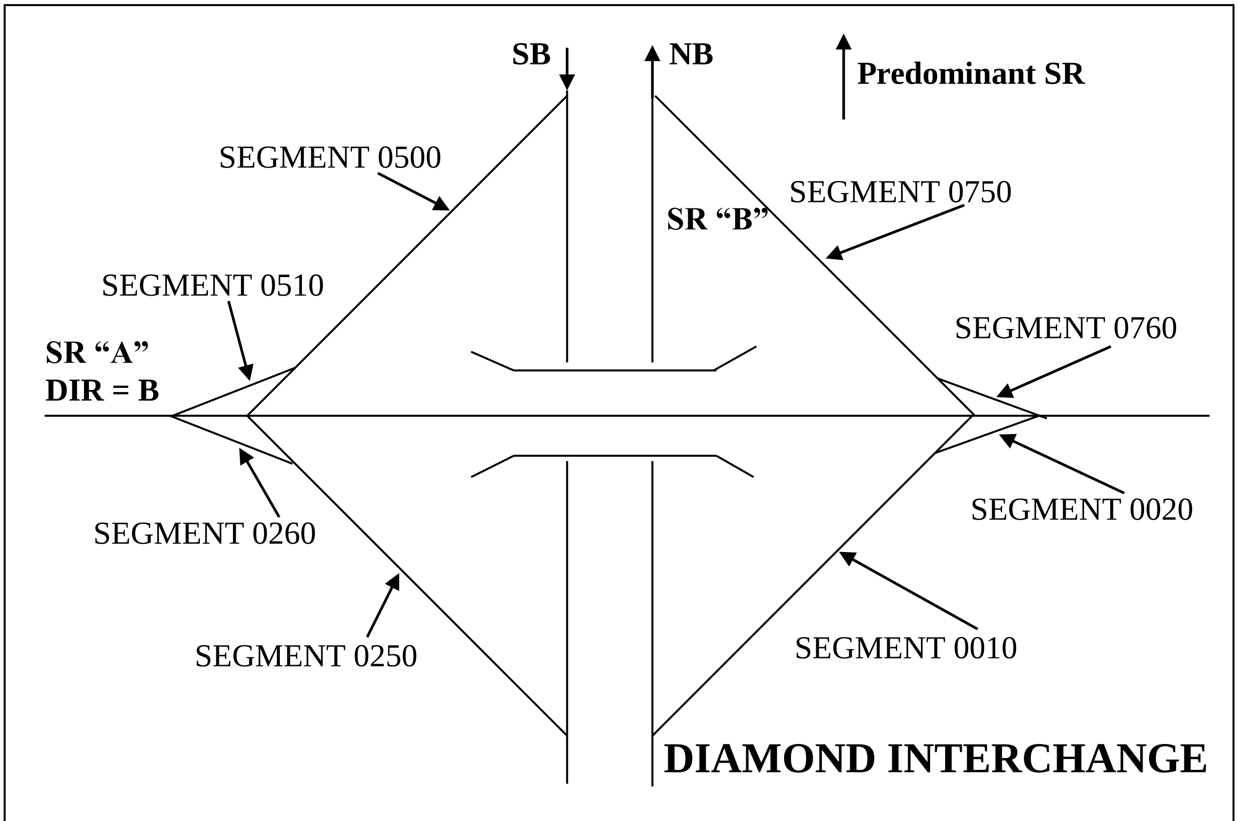
D. Interstate

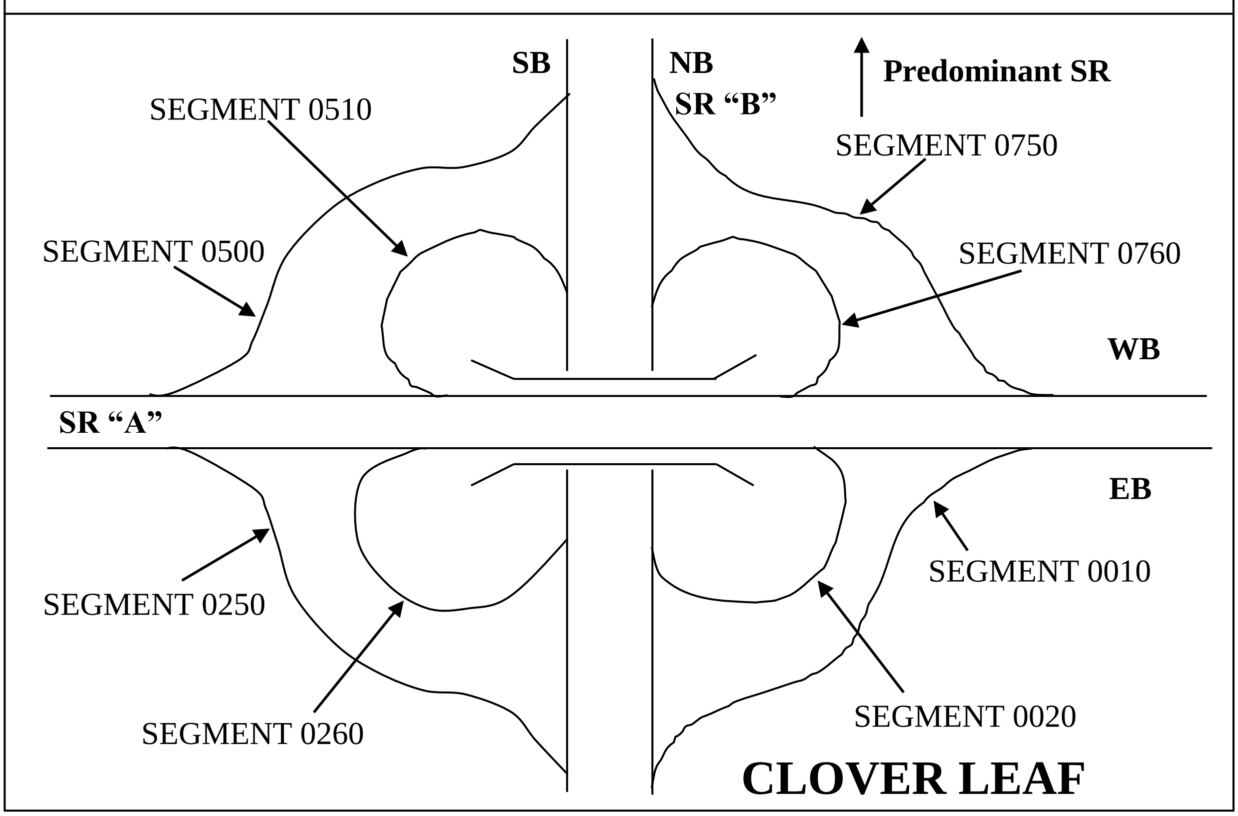
- Interstate Segmenting is associated with the milepost.

SEGMENTING ON INTERSTATE HIGHWAYS



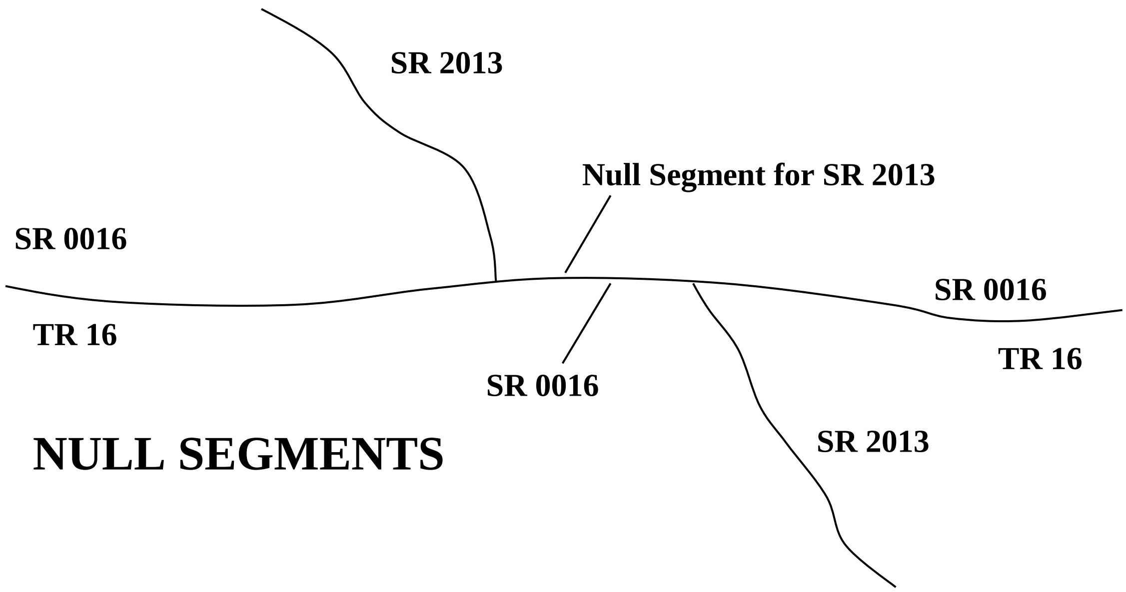
E. Common Interchange Configurations and Segmentation



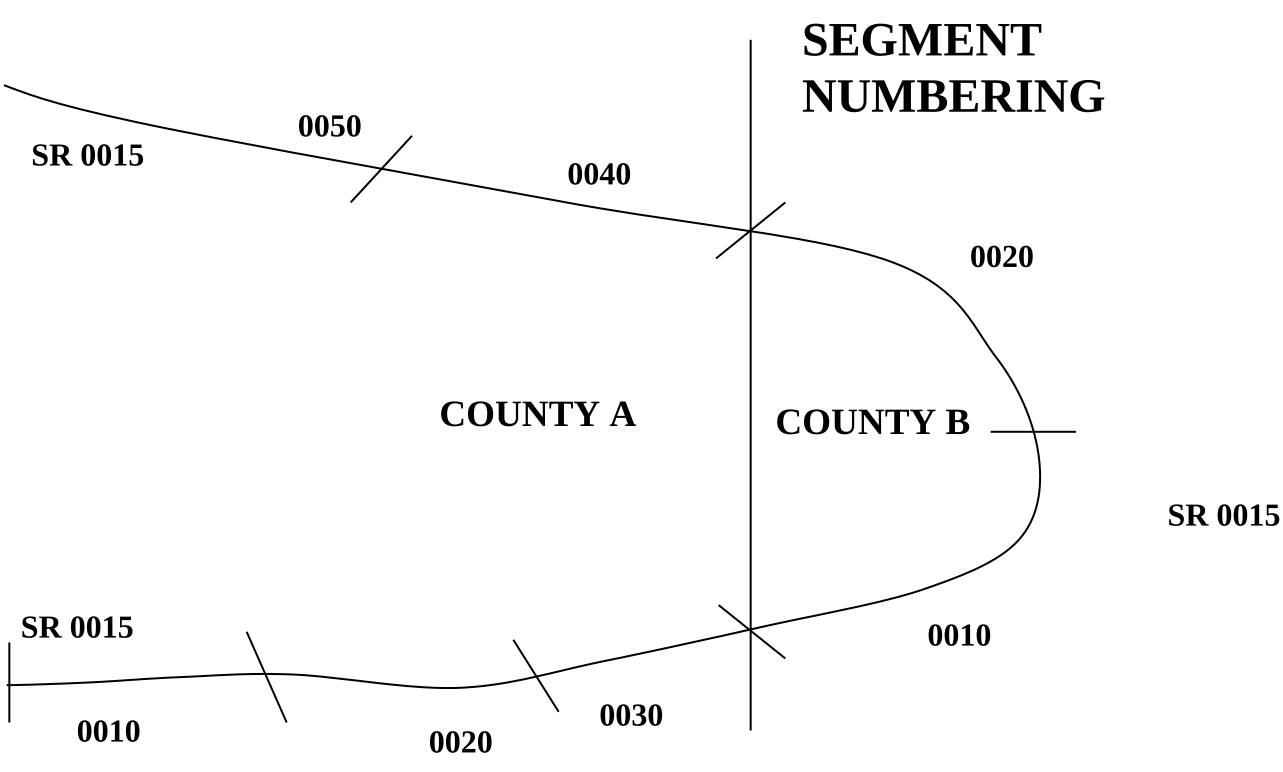


F. 7000 Series Segments: 7000 - 7999

- Turnbacks
- Abandonment
- Nulls



G. Segment Numbering of Traffic Routes at County Boundaries:



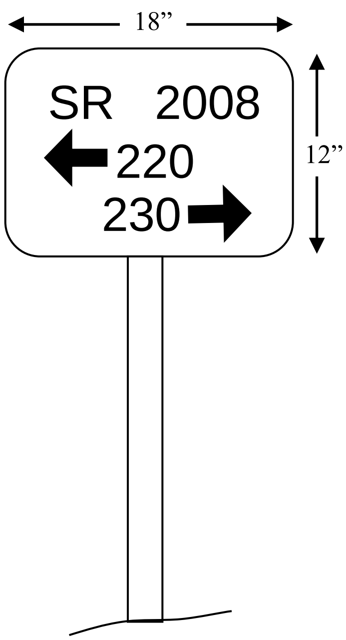
H. Signs

- Identifiable in field, easy for identification of maintenance/work areas on the State Highway System.

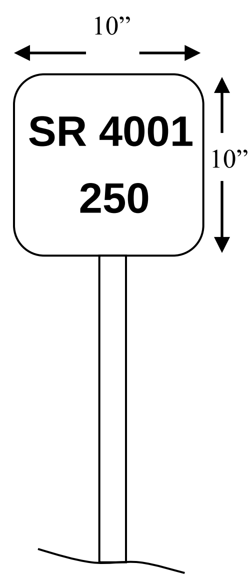
1. Segment Marker - indicates SR and segment number at the beginning and end of each segment. If the beginning or end of a segment occurs at a physical feature, then the point of reference is at the physical feature and NOT the sign.

2. Intersection - indicates segmentation at the intersection of 2 or more state owned highways.

Segment Marker at an Intersection

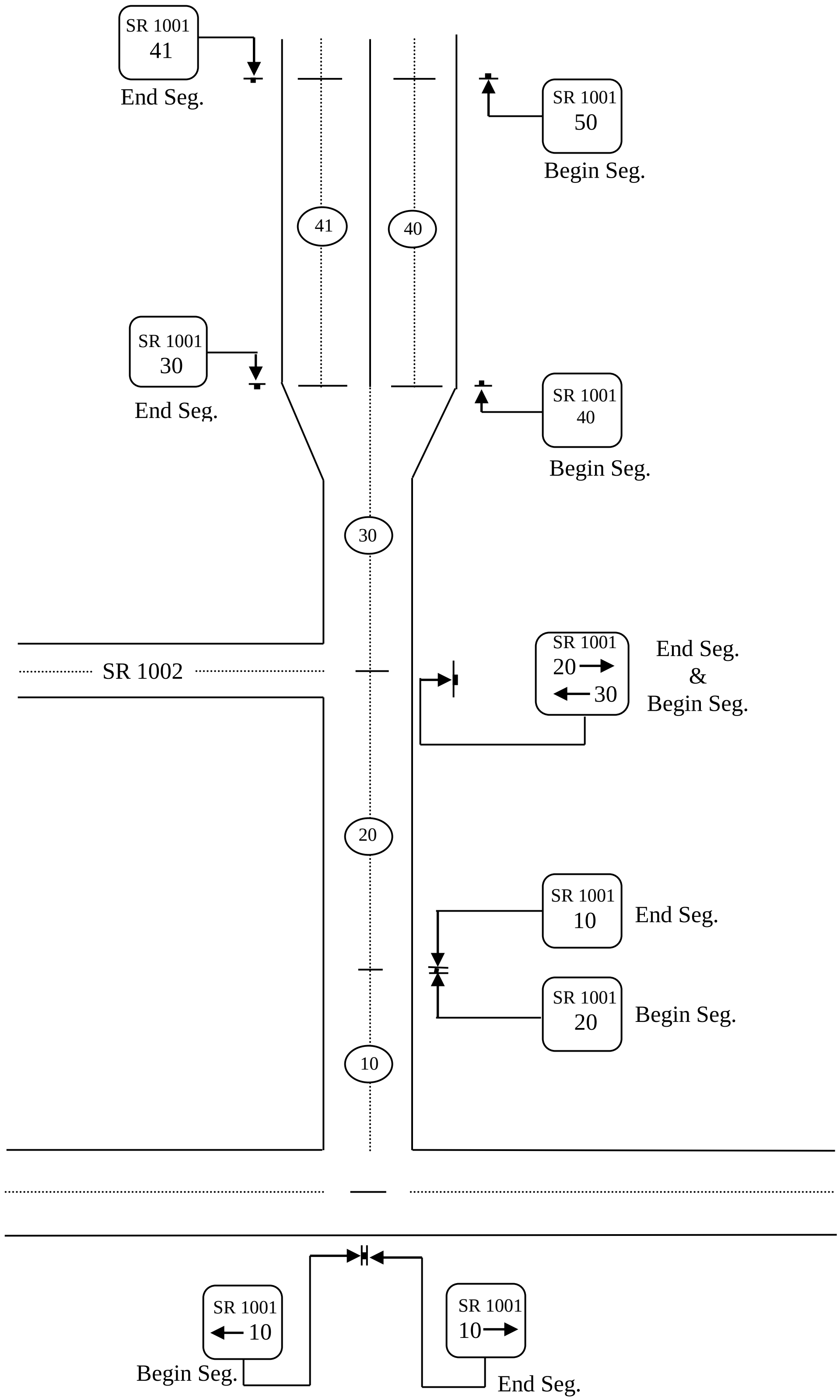


Segment Marker along the route



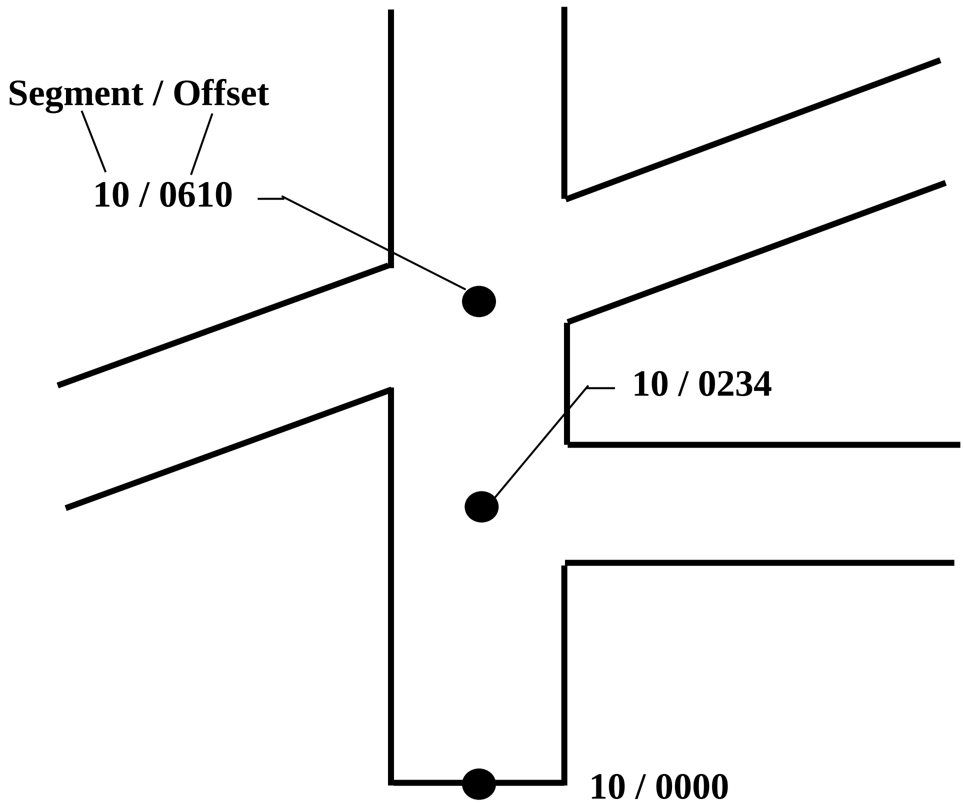
3. SR/Segment Sign Placement

SAMPLE STATE ROUTE SIGNING



<u>Offset (Offset)</u>

Distance in linear feet from the beginning of a segment to a point of interest measured in the INCREASING segment direction.



Survey Technique And Procedures

General:

Many instances will be encountered in the performance of the Pavement Condition Survey which do not exactly conform to the general descriptions and instructions in this manual. *Some of these are listed below, along with recommended procedures for evaluating*. For other unusual circumstances, good judgment should be exercised and notes added to the data file.

Multi-lane Roadways:

All roadway segments will be evaluated in one pass. Because the lane being surveyed will represent the entire roadway width, best judgment must be used to select which lane to survey. For purposes of pavement maintenance the surveyor should select the lane exhibiting the most distresses. In most cases this will be the right lane on multi-lane roadways.

Ramps:

At this time, no separate evaluation will be made of ramps, as any maintenance and rehabilitation of ramps will usually be performed in conjunction with work on the main line. Ramp acceleration and deceleration lanes will be ignored when evaluating the main line pavement and shoulders. Do not survey acceleration or deceleration lanes, but collect information up to where the shoulder continues on the other side of the ramp (gore area).

Bridges:

Pavement condition data will **not** be reported for the bridge portion of a segment. The bridge length, determined by the limits of the bridge superstructure, will be excluded from the length of pavement being evaluated when determining lengths of extents. Bridge approach slabs are included in the pavement condition evaluation. **No** pavement condition data will be reported for segments with bridges 50% of the segment length or greater.

All bridges **will** be included in roughness measurements.

Brick or block pavement:

Brick or block surfaces are rated as Flexible Surface Pavements. Only collect roughness and bituminous patching.

Definitions

General:

The following terms used in this manual are defined as follows:

Pavement: The portion of the roadway intended for regular vehicular traffic.

Bituminous Surface Pavement: A pavement with a bituminous riding surface on any type of base.

Rigid Pavement: A pavement with a Portland Cement Concrete riding surface. Rigid pavement includes Plain Cement Concrete Pavement (PCCP) or Reinforced Cement Concrete Pavement (RCCP). (70 series pavements)

Wheel Path Locations:

To properly locate where various distress measurements are made, the following descriptions of spacing between wheel paths, offset from pavement edge and locations and widths of various parts of the pavement surface are defined. It is very difficult to operate pavement data collection equipment on all pavements under all conditions and meet the definitions. In these instances, the judgment of the operator/driver concerning the safe operation of the vehicle and the safety of the traveling public takes precedence over data collection.

Distance Between Wheel Paths: For the purposes of profile data collection the centerline distance between the outside and inside wheel paths and the sensors mounted to collect data shall be 69 inches.

Width of Outside Wheel Path: The outside wheel path shall be 39 inches wide with the center of the wheel path referenced along the same centerline location as the sensor mounted for the outside wheel path profile measurement.

Width of Inside Wheel Path: The theoretical maximum inside wheel path width shall be 39 inches. There may be some instances on very narrow, secondary pavements where the inside wheel path must be less than 39 inches due to operational constraints.

Width of Lane Center: The width of the center of the travel lane shall be 30 inches. The right most edge of the area bounding the lane center shall be immediately adjacent to the left most side of the area that is bounded by the outside wheel path.

Location of the Center of Outside Wheel Path on the Lane: The center of the outside wheel path is nominally located at the following distances from the right pavement edge for the following lane widths. The center of the outside wheel path located as described below allow for edge deterioration coverage on Pennsylvania's many narrow, secondary roads.

Width	Distance from Edge to Centerline of Outside Wheel Path	Distance from Edge to Centerline of Inside Wheel Path
9.0 feet	26 inches	7.9 feet (95 inches)
10.0 feet	26 inches	7.9 feet (95 inches)
11.0 feet	31 inches	8.3 feet (100 inches)
12.0 feet	37 inches	8.8 feet (106 inches)

It is often difficult for the driver to follow perfectly in the wheel paths as defined above and it is not expected that the vehicle will always be able to collect data exactly as shown. It is the intention of the above descriptions to:

1) Define where the sensors, outside wheel path, and pavement center are located with respect to the vehicle, and
2) Provide guidance to the vehicle operator concerning the appropriate location for operating the vehicle the majority of the time.

Vehicle Operation in the Outside Wheel Path: Vehicle is to be operated in the wheel path where the majority of the traffic routinely drives. The wheel path is often easily recognized as a discoloration or contrasting color of the pavement surface. The vehicle operator is expected to drive the vehicle with the right wheel path sensors in the middle of the apparent right wheel path used by vehicles. This will ensure that the profile, rut depth, faulting, and high resolution cameras are collecting information where the majority of the traffic is driving on the lane.

Edge of Pavement:

The pavement edge has various definitions depending upon the pavement type and functional classification. For the purpose of this specification the following pavement edge definitions apply.

Bituminous pavements - unpaved shoulder: The pavement edge is defined as the rightmost transverse location where the bituminous paved surface ends and the unpaved surface of the shoulder begins. There may or may not be a paint lane stripe along these pavement types.

Bituminous pavements - paved shoulder: The pavement edge is defined as the side construction joint formed between the bituminous paved surface and the bituminous paved surface of the shoulder. In those locations where there is no construction joint or it cannot be readily identified, the pavement edge shall be the outside edge of the outside lane stripe.

Jointed concrete pavements - bituminous shoulder: The pavement edge is defined as the construction joint formed by the portland cement concrete slab and the bituminous paved shoulder.

Jointed concrete pavements - concrete shoulder: The pavement edge is defined as the rightmost construction joint between the travel lane and the shoulder.

Note: *These definitions assume that the data collection vehicle will be operated in the outside lane on multi-lane roads. In those situations where the vehicle operates in a lane other than the outside lane, the construction joint shall be used to identify the right side of the lane. If a construction joint cannot be readily identified then the right side pavement lane stripe shall be used. These definitions are expected to apply on most conditions found in Pennsylvania. In those situations where the definitions do not apply, PENNDOT will define the pavement edge.*

Lane Width:

The lane width will have various definitions depending upon the paving material.

Bituminous pavements: The lane width is defined as the transverse distance from the right side pavement edge to the left construction joint. If the construction joint is not readily discernible, the left side of the lane shall be defined by the lane paint stripe. Collect and report bituminous distresses according to the placement on the lane as detailed in the Condition Identification section of this manual. All bituminous distresses are to be evaluated on every segment, on a segment by segment basis.

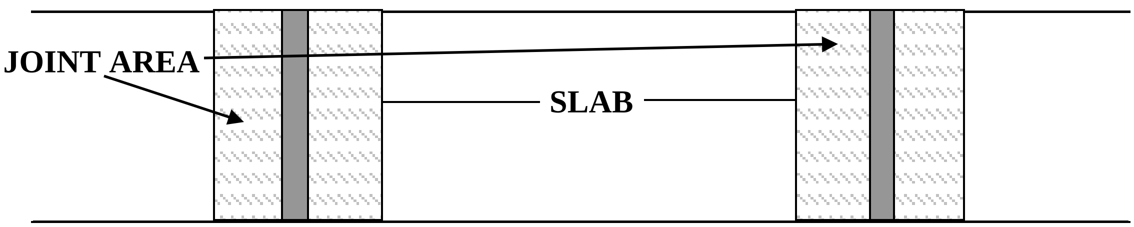
Jointed Concrete Pavements: The lane width is defined as the transverse distance from the right side of the pavement edge to the left construction joint forming the slab. In those situations where the construction joint is not readily discernible, the left pavement edge shall be defined by the lane stripe.

Jointed concrete pavements require additional definitions to define the location of joint and slab related conditions.

Joints: Joints are straight transverse or longitudinal discontinuities in the pavement surface caused by original construction or maintenance activities. A transverse joint should only be counted and evaluated if it is an original construction joint or a joint caused by a full width concrete pavement patch. Longitudinal joints should only be evaluated if it is the result of original construction or concrete patches that are large enough to be included in the patch area rating definitions in the Condition Identification Section of this manual. There will be a few cases where the longitudinal joint falls within the lane. In this case, count and rate both slabs created by the longitudinal joint.

Joint area for evaluation: The procedure for identifying joint conditions is: Identify the joint. Evaluate the pavement for the full lane width on either side of the joint for 1.0 ft each side of the joint. Assign the joint condition to the appropriate classification and severity rating. Collect and report all distress on a joint (the distresses are cumulative).

Slab Conditions: Slab interior from 1.0 ft of joint area as defined above to the next 1.0 ft area of the next joint. Collect and report all distress on a slab (the distresses are cumulative) with the exception of Broken Slab. Rating a slab as Broken supersedes all other slab distresses.



CONDITION IDENTIFICATION GUIDE

Profile Data Collection and Processing

Description:

Roughness on a traveled surface is the deviations of a surface from a true planar surface with characteristic dimensions that affect vehicle dynamics and ride quality (ASTM E950). It will be estimated by IRI which is calculated from longitudinal profile measurements. A longitudinal profile is the perpendicular deviations of the pavement surface from an established reference parallel to the lane direction.

Measurement:

Longitudinal profile is measured at least every 6.0 inches in the designated data collection lane for both the outside and inside wheel paths located 69 inches apart.

Computation:

The International Roughness Index (IRI) is used to indicate the amount of roughness. IRI is an index computed from the longitudinal profile using a quarter-car simulation. The summary statistic to be reported to PENNDOT is the average of both wheel paths. The IRI is summarized and reported every 528 feet.

Note: The profile must also be evaluated on Jointed Concrete Pavements over each slab. The profile is evaluated using a 20-foot moving window. When the distress data indicates a broken slab, the 20-foot summary IRI must be computed to assist in the broken slab severity rating. Refer to the Broken Slab definitions.

Measurement Units: IRI is reported in units of inches/mile (in/mi).

Rut Depth

Description:

This condition, which occurs longitudinally along the roadway, is characterized by the distortion of the pavement cross-section, with the wheel paths being lower than the centerline, pavement edge, or the center of the lane.

Possible Causes:

Rutting on flexible pavements can be caused by base or subgrade failure, which is usually indicated by the presence of fatigue cracking, by shoving of unstable asphalt mixes, or by wear.

Wear is the cause of rutting on rigid pavements. Rutting may be prevalent where studded snow tires are heavily used.

Rating Procedure:

For all pavement types, rutting consists of longitudinal depressions in one or both wheel paths. Rut depth is measured by laying a string line or straight edge (or software simulation) between the middle of the lane and either lane edge, depending on the wheel path measured. The distance from the bottom of the string line or straight edge to the pavement surface is the measured rut depth for that wheel path. The definition and measurement techniques are the same for all severity levels.

Rutting is collected in both wheel paths independently and reported for each wheel path. For automated equipment, the maximum allowable spacing between rut depth sampling intervals is 30 feet. Sampling performed and reported more often is acceptable. Each sample is assigned to one of the three severity levels described below.

Severity:

Low	Average Rut Depth $\geq$ 0.25 in and $<$ 0.5 in
Medium	Average Rut Depth $\geq$ 0.5 in and $<$ 1.0 in
High	Average Rut Depth $\geq$ 1.0 in

Extent:

Record the length for each severity level. Each wheel path will be recorded separately giving a total possible length of reported rut depth equal to twice the STAMPP segment length.

Example Reporting:

An 800-foot long STAMPP segment (total: 1600 feet of wheel path) has 300 feet of outside wheel path, medium severity rutting, 200 feet of inside wheel path, medium severity rutting and 350 feet of outside wheel path high severity rutting. The rating for this section is:
Outside Wheel Path: 150 ft. none, 300 ft. medium severity, 350 ft. high severity;
Inside Wheel Path: 600 ft. none; 200 ft. medium severity.

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BITUMINOUS SURFACE PAVEMENTS

Fatigue Cracking Description

Description:

Fatigue cracking is characterized by a series of longitudinal or interconnecting cracks that divide the pavement surface into many sided, sharp angled pieces resembling chicken wire or an alligator's hide. The pieces are less than 1 foot in any dimension. Fatigue cracking usually occurs in wheel paths or other areas subjected to loading. Fatigue cracking is an indication of a structural problem.

Possible Causes:

Fatigue cracking can be caused by weaknesses in the base or subgrade, which result in the fatigue failure of the asphalt concrete surface under repeated loading.

Rating Procedure:

Fatigue cracking is collected in both wheel paths on bituminous paved surfaces. The left wheel path data will only be used for MAP-21 reporting requirements. Both wheel paths are evaluated continuously along the STAMPP segment. If the cracks are sealed, the severity level is always low. If the cracks have opened up (missing sealant), rate at the appropriate severity level for the crack width.

Severity:

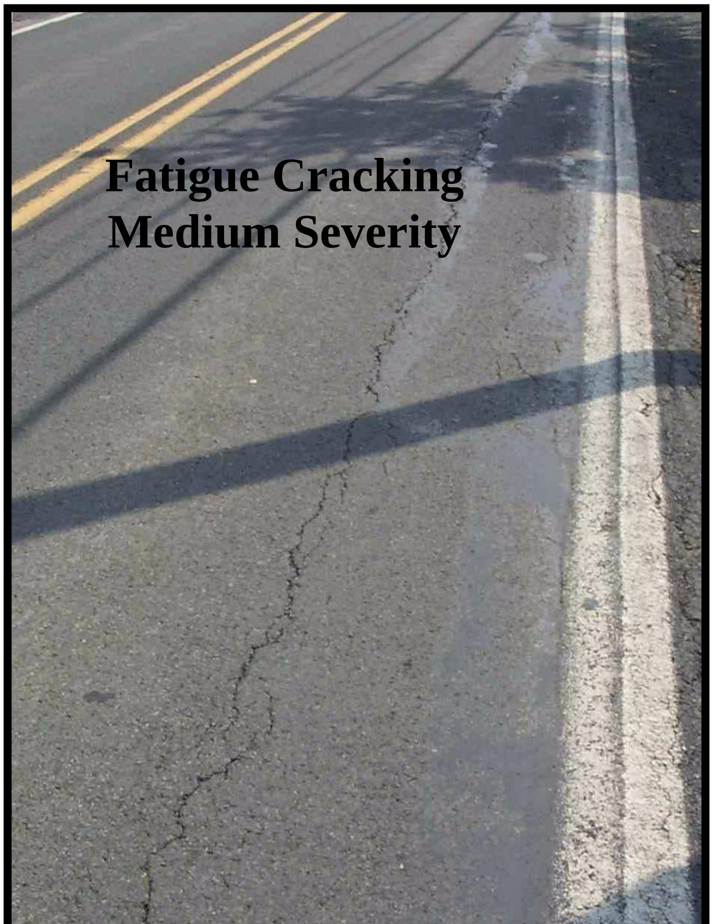
Low: Average Crack Width ≤ hairline
Fatigue cracking consisting of only longitudinal cracks in the wheel path. The size of the crack opening is often referred to as hairline since it is the width of a hair; just barely discernable. This severity rating indicates a pavement is beginning to suffer from structural loading but the cracks do not yet allow water to enter the pavement structure.

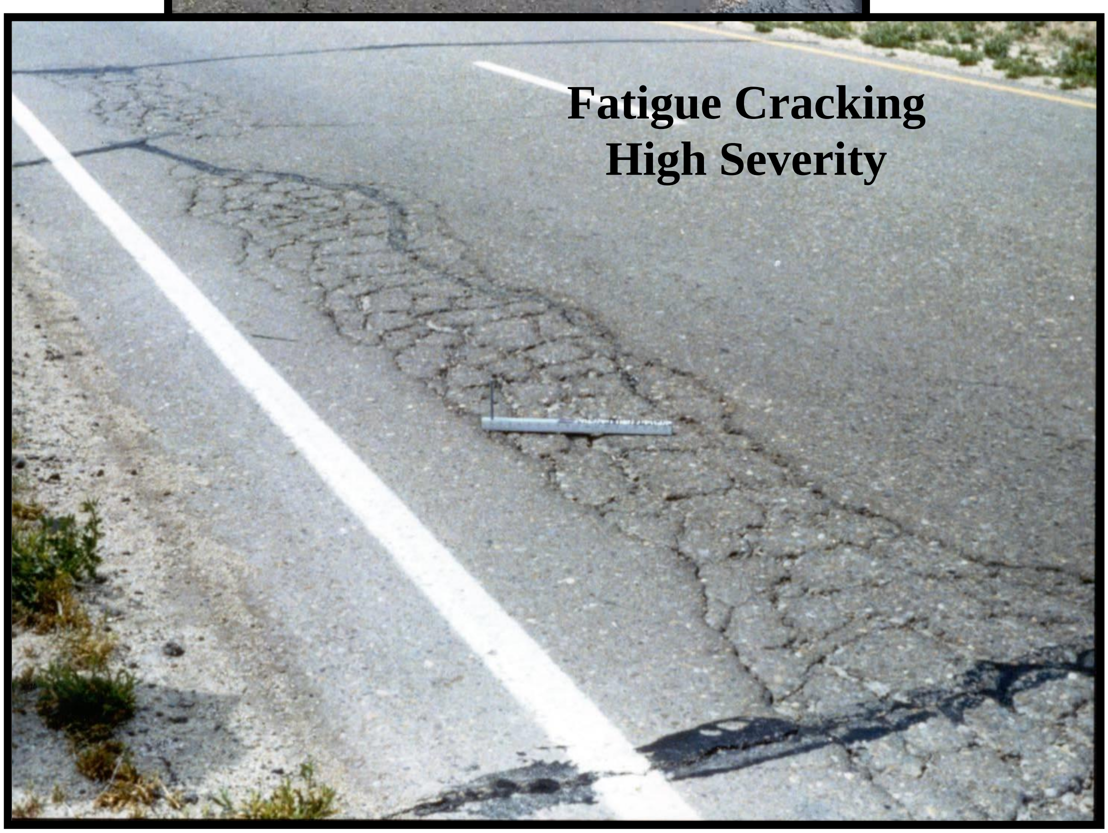
Medium: Average Crack Width > hairline and ≤ 0.25 in
Fatigue cracking consisting of longitudinal and interconnecting cracks typically forming a diamond shaped, chicken wire or alligator's hide pattern. The crack width ranges from fine, just over hairline cracking to widths that allow water to penetrate the surface as well as loss of some material from the surface or spalling.

High: Average Crack Width > 0.25 in
Fatigue cracking consisting of longitudinal and interconnecting cracks typically forming a diamond shaped, chicken wire or alligator's hide pattern. The cracks are sufficiently wide to allow water to enter the pavement surface. The width measurement includes loss of surface material or crack spalling.

Extent:

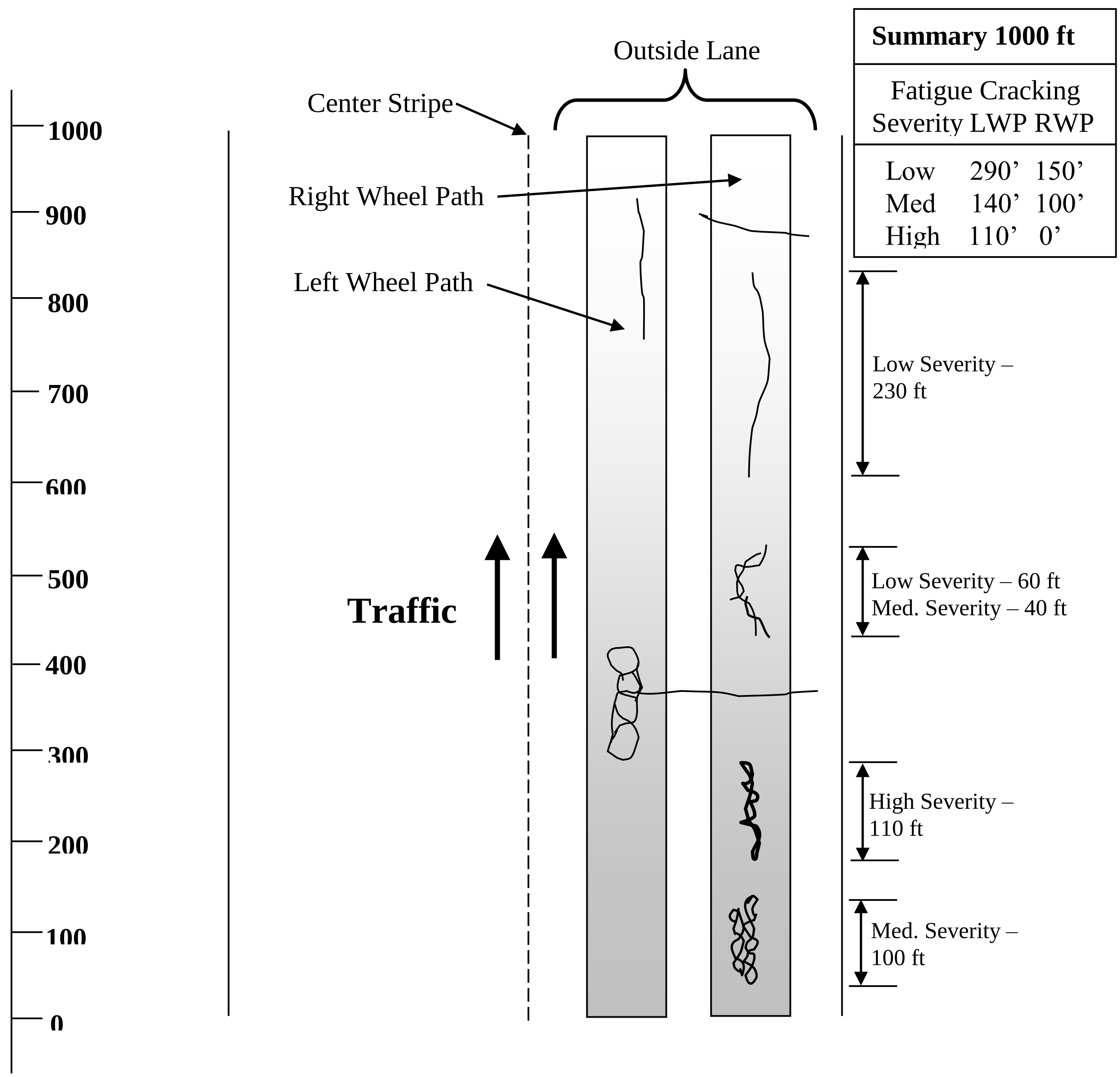
Record the length of the segment for each severity level.


Fatigue Cracking
Medium Severity


Fatigue Cracking
High Severity

Example Reporting:

On a 1000-foot STAMPP segment, in the right wheel path (RWP), there are 2 occurrences of low severity fatigue cracking of 230 and 60 feet, there are 2 occurrences of medium severity fatigue cracking of 40 and 100 feet and 1 occurrence of high severity fatigue cracking of 110 feet. In the left wheel path (LWP) there is 1 occurrence of low severity fatigue cracking (150') and 1 occurrence of medium severity fatigue cracking (100'). The rating for the STAMPP segment would be: LWP - 290 ft low severity fatigue cracking, 140 ft medium severity fatigue cracking, and 110 ft high severity fatigue cracking. RWP – 150' low severity and 100' medium severity fatigue cracking.



Fatigue Cracking Example

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Transverse Cracking

Description:

This condition is characterized by visible fractures or separations of the pavement surface occurring transversely across the roadway. Cracks are rated as transverse cracks if the angle formed by the crack and the pavement is between 45^o and 90^o to the direction of travel.

Possible Cause:

Transverse cracking may be caused by a poorly constructed paving joint, shrinkage of the surface due to low temperature, asphalt hardening, or a reflection crack from an underlying rigid base.

Rating Procedure:

The entire pavement lane width is analyzed for transverse cracking for the full STAMPP segment. Only transverse cracks that are ≥ 1 foot long are evaluated. If the cracks are sealed, the severity level is always low; this includes saw-and-seal joints in bituminous overlays on concrete pavement. If the cracks have opened up (missing sealant), rate at the appropriate severity level for the crack width.

Severity:

Estimate the average crack width for each crack and record number and length for each severity level. Each crack can have only one severity level. The average crack width can include spalls.

Low: Average Crack Width > hairline and ≤ 0.25 in

Medium: Average Crack Width > 0.25 in and ≤ 0.5 in

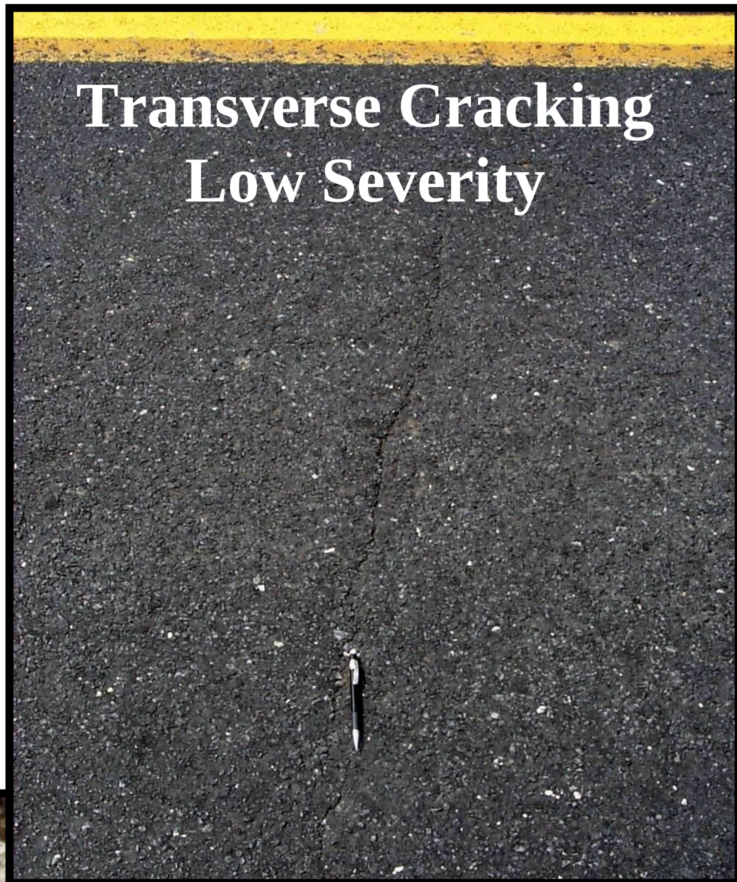
High: Average Crack Width > 0.5 in

Extent:

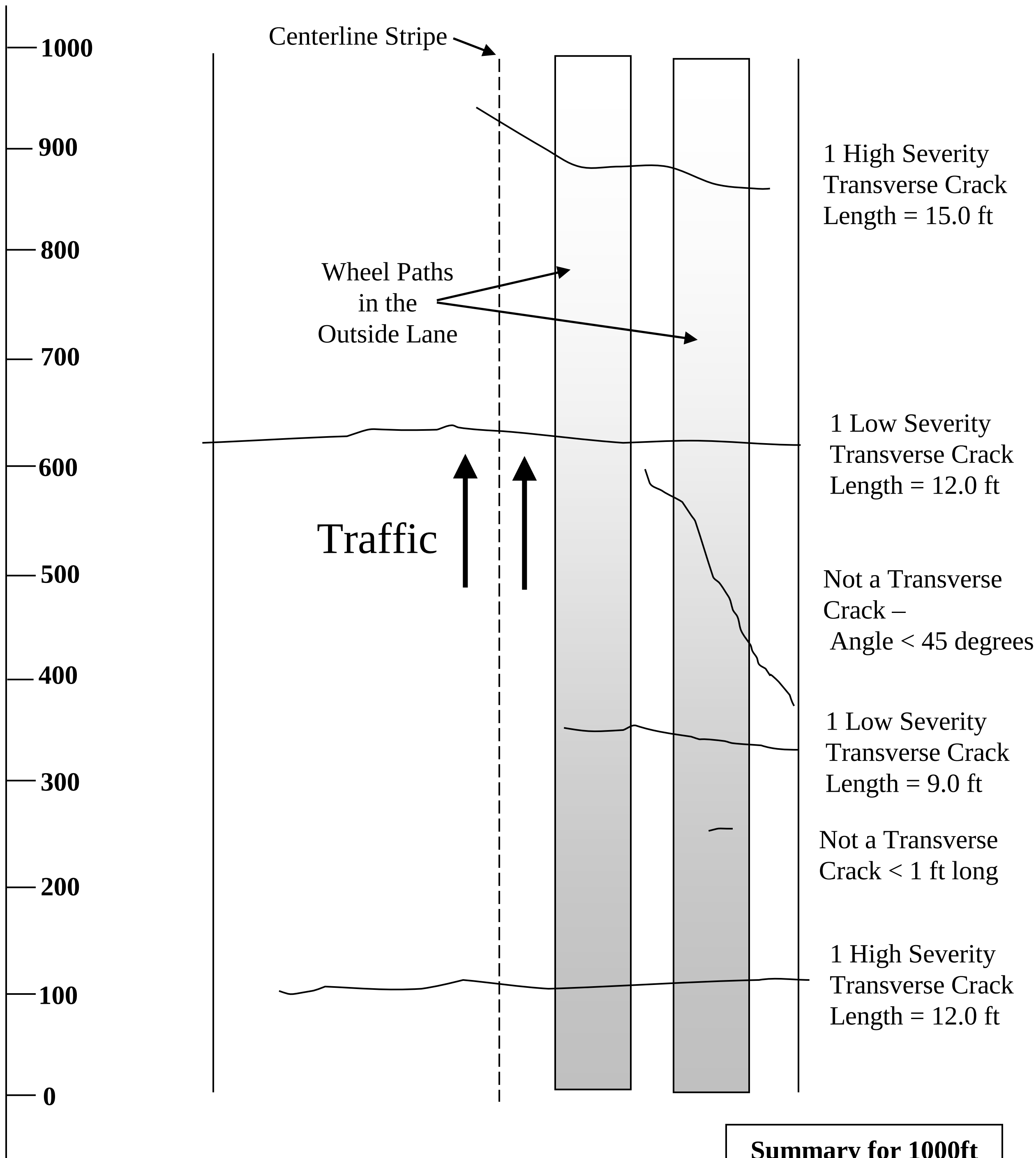
Record the number and length of Transverse Cracks in a segment for each severity level. Count all Transverse Cracks ≥ 1 ft long.

Example Reporting:

A 1000-foot STAMPP segment has four Transverse Cracks that are identified to be rated. Two of the cracks are low severity and two are high. The total length of the two low severity cracks is 21 feet. The total length of the high severity cracks is 27 feet.


Transverse Cracking
Low Severity


Transverse Cracking
High Severity



Transverse Cracking Example

Summary for 1000ft

Transverse Cracking Severity	Num.	Len.
Low	2	21
Medium	0	0
High	2	27

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Miscellaneous Cracking

Description:

This condition is characterized by visible fractures or separations of the pavement surface occurring longitudinally or randomly along the roadway.

Possible Cause:

This cracking may be caused by a poorly constructed paving joint, shrinkage of the surface due to low temperature, asphalt hardening, a reflection crack from an underlying rigid base or movement of subgrade material. This distress is characterized by longitudinal and transverse cracking occurring simultaneously with the resulting block pattern less than approximately 10 ft x 10 ft. Miscellaneous cracking tends to occur over large areas but generally on low traffic roads.

Rating Procedure:

This distress is recorded for the middle 30-inch strip of pavement defined earlier as the lane center. This pavement strip is evaluated continuously along the STAMPP segment. Report the length of the STAMPP Segment with miscellaneous cracking. If the cracks are sealed, the severity level is always low. If the cracks have opened up (missing sealant), rate at the appropriate severity level for the crack width.

Severity:

Estimate the average crack width and record in severity categories. Crack width can include width of spalling.

Low: Average Crack Width > hairline and ≤ 0.25 in

Medium: Average Crack Width > 0.25 in and ≤ 0.5 in

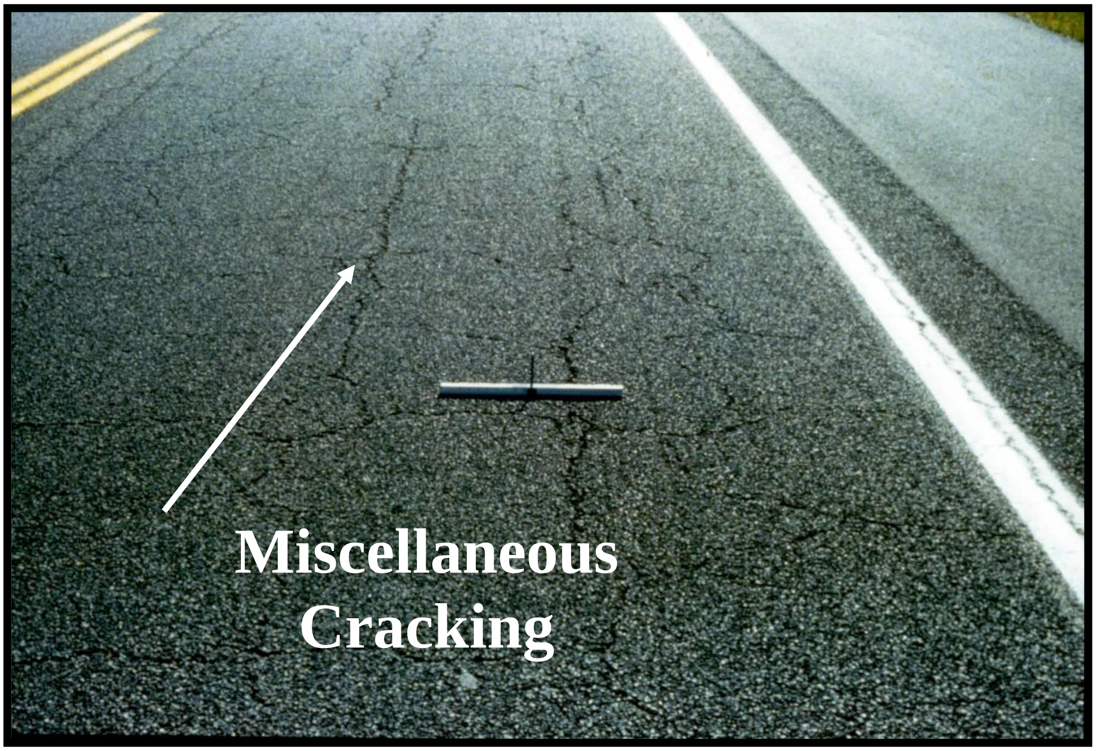
High: Average Crack Width > 0.5 in

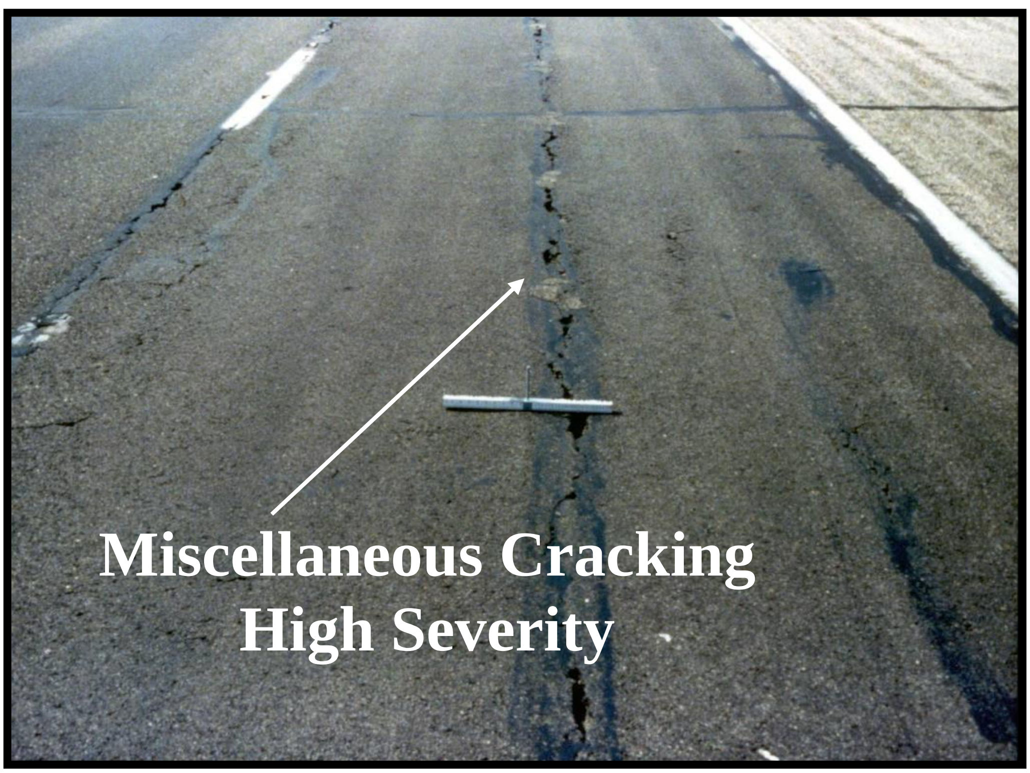
Extent:

Record the length of segment for each severity level. The total length of miscellaneous cracking cannot exceed the STAMPP segment length.

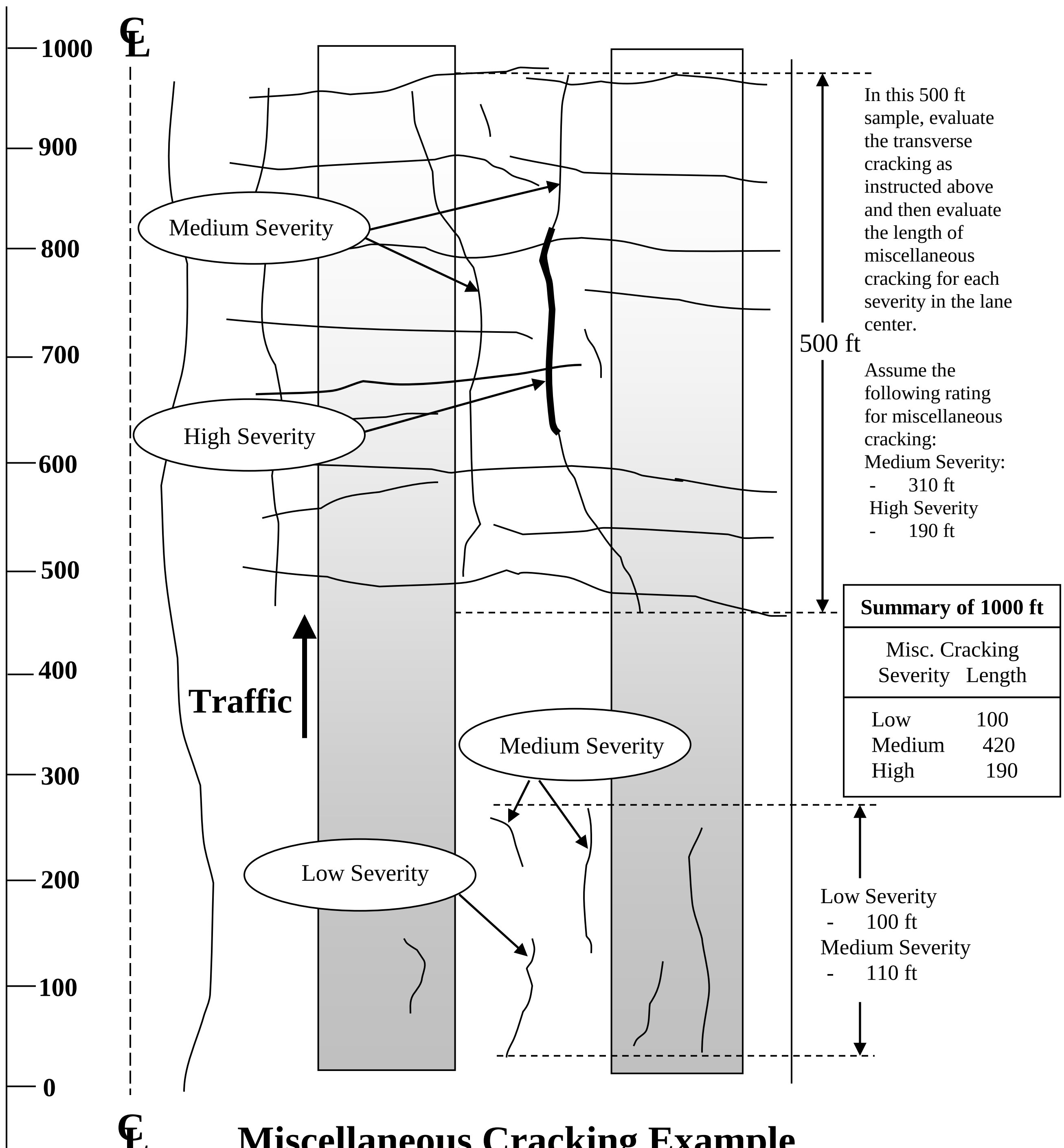
Example Reporting:

A 1000-foot STAMPP segment has two locations where miscellaneous cracking occurs. The first is longitudinal cracking in the lane center. This location is evaluated for the severity and length of miscellaneous cracking. The second is an occurrence of block cracking. This location is evaluated for transverse cracking first. Once the number and length of transverse cracks are recorded,


Miscellaneous
Cracking


Miscellaneous Cracking
High Severity

the length of the miscellaneous cracking is evaluated. In the example that follows: the section has 100 feet of low severity miscellaneous cracking, 420 feet of medium severity miscellaneous cracking and 190 feet of high severity miscellaneous cracking.



Miscellaneous Cracking Example

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Edge Deterioration

Description:

This condition is characterized by the progressive breakup of the pavement, beginning at the pavement edge and proceeding toward the centerline, confined within 1.0 foot of the pavement edge. (Anything within the first 1.0 ft of the pavement edge is called edge deterioration.)

Possible Causes:

Edge deterioration is usually caused by loading over an unsupported pavement edge. Unpaved or deteriorated shoulders contribute to this condition since they do not offer the support needed.

Rating Procedure:

Edge Deterioration is only collected along the 1.0 ft outside edge of the pavement in the direction of travel. Edge deterioration consists of generally crescent shaped or continuous cracks within 1.0 ft of and intersecting with the pavement edge. It also includes longitudinal cracks within the 1.0 ft edge band that do not intersect with the pavement edge.

Severity:

Estimate the average crack width and record in severity categories. The crack width can include width of spalling.

Low: Average Crack Width > hairline and ≤ 0.25 in
The width measurement may include crack spalling. No loss of pavement material is allowed in this category.

Medium: Average Crack Width > 0.25 in and ≤ 0.50 in. The edge of the pavement is becoming jagged.

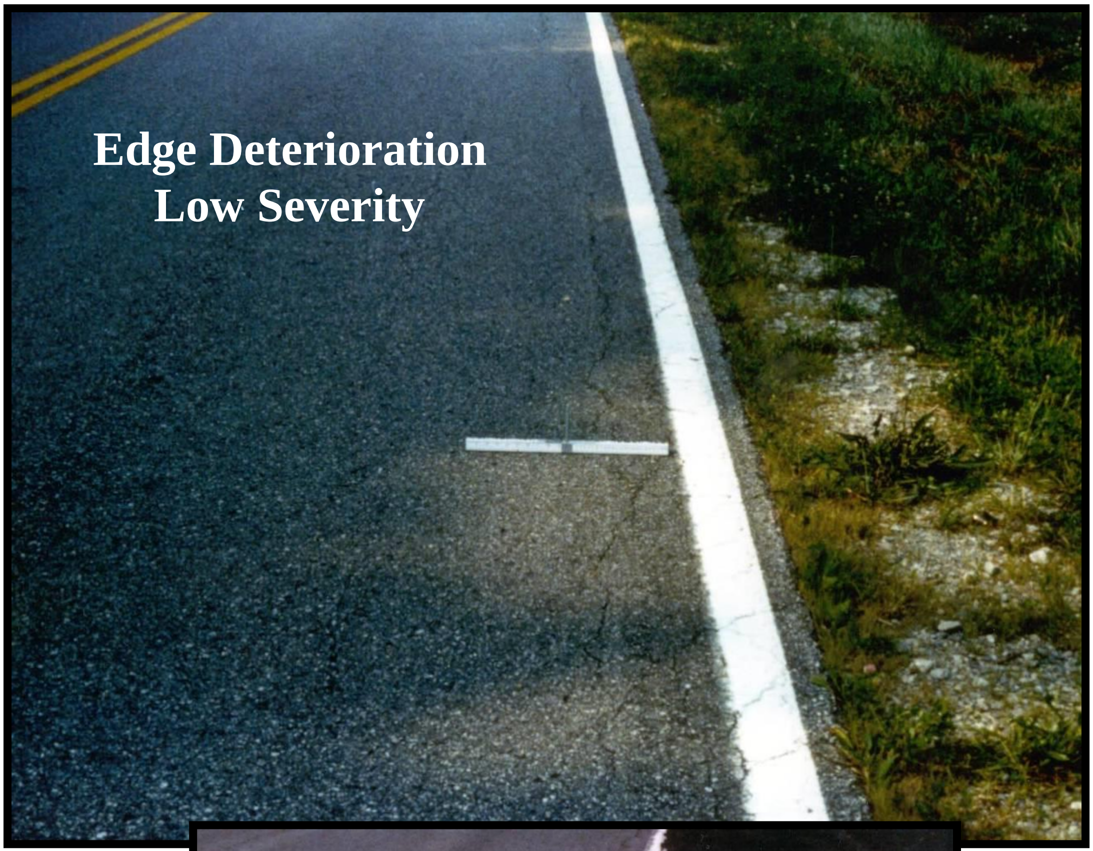
High: Average Crack Width > 0.50 in. The edge of the pavement is deteriorated and pieces of the pavement edge are broken loose or missing.

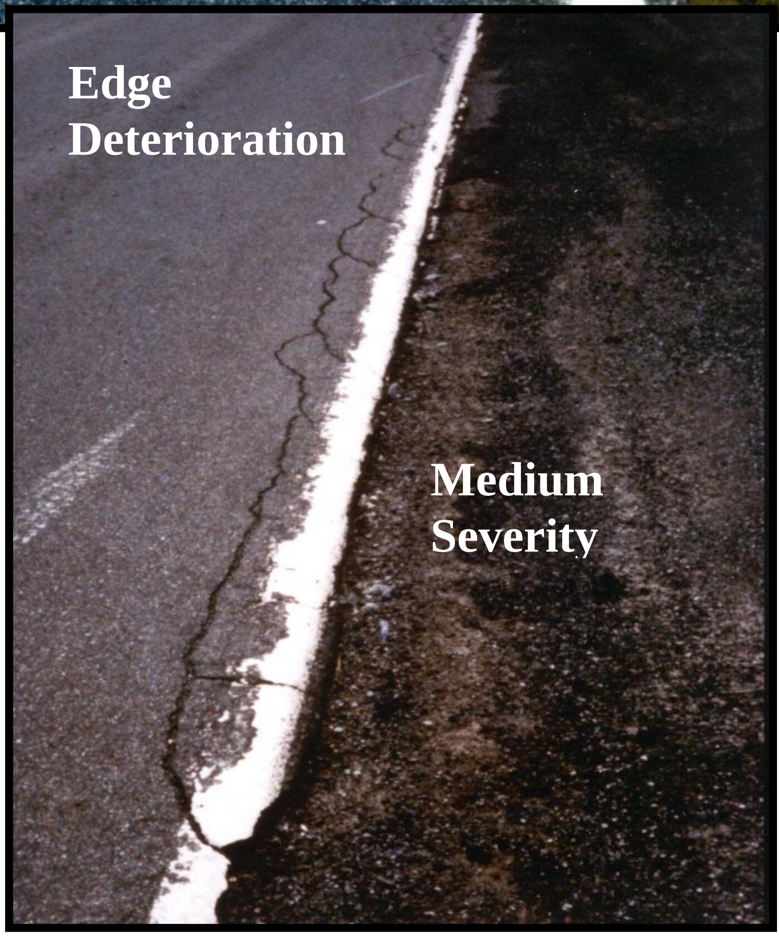
Extent:

Record the length of segment for each severity level.

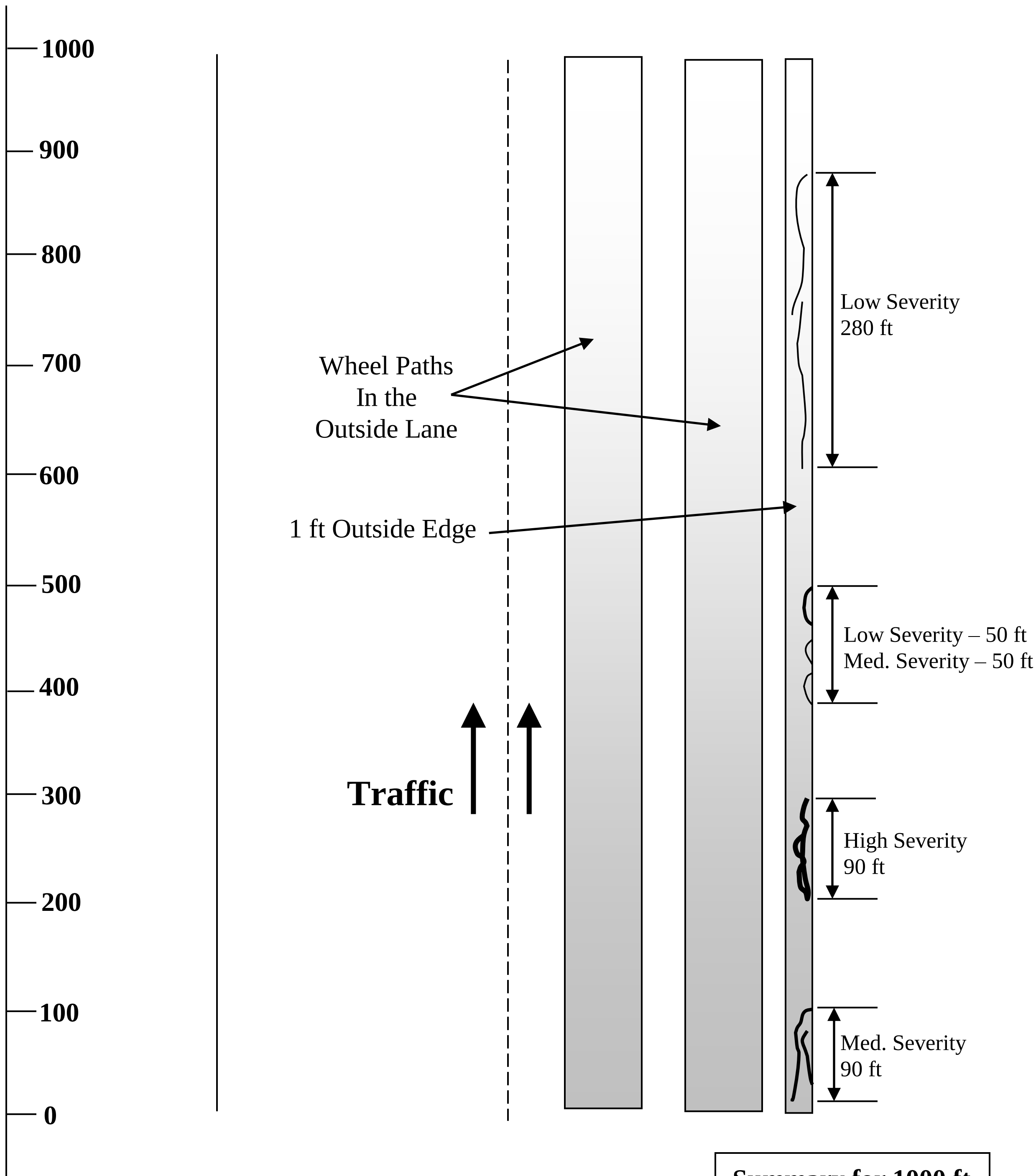
Example Reporting:

A 1000-foot STAMPP segment has 2 occurrences of low severity edge deterioration of 280 and 50 feet, 2 occurrences of medium severity edge deterioration of 50 and 90 feet and 1 occurrence of high severity edge deterioration of 90 feet. The rating for this STAMPP segment is: 330 ft low severity edge deterioration, 140 ft medium severity edge deterioration and 90 ft high severity edge deterioration.


Edge Deterioration
Low Severity


Edge
Deterioration
Medium
Severity


Edge Deterioration
High Severity



Edge Deterioration Example

Summary for 1000 ft	
Edge Deterioration Severity	**Length**
Low	330
Medium	140
High	90

Bituminous Patching

Description:

This condition is characterized by an area of the original pavement, which has been replaced by bituminous material. Patches are easily recognized because they will generally be darker than the surrounding pavement since they are newer. The patch must have a surface area of at least 1.0 sq ft to be counted. If a full-width patch is more than 400 ft long, do not rate as a patch - it is considered an overlay or surface seal.

Possible Cause:

Bituminous patching is usually the result of maintenance activities such as pothole patching.

Rating Procedure:

The entire lane surface is evaluated for patching.

Severity:

None. Rate the individual distresses present in a patch separate from the patch; rate the distresses in the appropriate distress category. The condition rating of a distressed patch will be reflected in the pavement rating for both the patch and the distress.

Extent:

Record the total number and area of patches.

Example Rating:

A 1000-foot long, 9-foot wide STAMPP segment has two patches that are within the correct size limitations for rating as patches. After evaluating the patches for distress, the area and number are recorded. The first patch is 100 feet long and 4.6 feet wide. The second patch is 30 feet long and 9.0 feet wide. The rating for patches on this segment is: 2 patches at 730 sq ft.

Bituminous Patching

Raveling / Weathering

<u>Description:</u>

This condition is characterized by wearing away of the pavement surface caused by the dislodging of aggregate particles (raveling) and loss of asphalt binder (weathering).

<u>Possible Cause:</u>

Raveling and weathering are normally caused by oxidation of the asphalt binder of the mix, resulting in loss of flexibility and ability to hold the aggregate, which is dislodged by traffic.

<u>Rating Procedure:</u>

The entire lane surface is evaluated for raveling and weathering. Rate only one severity level for each contiguous occurrence of raveling and weathering.

<u>Severity:</u>

Medium: Surface is rough and pitted, may have loose particles.

High: Surface is very rough and highly pitted.

<u>Extent:</u>

Record the length of the segment for each severity level.

<u>Example Rating:</u>

On a 1000-foot long, 9-foot wide STAMPP Segment there are two localized areas of raveling and weathering. The first contains a length of 125 feet of medium severity raveling and weathering. The second contains a length of 65 feet of high severity raveling and weathering. The rating for this section is: 125 feet medium severity raveling and weathering and 65 feet high severity raveling and weathering.


Raveling/Weathering
Medium Severity


Raveling/Weathering
High Severity


Raveling/Weathering
High Severity

Left Edge Joint

Description:

This condition is characterized by an open longitudinal construction joint (paving seam) sometimes accompanied by parallel, interconnected cracks that form jagged pieces. Severe cases of this distress result in spalling of the pavement and may require patching of the construction joint.

Possible Cause:

Undetermined.

Rating Procedure:

The longitudinal construction joint (paving seam) defining the left edge of the survey lane is evaluated for distress. The joint will be rated whenever it lies within one foot to the left or right of the pavement markings (paint stripes or reflectors) separating the surveyed lane from adjacent lanes. If the joint is sealed, with the sealant in good condition, no severity level is rated. If the joint has opened up (missing sealant), rate at the appropriate severity level for the crack width.

Severity:

Low:
- Construction joint open < ¼”.
- If any cracks parallel to the joint are present, they are hairline width.
- No loss of material in this category and no patching.

Medium:
- Construction joint open ¼” to ½”.
- Random adjacent cracks are ≤ ¼” wide and interconnected forming jagged pieces.
- Some minor loss of material (spalling) visible but no patching present.

High:
- Construction joint open > ½”.
- Random adjacent cracks are > ¼” wide and interconnected forming jagged pieces.
- Visibly severe loss or breaking of material (spalling) or patching of construction joint present.

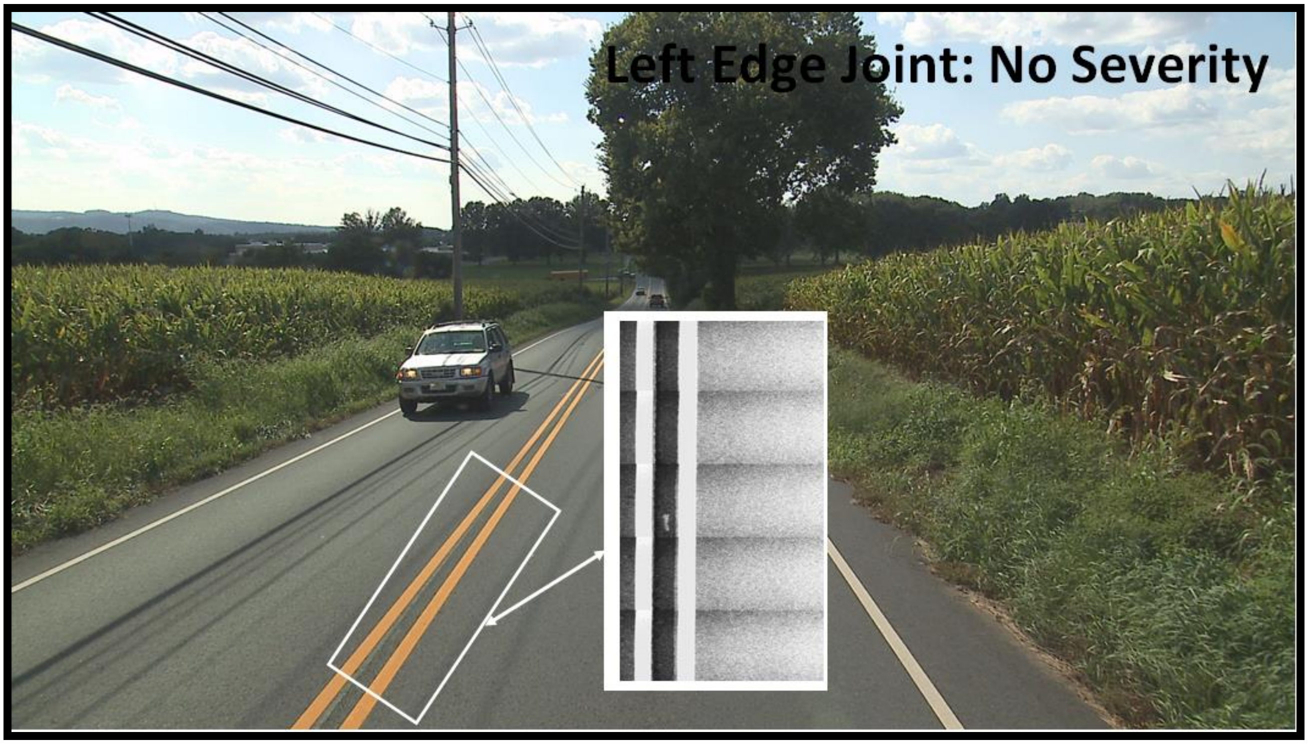
Extent:

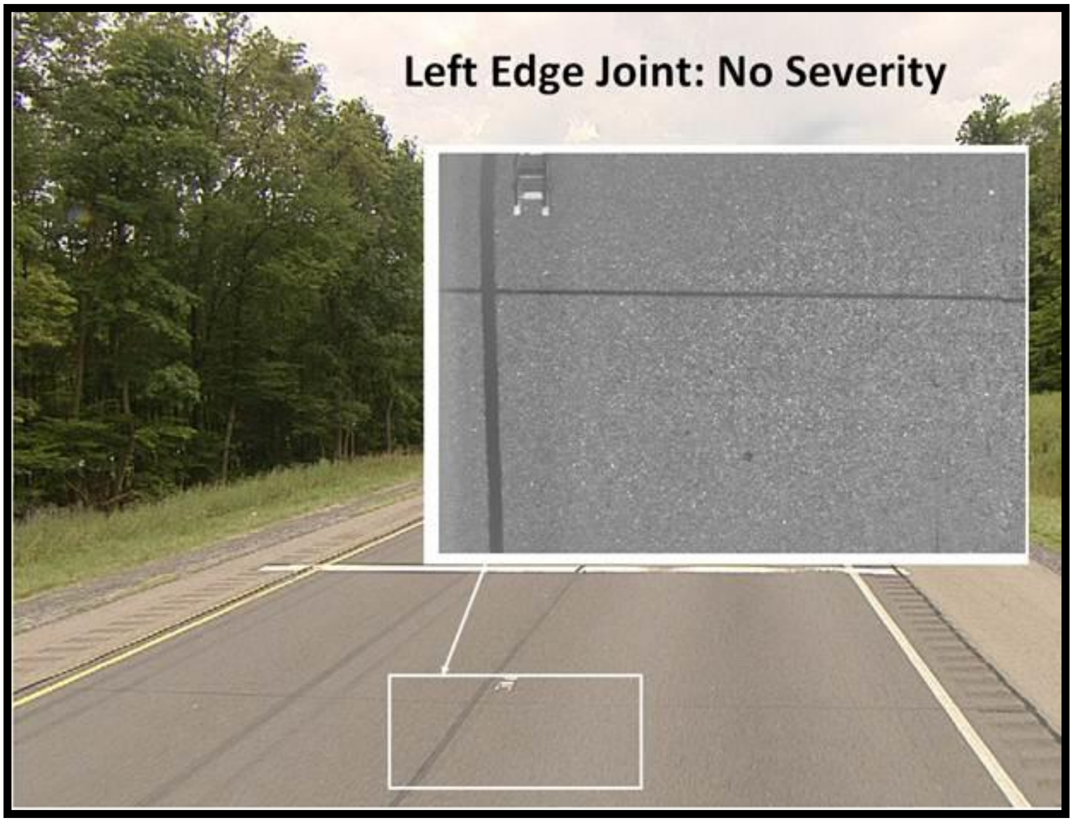
Record the length of the segment for each severity level.

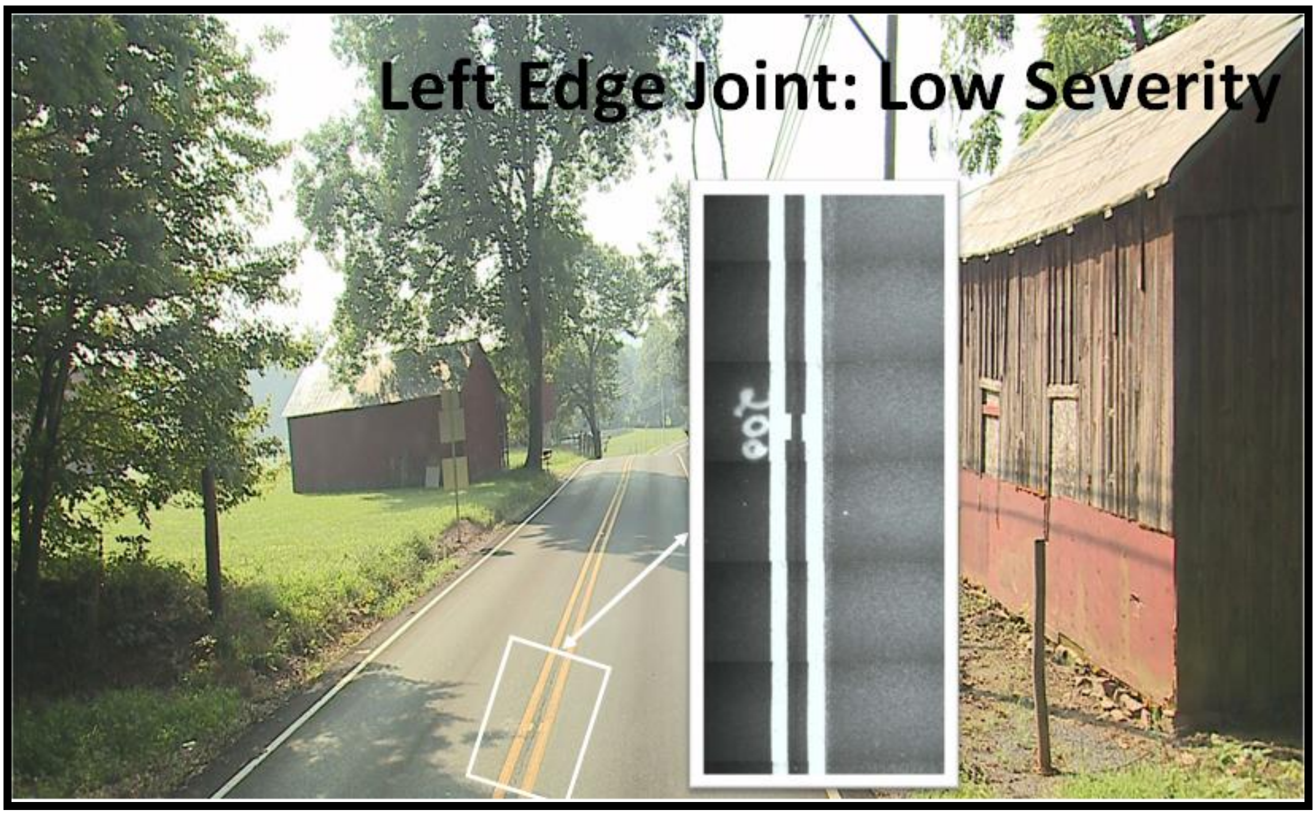
Example Rating:

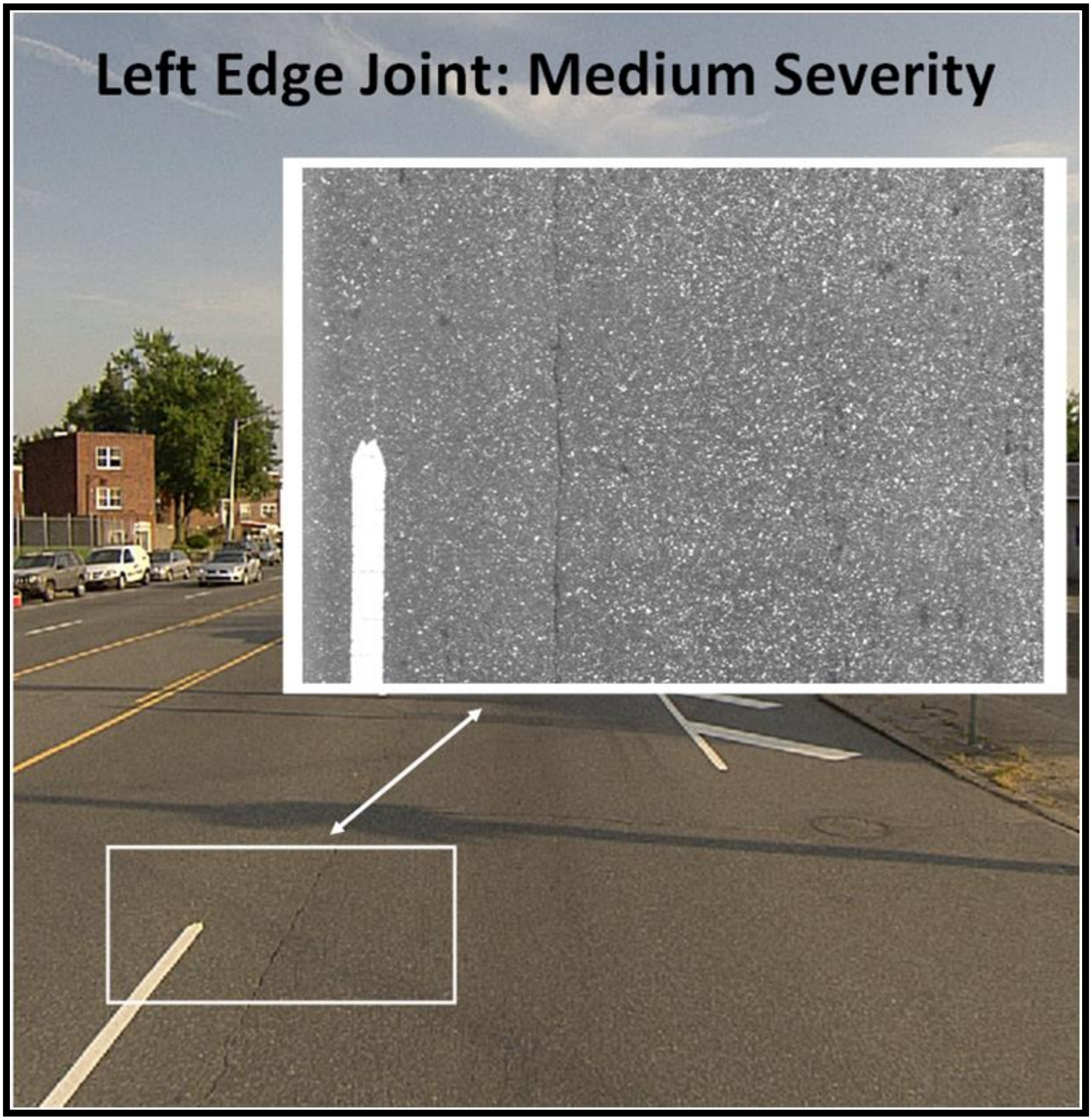
On a 2640-foot long, 12-foot wide STAMPP Segment there are two localized areas of left edge joint distress. The first contains a length of 1250 feet of low severity distress. The second contains a length of 650 feet of medium severity distress. The rating for this section is: 1250 feet low severity and 650 feet medium severity left edge joint distress.

Left Edge Joint Examples

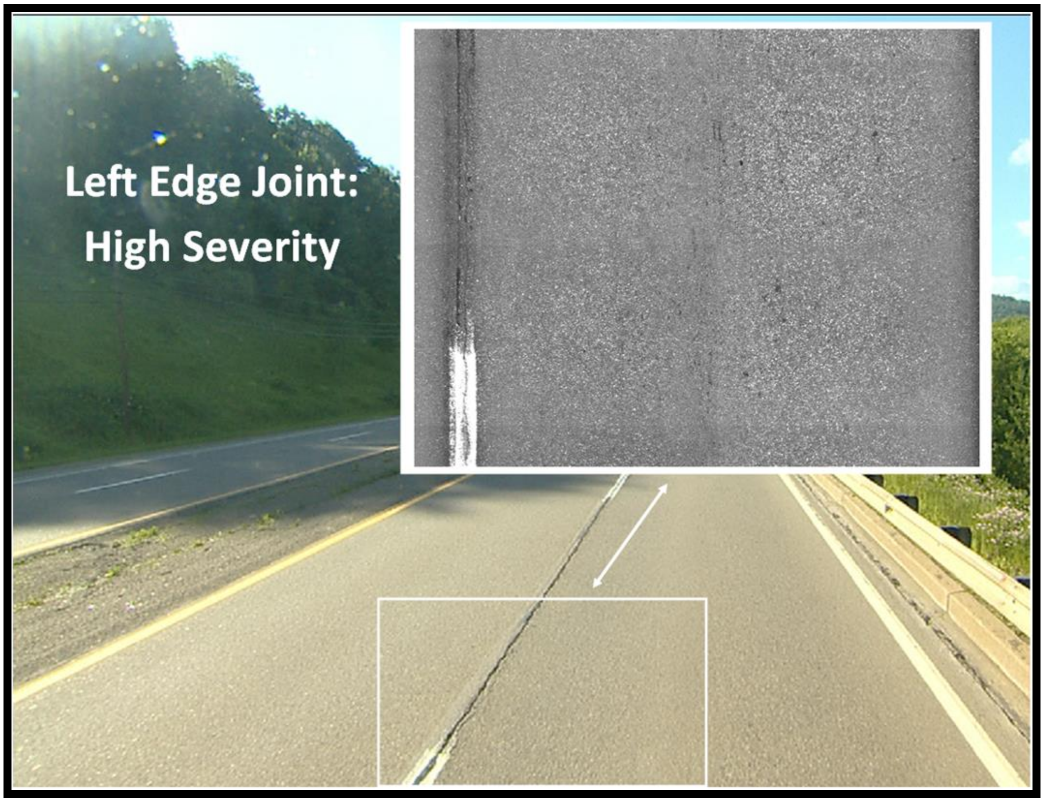


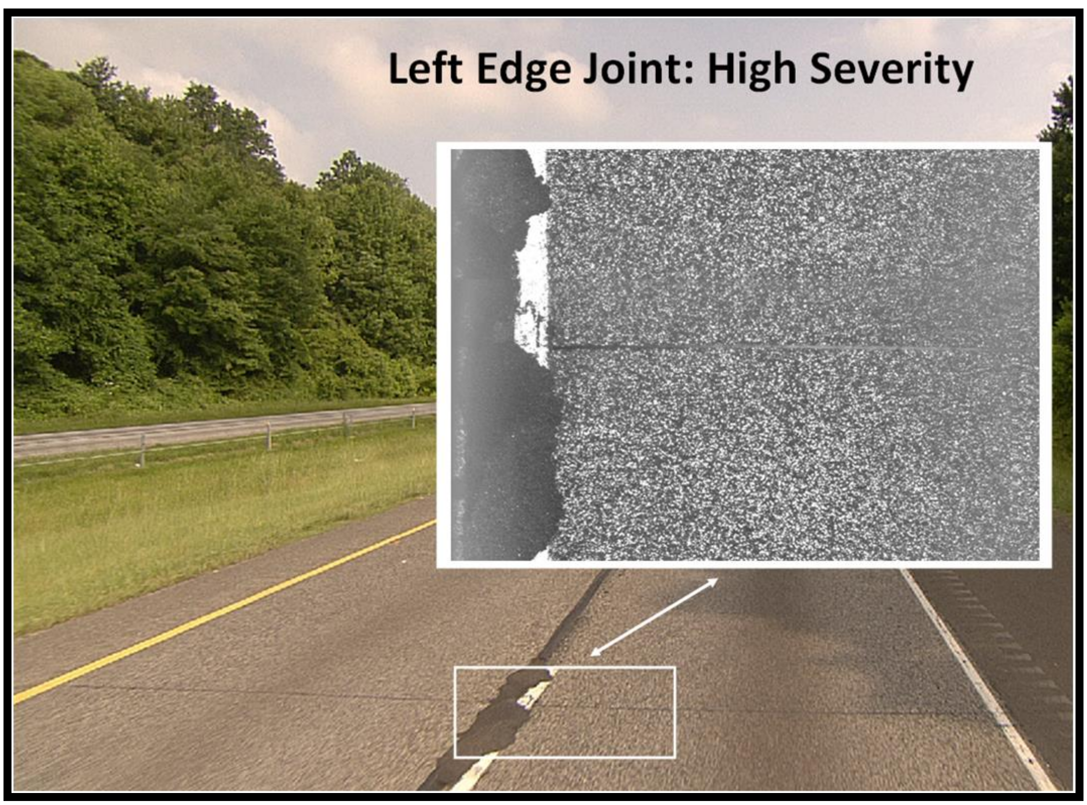



Left Edge Joint: Low Severity



Note: Assume construction joint is within one foot of the white lane markings for the purpose of this example.


Left Edge Joint:
High Severity


Left Edge Joint: High Severity

RIGID PAVEMENTS

Faulted Joints

Description:

This condition is characterized by a difference in elevation across a transverse joint.

Possible Cause:

Faulting can result from the erosion and re-depositing of base material beneath the slabs due to excess water in the base and heavy traffic loads.

Rating Procedure:

Faulting is measured in the outside wheel path as defined for profile data collection. Each joint, including concrete patch joints, is evaluated for faulting potential. Positive and negative faulting are categorized the same way by taking the absolute value of the measured fault.

Severity:

Medium: Absolute value of elevation difference is ≥ 0.25 in and < 0.5 in

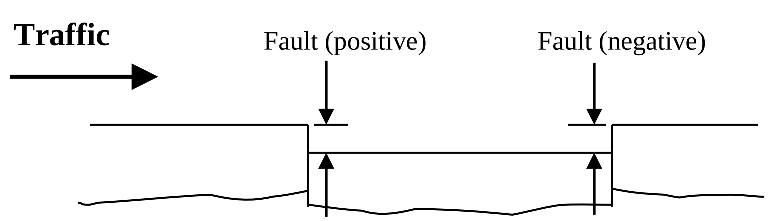
High: Absolute value of elevation difference is ≥ 0.5 in

Extent:

Record the number of joints that are faulted in each category.

Example Rating:

A 1000-foot STAMPP segment has 16 joints. Of these 16 joints, 3 are measured as medium severity and 5 as high severity. The rating for this section is: 8 joints none, 3 joints medium and 5 joints high severity faulting.



Faulted Joints Example


Faulted Joints
Medium Severity


Faulted Joints
Medium Severity

Broken Slab

Description:

This condition is characterized by the cracking or breaking of the slab into four or more pieces, within a 20-ft length of the slab, the pieces generally being greater than 1 sq ft in area.

Possible Cause:

Broken slabs can be caused by a condition of heavy load repetitions and poor base support.

Rating Procedure:

Each slab is evaluated separately for a broken slab condition. For the purposes of this distress, the "slab" is considered to begin 1-foot from the upstream traffic joint (the approach side) and end 1-foot before the downstream traffic joint (the leave side). On jointed concrete pavements, profile is evaluated for two sample intervals, the first for roughness and the second in 20-foot sample intervals along each slab. The second roughness measurement will be used to estimate the severity level for the slab. **Once a slab is rated as broken, no other distress shall be recorded for that slab.**

Severity:

Low: At least 4 pieces in a 20-foot length with average width ≤ hairline in the outside Wheel path, no faulting and IRI ≤ 100 in/mi.

Medium: At least 4 pieces in a 20-foot length with an average crack width > hairline and ≤ 0.25 in, may have faulting > 0.25 in and ≤ 0.50 in OR IRI > 100 and ≤ 200 in/mi.

High: At least 4 pieces in a 20-foot length with an average crack width > 0.25 in, may have faulting > 0.5 in OR IRI > 200 in/mi.

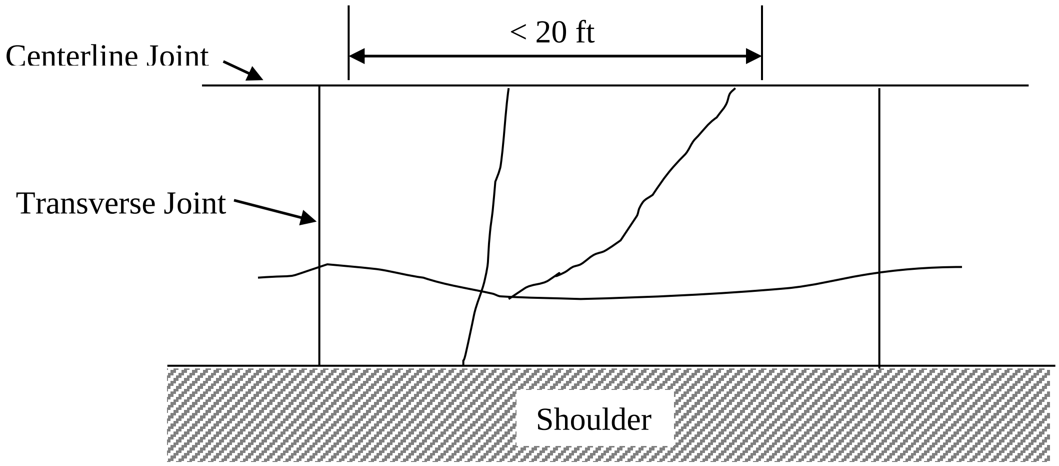
Extent:

Record the number of slabs in each severity category. If any one crack, faulting or IRI meets the criteria for the next highest severity, then rate at that severity level.

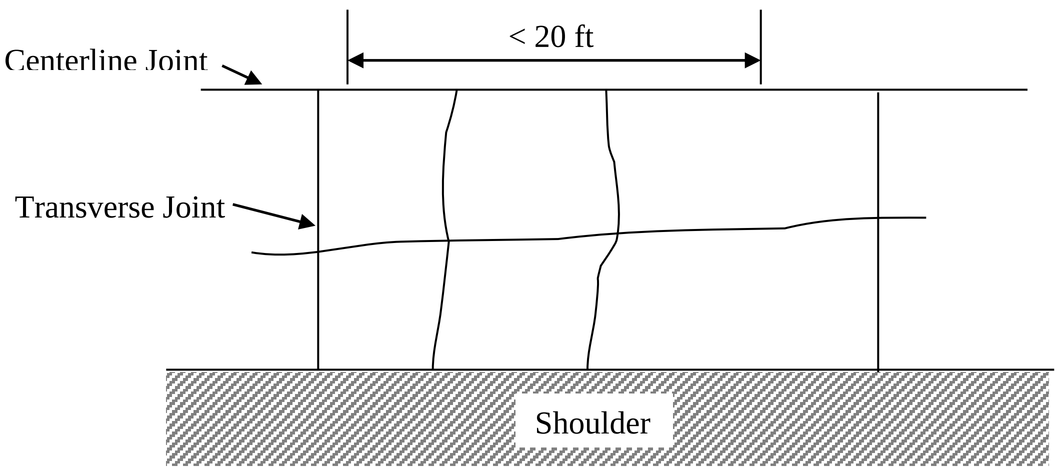
Example Reporting:

A 1000-foot STAMPP segment has 16 slabs. Of the 16 slabs, 2 have cracking patterns and roughness or faulting to place them in the medium severity level. The rating for this segment is: 14 slabs none and 2 medium severity broken slabs.

Broken Slab Examples



5 Sections in 20 ft

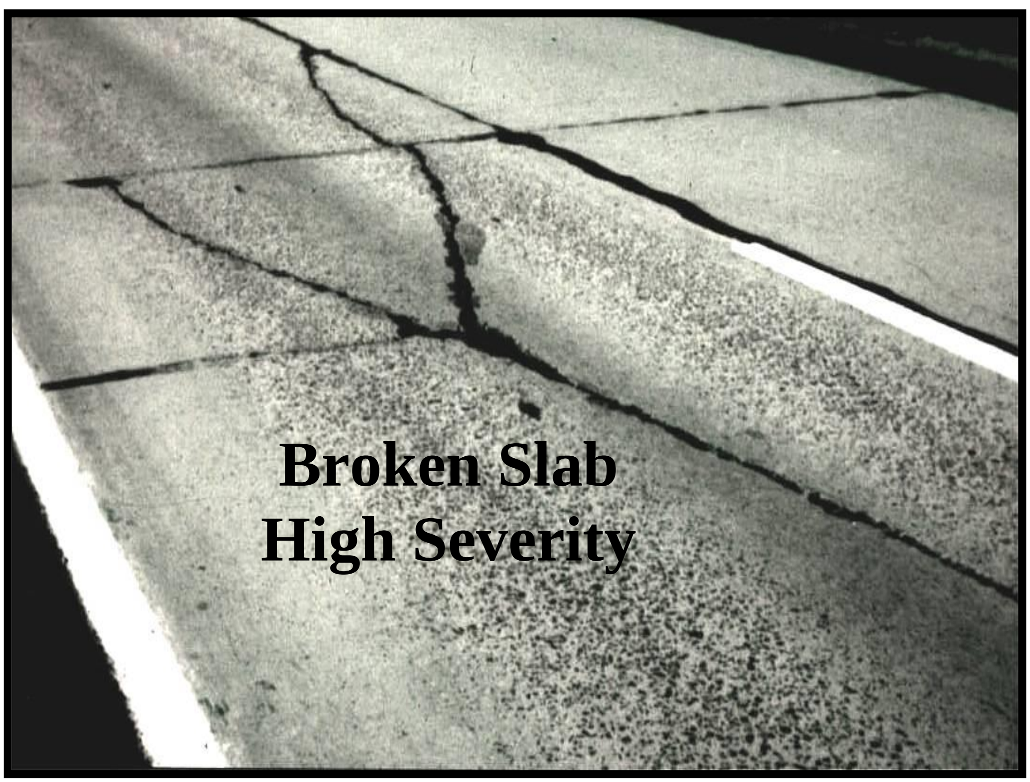


6 Sections in 20 ft


Broken Slab
Medium Severity


Broken Slab
High Severity
(Illustrates 20 ft
Length)


Broken Slab
High Severity


Broken Slab
High Severity

Transverse Joint Spalling

Description:

This condition is characterized by the cracking, breaking, or chipping of slab edges adjacent to a transverse joint or the transverse joint created by a patch. It usually does not extend through the thickness of the slab but meets the joint at an angle. It may be currently filled with bituminous material. If so, record the width of the spall as the width of the bituminous material.

Possible Cause:

Spalling is usually caused by excessive stresses at a joint due to infiltration of incompressible materials and subsequent thermal expansion of the concrete. It can also be caused by weak concrete at the joint combined with traffic loading, or poorly designed or constructed load transfer devices.

Rating Procedure:

Evaluate the pavement for spalling 1.0 foot on either side of the joint. The width of the joint shall be removed from the spall width estimates used in the evaluation. If a joint formed by a concrete patch is spalled and meets the criteria below, the new joint formed by the slab and patch must be included in that severity level. Count all transverse joints, including those formed by concrete patches, in the total number of joints per segment.

Severity Levels:

Low:	≤ 2.0 in wide for any length of the joint
Medium:	> 2.0 in wide for ≤ 50% of joint length
High:	> 2.0 in wide for > 50% of joint length

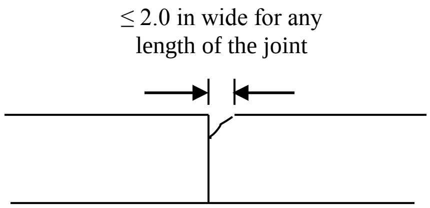
Extent:

Record the number of joints (original and created by concrete patches) for each severity level. The total is not to exceed the total number of joints in the segment.

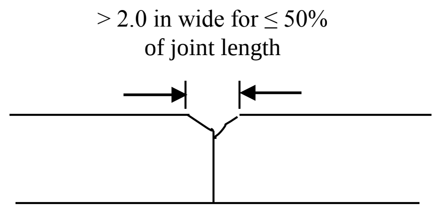
Example Rating:

A 1000-foot STAMPP segment has 16 transverse joints. Five joints have low severity spalling, 6 have medium and 3 have high. The rating for this segment is: 2 transverse joints none, 5 transverse joints low severity, 6 transverse joints medium severity and 3 transverse joints high severity spalling.

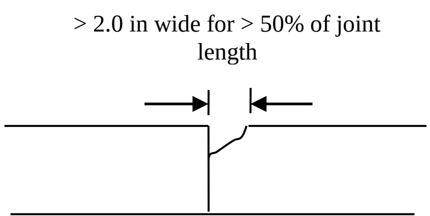
Transverse Joint Spalling Examples



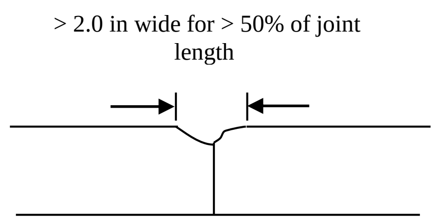
Low Severity Spalling



Medium Severity Spalling



High Severity Spalling



High Severity Spalling


Transverse Joint Spalling
Low Severity


Transverse Joint Spalling
Medium Severity


Transverse Joint
Spalling
High Severity

Transverse Cracking

Description:

This condition is characterized by random cracks, sealed or unsealed at least 6 feet in length. Cracks are rated as transverse cracks if the angle formed by the crack and the pavement is between 45^o and 90^o to the direction of travel.

Possible Cause:

These cracks are usually caused by a combination of heavy load repetition, thermal and moisture gradient stresses, and drying shrinkage stresses.

Rating Procedure:

The entire pavement lane width is analyzed for transverse cracking for the full STAMPP segment. Only transverse cracks that are ≥ 6 feet long are evaluated on a slab by slab basis. Each slab can have only one severity level. When a concrete patch exists within a slab, rate any transverse cracking on the patch as part of the slab. Record the slab at the highest severity level defined below.

Severity:

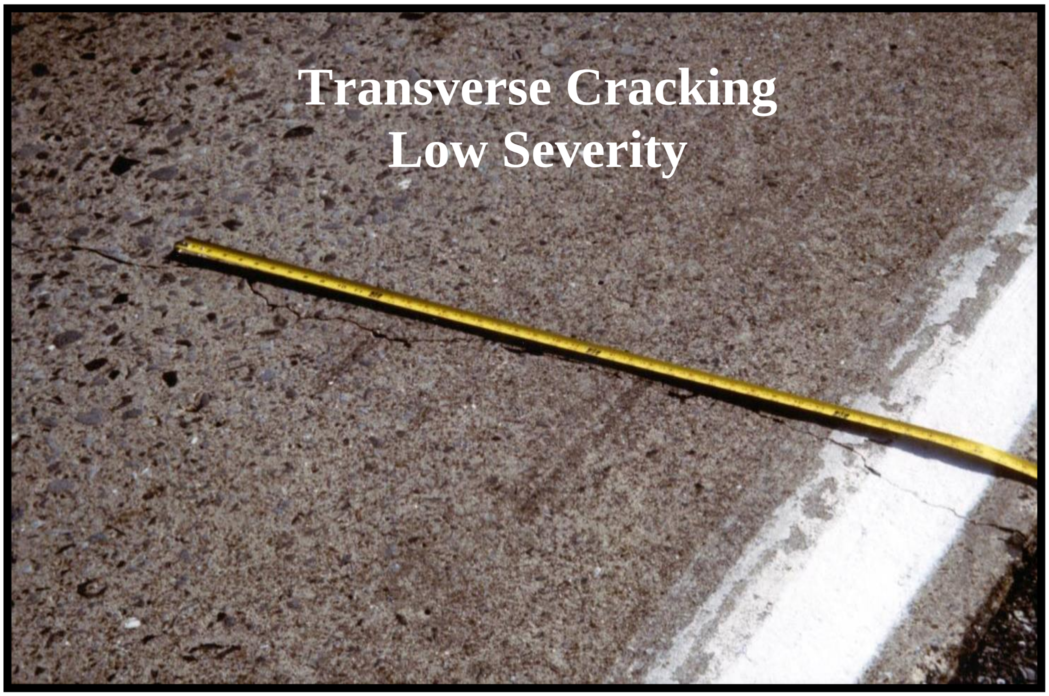
Low:	Average crack width ≤ hairline, no spalling, no faulting
Medium:	Average crack width > hairline & ≤ 0.25 in wide, Spalling ≥ 2.0 in wide for ≤ 50% length Or faulting ≥ 0.25 in and < 0.50 in
High:	Average crack width > 0.25 in wide, spalling ≥ 2.0 in wide for > 50% length Or faulting ≥ 0.5 in

Extent:

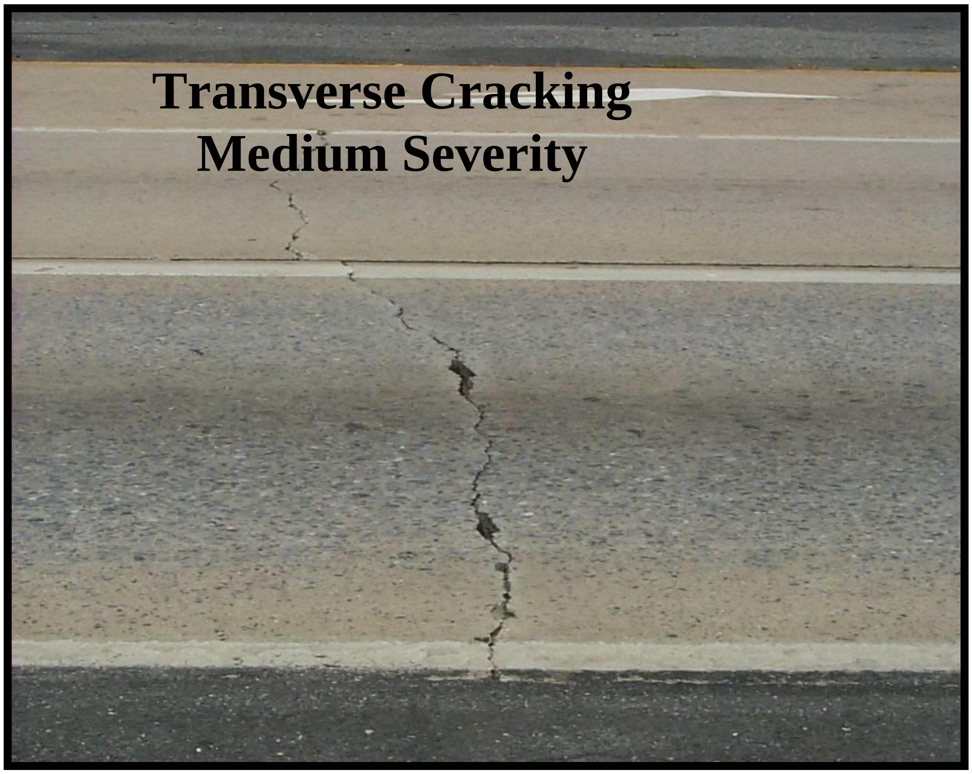
Record the number of slabs with each severity rating. If any one condition causes the transverse crack to be placed in the next highest severity rating, then record in the next highest severity rating.

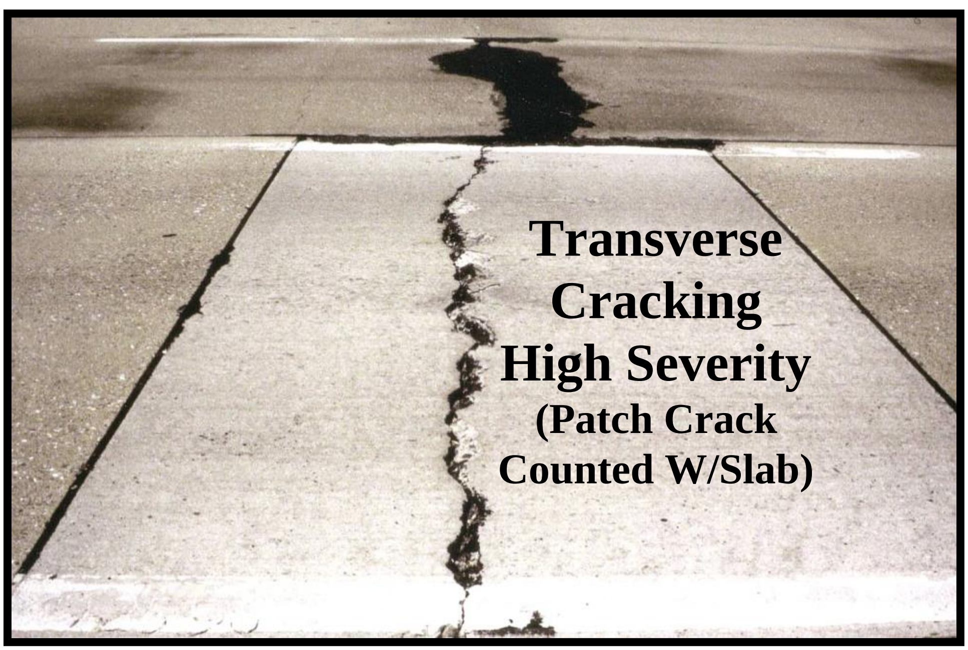
Example Rating:

A 1000-foot STAMPP segment has 16 slabs with 2 slabs showing transverse cracking in the low severity category and 6 in the medium severity category. The rating for this segment is: 8 slabs none, 2 slabs low severity and 6 slabs medium severity transverse cracking.


Transverse Cracking
Low Severity


Transverse Cracking
Medium Severity


Transverse Cracking
Medium Severity


Transverse
Cracking
High Severity
(Patch Crack
Counted W/Slab)

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Longitudinal Cracking

Description:
This condition is characterized by random cracks, sealed or unsealed. Cracks are rated as longitudinal cracks if the angle formed by the crack and the pavement is between 0^o and 45^o to the direction of travel.

Possible Cause:
These cracks are usually caused by a combination of reactive materials, heavy load repetition, thermal gradient stresses, and drying shrinkage stresses.

Rating Procedure:
The entire pavement lane width is analyzed for longitudinal cracking for the full STAMPP segment. Only longitudinal cracks that are ≥ 6 feet long are evaluated on a slab by slab basis. Each slab can have only one severity level. When a concrete patch exists within a slab, rate any longitudinal cracking on the patch as part of the slab. Record the slab at the highest severity level defined below.

Severity:

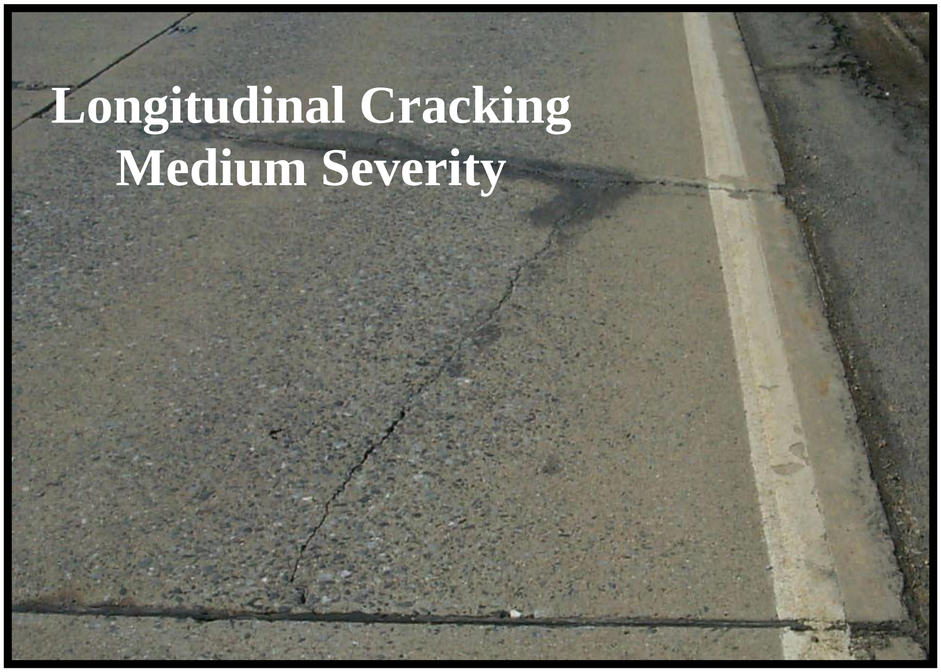
Low: Average crack width > hairline and ≤ 0.25 in wide

Medium: Average crack width ≤ 0.25 in wide, spalling ≥ 2.0 in wide for ≤ 50% length

High: Average crack width > 0.25 in wide, spalling ≥ 2.0 in wide for > 50% length

Extent:
Record the number of slabs with each severity rating. If any one condition causes the longitudinal crack to be placed in the next highest severity rating, then record in the next highest severity rating.

Example Rating:
A 1000-foot STAMPP segment has 16 slabs with 2 slabs showing longitudinal cracking in the medium severity category and 5 in the high severity category. The rating for this segment is: 9 slabs none, 2 slabs medium severity and 5 slabs high severity longitudinal cracking.


Longitudinal Cracking
Medium Severity


Longitudinal Cracking
High Severity

Longitudinal Joint Spalling

Description:

This condition is characterized by the cracking, breaking or chipping of slab edges adjacent to the longitudinal joint. It usually does not extend through the thickness of the slab, but meets the joint at an angle. It may be currently filled with bituminous material. If so, record the width of the spall as the width of the bituminous material.

Possible Cause:

Longitudinal joint spalling is generally caused by low quality concrete at the joint in combination with low air content in the concrete, wet-dry and freeze-thaw cycling and traffic loads.

Rating Procedure:

Rate the entire longitudinal joint (at the inside edge of slab) for longitudinal joint spalling. Record longitudinal joint spalling only when the total accumulated length (for all severity levels) is 25 feet or more. If there is more than one longitudinal joint within the lane being surveyed, count all joints in the total length of longitudinal joint spalling with the maximum total equal to the number of longitudinal joints times the segment length.

Severity:

Low: Average spalled width $\geq$ 1.0 in and $<$ 3.0 in for an accumulated spalled length of at least 25 feet

Medium: Average spalled width $\geq$ 3.0 in and $<$ 6.0 in for an accumulated spalled length of at least 25 feet

High: Average spalled width $\geq$ 6.0 in for an accumulated spalled length of at least 25 feet

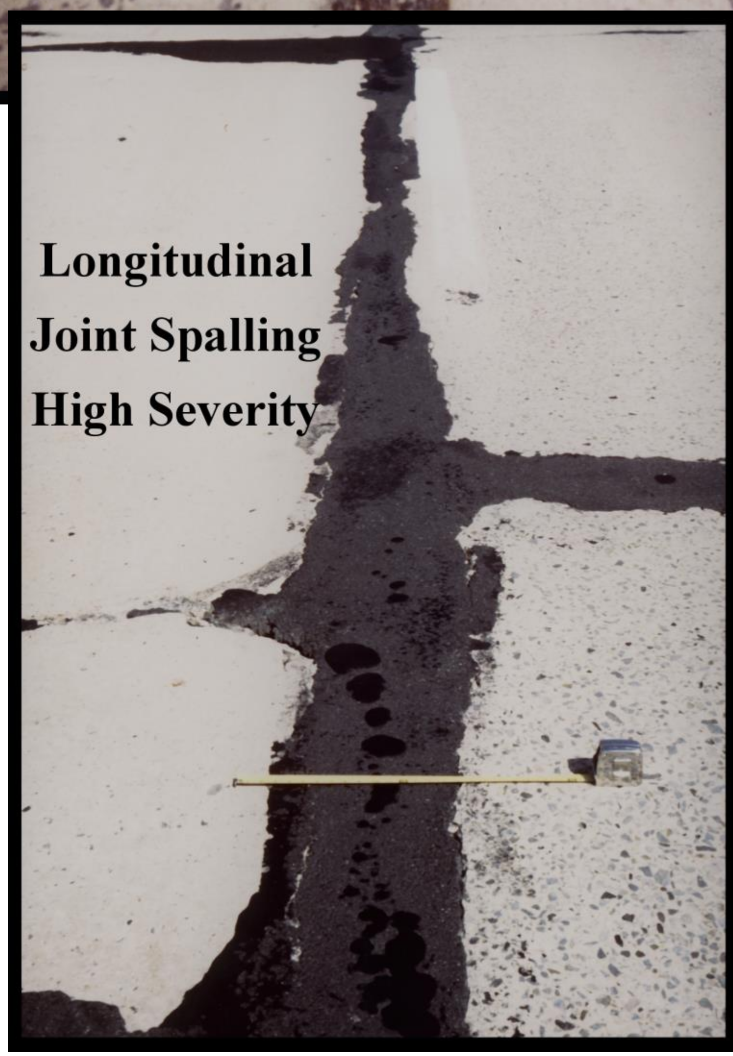
Extent:

Record the total length of each severity.

Example Rating:

The accumulated length of spalling on a 1000-foot STAMPP segment is broken down into the following two amounts: 200 feet of medium severity and 150 feet of high severity longitudinal joint spalling. The rating for this section is 650 ft none, 200 ft medium and 150 ft high severity longitudinal joint spalling.


Longitudinal
Joint Spalling
Medium Severity


Longitudinal
Joint Spalling
High Severity

Bituminous Patching

Description:

This condition is characterized by an area of the original pavement, which has been repaired with bituminous material greater than 36 sq ft in area it may be a surface or full depth patch.

Possible Cause:

Bituminous patching may have been required for one of several reasons such as high severity spalling, broken slab, faulting or surface defects.

Rating Procedure:

Evaluate the full pavement lane width and determine the number of bituminous patches with an area exceeding 36 sq ft. Report the number and total area.

Severity:

None

Extent:

Count the number and record the area.

Example Rating:

A 1000-foot long, 11-foot wide STAMPP segment has three bituminous patches. One of the patches is 1 foot long and six feet wide (6 ft^2), the second is 7.4 feet long and half a lane width (40.7 ft^2) and the third is 9 feet long and a full lane width (99.0 ft^2). The rating for this STAMPP segment is two bituminous patches and 139.7 ft^2 area.


Bituminous Patch


Bituminous Patch

Portland Cement Concrete Patching

Description:

This condition is characterized by an area of the original pavement that has been repaired with portland cement concrete material greater than 36 sq ft in area. It may be a surface or full depth patch.

Possible Cause:

Portland cement concrete patching may have been required for one of several reasons such as high severity spalling, broken slab, faulting or surface defects.

Rating Procedure:

Evaluate the full pavement lane width and determine the number of portland cement concrete patches with an area exceeding 36 sq ft. Report as the number and total area of patches.

Severity

None. If a patch is distressed, the condition rating will be reflected in the pavement rating for both the patch and the distress.

Extent:

Count the number and record the total area of all patching.

Example Rating:

A 1000-foot long, 11-foot wide STAMPP segment has three portland cement concrete patches. One of the patches is 2 feet long and 5 feet wide (10 ft^2), the second is 8.2 feet long and half a lane width (45.1 ft^2) and the third is 6 feet long and a full lane width (66.0 ft^2). The rating for this STAMPP segment is two portland cement concrete patches with 111.1 ft^2 total area.

APPENDIX G

PENNDOT HPMS PAVEMENT CONDITIONS

(HPMS Data Items 50, 51, and 52)

HPMS Item #50

RUTTING (HPMS Surface Type 2, 6, 7, 8 and 12) (*Bituminous*)

RUTTING is delivered as an Average Rut Depth to 0.01” at 1/10th mile increments, for all NHS Segments and HPMS Samples, including Local Roads.

HPMS Item #51

FAULTING (HPMS Surface Type 3, 4, 5, 9, 10 and 11) (*Concrete*)

FAULTING is delivered as an Average Fault depth to 0.01” for all joints in 1/10th mile increments, for all NHS Segments and HPMS Samples, including Local Roads.

HPMS Item #52

CRACKING (HPMS Surface Type 2, 6, 7, 8 and 12) (*Bituminous*)

Derive HPMS percentage of Cracking (1%).

BITUMINOUS CRACKING =

[((SRG0-BIT-FATIGUE-CRCK-LLO-FT + SRG0-BIT-FATIGUE-CRCK-LMD-FT +

SRG0-BIT-FATIGUE-CRCK-LHI-FT) x 3.25) + ((SRG0-BIT-FATIGUE-CRCK-RLO-FT +

SRG0-BIT-FATIGUE-CRCK-RMD-FT + SRG0-BIT-FATIGUE-CRCK-RHI-FT) x 3.25)] /

(SRG0-SURVEY-LENGTH x SRA0-TOTAL-WIDTH / SRA0-LANE-CNT)*100

Bituminous Cracking will be delivered as a percent Fatigue Cracking to the nearest 1% for both wheel paths at 1/10th mile increments, for all NHS Segments and HPMS Samples, including Local Roads.

CRACKING (HPMS Surface Type 3, 4, 5, 9, 10 and 11) (*Concrete*)

Derive HPMS percentage of Cracking (1%).

CONCRETE CRACKING =

((SRG0-CONC-TRANS-CRCK-LO-CT + SRG0-CONC-TRANS-CRCK-MD-CT +

SRG0-CONC-TRANS-CRCK-HI-CT + SRG0-CONC-BROKE-SLAB-LO-CT +

SRG0-CONC-BROKE-SLAB-MD-CT + SRG0- CONC-BROKE-SLAB-HI-CT) /

SRG0-CONC-SLAB-CT)*100

Concrete Cracking will be delivered as a percent Cracked Slabs to the nearest 1% at 1/10th mile increments, for all NHS Segments and HPMS Samples, including Local Roads.

APPENDIX H
DATA PROCESSING SKILLS MATRIX

FUGRO ROADWARE SKILLS MATRIX

0	Cannot perform task
1	Understands function but requires support
2	Trained- Can complete to standard without help
3	Training Planned (lower half box)

ROUTING (columns Project Setup through Keep Project Documentation Up to Date)

	Employee	Primary Function	Routing	Data Control	GPS	Segmenting	Distress	Surveyor	Data Analysis	Total Data Technician Cross Trained	Outside of Home Department Cross Trained	Other Skills	Project Setup	ArcGIS10.2 experience (import shapefile, open, modify att. table)	Q.C. Client Data : Review begin and end descriptions	Create Dogleg Program	Run Dogleg Program	Q.C. Client Data: Identify doglegs	Create Chainage Check Program	Run Chainage Check Program	Q.C. Client Data: Check Chainage	Q.C. Client Data: Check One-Ways	Review Offshore Data Accuracy: Random Audit	Update Input Database Structure in Excel	Create Allfields Program	Create AllFields Table	Create FOREFS Program	Create FOREFS	Create Master Program	Create MasterTable	Create Routing Template	Import Routing into *Vision*	Upload Routing to Routing Drive and FTP	Create Controls	Keep Project Documentation Up to Date
1	T. Joyce	Routing	98%	27%	0%	33%	0%	0%	0%	26%																									
1			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%																							
2			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%																							
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24			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%																							
25			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%																							
26			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%																							

APPENDIX H
DATA PROCESSING SKILLS MATRIX

FUGRO ROADWARE SKILLS MATRIX

0	Cannot perform task
1	Understands function but requires su
2	Trained- Can complete to standard w
3	Training Planned (lower half box)

	DATA CONTROL													GPS							SEGMENTING								
Employee	Configure Project Profile	Processing of Incomming Data	Import Data into Databases	Evaluate *Vision* Processors (LMCS GP, Image, Vehicle, Roughness)	Save Image QC Results, Import Workflow Comments	Split Batches to Project Rules	Q.C. Split Batches	Update Salesforce	Format Hard Drives	Ship Hard Drives to ARANs	Ship images offshore	QC & Deliver Video to Client	Keep Project Documents up to date	SBET Processing - Automated	Evaluate PosPac Results	Import using DCS	Evaluate Importing Results	SBET Processing - Manual	Update SalesForce	Keep Project Documents up to date	Run auto-segment tool	Segment data	Run Q.C. queries, correct issues	Replicate and send batch offshore	Q.C. offshore batches	Run Video QC	Restore batch, merge to database	Update Project Documentation	Project Setup
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APPENDIX H
DATA PROCESSING SKILLS MATRIX

FUGRO ROADWARE SKILLS MATRIX

0	Cannot perform task
1	Understands function but requires su
2	Trained- Can complete to standard w
3	Training Planned (lower half box)

	DISTRESS											SURVEYOR															
Employee	Process EVENTS	Process Distress (manual and automated)	Replicate batch, make available to offshore	Communicate with offshore re: schedule attainment	Download, extract, restore batch	Query Q.C. data, correct errors	Run Year - to - Year Distress Comparisons	Run Wisecrax processor	Run processors with Jenkins (Fault, Rut, WCX)	Merge data *(Replication Manager)*	Perform Project Setup	Create batches	Receive & Restore offshore data	Update Video Path	Perform random audit	Run and perform GIS check	Run SQL queries	Perform focused quality check (clean-up)	Merge batch	Export & review duplicates	Draw polylines of linear assets	Recieve and format Calibration data	Troubleshoot and complete calibration records	Q.C. Polylines	Place files on delivery network	Transform to client format	Transform to Geo-database
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APPENDIX H
DATA PROCESSING SKILLS MATRIX

FUGRO ROADWARE SKILLS MATRIX

0	Cannot perform task
1	Understands function but requires su
2	Trained- Can complete to standard w
3	Training Planned (lower half box)

	DATA ANALYSIS																							Other Skills											
Employee	Project Setup: Create queries	Project Setup: Update project documentation	ARAN Sign-Off: Set benchmarks and review runs	Perform Daily Verification of ARAN collection	Review repeatability of truck runs	Create ERD reports	Create elevation reports	Quality review - Segmenting data	Quality review - Distress data	Run Report Generator on data	Run update scripts	Merge transfers, Q.C. merged transfer delivery	Insert uncollected sections	Create year-to-year index, format input for Distress	Q.C. delivery: chainage, GPS flow, min/max outliers	Format to match data dictionary	Publish in *iVision*	Q.C. *iVision* publish	Perform peer-review	Prepare file list and FactorTable for vibing	Update "lessons learned" document	Assign batches to deliveries	Deliver to client	Dependability (On time, wiling to do OT, go the extra mile)	Trustworthy (work is completed with high quality, requires minimal QC)	Potential	Dedication (Does not leave things unfinished)	Eagerness (Pushing yourself, creating opportunities)	Respond to feedback(does not need to be reminded twice)	Process Improvement (will question the norm)	Adaptability(response to change)	Communication	Multi-Tasking	Leadership	Effective Trainer
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APPENDIX I
DISTRESS RATER CERTIFICATION MATRIX

INTER RATER CONTROLS COMPARISON Tolerance +/-10%

Legend
> +10%
< -10%

Layer ID	FILENAME	FAT	MISC	TRANS	EDGE	LE_Seam	ACPPatch	ACPPatch CNT	JCPPatch	JCPPatchC NT	Ravel	L_Jnt_SP	T_Jnt_Spall	T_Slab	L_Slab	Brk_Slab
BENCHMARK	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR1	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR2	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR3	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR4	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR5	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR6	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR7	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR8	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR9	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR10	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Layer ID	FILENAME	FAT	MISC	TRANS	EDGE	LE_Seam	ACPPatch	ACPPatch CNT	JCPPatch	JCPPatchC NT	Ravel	L_Jnt_SP	T_Jnt_Spall	T_Slab	L_Slab	Brk_Slab
BENCHMARK	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR1	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR2	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR3	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR4	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR5	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR6	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR7	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR8	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR9	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR10	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Layer ID	FILENAME	FAT	MISC	TRANS	EDGE	LE_Seam	ACPPatch	ACPPatch CNT	JCPPatch	JCPPatchC NT	Ravel	L_Jnt_SP	T_Jnt_Spall	T_Slab	L_Slab	Brk_Slab
BENCHMARK	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR1	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR2	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR3	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR4	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR5	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR6	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR7	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR8	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR9	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR10	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Layer ID	FILENAME	FAT	MISC	TRANS	EDGE	LE_Seam	ACPPatch	ACPPatch CNT	JCPPatch	JCPPatchC NT	Ravel	L_Jnt_SP	T_Jnt_Spall	T_Slab	L_Slab	Brk_Slab
BENCHMARK	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR1	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR2	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR3	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR4	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR5	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR6	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR7	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR8	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR9	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR10	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX I
DISTRESS RATER CERTIFICATION MATRIX

Layer ID	FILENAME	FAT	MISC	TRANS	EDGE	LE_Seam	ACPPatch	ACPPatch CNT	JCPPatch	JCPPatchC NT	Ravel	L_Jnt_SP	T_Jnt_Spall	T_Slab	L_Slab	Brk_Slab
BENCHMARK	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR1	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR2	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR3	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR4	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR5	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR6	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR7	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR8	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR9	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPERATOR10	FILENAME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Categories	PaveType	Full Distress Name
FAT	ACP	Fatigue
MISC	ACP	Miscellanious
TRANS	ACP	Transverse
EDGE	ACP-JCP	Edge Deterioration
LE_Seam	ACP-JCP	Left Edge Seam
ACPPatch	ACP-JCP	ACP Patching
ACPPatchCNT	ACP-JCP	ACP Patch Count
JCPPatch	ACP-JCP	JCP Patching
JCPPatchCNT	ACP-JCP	JCP Patch Count
Ravel	All	Raveling
L_Jnt_Sp	JCP	Long Joint Spall
T_Jnt_Sp	JCP	Trans Joint Spall
T_Slab	JCP	Transverse Slab
L_Slab	JCP	Longitudinal Slab
Brk_Slab	JCP	Broken Slab

	Operator Name
OPERATOR1	
OPERATOR2	
OPERATOR3	
OPERATOR4	
OPERATOR5	
OPERATOR6	
OPERATOR7	
OPERATOR8	
OPERATOR9	
OPERATOR10	
OPERATOR11	
OPERATOR12	
OPERATOR13	
OPERATOR14	
OPERATOR15	
OPERATOR16	

APPENDIX J
OPERATOR TRAINING MATRIX

Average % of all Crew	82.9 %	
# of Task	**91**	**Task Completed**
		Percentage of all Tasks Completed
		Field Operations Technician I
		Has completed Quality and HSE Orientation.
		Has successfully completed Smith Driving System Training.
		Has access to Confluence.
		Can perform safe operation of ARAN and can demonstrate proper driving technique as related to ARAN data collection and can drive consistently in the wheelpath.
		Can complete ARAN daily mechanical inspection checklist in SalesForce/understands why Checklist has to be completed prior to leaving for collection or transit.
		Can complete ARAN daily generator maintenance checklist in SalesForce.
		Has completed First Aid (with CPR/AED) Qualification within the first three months.
		Has basic knowledge of ARAN sub-systems and can identify all equipment.
		Can perform generator/sub-systems start up.
		Can perform basic Sub-System troubleshooting utilizing ACS Diagnostics.
		Can navigate with New ACS polyline maps, can distinguish sections, and how to plan routing the sections for collection by utilizing Mission Management without supervision.
		Can refer to section being collected on Map to verify that they are collecting the correct section of road.
		Can effectively collect a dummy section/run diagnostics and knows how to review acceptable data in the ARAN 9000 software under Review Data Tab without supervision.
		Can review data on sections of road collected, paying attention to skipped images from utilizing the end of day report function under Quality Video.
		Can access data file setup and systems check procedures using Diagnostics before data collection in the ARAN 9000 software without supervision.
		Can enter notes on the end of day report, selecting the type of collection, how to delete sections (explaining why sections were deleted).
		Can utilize Data Management, backup data, export data, and generate End of Day Report.
		Can access Daily Report, complete daily CSV report, and how to check quality of sample ROW video images.
		Understands importance of Fugro Safety Policies and performs all duties in a safe and professional manner.
		Can upload Daily Report to the FTP site effectively.

		Can perform a Field Inspection effectively and is aware of location of all Aran equipment.
		Can perform the Daily Report on SalesForce.
		Can perform data shipment, hard drive inventory, and can navigate through SalesForce/Saasmaint effectively without supervision.
		Completed Fugro Academy Courses
		Mandatory Fugro Academy Courses
		Fugro Academy HSE-E-206 Environmental Management
		Fugro Academy Code of Conduct Part 1
		Fugro Academy Code of Conduct Part 2
		Fugro Academy Code of Conduct Part 3
		Fugro Academy Intro to Fugro Impact HSE-E-101
		Fugro Academy Course: HSE-E-207 Safe Driving Behaviour
		Fugro Academy Submitting a Hazard Observation Card in Fugro Impact HSE-E-102
		Fugro Academy Course: Laser Safety
		Fugro Academy Course: Workplace Violence and Harassment Training
		Fugro Academy Course: Safe Manual Handling HSE-E-203
		Fugro Academy WHMIS/HAZCOM
		Fugro Anti-Bribery and Corruption Course
		Fugro Academy Course: HSE-E-200 Golden Rules of HSE
		Fugro Academy AODA-Training Accessibility Standard for Customer Service
		Fugro Academy Data Shipment Video
		Fugro Academy DMI Calibration Video
		Fugro Academy Collecting Multiple Districts Video
		Fugro Academy Hard Drive Inventory Video
		Confluence Lean Management Initiative Intro
		JJ Keller HSE Mandatory Courses
		Confluence Strobe Safety and High Voltage Training
		Field Operations Technician II
		Can perform all Field Technician Administration Duties (eg Update Saasmaint, HDD Shipment Logs/Requests, create/complete Work Orders, etc) without supervision.
		Can perform all aspects of Collection/QC/End of Day without supervision.
		Frequently checks screens during data collection and ensures Quality Data to prevent Re-Runs less than 2%.
		Can instruct/train a Field Technician 1 on the roles and responsibilities of that position.
		Can identify all ARAN electronic equipment with reference to sub-systems and explain use.
		Can install routing packages and maps by downloading from the FTP site.
		Can Run Control Sites without supervision
		Possesses basic troubleshooting skills for mechanical and electrical issues.
		Can competently collect and process data on Areascan (2D) and LCMS (3D) ARAN platforms.
		Can exhibit effective section routing methods to reduce dead haul during data collection.

		Can perform a DMI calibration and know how to utilize the proper DMI document from SalesForce to record the calibration data effectively without supervision.
		Can evaluate quality data and video to prevent reruns and understands importance of collecting quality data.
		Can calibrate IRI and verify with the bounce test calibration successfully by utilizing the Aran 9000 calibration software.
		Understands the concept of Lean Management and utilizes skills to their advantage.
		Minimum tenure - 12 months
		Field Operations Technician III
		Can perform a Project SetUp/Sign Off procedure.
		Can collect and verify Controls (inc used Control Tracker/perform DMI Cal/Upload Control Data, etc) without supervision.
		Possesses Intermediate troubleshooting and calibration skills.
		Can explain how each of the systems functions and what they collect.
		Can perform the ARAN Project Certification Process for Project Set-Up and Project exits contained in SalesForce.
		Has shown and understands what to do when a rerun is required due to equip. or operator error.
		Can perform Basic Troubleshooting utilizing a Multimeter to Troubleshoot AC/DC and Resistance with respect to sub-system electronic equipment operation.
		Can complete a surveyor loop and provide data, without supervision, for office review.
		Capable of providing in depth training to new hires.
		Capable of supervising an ARAN/Crew effectively and efficiently.
		Capable of offering solutions utilizing Lean Management and institute with positive results.
		Minimum tenure - 18 Months
		Senior Field Operations Technician IV
		Can perform advanced troubleshooting utilizing a Multimeter to troubleshoot AC/DC and Resistance with respect to all sub-system electronic equipment for proper operation.
		Has trained and reflects a genuine desire to mentor lesser experienced technicians on a consistent basis.
		Can complete full sub-system field calibrations (Lever Arms Angles) on Area Scan (2D) and LCMS (3D) ARAN platforms.
		Can perform advanced mechanical trouble shooting skills and generator diagnosis.
		Can perform advanced computer trouble shooting skills related to software and hardware.
		Has advanced knowledge of all ARAN operating systems.
		Consistently exhibits a positive attitude and sets the example for lesser experienced technicians.
		Has the technical knowledge to support Fleet CS effectively in most areas.
		Fully capable of managing an ARAN.
		Reflects a positive attitude towards Lean Management and encourages ideas.
		Minimum tenure- 24 months

		Senior Field Operations Technician V
		Has the technical ability to perform Project Lead responsibilities as required by Field Supervisors.
		Advanced Team-building/Inter-personal skills.
		Able to supervise a Field Operations Team.
		Able to supervise and manage Personnel.
		Understanding of Project Planning/Financial considerations.
		Possesses the leadership skills necessary for promotion to the Field Supervisor Level.
		Can supervise multiple Field Operations Teams/ARANS simultaneously.

Appendix K

Pennsylvania Turnpike Commission Data Quality Management Plan

May 2018

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Michael Baker INTERNATIONAL

Appendix K – PA Turnpike Commission DQMP

Contents

Appendix K – PA Turnpike Commission DQMP

1. Introduction

This Pavement Data Collection Quality Management Plan documents the quality management practices and responsibilities that Pennsylvania Turnpike Commission (PTC) utilizes specifically for pavement data collection. This plan includes equipment calibration and certification measures, manual distress data collection, pre-through post-production data quality control (QC) measures, data sampling/review practices, error resolution, and acceptance criteria. The QC activities documented will ensure 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 any 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, overall cost-savings, and reliable decision support for managers.

PTC contracts out the pavement condition data collections. The use of "Vendor" throughout this DQMP refers to the contractor collecting, analyzing, and reporting the pavement condition data required through 23 CFR Part 490 of MAP-21. 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. 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.

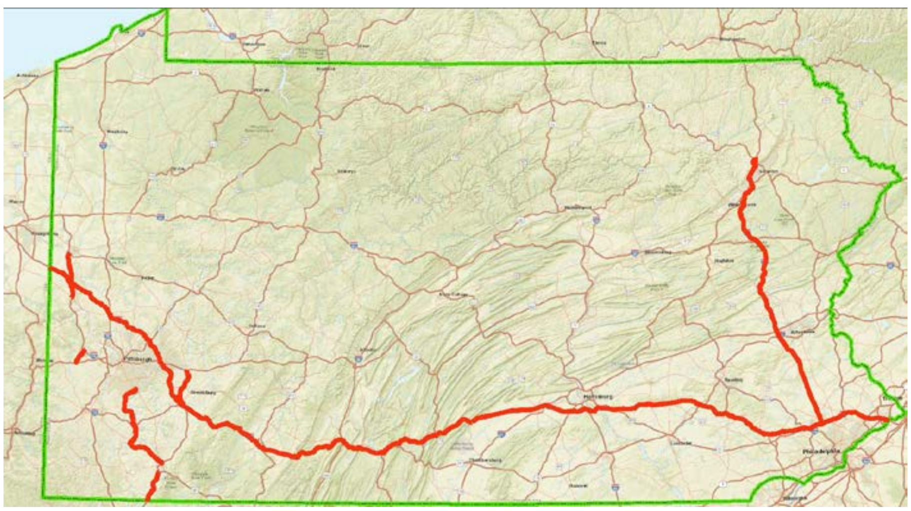
Topic	Document Reference	Page
Data Collection Equipment Calibration	Data Collection Equipment & Calibration	8
Data Collection Certification	NCAT Certification Process	14
	ALDOT Certification Process	App. C
Certification Process for Manual Data Collection	Distress Selector Rater Training	15
Data Quality 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	11

2. Data Collection Protocols

The Pennsylvania Turnpike Commission (PTC) maintains approximately 1,350 carriageway miles of toll roads (~1,130 mi.) and ramps (~220 mi.) across the Commonwealth. PTC's maintenance jurisdiction includes the primary mainline, five (5) extensions and 467 ramps. The major highways are:

- Mainline (portions of I-76, I-70 & I-276)
- Northeast Extension (portions I-476)
- Mon-Fayette Expressway (PA 43)
- Southern Beltway (PA 576) S
- Beaver Valley Expressway (PA 376)
- Amos K. Hutchinson Bypass (PA 66)

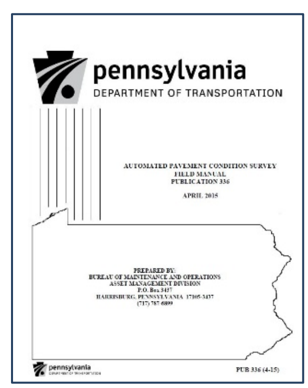
Figure 1. Pennsylvania Turnpike jurisdiction map.



2.1. PennDOT Publication 336 Protocol

- **Overview**

In 2016, PTC adopted the use of PennDOT's Pub 336 protocols to collect more detailed pavement condition data to support the implementation of a new pavement management system (PAMS) and changing HPMS requirements related to the reporting of pavement condition data. The Pub 336 manual is intended for use with the PennDOT's Pavement Condition Survey. According to Pub 336, the data collected is used for the following purposes (PennDOT 2015):



- To create a uniform statewide condition evaluation to improve program decision making.
- To provide management with the information to monitor condition of the network, assess future needs, establish condition rankings and optimize investments.
- To provide condition information to fulfill state requirements which requires the allocating of maintenance funds to individual counties based on need.
- To provide information for monitoring the performance of various pavement designs, rehabilitation and maintenance techniques.
- To provide information for identifying candidate projects for maintenance and betterment programs.

The Pub 336 provides thorough descriptions of PennDOT's definitions of pavement distresses and guidelines for assigning severity types, levels and extents. The manual is updated on an as-needed basis and can be found online at:

http://www.dot.state.pa.us/public/PubsForms/Publications/Pub%20336.pdf

Different distresses are classified and reviewed based on the pavement type. Below is a table of captured data elements (a full summary of the Pub 336 rating protocol can be found in Appendix K-A):

Table 2. Pub 336 Distresses.

Bituminous Surface (Asphalt)		
• Fatigue Cracking	• Transverse Cracking	• Miscellaneous Cracking
• Edge Deterioration	• Bituminous Patching	• Left Edge Joint
• Raveling \ Weathering		
Rigid Surface (Concrete)		
• Faulted Joint	• Broken Slab	• Transverse Joint Spalling
• Transverse Cracking	• Longitudinal Cracking	• Longitudinal Joint Spalling
• Bituminous Patching	• Concrete Patching	
All Surfaces		
• IRI	• Rutting	

For the purpose of this Data Quality Management Plan, the following distresses will be reported: roughness, rutting, cracking and faulting. Data collection consist of 100% of the system collected on a yearly basis.

➢ Data Collection Methodology

Field Data Collection

Pavement data is collected and processed for PTC in alignment with the Pub 336 protocols through a mix of automated and semi-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 on highways with two lanes and in the middle lane on carriageways with 3 lanes. The pavement condition data is collected in accordance with PTC's Location Referencing System, LRS. PTC's LRS is a linear reference system that is used to index and designate roadway network. All routes are assigned a unique identifier to which roadway features, including pavement type and conditions, are assigned.

Pavement condition data is collected based on the milepost linear referencing system (LRS). The pavement conditions required through this MAP-21 regulation will be summarized and reported at 1/10th mile increments based on the milepost LRS. Each Segment will be divided into 0.10-mile increments until the last increment before a pavement type change, a bridge deck, or the end of a Segment. If the last increment before any of these physical features is equal to or less than 52.8 feet, that short length will be added to the previous full 0.10-mile increment so no increment is over 0.11 mile. If the last increment is greater than 52.8 feet, it will be a separate increment that is less than 0.10 mile. The full 0.10-mile increment will reset to begin again with the new pavement type, on the leave side of the bridge, or with the next Segment on the route, and so on through the end of the route.

In both 2016 and 2017, data collection occurred in the October \ November timeframe. Data is submitted to PTC in Microsoft Office Excel format. All data points are broken down by highway (Mainline, Northeast Extension, Beaver Valley Expressway, Mon Fayette and Southern Beltway). The spreadsheet for each highway contains IRI, and rutting based on each highway section and every 1/10-mile section (11,707 segments exist for the entire network). A separate spreadsheet containing the Pub 336 distresses information is also provided to PTC that is used to populate the PAMS system. Data is summarized to one-tenth (0.1) mile highway sections and includes data on all ramps.

While certain types of surface distress can be automatically detected and classified through the LCMS alone, several of the Pub 336 distress cannot be detected automatically through current LCMS software algorithms. As a result, the Vendor has built a custom application (Distress Selector) that allows users to identify and classify additional distresses based on downward facing images generated from the LCMS in a semi-automated fashion. The table below shows the method of collection, capture and reporting resolution of each Pub 336 distress:

Table 3. Pub 336 method of data capture and resolution.

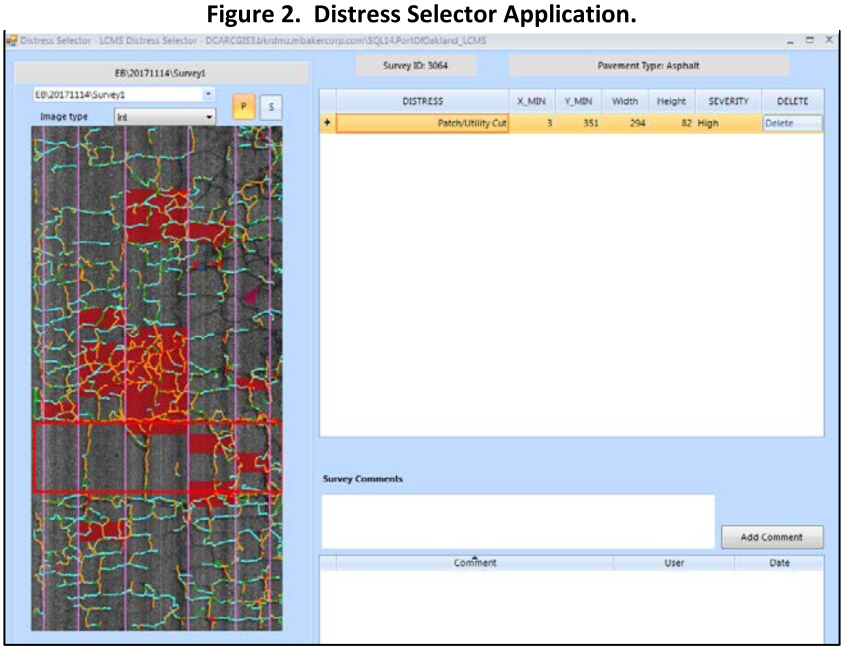
Distress	System of Capture	Method of Capture	Reporting Unit	Reporting Resolution
IRI	Inertial Profiler	Automated	in. / mi.	1 in./ mi.
Rut Depth	LCMS	Automated	Inches	0.01 in.
Fatigue Cracking	LCMS	Semi-Automated	Linear Feet	1 Foot
Transverse Cracking	LCMS	Automated	Linear Feet	1 Foot
Faulted Joint	LCMS	Automated	Joint Count	Joint Count
Broken Slab	LCMS	Semi-Automated	Slab Count	Slab Count

Distress Selector Application

A key component of the Vendor's data delivery and quality control process is the Distress Selector application. This custom-built application allows users to classify certain distresses that cannot be automatically acquired through LCMS post-processing software. The Distress Selector allows users to perform the following tasks:

- Toggle through all pavement images by route
- Assign appropriate distress type/classification
- Classify extents by highlighting distress areas on images
- Apply a condition or severity rating to each distress
- Add comments as necessary

Figure 2. Distress Selector Application.



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 any 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 Vendor's 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. Laser Crack Measuring System (LCMS)

The 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 AASHTO R 57-14, *Standard Practice for Operating Inertial Profiling Systems*, that consist of:

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

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

Longitudinal calibration involves calibration of the DMI unit to assure 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.

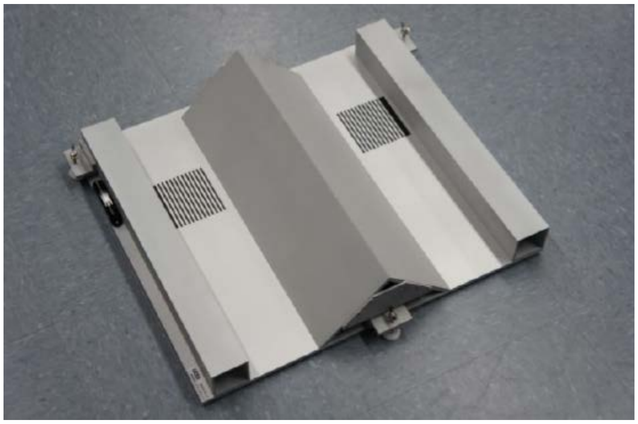
Longitudinal calibration of the LCMS is conducted monthly at minimum or when one of the following triggering events occur (whichever comes first):

- 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

<u>Height Verification (Block Test)</u>

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 3. 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

<u>Bounce Test</u>

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 AASHTO 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 properly warmed up.

- **LCMS Annual Maintenance**

The Vendor 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 the 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 method helps assure data consistency and integrity through a data collection project.

3.2. Surface Systems & Instruments

The Vendor's Inertial Profiler equipment meets the requirements of AASHTO M328-14, *Standard Specifications for Inertial Profiler* and AASHTO R56-14, Standard Practice for Certification of Inertial Profiling Systems (Section 5 - Equipment). The inertial profiler is specifically used to capture high accuracy, repeatable measures 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 4. SSI profiling system.

Profiler Calibration & Verification

Similar to the LCMS, profiler calibration is performed by certified field technicians in accordance with AASHTO 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 AASTHO R 57-15 and manufacturer's instructions. The following is Vendor'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

<u>Laser Height Verification (Block Test)</u>

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 5. 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 AASHTO 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 properly 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 6. 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 (left, right, and average)	AASHTO	1 in/mi	± 10% of as compared to Vendor's independent third-party review with Class I profiler	± 10% run to run for three runs
Rut Depth (average and maximum)	AASHTO	0.01 in	± 0.08 in compared to Vendor's independent third-party review	± 0.08 in run to run for three runs
Faulting	AASHTO	0.01 in	± 0.08 in compared to manual survey Vendor's independent third-party review	± 0.08 in run to run for three runs
Distress Ratings	Pub 336	See Table 6	± 10 percent compared to Vendor's independent third-party review	N/A
Panoramic Images	N/A	N/A	Signs legible, proper exposure, and color balance. Proper image clarity and images ordered correctly.	N/A
LCMS Pavement Images	N/A	N/A	1/8 in wide cracking visible on asphalt and concrete pavements. Proper exposure and images ordered correctly. Less than 5% of image contains 'Out of Range' data.	N/A

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. This represents 56 mi of the 1,130 mi highway network.

➢ 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** (% of Data Within Acceptance Test Limits)	**Acceptance Test**	**Frequency**	**Error Resolution** (Action if Criteria Not Met)
IRI, Faulting & Rutting	90%	Within 10% of Vendor's independent third-party review	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.
Other Pub 336 Distress Ratings	90%	Within 20% of year-over-year (YoY) value	Before deliverable submission	Document discrepancies and verify with pavement imagery and construction schedule.
		Global database check for range, completeness and logic.	Before deliverable submission	Deliverables cannot be submitted. Correct errors through recollection, process reconfiguration or distress re-extraction.
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 help ensure that accurate and complete pavement data is collected and processed in a repeatable manner. The Table 7 outlines Vendor's standard quality control measures that are in place for each pavement data collection project. Appendix K-B (*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**

Field Technician Training & Certification

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 proper 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 properly:

- 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 optimal 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 properly startup and configure the van for collection, follow LCMS data collection protocols, properly 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 Vendor.

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 *AASHTO 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 ensures 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 K-C. 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

By ensuring that the field technicians possess the proper knowledge and skills of the LCMS system, quality control measure can be more effectively and efficiently carried out on a day to day basis.

Distress Selector Rater Training

Users performing data collection utilizing the Distress Selector application must complete a comprehensive training and certification process prior to the manual extraction of distress data in the production environment. This measure helps increase the accuracy and consistency of distress and condition reporting within and between pavement management projects. The Quality Control Manager provides a full day training session on manual distress protocols to new users. During this training session, users receive a Distress Selector User's Guide which describes the training details, including:

- Application functionality and use
    - Selecting the route
    - Selecting the image type (Intensity, Range, 3D)
    - Drawing the distress box
    - 'Go to' image number
    - Assigning a comment
    - Deleting a distress
- Properly identifying and differentiating distress classification types
- Assigning appropriate condition and severity ratings
- Understanding the extent information
- Understanding how the data is stored in the Pavement Management database

The user may reference this guide during manual distress selection. This serves as a baseline for defining distress types and condition ratings to ensure consistent extraction between all users. During this training, the Quality Control Manager will demonstrate all application functionality and provide thorough explanation for the different distress types and how to identify them. The following distresses are categorized in the Distress Selector application for PTC:

- Broken Slab
- Spalling
- Bituminous Patch
- Fatigue Cracking
- Concrete Patch

Distress Selector Rater Certification

As a final part of the training course, raters are given a certification test on distress classification. A training database has been established and is used for the certification test. Raters are required to rate and classify distresses on a total of thirty (30) 1/10th mile sections that consist of 20 flexible sections and 10 rigid sections. Rating results are compared to an established baseline of the same sections extracted by the Quality Manager. Raters are scored on correctly identifying distress types, severity and extent. To achieve a passing grade, raters must classify distress type with 90% accuracy (compared to the baseline) on 90% of the sections for both asphalt and rigid sections and rate severity and extents within 10% of the baseline on 70% of the sections for both asphalt and rigid sections. Refer to the table below:

Table 9. Passing criteria for Distress Selection certification.

	Flexible Sections	Rigid Sections
Number of Test Sections	20	10
Scoring Criteria	**Passing Score**	
Identify Distress Type Correctly (90%)	18	9
Identify Severity + Extent (+/- 30%)	14	7

Raters must meet the minimum passing score on each pavement type to pass the certification test. For example, if a rater fails to meet the passing score for identifying severity and extent on rigid sections (7), the rater must retake the certification test on rigid sections. Table 10 is an example of a passing score on a flexible pavement section:

Table 10. Example of passing score on flexible pavement section.

Distress Type	Severity	Baseline Value	Rater Value	% Difference (+/- 10%)
Fatigue Cracking	Low	150 ft.	145 ft.	**-3.3%**
	Medium	45 ft.	41 ft.	**-10.0%**
	High	21 ft.	21 ft.	**0.0%**
Bituminous Patching	N/A	200 ft^2	210 ft^2	**+5.0%**

All rater values are within 10% of each classified distress and severity level, so this would be a passing section. The example below is representative of failed sections because medium and high-severity fatigue cracking are not within the 10% range. A rater could still pass the flexible pavement type component, given 14 of 20 (70%) sections are correct.

Table 11. Example of failing score on flexible pavement section.

Distress Type	Severity	Baseline	Rater	% Difference (+/- 10%)
Fatigue Cracking	Low	150 ft.	145 ft.	**-3.3%**
	Medium	45 ft.	60 ft.	**+33.3%**
	High	21 ft.	25 ft.	**+19.0%**
Bituminous Patching	N/A	200 ft^2	210 ft^2	**+5.0%**

If any user is deficient, additional training and testing will be required before beginning distress selection in a production environment. Once the rater possesses the required certification to correctly identify distresses, they will be certified to conduct manual distress selection in the production environment for the project year. Certifications are good for one (1) collection cycle.

➢ Define Quality Standards & Acceptance Criteria

It is required within the Vendor's SOP to have established Data Quality Standards and Acceptance Criteria before the start of any data collection project. See Section 4 on Data Quality Standards and Acceptance Criteria for the PTC data collection project.

➢ Equipment Configuration & Calibration

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

➢ Project Database Setup & Application Configuration

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:

- **Distress Selector** – Application that allows users to manual classify distresses off LCMS pavement images.
- **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. The Vendor 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 ensuring 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 eliminating 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 ensure adequate GPS acquisition and to check that the LCMS images are displaying with proper 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 must be 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 any issues arise in post-processing the data, the user can refer to these field notes for additional information or guidance and determine is 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 operating within the range recommended by the manufacturer of the data collection equipment. The roadway surface must be dry and ideally be free of debris. The Vendor will work with an agency to time 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. Ideally data collection occurs soon after a scheduled street sweeping program when roads would be effectively clean and free of debris.

Field technicians must ensure proper weather conditions 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 ensure that equipment is secured within and outside the vehicle (DMI attached properly, 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 all data collection systems are continuously recording valid data streams.

Table 12. Real-Time system checks with stop\pause conditions.

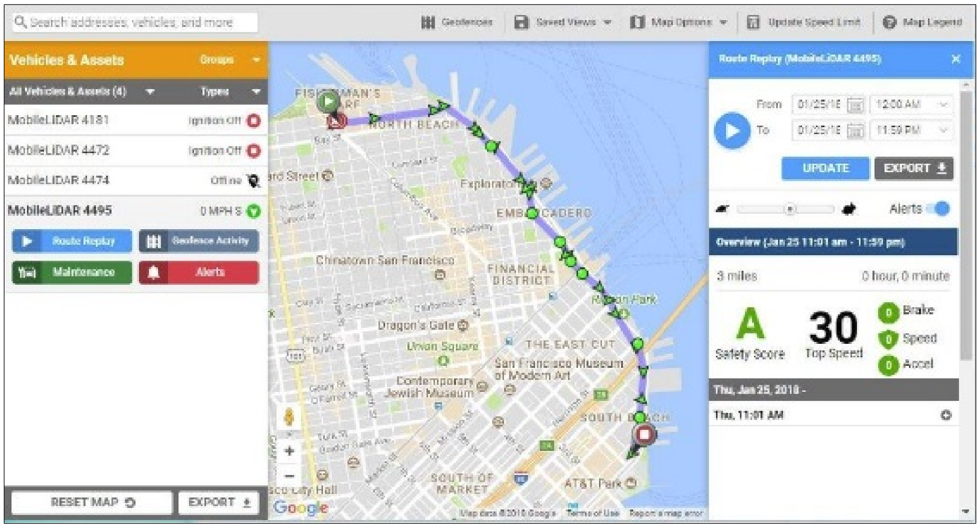
System	Checks	Stop \ Pause Collection Conditions
LCMS	• Images are in focus, clear with minimal 'Out of Range' data. • Good GPS data stream	• > 30 second delay in images appearing on screen • 5 consecutive bad images • GPS loss > 1 minute • Acquisition application or computer crash
Profiler	• Continuous 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 (middle lane for 3 lane carriageways, otherwise right-most lane) and make note of any areas where construction, lane closures, or other interferences prevented collection in the selected lane. In addition, both parties are responsible for ensuring 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 assure that the most accurate and representative data is collected for the roadway section.

➢ **Real-Time Vehicle Tracking**

Vendor'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 7. Vehicle real-time tracking system.

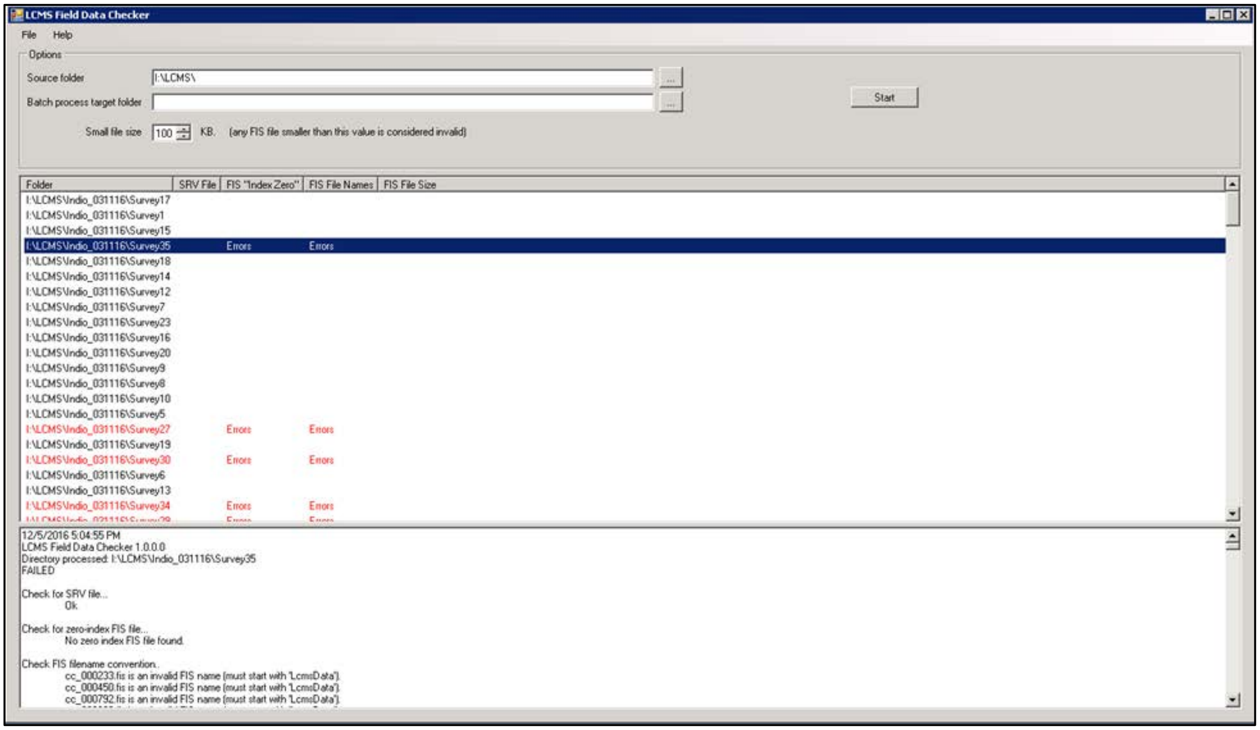


➢ **LCMS Field Data Checker**

After data collection is complete, field technicians run raw collected data through the Vendor's custom-build 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 properly or if the system operated properly. However, data discrepancies can indicate that operational errors may have occurred and errors produced from this tool must be documented and evaluated. It is required 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 8. LCMS Field Data Checker with error conditions in red.



Field technicians must complete and submit their Field Note logs to the Field Crew Coordinator at the end of each collection day and follow proper 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 9. LCMS XML Data Loader.

➢ **Distress Rater Consistency Checks**

During the production phase of distress classification and rating via the Distress Selector Application, data is randomly selected for data consistency. Approximately 2.5% of each rater's extracted data is checked weekly and reviewed for completeness and accuracy by a Quality Control Manager and subject to the same quality standards as the Distress Selector certification process. If the data does not meet the acceptance criteria, the rater will be retrained and the data extracted for that week will be recollected.

5.3. Post Production

➢ **Post-Data Collection Processing**

After data collection is complete, field technicians upload raw field data to a 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. Vendor's Pavement Subject Matter Expert (SME) will process the collected data through proprietary LCMS RoadInspect software and apply the standard processing configuration parameters which will define distress classification thresholds and image formatting. The Pavement SME may reprocess the data multiple times with different configurations to ensure distresses are correctly identified and classified. Once data processing is complete, the LCMS data is loaded to the project database.

LCMS data is processed into 26.4 ft. LCMS images where each image represents one survey. The spatial location of each survey is extracted through a database procedure and mileposted to PTC's Location Referencing System (LRS) linework using GIS tools. Once each survey is assigned a milepost, the data can be aggregated into 1/10th mile sections for each route. The project database contains queries and procedures to quantify the reported distress values at each 1/10th mile section. An export procedure formats the data for delivery.

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, 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 proper 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.

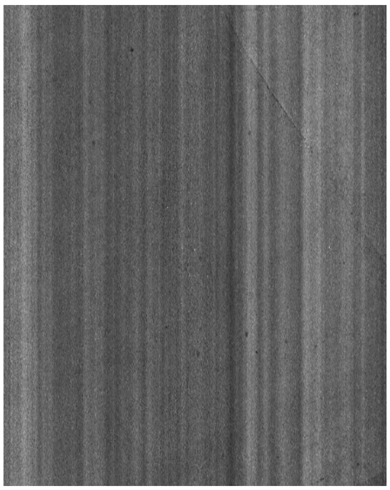
Distress Specific Database Checks

Review of the distress data (IRI, rutting, faulting, fatigue cracking, etc.) requires more 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:

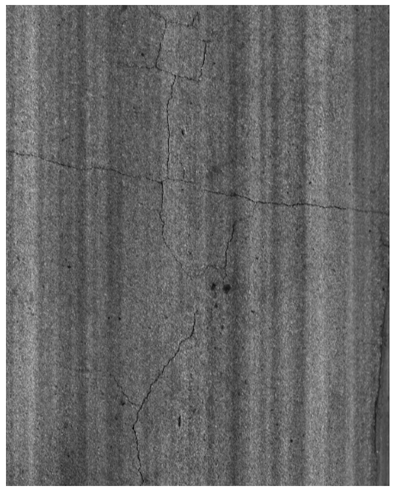
- Data exists for each road segment and milepost section
  - There should be ~20 FIS files for every 1/10th mile section
- Data is in the correct unit (mm, ft.) and rounded correctly
- Data is in the expected value range for the distress type
  - IRI should generally not have values of less than 30 or 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

Visual Verification of Distresses

As standard protocol, the LCMS Analyst will select 3% of sections for each distress type and condition rating. He/she 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 should 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 he/she 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, Vendor will perform field verification of distress and condition ratings to verify the data is accurate.

Compare Distress Values to Historical Data

Finally, 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 must be investigated. The reviewer should 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.

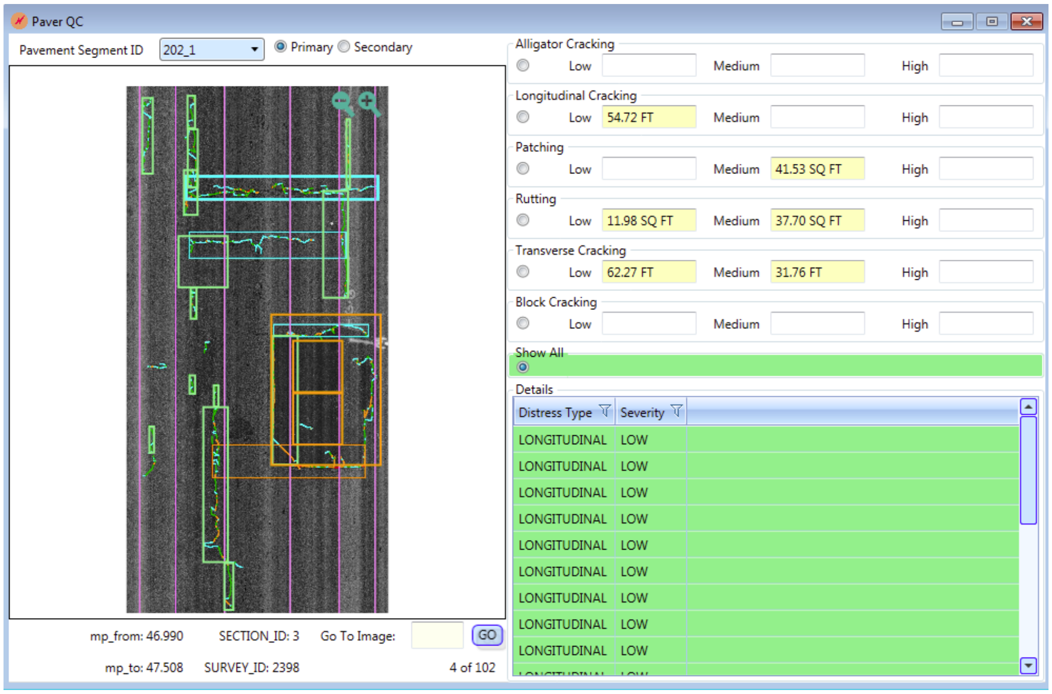
Table 13. Quality control activities.

Quality Control Activities			
Deliverable	**Quality Expectations**	**QC Activity**	**Frequency/Interval**
IRI Rut Depth Faulting GPS Coordinates	95% Compliance with Acceptance Criteria (Table 6)	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
Distress Ratings	95% Compliance with Acceptance Criteria (Table 6)	Rater Training and Certification	Pre-collection
		Manual Distress Quality Control Audits	Weekly
		Final data review	Prior to input into the PMS database
Location of Segment	100% Compliance with Acceptance Criteria (Table 6)	Comparison with Baseline File	Pre-collection
		Mileage review	Daily/Initial Post Process
		GIS Comparison	Daily/Initial Post Process
		Final data review	Prior to input into the PMS database
Panoramic Images LCMS Pavement Images	98% of each control section and not more than 5 consecutive images failing to meet criteria.	Startup checks, real-time monitoring, and field review	Daily
		Upload to workstation	Field delivery of data
		Final review	Prior to input into the PMS database

- **LCMS QA/QC Tool**

The Vendor 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 all work together to review a 2.5% sample of the network-level to assure 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.

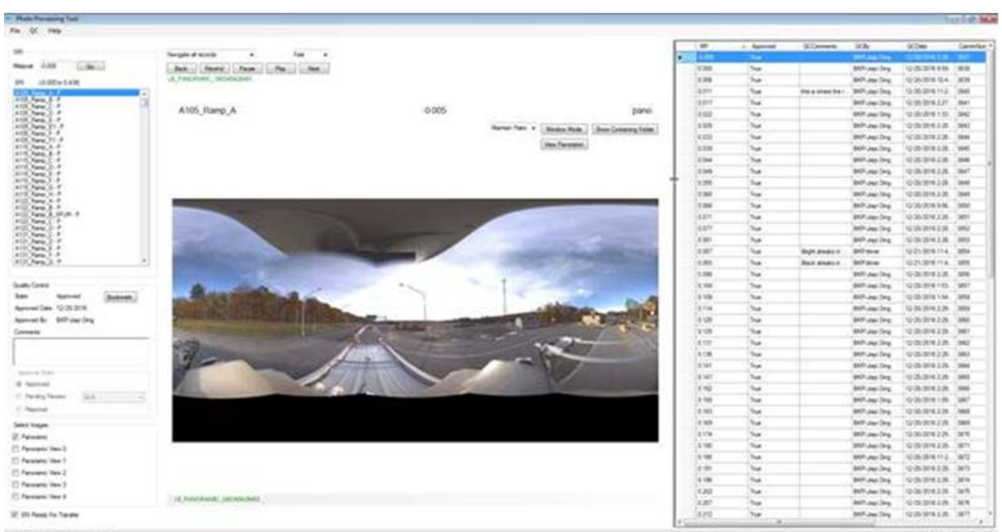
Figure 10. LCMS QA/QC Tool.



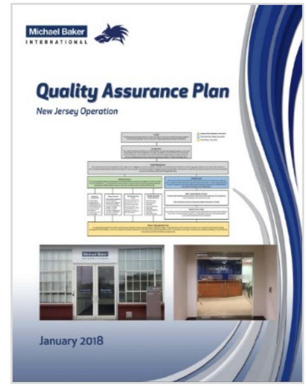
➢ Panoramic Image QA/QC Tool

The Panoramic Image QA/QC Tool is used to visually check all panoramic images across the network for clarity, focus, missing images, and appropriate lighting and contrast. While office processing staff conduct checks on 100% of the images, the Quality Manager and Data Processing Manager for the project all work together to review a 2.5% sample of the network-level to verify the review of office processing staff. If images do not meet Quality Standards, recollection is required if imagery is a required project deliverable.

Figure 11. Panoramic QA/QC Tool.

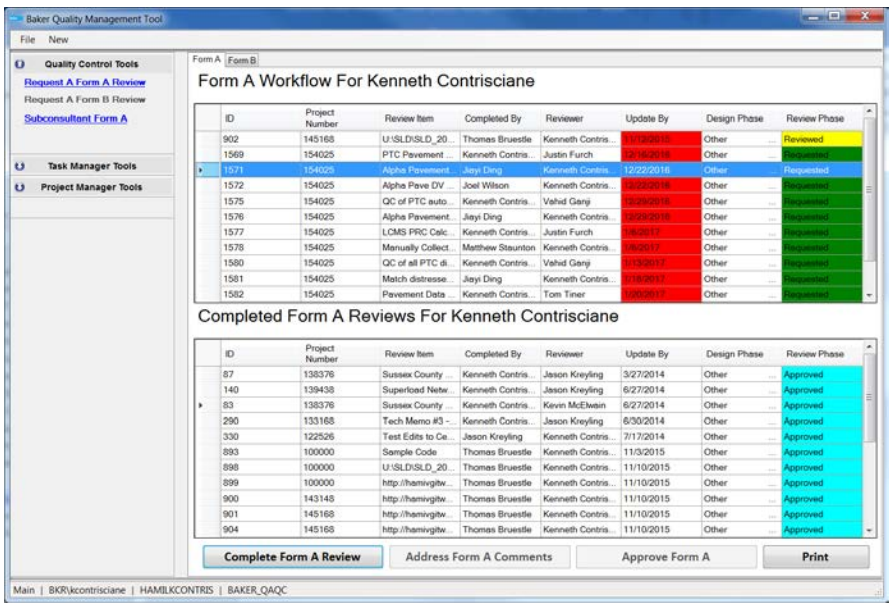


➢ Quality Management Reporting



All steps in the LCMS data review must be documented as per Vendor 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 Vendor 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 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 any 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 12. Vendor International Quality Management Tool.



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

APPENDIX K-A
Pub 336 Rating Protocol Summary

Distress	Severity Unit	Severity: Low	Severity: Medium	Severity: High	Reporting Unit	Comment
Rutting	Avg. Rut Depth	>= 0.25 and < 0.5 in. (6.35 - 12.7 mm)	>= 0.5 and < 1.0 in (12.7 - 25.4 mm)	>= 1.0 in (25.4 mm)	Section Length (ft)	• Measure along each wheel path independently • Maximum space between measurements is 30 ft (9.144 m) • Record length of each severity level
Bituminous Surface (Asphalt)						
Fatigue Cracking	Avg. Crack Width	<= hairline (up to 2 mm)	> hairline <= 0.25 in (2.0 - 6.35 mm)	>= 0.25 in (6.35 mm)	Section Length (ft)	• Only collect in outside wheel path • Sealed cracks are always 'Low' severity • ~Alligator Cracking • Record length of each severity level
Transverse Cracking	Avg. Crack Width	<= hairline (up to 2 mm)	> hairline <= 0.25 in (2.0 - 6.35 mm)	>= 0.25 in (6.35 mm)	Crack Length (ft)	• Cracks between 45 and 90 degress • Must be >= 1.0 ft (0.3048 m) in length • Sealed cracks are always 'Low' severity • Record number and length cracks at each severity level
Miscellaneous Cracking	Avg. Crack Width	<= hairline (up to 2 mm)	> hairline <= 0.25 in (2.0 - 6.35 mm)	>= 0.25 in (6.35 mm)	Section Length (ft)	• Measured between wheel paths. Transverse measured first • Sealed cracks are always 'Low' severity • Record length of each severity level. Can't exceed segment length • ~Block cracking and longitudinal cracking between wheel paths
Edge Deterioration	Avg. Crack Width	> hairline <= 0.25 in (2.0 - 6.35 mm)	> 0.25 and <= 0.5 in. (6.35 - 12.7 mm)	>= 0.50 in (12.7 mm)	Section Length (ft)	• Measured within 1.0 ft of right pavement edge • Record length of each severity level.
Bituminous Patching	Area	None			Patch Area (sq ft)	• Record number of patches and total area within a segment • Only patches >= 1.0 sq ft counted
Left Edge Joint	Avg. Crack Width	> hairline <= 0.25 in (2.0 - 6.35 mm)	> 0.25 and <= 0.5 in. (6.35 - 12.7 mm)	>= 0.50 in (12.7 mm)	Section Length (ft)	• Record length cracks at each severity level • Lies within 1 ft of left pavement marking strip
Rigid Surface (Concrete)						
Faulted Joints	Avg. Fault Measurement	No Low category	> 0.25 and <= 0.5 in. (6.35 - 12.7 mm)	>= 0.50 in (12.7 mm)	Joint Count	• Measured in outside wheel path only • Count number of joints that are faulted at each severity level
Broken Slab	Avg. Crack Width + Faulting + (IRI)	<=hairline No faulting IRI <= 100 in/mi	<=0.25 in (6.35 mm) > 0.25 and <= 0.5 in. (6.35 - 12.7 mm) IRI > 100 and <=200 in/mi	> 0.25 and <= 0.5 in. (6.35 - 12.7 mm) > 0.50 in (12.7 mm) IRI > 200 in/mi	Slab Count	• **If a slab is rated as broken, no other distresses are rated.** • Must have at least 4 broken pieces • Rate at highest distress level of the three
Transverse Joint Spalling	Spall Width	<= 2.0 in for any length of joint	> 2.0 in for <= 50% of joint length	> 2.0 in for > 50% of joint length	Joint Count	• Count total # of joints for each severity level.
Transverse Cracking	Avg. Crack Width	<= hairline (up to 2 mm)	> hairline <= 0.25 in (2.0 - 6.35 mm)	>= 0.25 in (6.35 mm)	Slab Count	• Cracks between 45 and 90 degress • Must be >= 6.0 ft (1.829 m) in length • Each slab has one severity level
Longitudinal Cracking	Avg. Crack Width	> hairline <= 0.25 in (2.0 - 6.35 mm)	> 0.25 and <= 0.5 in. (6.35 - 12.7 mm)	>= 0.50 in (12.7 mm)	Slab Count	• Cracks between 0 and 45 degress • Must be >= 6.0 ft (1.829 m) in length • Sealed cracks are always 'Low' severity • Record number and length cracks at each severity level
Longitudinal Joint Spalling	Spall Width	>= 1.0 and < 3.0 in, over 25ft	>= 3.0 and < 6.0 in, over 25ft	> 6.0 in, over 25ft	Section Length (ft)	• Record total length at each severity level
Bituminous Patching	Area	None			Patch Area (sq ft)	• Record number of patches and total area within a segment • Only patches >= 36 sq ft counted
Concrete Patching	Area	None			Patch Area (sq ft)	• Record number of patches and total area within a segment • Only patches >= 36 sq ft counted

APPENDIX K-B
Data Quality Activity Roles & Responsibilities Matrix

Appendix K-B - Data Quality Activity Roles & Responsibilities Matrix

Activity	Project Manager (PM)	Quality Manager (QM)	Field Crew Coordinator (FCC)	Fleet Manager (FM)	Field Crew (FC)	Distress Rater (DR)	Data Processing Manager (DPM)	Pavement Engineer (PE)
General Roles & Responsibilities	• Assure 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. • Assure that vehicle and equipment is maintained in a state of good repair.	• Perform field data collection.	• Perform distress rating in office (Distress Selector).	• Provide oversight of incoming raw field data through processed final deliverables.	• Serve as Technical Advisor and SME through the project.
Pre-Production Activities								
Personnel Training & Certification	• Assure that assigned staff & equipment have certification at project onset.	• Assure that assigned staff & equipment maintain certification throughout project. • Conduct Distress Rater certification program, training and testing & related documentation.	• FC training and documentation.	• Assure that assigned staff & equipment maintain certification throughout project. • Assure that profiler meets and maintains Class 1 status.	• Achieve and maintain NCAT certification status.	• Achieve and maintain Distress Rater certification.	• Assist QM with Distress Rating training and certification.	• Assist QM with Distress Rating training and certification.
Define Quality Standard & Acceptance Criteria	• Assure that data quality standards & acceptance criteria are well defined & documented before project onset.	• Communicate data quality standards & acceptance criteria to staff. • Assure 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.	• Awareness of data quality standards & acceptance criteria.
Equipment Configuration & Calibration		• Assuring equipment calibration process is documented.	• Training Field Crew on equipment calibration process	• Assure 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.	• Assure 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.	• Assure mission plan is documented.	• Develop mission plan and engage FC. • Assure 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			
Pre-Collection Test Runs	• Assure that test run results meet project quality standards & acceptance criteria.	• Assure that test run results meet project quality standards & acceptance criteria.	• Work with FC to conduct test runs		• Perform test runs in field.	• Perform distress rating of test runs.	• Oversee processing of test run data.	• Aid in test runs if needed.

Appendix K-B - Data Quality Activity Roles & Responsibilities Matrix

Activity	Project Manager (PM)	Quality Manager (QM)	Field Crew Coordinator (FCC)	Fleet Manager (FM)	Field Crew (FC)	Distress Rater (DR)	Data Processing Manager (DPM)	Pavement Engineer (PE)
Production Activities								
Daily Log Sheet	• Assure that Daily Log template is established for project.	• Perform periodic checks of Daily Logs for completeness	• Establish project Daily Log and assure 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	• Assure that WER report template is established for project.	• Perform periodic checks of WER report for completeness	• Establish WER report and assure 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.	• Assure issue with real-time data check issues.	• 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 any 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.	• Assure issues with Field Data Checker are resolved.	• Assure 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.	• Assure issues with XML Data Loader are resolved.					• Oversee application design and updates. • Run XML Data Loader and resolved issues. Log & report issues to QM.	
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.				• Correct issues resolving from consistency check issues. • Regain Distress Rater certification if necessary.		• Aid the QM with the distress rater consistency check.

Appendix K-B - Data Quality Activity Roles & Responsibilities Matrix

Activity	Project Manager (PM)	Quality Manager (QM)	Field Crew Coordinator (FCC)	Fleet Manager (FM)	Field Crew (FC)	Distress Rater (DR)	Data Processing Manager (DPM)	Pavement Engineer (PE)
Post-Production Activities								
Post-Data Collection Processing	• Approve issue resolution resulting from post-data collection processing.	• Assure 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.	• Assure 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.	• Assure issues with global data checks are resolved.					• Oversee global data checking process	
GPS Verification	• Approve issue resolution resulting from GPS verification.	• Assure 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.	• Assure proper 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.	• Assure proper 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. • Assure that all Quality Management activities have been conducted and documented. • Support PM with Quality Audits.	• 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.	• Document all role appropriate project related QA/QC activities using Baker Quality Management Tool.

APPENDIX K-C

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