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The Feasibility of Using an Instrumented Vehicle Equipped with Inertial Navigation Guidence System to Collect Roadway Grade and Cross-Slope Data for Safety Analysis

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THE FEASIBILITY OF USING AN INSTRUMENTED VEHICLE EQUPPED WITH INERTIAL NAVIGATION GUIDENCE SYSTEM TO COLLECT ROADWAY GRADE AND CROSS-SLOPE DATA FOR SAFETY ANALYSIS

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ABSTRACT

In 2005, the Federal Highway Administration (FHWA) requested the development for the initial version of the Model Minimum Inventory of Roadway Elements (MIRE). MIRE is a roadway inventory and traffic data collection data program that has a strong focus on improving the decision process in safety programs. MIRE is not a mandatory state program, but is strongly recommended based on its potential advantages. Some of the data required for MIRE was previously collected as a result of the requirements set from the Highway Performance Monitoring System (HPMS).

This thesis concentrates on the feasibility of determining as-built grade and cross-slope data using an instrumented vehicle equipped with GPS-aided MEM Inertial System by Crossbow, eliminating the need to manually extract data from design plans or use other methods. Instrumented vehicles should provide time savings in the data collection process and sufficient results, within the acceptable limits, for safety analysis. A calibration was performed on the Inertial Navigation Unit (INU) to test for any bias that may be present. Roadway data was collected by traveling multiple runs in each travel lane in both directions on the SCDOT Test Road and several road sections in Atlanta, GA. The included analysis tests the calibration of the INU by having a test road with high accurate as-built plans to test the grade, and survey data to test the cross-slope. The INU data was processed and compared to the obtained data to see what the absolute error was to determine if the results were acceptable for safety analysis.

DEDICATION

I dedicate this work to my parents, Carroll and Jackie Burrows, and my two brothers Jason and Jerrod Rhoades. Without their love and support through my entire life, I would not have been able to make it through college.

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CHAPTER 1

INTRODUCTION

In 2005, the Federal Highway Administration (FHWA) requested the development of the initial version of the Model Minimum Inventory of Roadway Elements (MIRE). MIRE is the counterpart to Minimum Model of Uniform Crash Criteria (MMUCC). MMUCC was developed to establish minimum collection and reporting requirements for crash reports and has led to better reporting programs and increased the use of the crash data. The purpose of MIRE is to establish an inventory of roadway and traffic elements that are critical to safety management [5]. Some of the data elements in MIRE are collected as a result of requirements from Highway Performance Monitoring System (HPMS). Other elements like roadway grade, superelevation and horizontal curvature would seem to be logically included in a standard roadway characteristics data, but according to Ogle [23], less than half the states responding to a survey indicated maintaining this information at all. The information about the roadway curvature and grade is valuable for the roadway serviceability, capacity, operations, and for making sound safety decisions.

Environmental Emissions Analysis is another area where roadway curvature and especially grade have a major impact. In recent history, new analysis tools and vehicles have been developed including Mobile6 Vehicle Emission Modeling Software (Mobile6) and fuel efficient hybrid vehicles with the change in grade have been developed. Mobile6 is a computer program that models vehicle emissions under different conditions.

The grade of the roadway is the main contributing factor on a roadway for increased emissions outside of congestion. Current research is also being done by Clemson University Mechanical Engineering to reduce the emissions in hybrid vehicles. By using the 3D roadway data, the power management system can determine when to be ready to use more energy and optimize engine performance with emissions.

Given the needs for geometric alignment data, and the limited availability of electronic source of this data, researchers are forced to go back to plan and profile sections. This tends to be inefficient and may not provide correct information if the plan sets are more than a few years old. However, an instrumented vehicle can be used to collect data on roadway geometrics, such as horizontal curves and grade, depending on the instrumentation configuration. For example, such a vehicle can be equipped to collect horizontal, vertical, and cross slope information along with video and GPS. These vehicles can be modified to fit the needs of a specific project. There are three predominant types of instrumentation that are capable of collecting data on the locations of the positions along a road. These three different types of instruments that are available to collect this type of data are the Global Positioning System (GPS) system, differentially corrected GPS (D-GPS), and the Inertial Navigation Unit (INU). The GPS provides location information that is valuable to discern the location of the roadway in a network. Even though the GPS is used for many specific applications, there is a major drawback due to intermittent signal loss that is involved with the GPS and causes a discontinuity in the trajectory of the data. That is why the inertial system is integrated in with the GPS to fill in the gaps when the GPS is timing out or if the satellite availability is not present.

D-GPS is similar to GPS, but is much more accurate. Most typical GPS units have an accuracy of 3 to 5 meters; however, with the differential corrections GPS receivers can obtain an accuracy of 1 meter or better. The D-GPS used in the Clemson University Instrumental Vehicle is equipped with Omnistar which is accurate to 1 meter.

INU aided with GPS has some added features that are not available on standard GPS units. Some of the features that are typically available on the INU are the high performance Kalman Filter, built in velocity and position measurements, heading and attitude measurements, and resistance to large vibrations. The INU also allows more frequent position reception. For the GPS systems, they are capable of collection data at a rate of 1 Hz, while the Inertial Navigation System is programmable up to 100 Hz with position at 4 Hz.

There are some Instrumented Vehicles currently being used now to collect roadway geometric alignment data, including the FHWA DHMV, MDOT vehicle, KDOT vehicle, Mandli Communication, Inc vehicle, etc. Mandli, MDOT, and FHWA vehicle all use D-GPS and INUs to collect grade and horizontal curve information. The KDOT vehicle uses GPS and videolog cameras to collect data for the evaluation of stopping sight distance. FHWA also added scanning lasers to collect data on superelevation and roadside features, such as slopes and location of hazardous obstacles. The FHWA has currently spent over 1 million dollars on their instrumented vehicle and related software [23]. MDOT received a federal grant to begin their instrumented vehicle for $101,000 [2].

MIRE has created a safety benefit with the push for data collection. Using an instrumented vehicle to collect roadway data increases the amount of data that can be collected and reduces the time that it takes to collect this data. It also keeps data collections personnel in the vehicle and out of harms way. The safety benefits are that it greatly enhances the decision process, because all of the roadway characteristics are available for review during the decision making process. MIRE may also improve access management by being able to share all the data electronically throughout the state agencies to reduce data discrepancies and improve in data management. It also benefits law enforcement divisions by providing a database in which roadway characteristics can be linked to crash locations to reduce police crash investigation time.

MIRE suggests a massive amount of data to be collected and stored for later use. It also prioritizes which data is more vital to collect and what data could be researched further and collected at a later project. These priorities are based primarily on whether the data are needed for various new safety analysis tools such as IHSDM, SafetyAnalyst and the Highway Safety Manual (HSM). Figures 1 and 2 show some of the characteristic that the MIRE requires [5].

Generic Variable Description	Definition	MMIRE Priority [12]	Ease of Data Collection [13]	HPMS [14]	IHSDM [15]	SafetyAnalyst [16]	TSIMS [17]	MMUCC
II. Roadway Alignment Descriptors								
II.a. Horizontal Curve Data (NOTE: Each data record will define an angle point or a single curve, even if the curve is a component of a compound or reverse curve. Spirals or other transitions are part of the curve.)								
100. Curve Identifiers and Linkage Variables	All variables needed to define location of each curve record and all variables necessary to link with other safety files	1	D*		Y			
101. Curve Feature Type	Type of horizontal alignment feature being described in the data record	1	D*					
102. Horizontal Curve Degree or Radius	Degree or radius of curve	1	D*	S	Y	S		YES
103. Horizontal Curve Length (Including Spiral)	Length of curve	1	D*	S	Y	S	E	YES
104. Curve Superelevation or Superelevation Adequacy	Either measured superelevation rate or percent or adequacy of superelevation when compared to AASHTO design standards	2	D*		Y			YES

Figure 1: Horizontal Curve Features in the MIRE (Source: [5])

Generic Variable Description	Definition	MMIRE Priority [12]	Ease of Data Collection [13]	HPMS [14]	IHSDM [15]	SafetyAnalyst [16]	TSIMS [17]	MMUCC
II.b. Vertical Grade Data (NOTE: Each data record will define an individual grade or the angle point or vertical curve linking two grades.)								
108. Grade Identifiers and Linkage Variables	All variables needed to define location of each vertical feature and all variables necessary to link with other safety files	1	E					
109. Vertical Alignment Feature Type	Type of vertical alignment feature being described in the data record	1	E					
110. Percent of Gradient	Percent of gradient	1	D*		Y	S	E	YES
111. Grade Length	Grade length	1	D*	S	Y			
112. Vertical Curve Length	Vertical curve length	1	D					

Figure 2: Vertical Curve Features in the MIRE (Source: [5])

Figures 1 and 2 show that all horizontal and vertical curve data elements except for the superelevation are a top priority for data that should be collected. Research is being done with instrumented vehicles to obtain this data at highway speeds. Currently some states are collecting this type of data. In the NCHRP 367 Report, a survey was sent out to all

50 states and only 20 of those states responded only 17 of them collect cross-section data and only 8 collect grade information and 7 collect horizontal curve information. Figure 3 shows the results from this survey [23].

Road Characteristics Data	Collect Comprehensively	Sample	As-Needed
Cross-Section Elements			
Number of lanes	17		
Lane width	17	1	
Lane type	15		
Shoulder width	17		
Shoulder type	17		
Edge treatments (SafetyEdge)	2		1
Median width	17		
Median type	17		
ROW width	7		1
Cross slope (normal crown)	4		
Barriers (type, length)	9	1	
Roadway Structure Elements			
Bridges	18		
Railroad crossings	16		
Multi-use paths/bike paths	7	1	
Pedestrian facilities	2	1	2
Tunnels			
Geometric Elements			
Grade	8	8	
Vertical curvature	7	6	
Horizontal curvature	9	6	
Superelevation	3	1	1
Sight distance	2	7	2
Speed limit	15	1	
Sign inventory	4		
Truck/weight restrictions	6		
Intersection Elements			
Number of lanes/approach	1	2	5
Signal timing	1	6	2
Traffic control	5	4	1
Pavement Elements			
Pavement material	15		
Pavement distress data	10	1	
Skid resistance	6		1
Ride quality	12	2	
Pavement markings	1		2

Note: ROW = right-of-way.

Figure 3: NCHRP 367 Survey of State DOTs (Source: [23])

According to FHWA reports on design exceptions, grade and cross-slope have an adverse affect on crash statistics [24]. Grade has effects on the accident rate along with the stopping sight distance. With an increase in the grade on a roadway, the accident rate also increases. This is especially apparent in big trucks because they cannot stop as quickly as they ascend steep downgrades. This increases the need for accurately measuring the grade with instrumented vehicles. Figure 4 shows the affect of the grade on the accident rate and what types of accidents are concerns based on roadway classification. As the grade increases, so too does the crash frequency.

Grade (%)	Accident Modification Factor
0	1.00
2	1.03
4	1.07
6	1.10
8	1.14

Safety and Operational Issues	Freeway	Expressway	Rural Two-Lane	Urban Arterial
Trucks losing control descending grade	X	X	X	
Risky passing maneuvers			X	X
Reduced speeds ascending grade	X	X	X	X
Reduced speeds descending grade	X	X	X	X
Run-off-road crashes, particularly where steep grades are combined with horizontal curves	X	X	X	
Rear end crashes descending grade	X	X	X	
Slick pavement (flat grades)	X	X	X	X
Water ponding on the pavement surface (flat grades)	X	X	X	X
Water spreading onto the traveled lanes (flat grades)				X

Freeway: high-speed, multi-lane divided highway with interchange access only (rural or urban).
Expressway: high-speed, multi-lane divided arterial with interchange and at-grade access (rural or urban).
Rural 2-Lane: high-speed, undivided rural highway (arterial, collector, or local).
Urban Arterial: urban arterials with speeds 45 mi/h (70 km/h) or less.

Figure 4: Accident Modification Factors for Grade (Source: [24])

Figure 5 shows safety risk associated with non-standard stopping sight distance with the change in grade based on various geometric conditions [24]. It shows that under a 3% grade, there is a relatively low safety risk, but when it increases to greater than 5% grade, there is a major safety risk.

Geometric Condition	Relative Safety Risk
Tangent horizontal alignment	Minor
Mild curvature >2000 ft (600m) radius	
Mild downgrade (<3%)	
Low-volume intersection	Significant
Intermediate curvature 1000 ft (300 m) to 2000 ft (600 m) radius	
Moderate downgrade (3–5%)	
Structure	
High volume intersection	Major
Y-diverge on road	
Sharp curvature <1000 ft (300 m) radius	
Steep downgrade (>5%)	
Narrow bridge	
Narrow pavement	
Freeway lane drop	
Exit or entrance downstream along freeway	

Figure 5: Safety Risk as related to Stopping Sight Distance (Source: [24])

Superelevation or cross-slope is also a major safety concern especially when it comes to deficiencies. Deficiencies in cross-slope can lead to an increase in run-off the road crashes and rollover crashes in large trucks. Accurately measuring the cross-slope of a roadway is important, but to what accuracy should it be measured and the accuracy can vary based on the application of the data. There are some other options out there to offset the deficiencies in cross-slope. One is to increase the friction by applying a high-friction surface treatment such as TYREGRIP® to the asphalt or concrete surface. TYREGRIP® increases the friction allow for better traction in a curve. The other option is to increase the radius of curvature, but this option is very expensive. Figure 6 shows the accident rate modification for the deficiencies in superelevation and what safety issues are concerns based on roadway classification [24].

Superelevation Deficiency	Accident Modification Factor
0.02	1.06
0.03	1.09
0.04	1.12
0.05	1.15

Safety & Operational Issues	Freeway	Expressway	Rural Two-Lane	Urban Arterial
Run-off-road crashes	X	X	X	
Cross-median crashes	X	X		
Cross-centerline crashes			X	
Skidding	X	X	X	X
Large vehicle rollover crashes	X	X	X	

Freeway: high-speed, multi-lane divided highway with interchange access only (rural or urban).
Expressway: high-speed, multi-lane divided arterial with interchange and at-grade access (rural or urban).
Rural 2-Lane: high-speed, undivided rural highway (arterial, collector, or local).
Urban Arterial: urban arterials with speeds 45 mi/h (70 km/h) or less.

Figure 6: Accident Modification Rates for Superelevation (Source: [24])

<u>Objective</u>

The objective of this research is to acquire, install, develop data collection procedure for and test the ability of the low-cost inertial navigation unit to collect accurate vertical grade and cross-slope data. Roadway data was tested by calibrating the instrumentation to a known test road. Data was collected by making multiple runs in each direction with the instrumented vehicle. The data was extracted to the correct formats and then compared to each other to check the precision of the instrumented vehicle; then compared to the roadway data collected from design plans and data obtained from other projects.

The remaining chapters of this thesis include:

- Literature Review – Summarizes previous research that was done on INU, GPS, and fleet studies.

- Methodology – Explains how GPS and INU data were collected on the Test Road and selected sites and the approach used to extract data.
- Results – Summarizes the grade and cross-slope analysis data for the validation on the Test Road and the analysis on the selected sites.
- Conclusions and Recommendations – Describes the results of the study and recommendation for future research based on the study.

CHAPTER 2

LITERATURE REVIEW

Grade data can be obtained from a number of sources. The most popular sources include surveying or obtaining as-built plan sets. Additionally, a number of mapping companies provide digital terrain to enable development of digital terrain models (DTM). A forth source involves using an instrumented vehicle to collect grade/cross-slope data. The literature review will predominantly focus on available instrumented vehicles, data that they provide, and a government field test of some of the commercial options. These sources range in cost from two hundred dollar systems for the Georgia Tech "Commute Atlanta" Project to over one million dollars for the FHWA DHMV vehicle. With the variation in cost, there is also a variation in accuracy. For instance, the FHWA DHMW obtains very accurate results shown in Figure 7 shown later in this section to several of the fleet studies with GPS units with 3-5 meter accuracy. Due to the limited publicized cost and accuracy data for several of the fleet and instrumented vehicles, only some of the feet and instrumented vehicles have the cost and accuracy data.

Digital Elevation Models (DEM) is represented as elevation information on computers to provide elevation data in a digital format [16]. DEM's show a computer representation of the Earth by it elevations. Different formats for this information are used and some of the most commonly used are the triangulated irregular networks (TIN), contour lines, and a standard grid. Some of the downfalls to DEM are that since the model is created by the use of aerial photogrammetry and reference datum. This creates discontinuities in the coverage and accuracy of the data.

Some of the different applications of DEM are used in scientific applications and commercial applications among others. A scientific application used is Geographical Information System (GIS) which uses this data to as a reference in creating coordinate systems and also can be used to geocode satellite images. Commercial applications use remote sensing in order to measure the Earth's elevation at the surface. There is also a large amount of data that is readily accessible to the commercial industry which data for elevations in large areas so that a surveying crew may not be needed out in the field. Another commercial aspect that uses DEMs is the planning and construction. It makes it easier for a road design group to be able to look at long stretches of area for a design of a new roadway. It also helps in other construction such as, railways, pipelines, and power lines to know the land profile for easier placement of materials.

Instrumented Vehicles

Instrumented Vehicles are used to study all different aspects of the driver behavior and roadway features. One of the current areas of study is the in use of fleets of instrumented vehicles. A few instrumented vehicle studies are currently being completed or the data is currently being analyzed are the "Commute Atlanta" Project, one by RPI, one by LUND in England, and Virginia Institute of Technology.

“Commute Atlanta” Project

The “Commute Atlanta” Project was conducted by the Georgia Institute of Technology (Georgia Tech) and was conducted in order to product multiple types of data. One of the types of data that was analyzed during this project was the driver behavior. Most instrumented vehicles are focused on roadway characteristics, but this project tried to take a closer look at the driver’s speed and behavior during normal driving conditions. The data processor inside these instrumented vehicles records data on the location, speed, and acceleration. Another purpose for the “Commute Atlanta” Project was the mapping of the commuting habits of the 500 different drivers and their behaviors.

Georgia Tech investigated many different options for collecting roadway characteristics, including conventional surveying of the roadway, GPS-aided surveying equipment, inertial guidance systems, the use of as-built plans, and the use of digital terrain models [11]. After the completion of this study, the researchers concluded that the traditional surveying and GPS-aided surveying were too labor intensive and time consuming, the inertial guidance systems, such as the ones being used in other instrumented vehicles by Michigan DOT, FHWA, and VISAT, were too expensive, and while using as-built plans provide accurate results, they are time consuming in a format easily lost or destroyed. The digital terrain models were found to have poor resolution due to being developed from high-altitude aerial photogrammetry surveys.

In conclusion of this research, the Georgia Tech researchers decided to use a fleet vehicle approach. Researchers mapped the commuting habits of 500 drivers in the Atlanta area. This project, the Commute Atlanta Project, recruited 275 households to use a “black box” in their vehicles to track their movements, transferring the data to the main server on Georgia Tech campus in real-time for analysis. All of the more than 100,000 trips generated from this project, provided data on the speed, position, and acceleration of the vehicles throughout the trips. The use of multiple trips is very useful for extracting the horizontal alignment information needed for data processing. One of the major applications of this type of instrumentation in vehicles is for geographic information systems and trip chaining.

Another type of information that came from the conclusion of this project is driver behavior. Researchers were able to study speeding habits in groups of all ages with respect to their total travel. The Federal Highway Administration had researchers study long distance travel. The Environmental Protection Agency (EPA) also has interest in the project because of the acceleration data that was collected. This could be used to map the areas that have higher amounts of emission release.

Additional advantages of this type of instrumentation is that it is much more cost efficient than the other methods. The box used in the Georgia Tech study cost less than two hundred dollars which is way less than the aircraft quality INUs and multiple Charge-Coupled Devices (CCD) cameras. Because of the reduced cost, hundreds of boxes were installed in vehicles to obtain the 100,000 trips that are currently in the database. A disadvantage to this type of data collection is that this GPS is not as accurate as some of the others, a situation addressed by the multiple trips which reduce the error.

Virginia Tech

The Virginia Tech Transportation Institute (VTTI) built an instrumented vehicle fleet on a smaller scale, but with more sophisticated equipment than that used by the Georgia Tech Project. They conducted a 100-car naturalistic study across one year of time to access crash safety. The study was more focused on the driver behavior with some of the same instrumentation that is used by other companies with instrumented vehicles [20]. One of the primary objectives for the VTTI study is to provide the essential data on pre-crashes so that a better analysis can be made as to what causes crashes. Another objective is to be able to refine and develop new countermeasures for potential crash avoidance and be able to test these countermeasures to see their potential consequences.

The VTTI study involved 100 vehicles that collected data over a year time period in the Northern Virginia and Washington D.C. areas. Seventy-eight out of the one hundred instrumented vehicles were privately owned by the participants and the other twenty-two were leased vehicles that were provided to the participants. Due to the vehicles being in multi-person households, there were 109 primary drivers included in the study. Also the occasional children and friends using the vehicles, there was an added bonus of 132 additional drivers where data was collected for the VTTI study.

The VTTI instrumented vehicles were equipped with an instrumentation packaged that was especially designed for this study and was engineered by VTTI. The data storage capacity for each vehicle allowed the vehicle to run for several weeks before the data had to be downloaded. Each system was equipped with accelerometers for longitudinal and lateral information, headway detection system to show the leading and lagging vehicles, side obstacle detection, lane tracking system that runs of the advanced video system, incident detection box, GPS, and video cameras. The most complicated design for the VTTI instrumented vehicles is the five camera setup in each vehicle. These cameras are an integral part of the system to show what is happening in and around the vehicle. The five cameras show the driver's face, the driver's side of the vehicle, the front view, the rear view, passenger's side of the vehicle, and a shoulder view of the surrounding area as seen by the driver. The "incident" box that is present in the vehicles is also interesting feature for the instrumented vehicle. The box allows the driver or passenger to send a silent call for help if anything suspicious is going on around them.

The collected data from the VTTI study has not been used in roadway analysis. This data is currently being used for pre-crash avoidance, but the GPS data can be used for speed and grade data in the future.

California PATH

California PATH researchers devised a plan to compute moving vehicle position with two centimeter by combining a highly accurate GPS receiver and an inertial system [4]. They developed an algorithm to allow for a more effective integration between the GPS, the INU, and magnetometers using a series of magnets to measure the distance between the cars and are embedded in the pavement. These magnetometers have an accuracy of 1.0 centimeters. In the test of this system, the results indicated that roadway data such as the horizontal features are easier to understand and analyze, while the vertical alignment data was found to be less precise only accurate to approximately 15 meters of the designed altitude of the roadway.

GPSVision System

GPSVision, a system installed and integrated in a vehicle, collects the same types of roadway geometric data as instrumented fleet vehicles [6]. It includes three key components: high resolution digital cameras, an inertial navigation system (INS), and a dual frequency GPS receiver, all of which combine in various configurations specific to the instrumentation desired. As a result, this system can be used on a variety of vehicles.

The GPS layer in the GPSVision System provides information on GPS timing, satellite data and status information, along with changes in direction and speed data. For this purpose, the system uses first and second generation receivers, the former for obtaining up to sub-meter accuracy, and the latter when the information requires accurate location information within 10 centimeters for the horizontal alignment.

When analyzing horizontal curvature, the INS positioning equation is used to create the prediction module illustrating the smoothing of the data. Although several filters can be applied for the best results past researchers indicate that the Kalman filter achieves the best smoothing results.

Mandli Communications, Inc., Vehicle

Mandli Communications has many different services available that have proven the versatility their instrumented vehicle service offerings in four different categories;

road, pavement, bridge, and rail. Mandli's vehicle collects vehicle position, velocity, attitude track, speed, and dynamics while traveling at posted highway speeds, up to seventy miles per hour. Mandli has expanded into software with one key software package, the Curve and Grade software, which converts the data collected into centerline maps of the roadway, and other geometric data such as the curvature, grade, and cross-slope output from the program [9]. The Curve and Grade software can be used for both roadway and rail systems.

The Mandli vehicle was designed to fit a Hummer H2 and was called the Digilog VX. This vehicle contains an integrated system designed for the collection of roadway data which can be customized for more specific tasks within the road systems data collection. Some of the customized systems include high-resolution imagery of a roadway, real-time GPS data logging, detailed curve and grade information, sign inventory and measurement information, and the retroreflectivity of road signs. The Digilog VX is equipped with an inertial measurement unit (IMU), two GPS receivers, and other data acquisition sensors. The reason for the two GPS receivers is because the Position Orientation System (POS) needs a dedicated receiver to function properly and the secondary GPS receiver averages values and serves a backup for the first receiver for when it is not operating properly. Simultaneously, the two receivers serve as a heading sensor, which improves the heading accuracy and the reliability of the GPS data because the IMU is the primary source for the collected data. This sensor measures position and orientation difference and it outputs the raw data representing 3-axis acceleration and angular rotation of the vehicle. The POS uses differentially Corrected GPS receivers which provided the real-time positioning of the vehicle.

Roadware Group, Inc. Vehicle

Roadware Group has been collecting data for 35 years with a specialization in Infrastructure and Pavement Management. The Roadware Group created their own instrumented vehicle service in order to collect different types of roadway information and characteristics. Roadware Group created Roadware's Automatic Road Analyzer (ARAN) in order to collect roadway characteristics and other information depending on the project. The ARAN was designed to be adaptable to multiple different variations of vehicles and is currently used on 6 different vehicles by the Roadware Group. The objective for Roadware Group is to ensure that the results can be repeated, eliminate subjectivity, and to have consisted data [13].

The ARAN has multiple applications that can be applied to roadway geometry. Some of the information that the ARAN can produce from the data that it collects is the grade, cross slope, super elevation on a curve, the degree and radius of curvature, and mark one the GPS spot where the start and stop of a curve was. This is done through the integration between the GPS and the inertial Reference System. The integration was completed in order to fill in the gaps between the GPS point in the instance that the satellite is lost due to available, tree overage, driving under an overpass, or various other obstructions that could cause a lapse in GPS data. The INU in this case would be able to fill in the gaps and keep a continuous path through a roadway.

The ARAN has been purchased by different state DOTs and private companies in order to do research and collect data information on their roadways. One group that purchased an ARAN was the Connecticut Department of Transportation (CTDOT). The CTDOT took their ARAN a step further and developed an algorithm to better process the data that the ARAN was producing. The algorithm uses the video log data and the data produced from the inertial measurement unit. The algorithm was part of a software package called the horizontal curve classification and display system (PLV-HC). The algorithm consists of three different parts: a curve finder, a curve fitter, and a curve patcher. The curve fitter is the most significant part of the algorithm for any type of analysis. The curve finder part identifies the arcs and tangents of the roadway, while the curve fitter identifies the best arc and applies that as the roadway centerline. The results given from this algorithm are improved in consistency with the use of multiple runs on the same roadway segment and also show improvement in accuracy with the as-built plans of the roadway.

The University of North Carolina conducted a study in their Highway Safety Research Center in order to fully evaluate the effectiveness of the CTDOT algorithm. This study was conducted on ten two-lane rural roadways segments and each segment had five runs made in each direction with the CTDOT ARAN in order to obtain a sufficient amount of roadway data. The results from this experiment showed that the centerline of the roadways varied from the as-built plans by less than 165 feet or 50 meters. Another result that was checked was the accuracy of the data. The accuracy showed that only 50% of the time the data produced from the runs was considered to be in good or excellent agreement with the as-built design plans.

RoSSAV Vehicle

The strategy of building a mobile system that collects information about the roadway was to be able to analyze the data for a safety analysis [15]. The Road Safety Survey and Analysis Vehicle (RoSSAV) was created in order to evaluate roadside safety. In order accomplish this task; multiple sensors are going to be installed in an instrumented vehicle. Some of the sensors that are used in this vehicle are GPS, inertial measurement unit, distance measurement instrument, and Charge-Coupled Device (CCD) cameras [14]. For all of the horizontal and vertical alignments, the GPS and the inertial sensors are the only two that are used for the relevant information. Only when the cross section information is needed, the laser scanners and the cameras are needed for further information.

The integration of the GPS and the inertial is conducted to get the best parts of each sensor. The GPS unit has high position accuracy over longer periods of time providing uniform accuracy of the extent of the data collection. The GPS unit has some downsides by having a low output rate compared to the inertial and noisy altitude information. The INU also has high position accuracy, but the difference between the inertial and the GPS unit is that the inertial is only good over a short period of time. Some upsides to the INU are that it has accurate altitude information, and no signal outages. The integration of these two systems was one of the first things that RoSSAV had to do. Along with the integration the synchronization of the timing within the different sensor is critical to be able analyze the data for different types of analysis. The road safety analysis done by the RoSSAV is accomplished by first synchronizing the GPS, inertial, front mount, and side mounts cameras.

TRG Vehicle

The Transportation Research Group, Inc (TRG) instrumented was created as one of the only models in Europe. This instrumented vehicle was originally designed in order to study driver behavior, but with the equipment onboard the TRG vehicle also has implications in the transportation [18]. The information about the driver's behavior on the roadway will allow for a better understanding of design purposes. The vehicle is equipped with a GPS specifically designed to take the positioning for the instrumented vehicle.

The vehicle is designed to collect data in two different modes, active and passive. With active mode, the vehicle is testing the subject driving along with the reaction of the driver ahead of them and the distances from which the car ahead of the test vehicle is traveling. With passive mode, the vehicle is designed to be observing the following traffic and with a range finder tracking the distances behind the vehicle.

Since the TRG deployment, this instrumented vehicle has been used in many different projects. Most of the projects have focused on driver behavior and speed. One of the projects that used the TRG vehicle is called DIATS. The DIATS project was designed to identify some options that are available for implementing co-operative driving, finding and developing areas where the highest potential for impact of a roadway system, and to develop and identify the key elements that need to be tested and/or implemented in the system.

VISAT Vehicle

The VISAT vehicle is different from most of the other instrumented vehicles because it uses two different GPS receivers. The reason for the two different GPS units is to increase the accuracy of the system while traveling at highway speeds and collecting data [14]. The system integrates technology from multiple sensors, such as inertial, satellite, and CCD cameras. System integration is an integral part in reaching the requirements for the survey market. The overall objective for the project of creating the VISAT instrumented vehicle is to obtain the accuracy rating of 0.3 meters with respect to a given control [17].

The GPS provides information that is valuable or designed for a specific application. Even though the GPS is used for the specific applications, there is a major drawback of the cycle slip that is involved with the GPS and causes a discontinuity in the trajectory of the data [14]. That is why inertial system is integrated in with the GPS to fill in the gaps when the GPS is timing out or if the satellite availability is not present.

The VISAT vehicle has many different applications for the technologies that van has in it. One of the applications includes the inventorying of the different structures and infrastructures present on a roadway. Another application is analyzing the road signs and the sign network and all of the collected data can be used in order to plan a network as well. One of the unique applications that is useful for the law enforcement department is the mapping and inventorying of the roadways. This provides a good support document for the local and state law enforcement departments.

Georgia Tech's GPS with an Attitude Vehicle

The Georgia Institute of Technology (Georgia Tech) used GPS technology with multiple antennas to collect roadway alignment, grade, and cross-slope data using an instrumented vehicle [12]. These characteristics were used in a geographic information system (GIS) to model vehicle emissions for the Environmental Protection Agency (EPA). Georgia Tech researchers also investigated several other methods for determining roadway characteristics, such as conventional surveying, GPS aided surveying, inertial guidance systems, the use of as-built plans, and the use of digital terrain models. It was determined that the both forms of surveying required too much time to collect data. The inertial guidance systems, such as those used by MDOT and in the VISAT vehicle, are typically too expensive to be used in this application. Using as-built plans provided accurate results but gathering the plans required too much time and some of these plans were dated. The digital terrain models were found to be difficult to use due to poor resolution.

The Georgia Tech vehicle focused their efforts on a low cost vehicle with multiple GPS antennas and one multichannel receiver to collect data. After several layouts for the multiple GPS antennas were tested, the shape that provided the most accurate results was found to be the cross shape. The multiple antennas were used to accurately determine the attitude of the vehicle, which was then post-processed into cross-slope and grade data.

FHWA DHMV Vehicle

The FHWA DHMV vehicle, one of the more advanced instrumented vehicles available in the market today, collects data on roadway geometry for assessing the pavement conditions [19]. This vehicle includes some of the modern technologies used in aircraft, for example the high-resolution inertial navigation unit is used to determine the location of the airplane. In highway research, this unit plays an integral role in determining the highway geometry. Another crucial component in the FHWA DHMV vehicle is the high accuracy nationwide differential geographic positioning system (HA-NDGPS) unit.

This FHWA DHMV instrumented vehicle was first used in a field test conducted for Pennsylvania DOT. This project involved collecting data on the retroreflectivity of pavement markers to improve roadside safety in rural areas. The information collected by the lasers, INU, and GPS was used to create a visual model of each roadway traveled. The FHWA vehicle also uses sensor for object locations. This is used for sign inventory and locating them to determine clear zone characteristics.

FHWA has set the standard for instrumented vehicles, but they also have the most funding available. Figure 7 shows accuracy of the Digital Highway Measurement Vehicle (DHMV) that FHWA has been researching and building of the past several years [23].

Parameter	Accuracy
Pavement Marking	Less than 1 in.
Edge of Pavement	Less than 6 in.
Vehicle Wander	Less than 1 in. when pavement markings are available
Cross-Slope	0.01%
Roadside Profile	0.03 in. at range of 7 ft 0.14 in. at range of 30 ft 0.24 in. at range of 50 ft
Horizontal Alignment	Less than 2 ft
Vertical Alignment	0.01%

Figure 7: Accuracy of the DHMV built by FHWA

The FHWA is one of the most expensive instrumented vehicles for collecting geometric data of roadways. The current cost of the FHWA DHMV is approximately $1 million [23]. Future researchers hope to determine whether a lower grade GPS and inertial equipment can be used instead of the equipment used in expensive aircraft guidance systems.

Kansas DOT Vehicle

The Kansas Department of Transportation has been systematically collecting GPS longitude, latitude, and elevation data, on its roadways since 1997, videologing the roadway and pavement management systems through two projects over the past decade [15]. Since the beginning of these projects, GPS data on approximately 11,500 miles of Kansas roadway have been collected, amounting to more than 11 million data points. Using these GPS data, new high-accuracy geometric highway models have been produced for Geographic Information Systems (GIS) purposes, including the creation of geometric models for Kansas highways. One application of these new models of the state highway system was the sub-standard stopping sight distance (SSD). In addition, using multi-run GPS data, a highly accurate spatial model was created.

The sizeable amount of highways surveyed complies with the increased amount of GPS points improves the number of GPS points means an improved accuracy in modeling the highway geometry. Currently the Kansas DOT is using these data to evaluate the vertical sight distance on a roadway, and in future projects, it hopes to evaluate the horizontal sight distance, sight distance at access points, and maintaining the GIS maps.

In the evaluation of the roadway, Kansas DOT breaks it up into segments around 0.2-.04 miles long and uses the least squares method which minimizes and estimates the polynomial parameters. Boundaries constraints are then included at the intersections on successive sections of roadway. The residuals from the polynomial parameter estimates were then used to estimate bias for each GPS track until it fits with the model. The final adjustment is done with an absolute position uncertainty measurement.

<u>Michigan DOT Vehicle</u>

After the federal mandate to inventory roadway curvature and grade, Michigan DOT decided to build an instrumented vehicle in order to do the work. This was after the manual measurements for the roadway curvature and grade were determined to be very labor intensive. So Michigan DOT proposed to FHWA to receive a $101,000 grant to build an instrumented vehicle like the FHWA van for data collection purposes [2].

The Michigan DOT vehicle was a two phase process with the first phase was the instrumentation of a Chevy van with a computer system and an inertial system. The inertial navigation unit is aircraft grade costing $69,000 itself. The INU was used to produce the data for test sites with curve and grade information. The second phase of the project incorporated a sub-meter GPS unit to provide an improvement in accuracy for the curve and grade data. Integrating the high grade GPS with the INU helps to minimize the limitations of using the inertial navigation unit alone.

Michigan DOT uses the Kalman filter for a smoothing algorithm on the roadway curvature data, after research was done to determine which filter to use one reason for using the Kalman filter was to stay within the limitations present in an INU [3].

NCDOT Instrumented Vehicle Rodeo

In an effort to help states inventory their state highway system, NCDOT tried to identify the most useful, cost-effective way of inventorying roadways with the new advances in technologies [22]. NCSU researchers came up with a way to compare outputs from different instrumented vehicles. Participating vendors collected data on a 95-mile test course near Raleigh, NC to test their accuracy in collecting various data such as pavement data, bridge information, geotechnical features, and roadside appurtenances. This research was a "sealed envelope" project "wherein the identification, location, description, and quality of the asset data elements ate known only to NCSU researchers" [23].

The participating venders collected the given data on the 95 mile section of roadway and then processed the information to be compared by the researchers. The researchers manually surveyed the roadway information to obtain the most accurate results possible to compare the instrumented vehicle results to. The venders that participated in collecting data on the roadside appurtenances collected data on horizontal curves and vertical curves. This information was useful for understanding efficiencies and accuracy levels of the instrumented vehicles. The results from the NCDOT Rodeo for the Horizontal Curve measurement and the Vertical Curve Measurements are shown in Figures 8 and 9, respectively.

			Vendor Observed/Classified					
Factor	Level	Manual	Navteq		Pathway		Roadware	
		# Obs.	#	%	#	%	#	%
# of Horizontal Curves	Total	4	4	100%	4	100%	4	100%
Average Length Difference[a]	Average	---	652	97%	549	90%	414	60%
Average Radius Difference[b]	Average	---	571	26%	1987	99%	1145	49%
Average Cross Slope Difference[c]	Average	---	--[d]	n/a	2	28	1	23%

[a] Average of horizontal curve length difference in feet and percent between manual and vendor data.
[b] Average of horizontal curve radius length difference in feet and percent between manual and vendor data.
[c] Average of horizontal curve cross slope difference in slope and percent between manual and vendor data.
[d] Data not provided.
n/a: Not Applicable.

Figure 8: Results for the Horizontal Curve from the NCDOT Rodeo

Factor	Level	Manual	Vendor Observed/Classified					
			Navteq		Pathway		Roadware	
		# Obs.	#	%	#	%	#	%
# of Vertical Curves	Total	12	12	100%	7	58%	12	100%
Average Length Difference[a]	Average	12	147	19%	1381	177%	285	40%

[a] Average of vertical curve length difference in feet and percent between manual observation and vendor data

Figure 9: Results for the Vertical Curve from the NCDOT Rodeo

The results from the horizontal curve portion show that for the cross-slope data, Roadware was the closest to the manual data collection. The chart is showing that there data was 23% different from what was manually collected in the field compared to the 28% produced by Pathway. The results for the Vertical Curve read the same way. Naveteq was the most accurate in their data collection and processing by only being 19% different than what was manually collected in the field.

This raises the question as to what is the acceptable limit for the grade and cross-slope data. The results from the NCDOT Rodeo said that before a study like this is done, a state should have a crystal clear set of specifications from the beginning [23]. Also before doing a study like this, a state should have the vendor do a sample run of data and check for discrepancies before embarking on the full project.

Data Requirements

With all types of data collection, there are certain types of data that is required in order to obtain the best results possible. For the vertical alignment data produced by the GPS and the INU, there are multiple data elements that are required in order to be able to specify the vertical alignment of a given roadway. These elements are given in the IHSDM as the vertical point of intersection, cross slope and station equation [7].

IHSDM has defined the different roadway characteristics based on their requirements. The first element of vertical alignment is the vertical point of intersection (VPI) which defines the point where the back grade and the forward grade would intersect. The back grade and forward grade are the grade of the roadway, measured in percent, at the vertical point of curvature (VPC) and the vertical point of tangency (VPT), respectively. Other design elements for the VPI are the back length, forward length, and the VPI station. The back length is the distance, measured in feet, from the VPC to the VPI, and the forward length is the distance from the VPI to the VPT. The VPI station is the location along the stationing of the curve that the VPI is located. The vertical tangent and the vertical curve can be derived from information in the VPI. This is done with the stationing and grade elements.

The next element to a vertical alignment is the cross slope of the roadway. The cross slope is defined as the superelevation of the roadway. The cross slope is only defined at four points along the roadway segment. These are the normal cross slope, full superelevation, runout-runoff transition, and flat. The normal cross slope is when the roadway has a cross slope between the grades of -1% and -7% and is measured from the center of the road to the edge of pavement. Full superelevation is achieved when each direction of travel along the roadway has the same slope, but with a different sign. Runout-runoff transition occurs when one side of the roadway is at 0% slope and the other side of the roadway is still at normal cross slope. Flat is represented when both sides of the roadway are at 0% slope. This condition only occurs during a horizontal curve.

The heading element is the direction at which the roadway segment is facing and is used for the stationing element. More specifically, the heading is the instantaneous azimuth heading of the centerline. The elements that are associated with the heading are the station, northing coordinate, and easting coordinate. The station is the specific location of a point when being associated with a highway or design element. The northing and easting coordinates represent the X and Y coordinates, respectively.

IHSDM is a widely used safety analysis tool that requires large amount of data, which included both crash and highway and design data. The data elements previously discussed are usually extracted from the as-built roadway plan profile sheets that can be obtained from each state department of transportation.

Summary

There are still some questions left unanswered about the instrumented vehicles and the technologies available for them. One question still being researched is what are the limitations for reporting the positioning of roadways and what effect does this have on accuracy. Another question that is present is how these problems can be fixed. Or what improvements in technologies need to be introduced in order to fulfill the improvement in positioning for data collection. Other information that would be useful for advancement in software technology is real-time mapping. Real-time mapping allows researchers to click on the keyboard and start and stop to show the location of a road sign or many other features that are available on the roadside while in the field so that validation can be performed.

Most of the different vehicles have the same objectives outside of the normal collection of GPS data. The information that the instrumented vehicles collect could be used in order to expand the efforts into the GIS mapping is to code the locations of various roadside features. These features include bridges, guard rails, road sign locations, rail crossings, and many other features.

Due to the limited publicized cost and accuracy data for several of the fleet and instrumented vehicles, only some of the feet and instrumented vehicles have the cost and accuracy data.

CHAPTER 3

METHODOLOGY

The Civil Engineering Mobile Transportation Lab of Clemson University was used to collect data to test low cost GPS and INU data acquisition systems against a specially built test road in South Carolina and other sections in Georgia. Many of the systems in use today are very expensive and may be unachievable for small states and jurisdictions due to cost of initial purchase and maintenance. The overall desired outcome was to be able to save time and money for the engineering analysis by the DOT and safety engineers.

Technology Tools and Software

The Civil Engineering Mobile Transportation Lab of Clemson University (Transportation Van) was used to collect roadway data for analysis in this project. The components and software that are used in the collection and analysis include:

- Trimble AgGPS 132 Global Positioning System (GPS)
- Crossbow GPS-Aided MEMS Inertial System (INU)
- Vehicle-Mounted FireWire Cameras
- On-Board Computer
- Maptitude Software by Caliper Corporation
- V-log software by Clemson University
- MicroStation v8 Software by Bentley, Inc.

- Nav-VIEW 1.05 by Crossbow, Inc.
- AutoCAD 2006 Software by Autodesk, Inc.
- Microsoft Office 2003 Software by Microsoft Corporation
- Notepad Software by Microsoft Corporation

The GPS system was used to collect data on latitude, longitude, time, heading, speed, Differential GPS (DGPS) reading, and horizontal dilution of precision (HDOP) once every second. The Inertial system was used to collect data on time, roll, pitch, yaw, roll rate, pitch rate, yaw rate, velocity north, velocity east, velocity down, longitude, latitude, altitude, status BIT, and ITOW at a rate of 100 Hz. The GPS unit is differential corrected to achieve an accuracy of 1 meter or less, while the INU only has an accuracy of 3 meters. The DGPS data was displayed and collected using the Maptitude Software package. The INU data had to be processed and changed into different forms in order to create a mapped version of the data. This process will be explained in a later section. The Transportation Van has two FireWire cameras, one attached on the front Windshield near the rearview mirror and one attached to the rear window of the vehicle. Both record views of the roadway and shoulder information and are linked to the GPS data. The Video Log (v-log) software runs the two cameras and is capable of recording detail at a rate of 1, 2, or 15 frames per second. The Nav-VIEW Software was used to collect and record the position information from the INU. This data is stored in an output file for later evaluation. The on-board computer is used for recording and viewing the GPS data, the v-log images, and the inertial data. The remainders of the software packages were used in the analysis process of the data and the site selection process.

Installation of the Inertial Navigation Unit

To install the INU in the Transportation Van, a series of steps were completed to find the center of gravity of the van for purposes of locating the optimal installation position for the INU. The first step in finding the Center of Gravity (CG) is the take a series of weight measurements for the Transportation Van. These measurements are all done on a set of independent scales for each tire. The measurement used in the calculation of the CG were the level weight of the Transportation Van while empty, the Transportation Van tilted 2º to the left and 2º to the right while empty, a measurement with a driver and no passenger, and a measurement with no driver and a passenger in the data collection position. A picture of one measurement is shown here in Figures 10 and 11.

Figure 10: Transportation Van with 2% Tilt

Figure11: Sample Scale Readouts

The second step was to use these measurements and determine the CG of the Transportation Van. Dr. David Moline of the Mechanical Engineering department assisted with data collection and the calculations for the location of the CG. He used a spread sheet and preferred to not give it to me to protect his research and methods in the programs. During the measurement process, the measurements with the driver and with a passenger are rather precise in weigh and would the CG change with a drastic change in driver or data collector weight. The exact sensitivity of changes in weight and position within the van on CG are unknown. What is the sensitivity of the measurement to weight change to the CG? Since the CG was calculated, there have been some changes to the Transportation Van in that the computer station has moved and now there is a desk instead of a seat in the vehicle.

The third step was to create a protective case around the INU to protect it from the elements. The protective case was comprised out of three-fourths inch thick Lexan. Lexan is a clear plastic material that is very tough to break or scratch and is strong enough to withstand a person standing on the case without breaking.

The fourth step was to install the external GPS antenna. This GPS antenna was an ordinary coax antenna that was installed on the roof of the Transportation Van and the cable was run down to the INU to be attached for use. The power supply for the INU is a standard plug for a cigarette lighter. This made powering the unit much easier than hard wiring to the inverter, but could produce error in the data through fluctuation in the power feed.

The final step was to mount the INU in the protective case in the CG of the Transportation Van. The CG was determined in an x, y, and z coordinate, so locating this point is imperative to obtaining accurate results. Once this location was found, the INU was installed in the correct orientation. The INU also has to be given at least sixty seconds after being plugged into the power source to warm up before it is able to be utilized.

Data Collection Methodology

Data Collection Sites

Two different sites were tested during this project. The sites that were used include the SCDOT Test Road and select sites in the Atlanta, GA region. The sites analyzed were chosen for two different methods of comparison. The sites that were used in the validation of the INU were selected based on the accuracy of measurements. These were also broken down into two different categories. The first "test" site that was chosen is the SCDOT test road. It was chosen because the test road was constructed to be very accurate and consistent with the plans. It was constructed at the 0.1 feet accuracy level. Also, the SCDOT has completed surveys to measure the cross slope at particular points along the roadway stretch. The road is located in Fairfield County in South Carolina along US route 321. US 321 is used as a hurricane evacuation route, and the section that was tested was the southbound movement. The southbound lanes were the only lanes tested with this process due to the cost of building the roadway at this accuracy. Figures 12-14 show the approximate location of the start and end points for the SCDOT test road.

The select roadways from Georgia were used to determine consistency with general plan and profile information. The sites were originally picked for study dealing with horizontal curve operating speeds. In all, Georgia Tech conducted this study on around 100 segments. Out of the 100 segments, eleven segments were selected for the study because of the convenience of the location. The locations of the eleven segments were outside of the Atlanta city limits. These segments vary in length and are located in various parts around the outer ring of Atlanta. Figures 15-25 show the segment locations and the individual segments.

Design drawings for the SCDOT Test Road (United States Route 321) were obtained from SCDOT in Adobe PDF format. The drawings provided were the most recent as-built plans for the roadway. These drawings were dated in the 1970's. The surveyed data from 2006 on United States Route 321 was also obtained from SCODT in Microsoft EXCEL format and showed the detail for various points along the roadway.

Figure12: SCDOT Test Road*

Figure 13: Approximate Starting Location (US 321 and County Road just south of 2 Creek Rd)*

Figure 14: Approximate Ending Location (US 321 and White Oak Tower Rd)*

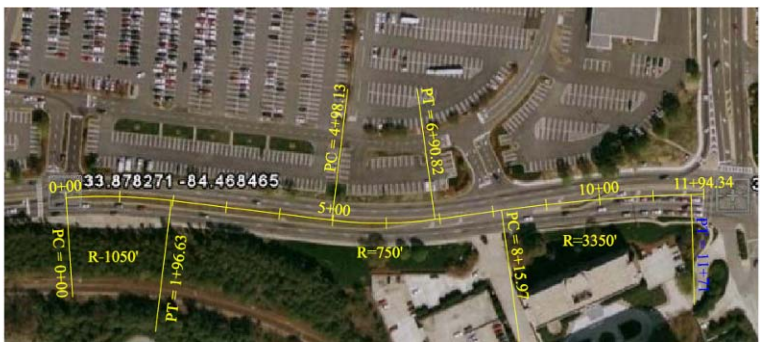


Figure 15: Segment Number 9 (County Road 2026, Cobb County)*

Figure 16: Segment Number 14 (Local Road 253, Fulton County)*

Figure 17: Segment Number 15 (Local Road 253, Fulton County)*

Figure 18: Segment Number 16 (State Route 9, Fulton County)*

Figure 19: Segment Number 17 (State Route 9, Fulton County)*

Figure 20: Segment Number 21 (State Route 947, Fulton County)*

Figure 21: Segment Number 22 (County Road 5156, DeKalb County)*

Figure 22: Segment Number 23 (County Road 5152, DeKalb County)*

Figure 23: Segment Number 40 (County Road 2019, Cobb County)*

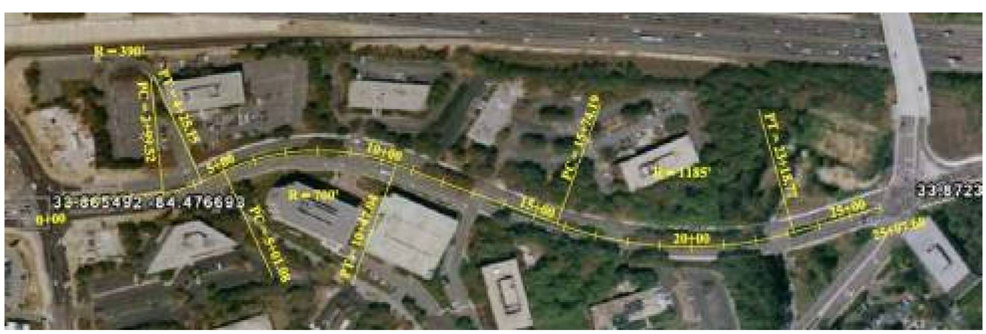


Figure 24: Segment Number 41 (County Road 1921, Cobb County)*

Figure 25: Segment Number 42 (County Road 1921, Cobb County)*

*Aerial and satellite photographs provided by Google Earth

Data Collection and Extraction

The following sections overview the procedure used to collect the data with the GPS and INU, and to extract and process the data into grade analysis. The GPS and Inertial data was collected using the Clemson University Mobile Transportation Lab and the data points were then exported into a Microsoft Access Database. The data was then filtered and exported into Microsoft Excel. Excel was to make the comparisons and convert the data into a useable format. The following sections give more details on this process and the sections include:

- Data Collection Procedure
- Converting Inertial Data to Mapped Points
- Extracting GPS Coordinates
- Converting GPS and Inertial Data into Stationing
- Inputting Data into Grade and Cross-Slope Analysis Spreadsheet

Data Collection Procedure

Data was collected on the selected roadways using the Civil Engineering's Instrumented Vehicle. The roadway sections were traveled two times in each direction with exception of SCDOT Test Road which was a divided highway and data was collected in southbound direction. The number of runs was limited by the data collection budget. Two people were required in order to collect the data, one to drive the instrumented vehicle as consistent as possible and the other to monitor the computer and operate the other equipment. The purpose for two persons for collection is to ensure the safety of the driver, by not running a computer and driving, and the safety of others, distraction to check equipment instead of driving. Also, the driver had to focus on making sure that the vehicle was driven with as little lane variation or correction as possible due to the sensitivity of the Inertial System. The computer operator had multiple tasks to keep track of. The tasks include monitoring the horizontal dilution of precision (HDOP), monitoring the inertial output to check for loss of signal, and making sure the videolog was still recording properly. Problems associated with HDOP and inertial output could be dealt with by slowing down as safely as possible and allowing for the signal to increase, or in a worse case pull over and let the satellite regain signal. The videolog had to be corrected by stopping the system and restarting the system again. When the HDOP value increases, the accuracy of the horizontal measurement and position of the vehicle is reduced. To ensure good operating conditions, the Clemson University Van, including hardware and software, were tested on site before leaving on data collection trips. The vehicle was driven to a position near the starting point of the data collection site so that the equipment and software could be initialized and ready for collection.

The first step in preparing the Mobile Transportation Lab for data collection was safety. The van was equipped with two “Slow Moving Vehicle” reflective orange signs and a flashing orange light on the rear of the van. These were used to alert the drivers behind the vehicle so that they would slow down. Figures 26 and 27 show a picture of the “Slow Moving Vehicle” signs and the flashing beacon, respectively. Figure 28 shows the equipment attached to the rear of the vehicle. The hazard lights were also used to try and alert the drivers to slow down.

Figure 26: Slow Moving Vehicle Sign

Figure 27: Orange Flashing Beacon

Figure 28: Safety Devices on Mobile Transportation Lab

For the first calibration testing, a slower speed was preferred because the GPS could only collect at a rate of one point per second. The faster the vehicle is moving the greater the distance between data points, so the slow movement improves the filtering of the INU. For the first set of testing, the van was driven at approximately 20 to 25 miles per hour so that the data points would be less than 50 feet part. For these speeds, the data points were approximately 29 to 37 feet apart. The distance between points was calculated using Equation 1 below:

$$D = V * \frac{5280\,ft}{1 mile} * \frac{1 hr}{60\min} * \frac{1\min}{60\sec} * 1\sec \qquad (1)$$

where

D = Distance between data points in feet

V = Speed of instrumented vehicle in mph

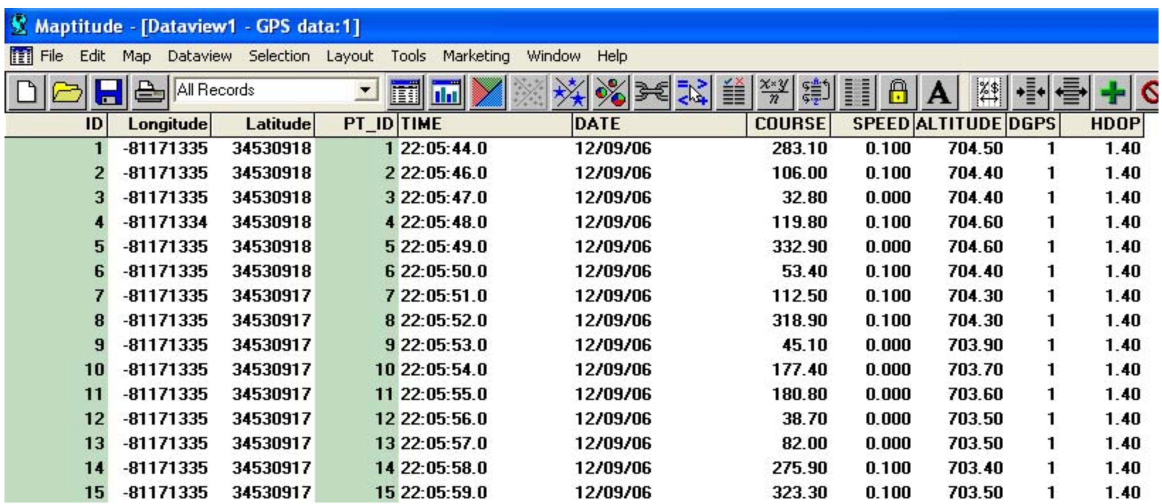
For example, a speed of 20 miles per hour and 55 miles per hour, roadway speed limit, the difference of 51.3 feet in the distance between points and the calculation are as follows:

$$D = 20mph * \frac{5280\,ft}{1mile} * \frac{1hr}{60\min} * \frac{1\min}{60\sec} * 1\sec = 29.3\,ft \qquad (2)$$

$$D = 55mph * \frac{5280\,ft}{1mile} * \frac{1hr}{60\min} * \frac{1\min}{60\sec} * 1\sec = 80.7\,ft \qquad (3)$$

Therefore, the slower the vehicle movement, the closer the data points, and a better projection of the roadway profile on Maptitude. Data points closely spaced make the analysis of the data and the comparison to the inertial easier. The GPS data being approximately 30 feet apart make the comparison to the inertial data, which is approximately one-fourth of the distance apart, much easier. The inertial data is recorded at 4 Hz, where GPS is recorded at 1 Hz, thus there is only 1 GPS locations for every 4 inertial location. The only potential problem to driving at 20 miles per hour is that it creates a safety problem. Vehicles traveling in the same direction approach would approach the vehicle rapidly. This situation could result in a rear-end collision, which is the reasoning for using the "slow moving vehicle" signs along with the hazard and flashing beacon lights. The SCDOT Test road made a good location for slower speed data collection because the four lane roadway is primarily used as an evacuation route and the daily traffic is minimal.

The next step in data collection is to start the computer and power up all the equipment. Maptitude software was opened first and a map of Fairfield County, SC was loaded. Overlaid on this map, a layer designated for the GPS data was created. Once the software was ready for use, the GPS receiver was powered on and the receiver output was checked in order to make sure that the number of satellites was at a minimum of four so that the GPS data was more accurate. An example of the Dataview from Maptitude showing the data that was logged while running the Maptitude software is shown in Figure 29 below.



ID	Longitude	Latitude	PT_ID	TIME	DATE	COURSE	SPEED	ALTITUDE	DGPS	HDOP
1	-81171335	34530918	1	22:05:44.0	12/09/06	283.10	0.100	704.50	1	1.40
2	-81171335	34530918	2	22:05:46.0	12/09/06	106.00	0.100	704.40	1	1.40
3	-81171335	34530918	3	22:05:47.0	12/09/06	32.80	0.000	704.40	1	1.40
4	-81171334	34530918	4	22:05:48.0	12/09/06	119.80	0.100	704.60	1	1.40
5	-81171335	34530918	5	22:05:49.0	12/09/06	332.90	0.000	704.60	1	1.40
6	-81171335	34530918	6	22:05:50.0	12/09/06	53.40	0.100	704.40	1	1.40
7	-81171335	34530917	7	22:05:51.0	12/09/06	112.50	0.100	704.30	1	1.40
8	-81171335	34530917	8	22:05:52.0	12/09/06	318.90	0.100	704.30	1	1.40
9	-81171335	34530917	9	22:05:53.0	12/09/06	45.10	0.000	703.90	1	1.40
10	-81171335	34530917	10	22:05:54.0	12/09/06	177.40	0.000	703.70	1	1.40
11	-81171335	34530917	11	22:05:55.0	12/09/06	180.80	0.000	703.60	1	1.40
12	-81171335	34530917	12	22:05:56.0	12/09/06	38.70	0.000	703.50	1	1.40
13	-81171335	34530917	13	22:05:57.0	12/09/06	82.00	0.000	703.50	1	1.40
14	-81171335	34530917	14	22:05:58.0	12/09/06	275.90	0.100	703.40	1	1.40
15	-81171335	34530917	15	22:05:59.0	12/09/06	323.30	0.100	703.50	1	1.40

Figure 29: GPS Dataview from Maptitude software

Then, the video logging program, V-Log, was started and the camera angles of the two cameras located in the front and back of the vehicle were checked to make sure that the desired direction was in view using the computer monitor and a test run. The v-log software stores an image that can be later linked to the related GPS coordinate. This is done through the time stamp that was sinked between the GPS receiver and the computer. The v-log uses the computer clock to record the time of each picture. The composite from the front and rear cameras can then be visually compared to the GPS data points to check the tracking on the computer. For example, if on a curved section of roadway, the corresponding picture shows a straight section, then something may be wrong with the data and further checks may be needed to verify the GPS coordinates.

The INU is the next piece of equipment to be started. The INU has more a complex process. When the device is first powered up, the unit needs to sit for 60 seconds so that it will warm up. After the unit warms up, it is plugged up to the computer system. The computer system recognizes the INU, and it is ready for use. To run the INU, the researcher starts up the Nav-VIEW 1.05 Software. The Nav-VIEW software will recognize that the INU is running and the serial number displays. Next, the researcher selects the location where the file is to be saved by pressing the file button at the bottom of the program and designating the location. The next item is to make sure that the software is recording the NAV Packet which in the DMU menu. If it is not in the NAV Packet, the data will not record in the proper format. After that, the researcher selects start log to start running the software. The output for this program saves into a text file because of the extreme number of data points of the output (100 Hz for roll, pitch, yaw, etc.). Figures 30 and 31 display the Dataview from Maptitude for the INU. Figure 32 displays the SCDOT Test Road section that was tested and all of the components Mapped, including the GPS, Inertial, and Cross Slope Verification Points. In Figure 32, the green dots are INU points, the blue dots are GPS points, the grey triangles are GPS points from another data run, and the triangles with enclosed dots are the cross slope verification points.

Maptitude - [Dataview1 - Run1]

ID	Longitude	Latitude	[ID:1]	TIME__S_	ROLL__DEG_	PITCH__DEG	YAW_HDG__D	ROLL_RATE_	PITCH_RATE	YAW_RATE__	VELOCITY_N
7657	-81170460	34524150	7657.00000	96.99200	-4.67500	-0.45600	145.64000	-0.67291	0.51910	-1.48041	-11.58594
7658	-81170460	34524150	7658.00000	97.00201	-4.68000	-0.45000	145.62900	-0.65368	0.63446	-1.42273	-11.58594
7659	-81170460	34524150	7659.00000	97.01200	-4.67500	-0.46700	145.61300	-0.69213	0.46142	-1.63422	-11.65625
7660	-81170460	34524150	7660.00000	97.02200	-4.68000	-0.46100	145.59600	-0.76904	0.76904	-1.53809	-11.64844
7661	-81170460	34524150	7661.00000	97.03200	-4.69100	-0.45000	145.58000	-0.84594	0.98053	-1.49963	-11.64844
7662	-81170460	34524150	7662.00000	97.04201	-4.69700	-0.44500	145.56300	-0.74981	0.82672	-1.80725	-11.64063
7663	-81170460	34524150	7663.00000	97.05190	-4.70200	-0.43900	145.54700	-0.51910	0.80749	-1.44196	-11.64063
7664	-81170460	34524150	7664.00000	97.06180	-4.70800	-0.42800	145.53000	-0.44220	0.96130	-1.48041	-11.63281
7665	-81170460	34524150	7665.00000	97.07171	-4.70800	-0.42300	145.51400	-0.46142	0.99975	-1.51886	-11.63281
7666	-81170460	34524150	7666.00000	97.08160	-4.71300	-0.41200	145.49700	-0.36529	0.99975	-1.49963	-11.62500
7667	-81170460	34524150	7667.00000	97.09151	-4.71900	-0.40600	145.48100	-0.30761	0.96130	-1.48041	-11.61719
7668	-81170460	34524150	7668.00000	97.10140	-4.72400	-0.39600	145.46400	-0.51910	0.90362	-1.61499	-11.61719
7669	-81170460	34524150	7669.00000	97.11131	-4.72400	-0.39000	145.44800	-0.36529	0.78826	-1.59576	-11.60938
7670	-81170460	34524150	7670.00000	97.12121	-4.73000	-0.38500	145.43200	-0.34606	0.67291	-1.59576	-11.60938
7671	-81170460	34524150	7671.00000	97.13110	-4.73000	-0.37900	145.39900	-0.28839	0.63446	-1.57654	-11.60156
7672	-81170460	34524150	7672.00000	97.14101	-4.73500	-0.37400	145.38200	-0.44220	0.51910	-1.63422	-11.60156
7673	-81170460	34524150	7673.00000	97.15060	-4.74100	-0.37400	145.36600	-0.61523	0.46142	-1.65344	-11.59375

Figure 30: Inertial Dataview part I

VELOCITY_N	VELOCITY_E	VELOCITY_D	LONGITUDE	LATITUDE	ALTITUDE	STATUS_BIT	ITOW__MS
-11.58594	6.97656	-0.16406	-81.17046	34.52415	142.00000	0.00000	9419.00000
-11.58594	6.98438	-0.16406	-81.17046	34.52415	142.00000	0.00000	9671.00000
-11.65625	6.98438	-0.13281	-81.17046	34.52415	142.00000	0.00000	9671.00000
-11.64844	6.99219	-0.13281	-81.17046	34.52415	142.00000	0.00000	9671.00000
-11.64844	6.99219	-0.13281	-81.17046	34.52415	142.00000	0.00000	9671.00000
-11.64063	6.99219	-0.13281	-81.17046	34.52415	142.00000	0.00000	9671.00000
-11.64063	7.00000	-0.13281	-81.17046	34.52415	142.00000	0.00000	9671.00000
-11.63281	7.00000	-0.13281	-81.17046	34.52415	142.00000	0.00000	9671.00000
-11.63281	7.00000	-0.12500	-81.17046	34.52415	142.00000	0.00000	9671.00000
-11.62500	7.00781	-0.13281	-81.17046	34.52415	142.00000	0.00000	9671.00000
-11.61719	7.00781	-0.13281	-81.17046	34.52415	142.00000	0.00000	9671.00000
-11.61719	7.00781	-0.13281	-81.17046	34.52415	142.00000	0.00000	9671.00000
-11.60938	7.00781	-0.13281	-81.17046	34.52415	142.00000	0.00000	9671.00000
-11.60938	7.01563	-0.13281	-81.17046	34.52415	142.00000	0.00000	9671.00000

Figure 31: Inertial Dataview part II

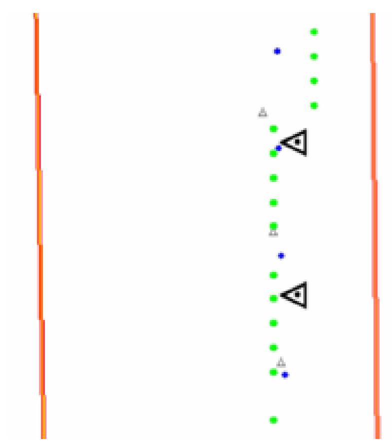


Figure 32: Mapped Inertial, GPS, and Cross Slope Verification Points

Once all the equipment was powered up, tested, and prepared, the driver would start driving on the designated route. The driver would concentrate on maintaining consistent travel in the center of the travel lane and at a constant speed of 40 miles per hour. Driving in the center of the lane reduced lane wander, side-to-side movement in the lane, and increased accuracy of the readings.

Converting Inertial Data to Mapped Data Points

The data that was collected from the Inertial Navigation Unit was stored in a text file that is not usable by Maptitude for mapping purposes. Also, the data in a text file is not useful for processing and analysis. To get the data into a useable form, the text file must first be converted into a Microsoft Access database. After being converted into a database, the file can be exported to Excel for data analysis and can be exported in a different format for conversion into a mapped data set.

The first step is to clean the data inside of the text file. The text file comes with a header from the Nav-VIEW 1.05 Software. The header is not needed for analysis, but may be useful in the future, so saving a copy of the file with a different name is advised for all of the data so that collection would not have to be repeated for lost or corrupted files. After a copy is saved, the file was opened and the header and blank lines were removed until the column headings were the first line of the file. After this, a new Access Database was created and the cleaned text file was imported. After the data was imported, there is a possibility that some of the data may not have converted properly. In this case the data can be entered manually for the select datafields that were outputted in the Import Errors File. This process was repeated for all runs on each segment.

The next step comes after all the data run files are imported into Access and errors fixed. The data is then exported into two different formats. The first is to export the data into a Microsoft Excel format that will be used for data analysis. The other is to export the data in an older version of Access, database IV, so that it can be formatted and mapped in Maptitude. The analysis part will be discussed in a future section on data analysis.

The final step is to open up Maptitude and create the mapped data for the INU in order to do a visual comparison with the GPS data. To do this, select the file open in Maptitude and change the file type to the Access database IV (.dbf) extension. Maptitude will ask if you want to create a geographic file out of the data, and this will map the data and allow it to be exported in the next section.

Extracting GPS Coordinates

Now that the collected GPS and INU data points are stored in Maptitude map layer, the latitude and longitude coordinates can be extracted in a format other than the collected form, degrees. To determine distances and analyze the data, these coordinates need to be converted into feet. To do this, all the coordinates were exported as North America NAD27 (U.S. State Plane) Zone 3901: South Carolina North Coordinate System as a Text/Geo File, GEO extension file, using Maptitude. This procedure allowed the data to be imported into Excel as a comma delimited file and saved as an Excel spreadsheet. This data was then imported into Access to be matched with the rest of the output data from the INU to allow for data manipulation and analysis.

Converting GPS and Inertial Data into Stationing

This step is done for all the different sections of the data analysis. The first step is to take the extracted GPS and Inertial Data from Maptitude that was previously saved in a Microsoft Access (Access) database. The Access files contain the longitude, latitude, and other data that will be discussed later. The Access file can then be exported from Access into a Microsoft Excel (Excel) format. Once this is completed, then the longitude and latitude can then be converted into stations. The stations are added by comparing data with the plan profile sheets that were obtained from the SCDOT and Georgia Tech.

The stationing equation is used to determine the station each point. The distance calculated between each point is added to the previous station to give the new station. The equation used for stationing is given in equation 4.

$$Station = P + \sqrt{\Delta x^2 + \Delta y^2} \tag{4}$$

where

P = Stationing at previous point,

Δx = Change in X coordinates from previous point to current point in feet, and

Δy = Change in X coordinates from previous point to current point in feet.

After the stations have been determined, the stations can be matched to reference points on the SCDOT Test Road for calibration and also serve as reference point on the

Atlanta roadway segments. Table 1 provides an excerpt from a spreadsheet demonstrating stationing.

Table 1: Example Spreadsheet Used for Stationing

ID	Latitude (deg)	Longitude (deg)	Latitude	Longitude	New X	New Y	Station	Pitch (deg)	Roll (deg)	Altitude (m)
	34.53092	**-81.17133**	**Approximate Starting Location**							
12	34.5309181	-81.1713028	1948405.8	557151.6742	10.82722	21851.67	122+22.62	-0.0504	1.17024	140
13	34.5308914	-81.1713028	1948405.8	557140.7566	10.8088	21840.76	122+33.54	-0.005833	1.112042	140
14	34.5308609	-81.1713028	1948405.8	557129.839	10.79037	21829.84	122+44.45	-0.01172	1.049	139.75
15	34.5308304	-81.1712952	1948405.8	557118.9214	10.77195	21818.92	122+55.37	-0.12712	0.91904	140
16	34.5307999	-81.1712952	1948405.8	557108.0037	10.75352	21808	122+66.29	-0.20152	0.80812	140
17	34.5307655	-81.1712952	1948405.7	557097.0861	10.73509	21797.09	122+77.21	-0.30556	0.62512	140
18	34.530735	-81.1712952	1948405.7	557086.1685	10.71667	21786.17	122+88.12	-0.429423	0.463808	140.5
19	34.5307007	-81.1712875	1948408.7	557071.6066	13.70403	21771.61	123+02.99	-0.530708	0.411833	140.5

Inputting Data into Grade and Cross-Slope Analysis Spreadsheet

Excel was used to create the Stationing sheet, as shown in Table 1, and to analyze the Grade and Cross-Slope. To get the data into Excel, Access was used to sort and paste the data generated by the INU. A large amount of output data was produced by the INU, roughly 50,000 data points for a 1.5 mile section of roadway per run, Access can sort and process that data at a much faster and accurate rate than manually processing in Excel. Access was used to open the text files created by the Nav-VIEW software. This text file contains the data shown previously in Figures 24 and 25. Once the data was imported into Access, the data was then sorted using Crosstab Queries. The main components for the INU output for the Grade and Cross-Slope are the Pitch and Roll, respectively. For every Latitude and Longitude Coordinate, about twenty-five different pitch and roll were recorded. Also, it is important when using Crosstab Queries to include the ID field and average it. This will allow the ID field to be sorted in ascending order, and if not, the Crosstab Query will sort the Latitude (X) and Longitude (Y) in ascending order changing the data order completely. Once this operation is complete for each run, the query outputs can be exported as Excel files and combined for further analysis.

With the X and Y Coordinates in the Excel sheet, the next step is to convert the coordinates into stations using Equation 4. Once converted, stations were manually checked against the length of segment from the plan and profile sheets. The grade and cross-slope were calculated next. To obtain this data, the tangent and sine was taken on the pitch and roll, respectively. Table 2 demonstrates the Stations, Grade, and Cross-Slope.

Table 2: Grade and Cross-Slope Calculation Table

ID	Latitude (deg)	Longitude (deg)	Latitude	Longitude	Station	Pitch (deg)	Roll (deg)	Grade	Cross-Slope
11	34.5309448	-81.1713028	1948405.84	557158.9526	122+15.34	-0.06752	1.09032	**-0.12%**	**1.90%**
12	34.5309181	-81.1713028	1948405.827	557151.6742	122+22.62	-0.0504	1.17024	**-0.09%**	**2.04%**
13	34.5308914	-81.1713028	1948405.809	557140.7566	122+33.54	-0.005833	1.1120417	**-0.01%**	**1.94%**
14	34.5308609	-81.1713028	1948405.79	557129.839	122+44.45	-0.01172	1.049	**-0.02%**	**1.83%**
15	34.5308304	-81.17129517	1948405.772	557118.9214	122+55.37	-0.12712	0.91904	**-0.22%**	**1.60%**
16	34.5307999	-81.17129517	1948405.754	557108.0037	122+66.29	-0.20152	0.80812	**-0.35%**	**1.41%**
17	34.5307655	-81.17129517	1948405.735	557097.0861	122+77.21	-0.30556	0.62512	**-0.53%**	**1.09%**
18	34.530735	-81.17129517	1948405.717	557086.1685	122+88.12	-0.429423	0.4638077	**-0.75%**	**0.81%**
19	34.5307007	-81.17128754	1948408.704	557071.6066	123+02.99	-0.530708	0.4118333	**-0.93%**	**0.72%**
20	34.530674	-81.17128754	1948408.686	557060.689	123+13.91	-0.632577	0.4041923	**-1.10%**	**0.71%**

Once the stations, grade, and cross-slope for each run was calculated, the next step in the validation process was to identify the different types of vertical curves along with the tangent sections. A tangent section was identified by reviewing the as-built plans for the SCDOT Test Road. After identifying the exact starting point of the Test Road, the stations could be ordered by the GPS coordinates. The comments column identifies a sag vertical curve, a crest vertical curve, a horizontal and sag vertical curve, a horizontal and crest vertical curve, and a tangent section. These different curve types were separated to check what the effects vertical curves have on the results, mainly the relationship between change in grade and error.

To determine the error, first the grade along a curve has to be determined. Since the INU produces approximately one point for every ten feet, the grade had to be calculated with equation 5.

$$G(in\%) = -g_2 - X''\left(\frac{A}{L}\right) \tag{5}$$

where

G = grade at any point along the curve

$-g_2$ = grade exiting the curve

X" = distance from the end of vertical curve

A = Algebraic difference in grade $|A = g_2 - g_1|$

L = Length of Curve

After the grade along a curve was calculated for all of the different curve types, the next step in the data processing is to obtain the error between the measured data and the plan profile data. This was calculated using equation 6.

$$Error = abs(Profile - Collected) \quad (6)$$

where

Error = Absolute Error in the data

Plan Sheet = grade value obtained from the plan and profile sheet

Collected = grade value collected with the INU

Table 3 is an example of curve data and a summary can be found in the Appendix.

Table 3: Example Analysis Grade and Cross-Slope Spreadsheet

ID	Longitude (deg)	Latitude (deg)	L	G1	G2	DOT Stationing	X"	Altitude (m)	Cross Slope	Grade	DOT Profile Sheet Grade	A = |G2-G1|	error	Comments
36	-81.17128754	34.53069305	500	2.72%	-4.70%	123+03.28	496.72	135.25	**0.63%**	**-0.71%**	**2.67%**	**-7.42%**	**-3.38%**	CREST VERTICAL CURVE
37	-81.17128754	34.53068161	500	2.72%	-4.70%	123+06.92	493.08	135.25	**0.49%**	**-0.82%**	**2.62%**	**-7.42%**	**-3.44%**	
38	-81.17128754	34.53067398	500	2.72%	-4.70%	123+10.56	489.44	135.75	**0.50%**	**-0.97%**	**2.56%**	**-7.42%**	**-3.54%**	
39	-81.17128754	34.53066635	500	2.72%	-4.70%	123+10.56	489.44	135.75	**0.44%**	**-1.05%**	**2.56%**	**-7.42%**	**-3.62%**	
126	-81.17121124	34.52893066	300	-4.70%	3.08%	129+51.40	273.00	143.00	**1.54%**	**-3.36%**	**-4.00%**	**7.78%**	**0.64%**	HORIZ AND SAG VERTICAL CURVE
127	-81.17121124	34.52890396	300	-4.70%	3.08%	129+62.32	262.08	143.25	**1.57%**	**-3.37%**	**-3.72%**	**7.78%**	**0.34%**	
128	-81.17121124	34.52888107	300	-4.70%	3.08%	129+69.60	254.80	143.50	**1.62%**	**-3.35%**	**-3.53%**	**7.78%**	**0.18%**	
129	-81.17121124	34.52885818	300	-4.70%	3.08%	129+76.87	247.53	143.75	**1.69%**	**-3.29%**	**-3.34%**	**7.78%**	**0.05%**	
176	-81.17119598	34.52763367	400	3.08%	-0.94%	134+27.11	342.89	142.00	**1.83%**	**-1.27%**	**2.51%**	**-4.02%**	**-3.78%**	HORIZ AND CREST VERTICAL CURVE
177	-81.17119598	34.52760315	400	3.08%	-0.94%	134+38.03	331.97	142.00	**2.26%**	**-1.42%**	**2.40%**	**-4.02%**	**-3.82%**	
178	-81.17119598	34.52757645	400	3.08%	-0.94%	134+45.30	324.70	142.00	**2.71%**	**-1.47%**	**2.32%**	**-4.02%**	**-3.79%**	
179	-81.17118835	34.52754974	400	3.08%	-0.94%	134+56.63	313.37	142.00	**2.85%**	**-1.48%**	**2.21%**	**-4.02%**	**-3.69%**	
286	-81.17028809	34.5239563				148+22.01		141.5	**-9.02%**	**-1.27%**	**0.86%**		**-2.13%**	TANGENT SECTION
287	-81.1702652	34.52393723				148+31.45		141.75	**-8.93%**	**-1.23%**	**0.86%**		**-2.09%**	
288	-81.17024231	34.52391434				148+45.63		141.75	**-8.87%**	**-1.25%**	**0.86%**		**-2.11%**	
289	-81.17022705	34.52389145				148+53.50		141.75	**-8.84%**	**-1.27%**	**0.86%**		**-2.13%**	
386	-81.16792297	34.52235413	500	2.36%	-2.08%	157+84.56	415.44	143.75	**-1.79%**	**-1.22%**	**1.61%**	**-4.44%**	**-2.83%**	SAG VERTICAL CURVE
387	-81.16788483	34.52234268	500	2.36%	-2.08%	157+97.15	402.85	143.75	**-1.43%**	**-1.10%**	**1.50%**	**-4.44%**	**-2.60%**	
388	-81.16785431	34.52233124	500	2.36%	-2.08%	158+06.89	393.11	143.75	**-1.08%**	**-1.16%**	**1.41%**	**-4.44%**	**-2.57%**	
389	-81.16782379	34.52231979	500	2.36%	-2.08%	158+16.63	383.37	144.00	**-0.74%**	**-1.24%**	**1.32%**	**-4.44%**	**-2.56%**	

The next calculation in the data processing to obtain a weighted average for the absolute error based on the different curve types. The first step is to calculate the length for the different curve types and then to weight the absolute errors based on the length of each curve type. The length of curve was manually obtained from the plan and profile sheets. This calculation was done using equation 7.

$$Weighted\ Average = \frac{(abs\ error\ 1{*}L\ 1) + (abs\ error\ 2{*}L\ 2) + \dots}{sum(L1 + L2 + \dots)} \tag{7}$$

where

Weighted Average = absolute error weighted based on how much of the total section is each curve type

abs error = absolute error for each curve type

L = length in feet for each of the different curve types

Table 4 shows an example a weighted average for the different curve types.

Table 4: Example of Weighted Averages

	Grade - Absolute Error				
Type	Run 2	Run 3	Run 4	Length of Curve Types	**Average**
Crest Vertical Curve	1.97%	1.79%	1.77%	450	**1.84%**
Sag Vertical Curve	0.83%	2.09%	0.69%	400	**1.20%**
Tangent Section	0.65%	1.58%	0.81%	2803	**1.01%**
Absolute Error (Weighted)	**0.83%**	**1.66%**	**0.91%**		**1.14%**

The results in the following section will provide accuracy levels for the grade data obtained from the SCDOT Test Road along with the roadway segment around Atlanta, GA. The results also will include the accuracy levels obtained for the cross slope data on the SCDOT Test Road.

CHAPTER 4

RESULTS

The SCDOT Test Road was used to calibrate the INU. This road was built with a high level of accuracy during testing of a new method of construction. The as-built plans for the roadway, although old, are accurate. The cross slope for the road was also surveyed in known locations by SCDOT in 2006. The Test Road provided a good location to validate and calibrate the INU before use.

The starting and ending points of the segment were determined manually via a comparison with control points identified at the test road. The INU provides four times the number of GPS locations than the D-GPS does, which allows for a closer approximation of the starting and ending point for each section. The INU worked much better than the GPS for this approximation, even considering the potential error of up to 3 meters.

Upon completing the data collection, procedures were performed on the data to obtain a set of data ready for analysis. The INU can be used in areas where GPS is not available. The INU is capable of using an initial starting point and continuous 3D (roll, pitch, yaw) van movements to derive data points. The SCDOT Test Road data was examined to determine what level of calibration was needed and what outside problems may be associated with the data. Each section of data was analyzed to determine the grade and cross-slope based on the data collected. Some of the various factors that can affect the data quality include vehicle factors (suspension, weight balance), traffic level, and driver imposed lane wander.

Grade Comparisons

SCDOT Test Road

The grade data collected on the Test Road was compared to the plan profile sheets. The grade was plotted based on from the plan profile sheets and visually analyzed for any bias. Figure 33 show a representation for the three different travel runs compared to the plan profile sheet. SCDOT measured twenty-five locations along a mile and a half long section and the bias analysis was performed based on these measured locations. These locations were marked on the roadway and the Transportation Van was used to mark these locations by taking roughly fifteen to twenty D-GPS readings at each point to enable matching the GPS coordinate to the collected data. These locations were then plotted on a Maptitude map and manually located and the grade and cross-slope data was observed.

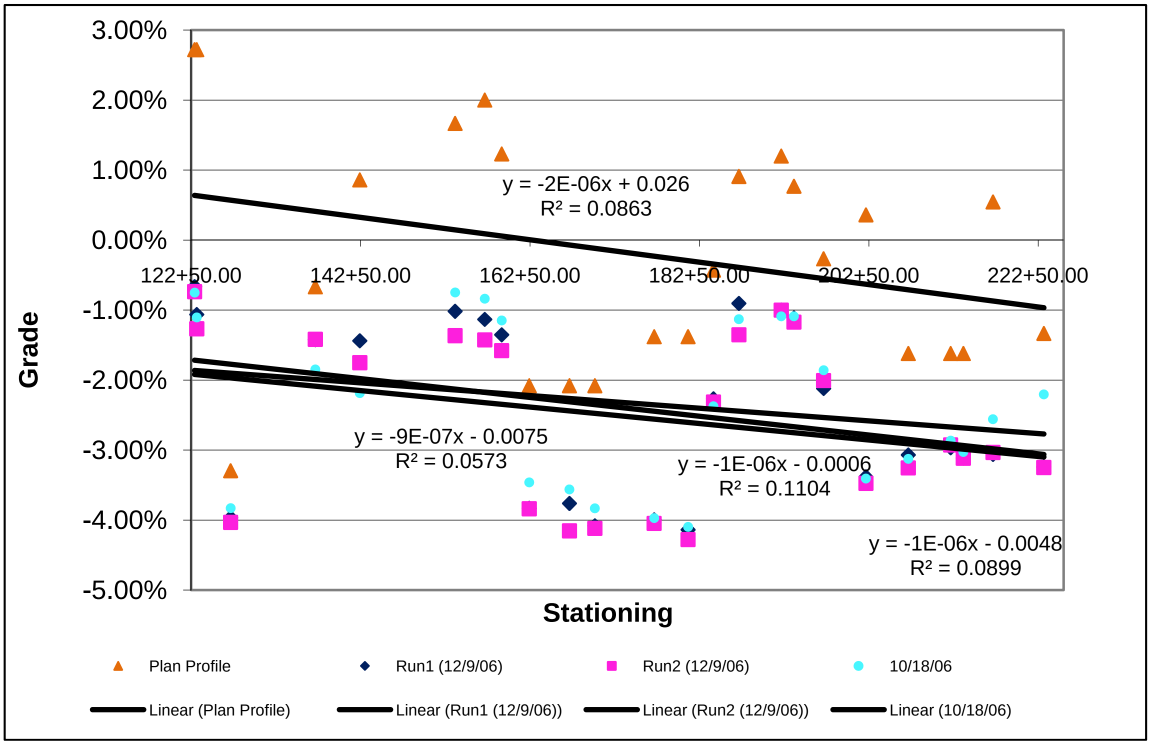


Figure 33: Grade Comparison

Regression lines were then added to each data set and it was determined that there was an approximate two percent bias in the grade data. The approximate two percent bias was removed from the collected data to determine if this showed a better representation for grade on the Test Road. The two percent reduction is shown in Figure 34.

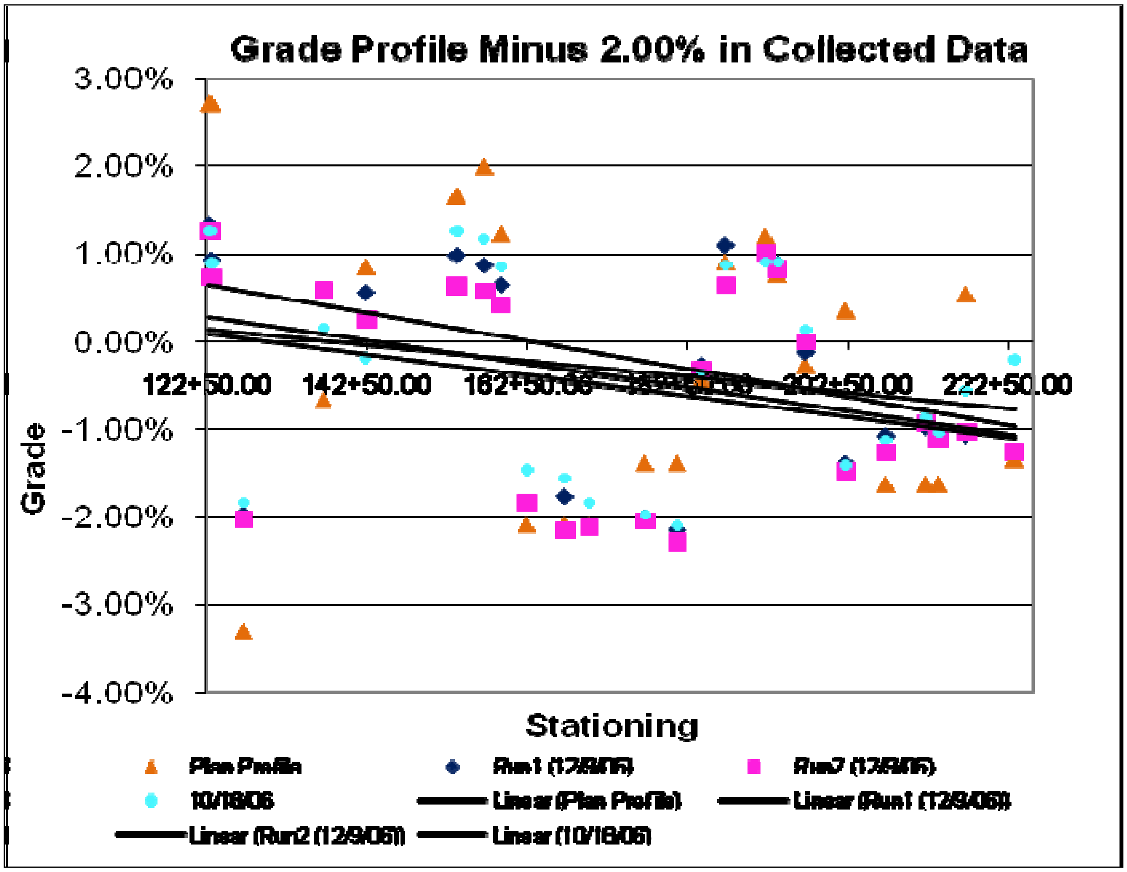


Figure 34: Grade Comparison with 2% Reduction in Collected Data

The bias was used to calibrate the INU to a more accurate result for the grade. The two percent bias was removed from the collected data after this discovery for future analysis on curve data. The crest vertical curves, sag vertical curves, and tangent sections were then separated and analyzed individually to test the effect of vertical curves on the grade. A comparison was done for each of the aforementioned curve types. The three different runs on the roadway segment were visually and computationally compared based on the absolute error from the plan profile grade. Figures 35, 36, and 37 show the visual comparison for the crest vertical curve, sag vertical curve, and tangent section, while Table 5 shows the absolute error in the data sets.

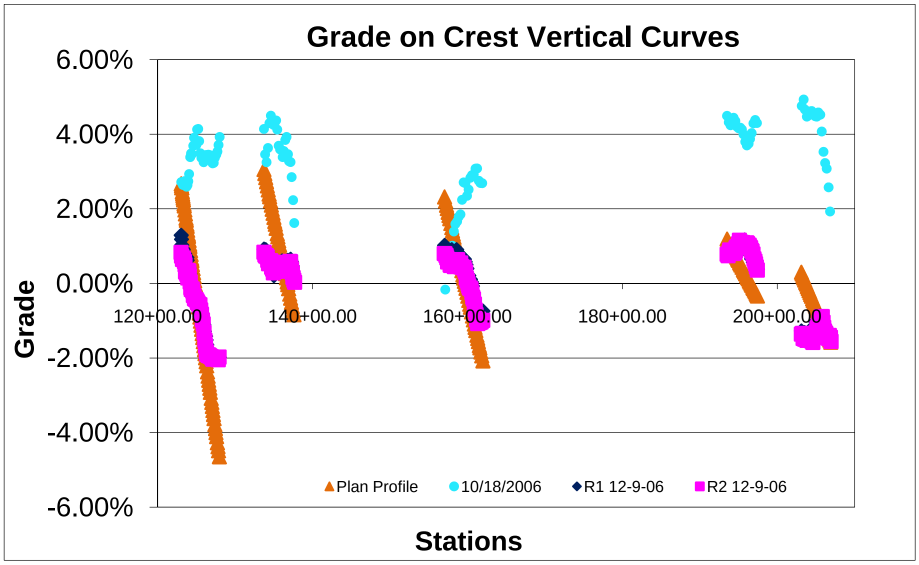


Figure 35: Grade on Crest Vertical Curves

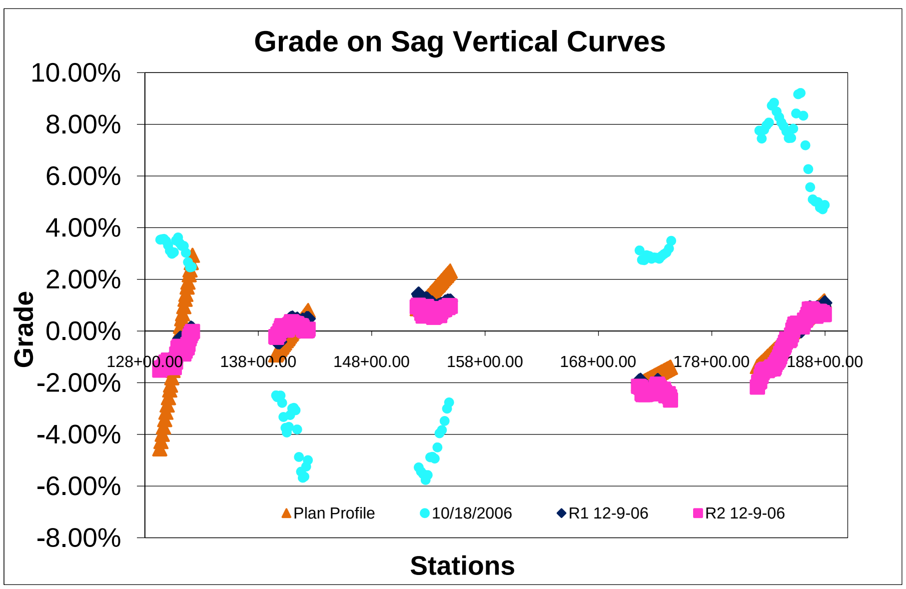


Figure 36: Grade on Sag Vertical Curves

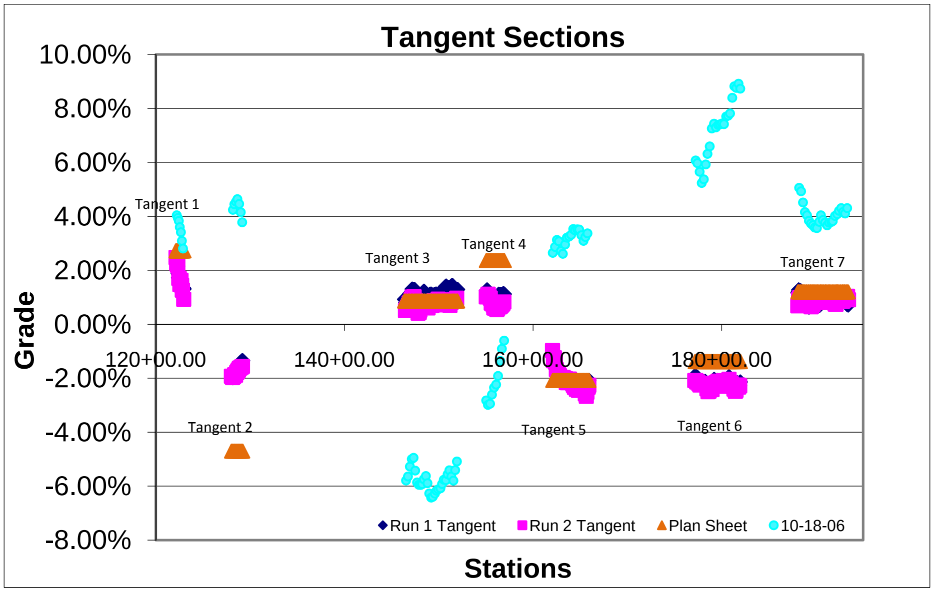


Figure 37: Grade on Tangent Sections

Table 5: Absolute Error in Curve Data

	Grade - Absolute Error						
Type	10/18/06	12/9/06 Run1	12/9/06 Run2	Length of Curve Type	Curve Type Average	Best Case Avg Min 10/18	Worst Case 10/18 and Run2
Crest Vertical Curve	3.61%	0.72%	0.69%	15+57.00	**1.67%**	0.70%	2.15%
Horizontal and Crest Vertical Curve	3.31%	1.04%	1.08%	6+68.00	**1.81%**	1.06%	2.19%
Horizontal and Sag Vertial Curve	4.09%	0.81%	0.90%	9+00.00	**1.93%**	0.86%	2.49%
Sag Vertical Curve	6.93%	0.39%	0.48%	9+00.00	**2.60%**	0.44%	3.71%
Tangent Section	5.61%	0.68%	0.64%	23+97.00	**2.31%**	0.66%	3.12%
Absolute Error (Weighted)	4.86%	0.70%	0.71%		2.09%	0.71%	2.78%

Table 5 shows that after analyzing the different curve types, Run1 had a significantly higher absolute error than Runs 2 & 3. The high error is apparent for Run 1 in Figures 35, 36, and 37. The absolute error for Run 1 was 4.71% compared to 0.73% and 0.76% for Runs 2 & 3, respectively. The data was then analyzed for a range of absolute errors, i.e. the best case and worst case scenarios of the data set. The SCDOT Test Road produced a range from 0.71% to 2.78% absolute error. During the data collection on Run 1, the GPS antenna connected to the INU was going in and out of reception and shortly after this day of collection had to be replaced. This data was still used for analysis purposes. These high errors are considered to be unacceptable and are not comparable to Runs 2 & 3 either. Runs 2 & 3 were conducted on a different day with a new antenna producing much better results. The sag vertical curve had the most accurate results when comparing Runs 2 & 3, but when Run 1 was added it produced one of the highest absolute errors. The Videolog and GPS data was reviewed for Run 1 to determine where the source for error occurred. Based on this review, the only difference in the Run 1 and Runs 2 & 3 was the speed of travel. The speed of travel for Run 1 was approximately 55 miles per hour and for Run 2 & 3 it was about 35 miles per hour.

In Figure 28, the tangent sections showed that Runs 2 & 3 more closely fit to the plan profile of the roadway and they also closely match each other. Run 1 that was taken on 10/18 when the GPS antenna was not functioning properly produced some erratic data sets when compared to the other two runs. Figures 38, 39, and 40 show the variation in the INU over the tangent sections 3, 5, and 7 for the SCDOT Test Road. They show that even on the straight section of roadway, there is some oscillation or noise in the data.

This could be from an inconsistency in the power supply causing a change in the voltage going to the INU.

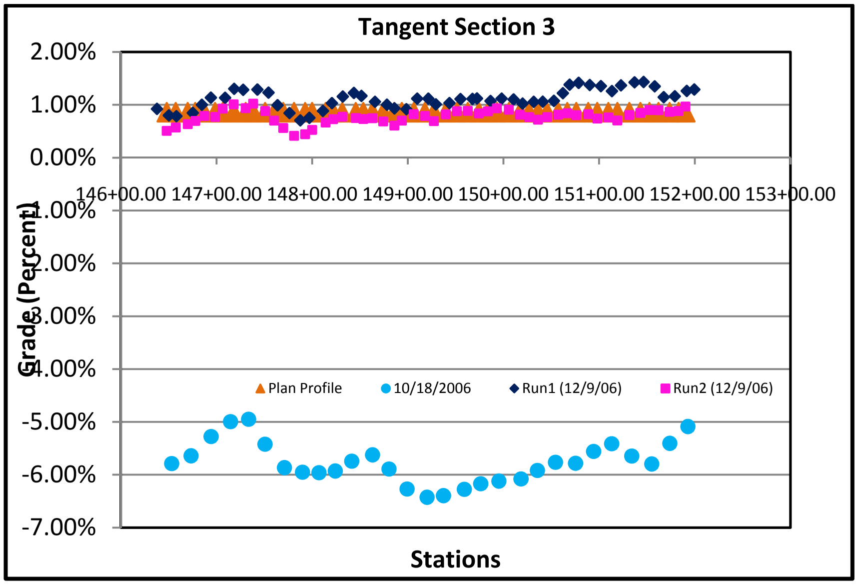


Figure 38: Tangent Section 3 on SCDOT Test Road

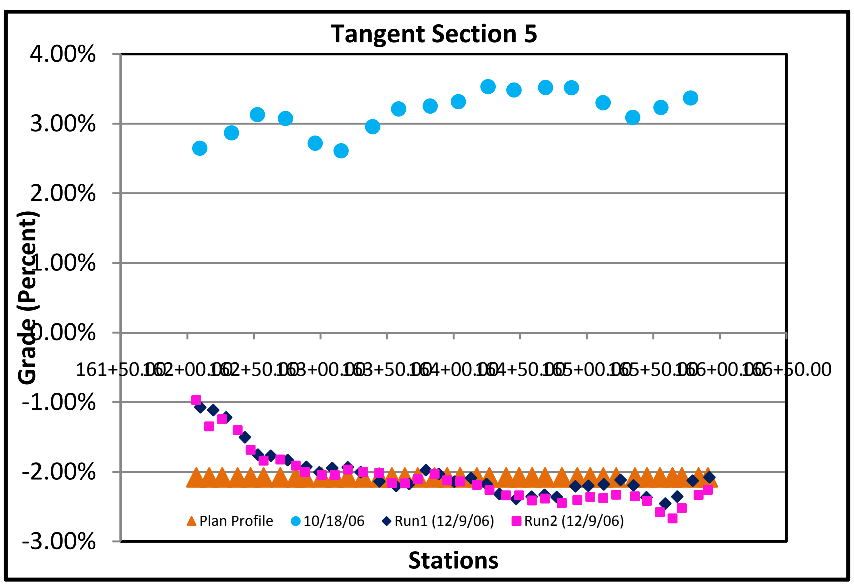


Figure 39: Tangent Section 5 on SCDOT Test Road

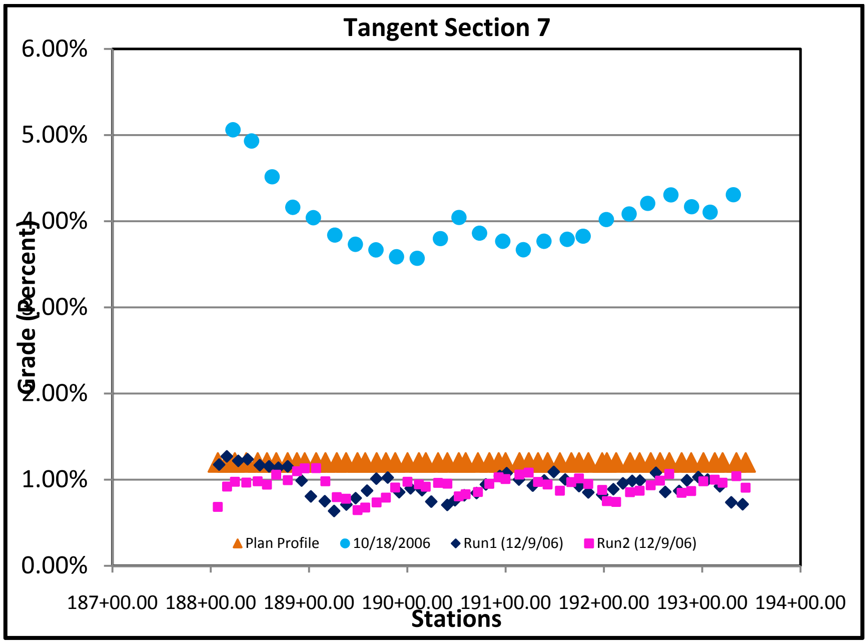


Figure 40: Tangent Section 7 on SCDOT Test Road

Atlanta Segments

A comparison was conducted between the data collected on Atlanta roadway segments to the plan profile sheets for the grade obtained from the Georgia Department of Transportation (GDOT). Data was collected on eleven segments in the Atlanta area, but plan sheets were only available for two of the segments. GDOT was contacted at the state, area, and county level to try to obtain these plans. The comparative analysis was conducted on the two available segments to determine the absolute error in the data from the plan profile sheets to the collected data. The same process of comparison was used as mentioned for the Test Road. Figures 41 and 42 show a visual grade comparison for segments 21 and 42, respectively. To show all the travel runs in the same orientation, the inverse on the grade was taken for the travel runs in the opposite direction. Tables 6 and 7 show the absolute error for the segments 21 and 42, respectively.

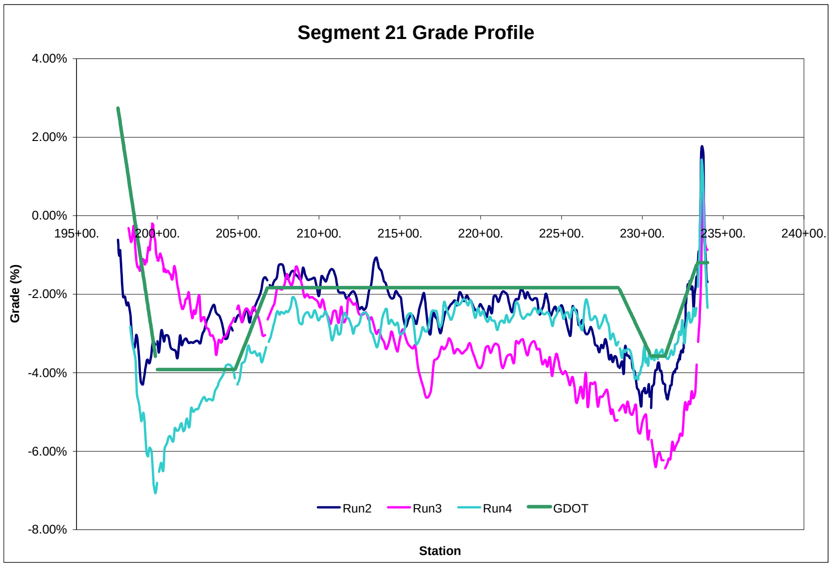


Figure 41: Grade Comparison on Segment 21

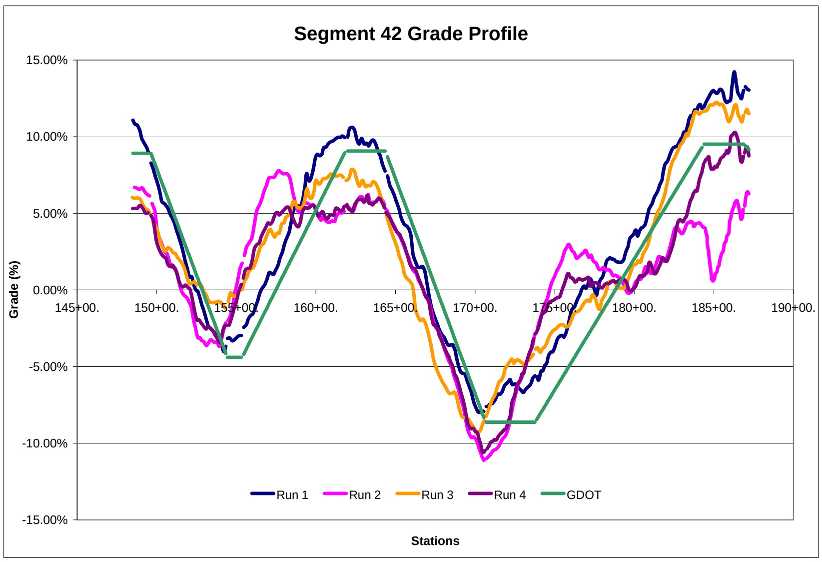


Figure 42: Grade Comparison on Segment 42

Table 6: Absolute Error in Grade for Segment 21

Type	Grade - Absolute Error						
	Run 2	Run 3	Run 4	Length of Curve Types	Average	Best Case Run 2&4	Worst Case Run 3&4
Crest Vertical Curve	1.97%	1.79%	1.77%	450	1.84%	1.87%	1.78%
Sag Vertical Curve	0.83%	2.09%	0.69%	400	1.20%	0.76%	1.39%
Tangent Section	0.65%	1.58%	0.81%	2803	1.01%	0.73%	1.19%
Absolute Error (Weighted)	**0.83%**	**1.66%**	**0.91%**		**1.14%**	**0.87%**	**1.66%**

Table 7: Absolute Error in Grade for Segment 42

Type	Grade - Absolute Error							
	Run 1	Run 2	Run 3	Run 4	Length of Curve Type	Average	Best Case Run 1&3	Worst Case Run 2&4
Crest Vertical Curve	1.13%	2.87%	3.05%	2.58%	1140	2.41%	2.09%	2.73%
Sag Vertical Curve	2.37%	4.21%	2.28%	3.12%	1711	3.00%	2.33%	3.67%
Tangent Section	1.97%	4.65%	2.76%	2.17%	1027	2.89%	2.36%	3.41%
Absolute Error (Weighted)	**1.90%**	**3.94%**	**2.63%**	**2.71%**		**2.79%**	**2.27%**	**3.32%**

Tables 6 and 7 show that after analyzing the different curve types, all producing a range of absolute error. In table 6, all three runs produce acceptable results, but since only two runs are required for best case Run 2 and 4 were averaged producing very good results. The crest vertical curve for Segment 21 had the highest absolute error for the plan data. The range of absolute error for Segment 21 was from 0.87% to 1.66% error. In table 7, Run 2 produced significantly higher error results than the other three runs especially for the sag vertical curve and tangent section. With only two runs required, Runs 1 and 3 were selected and they produced results that were considered borderline acceptable based on the application. The absolute error range for Segment 42 was 2.27% to 3.32%. As shown in Figure 42, the data seems to be shifted to the left of center of the GDOT data that was obtained from the plan profile sheets. The data collection seems to be around one hundred feet off of center. This could be due to the method of stationing or the process for finding the beginning and ending locations in the data sets.

To test the overall accuracy of the INU, the absolute errors for the curve types were averaged from the Test Road and the two roadway segments in Atlanta. The two vertical curve types and tangent section were the three different comparisons tested for absolute error. These results are shown in Tables 8 and 9 with Table 8 showing the best case scenario and Table 9 showing the worst case..

Table 8: INU Grade Comparison for Best Case Scenario

	Grade - Absolute Error (Best Case)			
Type	SCDOT Test Road	Segment 21	Segment 42	**Average**
Crest Vertical Curve	0.88%	1.87%	2.09%	**1.61%**
Sag Vertical Curve	0.65%	0.76%	2.33%	**1.25%**
Tangent Section	0.66%	0.73%	2.36%	**1.25%**
Absolute Error	**0.73%**	**0.87%**	**2.27%**	**1.29%**

Table 9: INU Grade Comparison for Worst Case Scenario

	Grade - Absolute Error (Worst Case)			
Type	SCDOT Test Road	Segment 21	Segment 42	**Average**
Crest Vertical Curve	2.17%	1.78%	2.73%	**2.23%**
Sag Vertical Curve	2.34%	1.39%	3.67%	**2.47%**
Tangent Section	3.12%	1.19%	3.41%	**2.57%**
Absolute Error	**2.54%**	**1.45%**	**3.27%**	**2.42%**

Table 8 shows that after analyzing the different curve types, the combined absolute error was 1.29%, while Table 9 shows a combined worst case of 2.42%. Analysis shows that the tangent section has the best overall average absolute error as expected. Table 8 also shows that for the two curve types and the tangent section, the Test Road produced the best results. This was expected based on the method of construction on the Test Road. The crest vertical curve produced the highest overall average absolute error of the different types. This was to be expected because of the bias in the vehicle. The positive two percent that was added to the grade means that the vehicle never got to a horizontal while traveling and on a crest vertical curve, the vehicle never made it to the peak grade.

Cross-Slope Comparison

The cross-slope for the Test Road for all three runs was arranged and analyzed in an Excel spreadsheet also. Table 10 shows the absolute error for each run for the cross-slope data as compared to the surveyed data obtained from the SCDOT. SCDOT survey data was only collected at twenty-five locations along a mile and a half long section. Thus, the absolute error comparison could only be performed for twenty five locations. The last row in Table 10 shows the absolute error for the collected cross-slope data for the average of all three runs. Figure 43 shows a graphical representation of the Cross-Slope Comparison.

Table 10: Absolute Error in Cross-Slope Data for Test Road

Run	Cross-Slope Absolute Error
10/18/06	0.00395
12/9/06 Run1	0.00368
12/9/06 Run2	0.00497
Absolute Error	**0.00420**

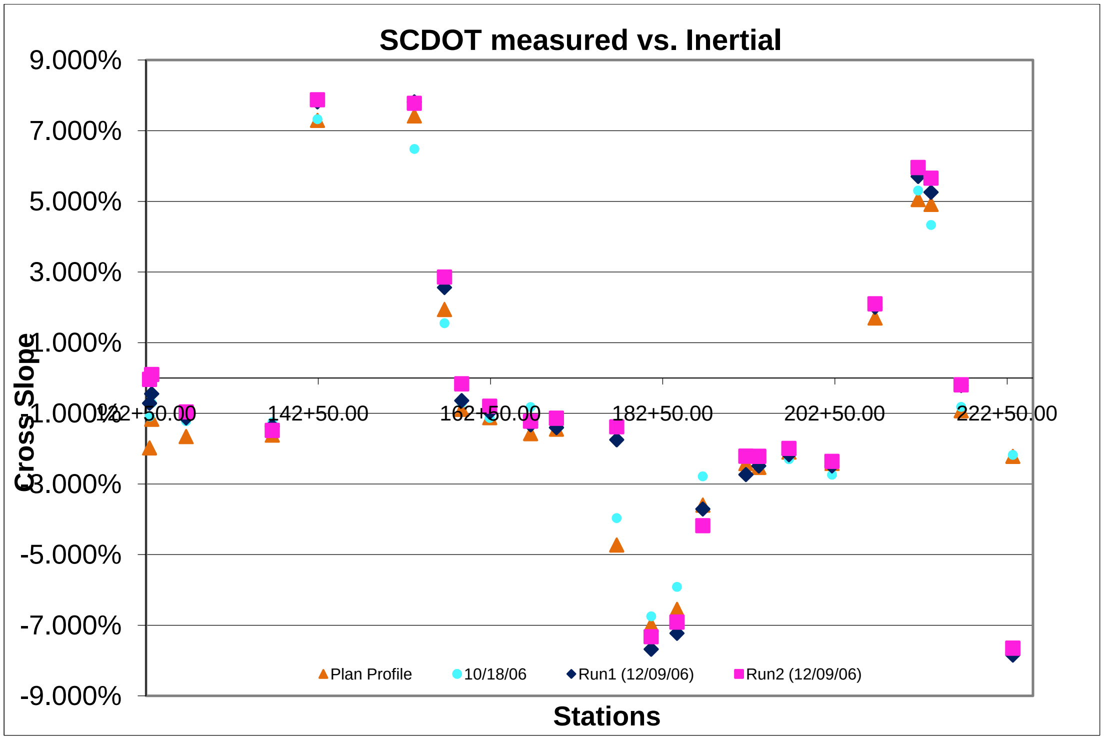


Figure 43: Cross-Slope Comparison versus Survey Data

The absolute error for the cross-slope obtained on the Test Road was determined to be acceptable for future analysis. As seen on Figure 43, there are two points on the graph that are skewed from the other results on the graph. These locations in the middle and at the end of the segment produced errors from the surveyed data of 3.35% and 5.43%, respectively.

The first location was found to be in a horizontal curve and the second was in a crest vertical curve and were determined to be anomalies in the data based on a manual review. The Videolog data for both runs were analyzed at these locations to determine if any factors such as erratic driving, traffic congesting, heavy tree cover, wrong travel lane, etc. could have caused these high errors. In both cases, there were no other vehicles on the roadway, a sufficient clear zone on the right side, clear skies, and a wide and clear grass median on the left side of the travel way providing adequate geometry for data collection.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This research was a feasibility study for determining if an instrumented vehicle can be used to collect Grade and Cross-Slope data for safety analysis. Multiple analysis techniques were researched to develop an approach to collect and extract GPS and INU data. A calibration test was conducted to validate and determine if any bias was present in the INU. The SCDOT Test Road and eleven roadway segments used in Atlanta were driven with an instrumented van to collect grade and cross-slope information. Based on the results obtained from the study, conclusions on the feasibility of using the Transportation Van for collecting the Grade and Cross-Slope data and recommendations for its use were developed.

The results for determining the grade of a roadway were considered to be acceptable based on the application after the calibration process was completed. The bias for the INU was determined to be a negative two percent. After this was determined, two percent was added to the grade data output from the INU. The Test Road then produced an absolute error of 2.09% with three runs of data. In order to do a safety analysis, only two runs of data are required so Run 1 was removed due to the large error and skewed graphical representation compared to Runs 2 & 3. Runs 2 & 3 gave an absolute error of 0.71% producing much better results. However, if runs 1 and 2 were the only runs available, the absolute error would have been 2.78% thus, additional work still needs to e completed to determine exact factors that increase and decrease the validity of the results.

The two Atlanta roadway segments that profile data was able to be obtained on produced absolute errors of 1.14% and 2.79% with all available data factored in. With all three runs of data, Segment 21 produced a 1.14% absolute error which are good results, but when only two runs of data were used an absolute error of 0.87% was achieved. Segment 42 produced a 2.79% absolute error when all four runs of data were averaged, but when only the two best runs of data were used, a 2.27% absolute error was achieved. On segment 42, the graphical representation shows that the data matches the grade profile of the roadway, but with the data shifted to the left of the GDOT plan data. This could be from an error in the method for stationing.

When all the data from the Test Road and Atlanta segment were analyzed together, it was determined that the crest vertical curve had the highest absolute error. It was also determined that the tangent section produced the best results for the absolute error. These results were expected based on the tangent section being a constant grade and the crest vertical curve being the peak of grade that was not obtained during data collection.

The results for the grade are acceptable based on the application that they are used for. However, an absolute error of plus or minus 2% would not be acceptable for use in determining stopping sight distance. Stopping sight distance would require much more accurate results in order this process to be an acceptable alternative. Knowing there would be a 2% error going into the data collection, a factor of safety could be built into the process in order to make the results conservative enough so that they would be acceptable. When the data is used in the application of determining stopping sight distance, grade measurements need to be more accurate for calculation purposes. When calculating stopping sight distance, if the grade is inaccurately measured, then the stopping sight distance will not be up to design standards opening the agency up to tort liability cases.

The results for determining the cross-slope of a roadway for the Test Road were used as the calibration and validation of the INU. The Test Road produced an absolute error of 0.42% with three runs of data that were collected. The cross-slope data shows that if using the INU to measure the normal crown of a roadway, the values could range from 1.6% to 2.4%. From the graph of the cross-slope comparison, only two of the locations that were surveyed showed to have high errors. The first location was in the beginning of a horizontal curve and the second location was in a crest vertical curve. Thus, it may be prudent to try additional processing to remove errors from curve sections.

Recommendations

As a result of this study and previous research, some recommendations can be made to improve the use of instrumented vehicles with GPS and Inertial Navigation Systems.

- Check to see if As-Built, Construction, or any form of roadway plans are available for a roadway to ensure that during the road section can be compared within the analysis process analysis can be done to the roadways. This should occur before the roadways are selected and data collected. With the Atlanta, GA roadway sections, plans were only available on two of the eleven selected roadway segments.

- As-Built plans that are current within the past twenty years should be obtained for the selected roadways to ensure that more accurate results can be evaluated with the instrumented vehicle.
- Based on the calibration model, it was determined that a travel speed during data collection of thirty to forty miles per hour obtained better results than collecting data at fifty-five miles per hour.
- For safety analysis, two runs per lane was determined to be sufficient for data analysis on the grade and cross-slope.
- Attaining Survey data for the roadway to be able to compare the cross-slope or superelevation data to is important to the calibration process for the inertial navigation unit.
- Data processing for the INU takes approximately four to seven hours to extract from the text file to Access, query out the data, export to Excel, and analyze. Once the Excel Spreadsheets and queries are setup, the process may go faster.
- Explore options for using the INU in a more rigid system. The INU is sensitive to even small movements in the Transportation Van. Some of this error is taken care of in the internal Kalman filter, but the use of a vehicle with a more rigid suspension system would remove some of the unnecessary noise in the data and help to reduce the error. In addition, the vehicle should likely be a single purpose

unit without a 26 foot extendable boon mounted in an off center location. This mast may have been the sole cause of much of the error in the system.

Recommendation for Future Research

Future research should be done to resolve some of the issues that occurred during the data collection. These issues include the rigidness in the Transportation Van, traffic congestion during data collection, human error, lane wander, and the power supply. These factors when added together can greatly impact the data in a negative way. Each issue is discussed in more detail along with some recommendations as to how to address each instance.

The Transportation Van produced some additional problems with data collection. The Van has a standard suspension and not a rigid one which allows for more bounce when traversing potholes or manholes in the roadway. With a standard suspension, any sudden movement or evasive maneuver causes extra error in the data with a recoil effect as well. The recoil effect is when the vehicle sways back and forth after a sudden movement until it gets back to level. This effect is amplified with the additional equipment installed in the Transportation and the mast arm. The recoil effect has the greatest effect on the cross-slope data. This creates additional noise in the data that the Kalman filter does not remove and can greatly affect the data. The recoil effect can be minimized by practicing safe driving and not following too closely and making sure to just stop and not swerve.

The mast arm and the addition section added to the top of the vehicle add additional error to the data collection process. These additions create extra tilt in the van when traversing curves creating unnecessary measurements that can skew the data. The mast arm did not seem to have as much of an effect on the cross-slope data as it did on the grade data. The consistent movement while traversing a curve did not affect as much as the constant weight on the front of the van. This could be the reasoning behind the crest vertical curves having a higher error than the other analysis types.

The Atlanta traffic presented a problem during data collection. Data was collected on a Sunday because it was determined to have the least amount of traffic to conflict with data collection. One problem was having to constantly accelerate and decelerate even with the lower amount of traffic not allowing for a constant speed of travel. Some of the roadway segments still had large amounts of traffic that made data collection more difficult. Surface conditions of the roadway can create noise in the data. Some of the roadways had potholes/manholes and had to be hit to stay in the middle of the lane. The INU has an internal Kalman filter program into it and this reduces some of this noise.

Human error is another contributing factor that can contribute to an error in data collection. This error is caused by not staying in the middle of the lane at all times called lane wander. Driving at a constant speed and in the center of the lane is a hard task for any driver to do during data collection. Some things that could be tried are changes in driving methods. The addition of a line in the windshield would give a line of reference to keep between the driver and the centerline of the roadway to help keep the driver as close as possible to the center of the lane. Lane wander has also been researched by FHWA and been determined that it can be reduced significantly by the addition of scanning lasers [19].

The power supply can cause some other problems in data collection as well. The inertial navigation unit is powered by the cigarette lighter which is attached to the alternator. The alternator produces a varying power source that can cause additional noise in the data collection. By changing the power supply to the inverter that is present in the Transportation Van, the INU would be getting a constant power supply with no variations. The manual for the INU indicates that it can take varying power, but removing all chances for noise in the data collection process would greatly improve the chances of not having noise in the data.

These factors can be resolved by using a vehicle without a mast arm or other vehicle modifications. The rigidness, or lack thereof, of the suspension for the vehicle collecting the data should be evaluated and alternatives established for future studies. Another thing that can be changed is the time of the data collection. One possibility is during late hours of the night. This minimizes the amount of traffic on the roadway. Another issue that can be reduced is the acceleration and deceleration at the beginning and end of the segment. By starting the data run long before the beginning of the segment, the vehicle can get up to a constant speed before the data collection starts, when roadway allows, and remove some effect on grade. This will continue through the end of the segment. The addition of scanning lasers or other such technologies would reduce the affect of lane wander on data collection.

The results have some limitations for the analysis of the grade and cross slope. The grade data is only as accurate as the as-built plans that are available for the roadway. As-built plans are not always available for the roadways segments that are evaluated for data collection, and if available are sometime out of date. The cross slope data can be derived from the as-built plans by using the curve data. The best way to get accurate results for cross slope data is to survey the roadway. These issues can be resolved by choosing roadways that were built in the last five years that have current as-built plans for future analysis.

Research could be conducted on new technologies that are available for the Transportation Van that would help reduce the effects of lane wander and improve data collection. Since the installation of the INU, a newer version of the INU is available that allows for addition of a more advanced GPS antenna. With some additional research, the DGPS present in the Transportation van might be able to be connected to the INU to account for more accurate results with this newer unit. Another addition could be the addition of scanning lasers. Scanning lasers, such as the ones used in the FHWA DHM vehicle, can be used to obtain more accurate cross slope information, provide another data verification check, and reduce the effects of lane wander.

Overall, the first test produced promising results, and better results would be expected if some of the variable elements were removed as described above. This type of low cost system has potential to provide sufficient data to build roadway inventories for safety analysis.

APPENDICES

APPENDIX A

Data Manual

GPS DATA COLLECTION PROCEDURES

SYSTEMS START UP:

1. Flip converter switch on located under the front passenger seat.
2. Use black key to unlock the CPU cabinet (located in the back of the van).
3. Put Laptop into docking station and startup Laptop.
4. While Laptop is starting up, open the cabinet containing the monitor located at the front of the van above the driver/passenger seats.
5. Secure the doors open with the Velcro on each door.
6. Use the remote control located on the left cabinet door to turn on the monitor.
7. Build a new daily folder, always using the month, day, year (e.g., 71906).
8. As soon as the screen displays all icons, click on “VLOG”, located on the right side of the screen towards the bottom.
9. Then locate the folder in which you are going to save the data into on that day.
10. Open the new folder and verify that it is empty, then click “ok”.
11. Go to Settings, Frame Rate, then select 1 or make sure that 1 is the current rate.
12. Drag window down to bottom of the screen.
13. Next, click on the “Maptitude” or “TRANSCAD” icon.

14. Select “create new map”, then “OK”.
15. Select “a county”.
16. Next enter the appropriate county name placing a comma after the county, then space, then finally entering “sc” (e.g., oconee, sc).
17. Then click “Next” and “Finish”.
18. When the map comes up on the screen, go to the cabinet in the back of the van and flip the “GPS Main” switch (the red light will appear).
19. Go to “Tools”, then GEO Utilities and select “read GPS data”.
20. Next, Click “ok” and “ok” again.
21. Locate “Today’s Folder”, and enter the file name (e.g., run1) and “save”. (If you are not ready to begin collecting the video log data, then wait until you are at your start point to click “save”.)

SHUT DOWN PROCEDURES:

1. Close all windows on the monitor.
2. Shut down the computer.
3. Turn off the converter.
4. Lock the cabinet.

CONVERT GPS DATA INTO MAPPED WITH PICTURES

1. Open Maptitude
2. Open Map of area as previously stated.
3. Open Layers, Select “Add Layers”
4. Add the GPS data that was collected during the data collection runs
5. Go to File Open, change file type to .csv and find the folder where the vlog was saved and select the “single-entry.csv”
6. With the current layer set to GPS Data, join the data views. Join the GPS Data (or if you renamed it to a run number and the single-entry) and the field to join is time.
7. Save as a Workspace. (If you save as a regular file, the join will be temporary and it will be gone when you close)

INERTIAL UNIT DATA COLLECTION PROCEDURES

1. Plug in INU into power source and allow it to warm up. (the INU require at least 1 minutes or continuous power before it is ready to use)
2. Plug the INU into the Laptop. (Do this after the INU has completed Step 1)
3. Startup the “Nav-VIEW 1.05 Software”. (If the Inertial was allowed to war up properly, the software will recognize the INU and the Serial Number will be displayed)

4. Select the “File” button near the bottom of the page and locate the place where you would like to store the run data.
5. Select the “DMU” Drop down menu and make sure that the NAV Packet is selected.
6. Select “Start Log” when you are ready to start data recording.
7. To shut down the INU, close the “Nav-VIEW 1.05 Software” and then unplug the INU.

INPUTTING INERTIAL DATA INTO EXCEL SPREADSHEET

1. Inertial Data is saved in as a text (.txt) file.
2. Remove Title Section where Column Headers are on the First Line.
3. Import data into Access.
4. Import Latitude(x) and Longitude (y) coordinates that were exported from Maptitude into Access.
5. Create relationship between the x and y table and the Inertial data table with the ID field.
6. Create a Query table with the Imported x, y and the ID, Lat, Long, Roll, Pitch, and Altitude from the Inertial Data Table.
7. Add a column to the Query table saying Expr1:1. This will make a column full of 1’s and will be used exclusively for the Crosstab Queries.

8. Use Crosstab Queries to average the Run Data (for every GPS location, there are approximately25 values for Roll, Pitch, and Altitude).
9. Crosstab Queries allow for 3 columns to be averages across. (one must be the ID field and after running the query, modify in design view to average the ID field). The 3 columns to use are the Lat, Long and ID, the column header in the query is the Expr1 field that was created.
10. Run these Crosstab Queries for the x, y, Roll, Pitch, and Altitude while making sure that all the table have the same amount of results.
11. Export each of these Runs as an Excel file.
12. Open all files in Excel and sort the Average ID field in ascending order (Crosstab sorts the first column in ascending, therefore, putting the data out of collection order).
13. Combine the x, y, Roll, Pitch, and Altitude Excel Spreadsheets to form the run data. Do this for each run of data.

APPENDIX B

Grade and Cross-Slope Data Spreadsheets

Table A-11: 10-18-06 Run on SCDOT Test Road Grade and Cross-Slope Analysis Spreadsheet

ID	Longitude (deg)	Latitude (deg)	L = Length of curve	G1	G2	DOT Stationing	Distance from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
	-81.171	*34.5309*		Approximate Starting Location													
12	34.530918	-81.171303				**122+22.62**		-0.0504	1.1702	140	**-0.09%**	**2.04%**	**4.04%**	**2.72%**		**1.32%**	TANGENT SECTION
13	34.530891	-81.171303				**122+33.54**		-0.0058	1.112	140	**-0.01%**	**1.94%**	**3.94%**	**2.72%**		**1.22%**	
14	34.530861	-81.171303				**122+44.45**		-0.0117	1.049	139.75	**-0.02%**	**1.83%**	**3.83%**	**2.72%**		**1.11%**	
15	34.53083	-81.171295				**122+55.37**		-0.1271	0.919	140	**-0.22%**	**1.60%**	**3.60%**	**2.72%**		**0.88%**	
16	34.5308	-81.171295				**122+66.29**		-0.2015	0.8081	140	**-0.35%**	**1.41%**	**3.41%**	**2.72%**		**0.69%**	
17	34.530766	-81.171295				**122+77.21**		-0.3056	0.6251	140	**-0.53%**	**1.09%**	**3.09%**	**2.72%**		**0.37%**	
18	34.530735	-81.171295				**122+88.12**		-0.4294	0.4638	140.5	**-0.75%**	**0.81%**	**2.81%**	**2.72%**		**0.09%**	
Crest VC starts at 123+00																	
19	34.530701	-81.171288	500	2.72%	-4.70%	**123+02.99**	497.01	-0.5307	0.4118	140.5	**-0.93%**	**0.72%**	**2.72%**	**2.68%**	**-7.42%**	**0.04%**	CREST VERTICAL CURVE
20	34.530674	-81.171288	500	2.72%	-4.70%	**123+13.91**	486.09	-0.6326	0.4042	140.5	**-1.10%**	**0.71%**	**2.71%**	**2.51%**	**-7.42%**	**0.19%**	
21	34.530643	-81.171288	500	2.72%	-4.70%	**123+24.82**	475.18	-0.7182	0.3671	140.75	**-1.25%**	**0.64%**	**2.64%**	**2.35%**	**-7.42%**	**0.29%**	
22	34.530613	-81.171288	500	2.72%	-4.70%	**123+35.74**	464.26	-0.7457	0.3984	140.75	**-1.30%**	**0.70%**	**2.70%**	**2.19%**	**-7.42%**	**0.51%**	
23	34.530582	-81.171288	500	2.72%	-4.70%	**123+46.66**	453.34	-0.7755	0.4245	141	**-1.35%**	**0.74%**	**2.74%**	**2.03%**	**-7.42%**	**0.71%**	
								....									
53	34.529465	-81.171265	500	2.72%	-4.70%	**127+56.11**	43.89	-2.2856	0.8336	139	**-3.99%**	**1.46%**	**3.46%**	**-4.05%**	**-7.42%**	**7.50%**	
54	34.529423	-81.171265	500	2.72%	-4.70%	**127+70.67**	29.33	-2.2672	0.8812	139	**-3.96%**	**1.54%**	**3.54%**	**-4.26%**	**-7.42%**	**7.80%**	
55	34.529377	-81.171265	500	2.72%	-4.70%	**127+85.22**	14.78	-2.263	0.9815	138.75	**-3.95%**	**1.71%**	**3.71%**	**-4.48%**	**-7.42%**	**8.19%**	
56	34.529339	-81.171265	500	2.72%	-4.70%	**127+99.78**	0.22	-2.2335	1.1049	138.75	**-3.90%**	**1.93%**	**3.93%**	**-4.70%**	**-7.42%**	**8.63%**	
Crest VC ends at 128+00						**5+00.00**											

ID	Longitude (deg)	Latitude (deg)	L = Length of curve	G1	G2	DOT Stationing	Distance from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
57	34.529293	-81.17126				**128+17.98**		-2.20319	1.2857	138.75	**-3.84%**	**2.24%**	**4.24%**	**-4.70%**		**8.94%**	TANGENT SECTION
58	34.529247	-81.17126				**128+32.53**		-2.15696	1.403	138.5	**-3.76%**	**2.45%**	**4.45%**	**-4.70%**		**9.15%**	
59	34.529202	-81.17126				**128+50.73**		-2.06908	1.4566	138.5	**-3.61%**	**2.54%**	**4.54%**	**-4.70%**		**9.24%**	
60	34.529156	-81.17126				**128+65.29**		-2.02096	1.5102	138.5	**-3.53%**	**2.64%**	**4.64%**	**-4.70%**		**9.34%**	
61	34.529114	-81.17126				**128+83.48**		-1.9714	1.4089	138.5	**-3.44%**	**2.46%**	**4.46%**	**-4.70%**		**9.16%**	
62	34.529064	-81.17126				**129+01.68**		-1.94325	1.2331	138.25	**-3.39%**	**2.15%**	**4.15%**	**-4.70%**		**8.85%**	
63	34.529022	-81.17125				**129+16.54**		-1.92665	1.0203	138.25	**-3.36%**	**1.78%**	**3.78%**	**-4.70%**		**8.48%**	
PC starts at 129+21.3885																	
Sag VC starts at 129+24.4																	
64	34.528973	-81.17125	300	-4.70%	3.08%	**129+34.74**	289.66	-1.91372	0.8824	138.25	**-3.34%**	**1.54%**	**3.54%**	**-4.43%**	**7.78%**	**7.97%**	HORIZONTAL AND SAG VERTICAL CURVE
65	34.528927	-81.17125	300	-4.70%	3.08%	**129+49.30**	275.10	-1.88684	0.8909	138.25	**-3.29%**	**1.56%**	**3.56%**	**-4.05%**	**7.78%**	**7.61%**	
66	34.528877	-81.17125	300	-4.70%	3.08%	**129+67.49**	256.91	-1.86088	0.9004	138	**-3.25%**	**1.57%**	**3.57%**	**-3.58%**	**7.78%**	**7.15%**	
67	34.528831	-81.17125	300	-4.70%	3.08%	**129+85.69**	238.71	-1.80112	0.8514	138	**-3.14%**	**1.49%**	**3.49%**	**-3.11%**	**7.78%**	**6.60%**	
								....									
77	34.528347	-81.17124	300	-4.70%	3.08%	**131+60.62**	63.78	-1.40308	0.5889	137.5	**-2.45%**	**1.03%**	**3.03%**	**1.43%**	**7.78%**	**1.60%**	
78	34.528297	-81.17123	300	-4.70%	3.08%	**131+79.06**	45.34	-1.37388	0.3852	137.25	**-2.40%**	**0.67%**	**2.67%**	**1.90%**	**7.78%**	**0.77%**	
79	34.528252	-81.17123	300	-4.70%	3.08%	**131+97.26**	27.14	-1.2585	0.2681	137.25	**-2.20%**	**0.47%**	**2.47%**	**2.38%**	**7.78%**	**0.09%**	
80	34.528206	-81.17123	300	-4.70%	3.08%	**132+11.82**	12.58	-1.25542	0.2767	137.25	**-2.19%**	**0.48%**	**2.48%**	**2.75%**	**7.78%**	**0.27%**	
Sag VC ends at 132+24.4						**3+00.00**											
81	34.528152	-81.17123				**132+33.65**		-1.35388	0.4514	137.25	**-2.36%**	**0.79%**	**2.79%**				HORIZONTAL CURVE
82	34.528107	-81.17123				**132+48.21**		-1.33652	0.6643	137.5	**-2.33%**	**1.16%**	**3.16%**				
								....									
87	34.527866	-81.17123				**133+35.55**		-1.25488	1.2023	136.75	**-2.19%**	**2.10%**	**4.10%**				
88	34.527821	-81.17123				**133+53.74**		-1.04963	1.4631	136.75	**-1.83%**	**2.55%**	**4.55%**				
Crest VC starts at 133+70																	
89	34.527771	-81.17123	400	3.08%	-0.94%	**133+71.94**	398.06	-0.8464	1.2261	136.75	**-1.48%**	**2.14%**	**4.14%**	**3.06%**	**-4.02%**	**1.08%**	HORIZONTAL AND CREST VERTICAL CURVE
90	34.527725	-81.17123	400	3.08%	-0.94%	**133+86.50**	383.50	-0.82288	0.8362	137	**-1.44%**	**1.46%**	**3.46%**	**2.91%**	**-4.02%**	**0.55%**	
91	34.527676	-81.17122	400	3.08%	-0.94%	**134+04.94**	365.06	-0.8165	0.7164	136.75	**-1.43%**	**1.25%**	**3.25%**	**2.73%**	**-4.02%**	**0.52%**	
92	34.52763	-81.17122	400	3.08%	-0.94%	**134+23.14**	346.86	-0.90442	0.9345	136.75	**-1.58%**	**1.63%**	**3.63%**	**2.55%**	**-4.02%**	**1.09%**	
								....									
109	34.526833	-81.1712	400	3.08%	-0.94%	**137+14.83**	55.17	-1.05767	0.7171	138.25	**-1.85%**	**1.25%**	**3.25%**	**-0.39%**	**-4.02%**	**3.64%**	
110	34.526787	-81.1712	400	3.08%	-0.94%	**137+29.39**	40.61	-1.14738	0.4883	138.5	**-2.00%**	**0.85%**	**2.85%**	**-0.53%**	**-4.02%**	**3.38%**	
111	34.526741	-81.1712	400	3.08%	-0.94%	**137+47.58**	22.42	-1.21554	0.1331	138.5	**-2.12%**	**0.23%**	**2.23%**	**-0.71%**	**-4.02%**	**2.95%**	
112	34.526699	-81.17119	400	3.08%	-0.94%	**137+62.45**	7.55	-1.23804	-0.218	138.5	**-2.16%**	**-0.38%**	**1.62%**	**-0.86%**	**-4.02%**	**2.48%**	
Crest VC ends at 137+70						**4+00.00**											

ID	Longitude (deg)	Latitude (deg)	L = Length of curve	G1	G2	DOT Stationing	Distance from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
113	34.52665	-81.17119				**137+80.64**		-1.2561	-0.4397	138.5	**-2.19%**	**-0.77%**	**1.23%**				HORIZONTAL CURVE
114	34.52661	-81.1712				**137+95.51**		-1.059	-0.2539	144	**-1.85%**	**-0.44%**	**1.56%**				
								....									
125	34.52624	-81.1712				**139+30.16**		-1.1056	-2.209	144.5	**-1.93%**	**-3.86%**	**-1.86%**				
126	34.52621	-81.1712				**139+41.08**		-1.1528	-2.4803	144.5	**-2.01%**	**-4.33%**	**-2.33%**				
Sag VC starts at 139+50																	
127	34.52617	-81.1712	300	-0.94%	0.86%	**139+55.63**	294.37	-1.1701	-2.5692	144.5	**-2.04%**	**-4.49%**	**-2.49%**	**-0.91%**	**1.80%**	**1.58%**	HORIZONTAL AND SAG VERTICAL CURVE
128	34.52614	-81.1712	300	-0.94%	0.86%	**139+66.55**	283.45	-1.2106	-2.6075	144.5	**-2.11%**	**-4.55%**	**-2.55%**	**-0.84%**	**1.80%**	**1.71%**	
129	34.5261	-81.1712	300	-0.94%	0.86%	**139+81.11**	268.89	-1.202	-2.5886	144	**-2.10%**	**-4.52%**	**-2.52%**	**-0.75%**	**1.80%**	**1.77%**	
130	34.52606	-81.1712	300	-0.94%	0.86%	**139+95.66**	254.34	-1.1668	-2.5713	143.75	**-2.04%**	**-4.49%**	**-2.49%**	**-0.67%**	**1.80%**	**1.82%**	
								....									
143	34.52553	-81.17113	300	-0.94%	0.86%	**141+91.09**	58.91	-0.961	-4.3886	144.5	**-1.68%**	**-7.67%**	**-5.67%**	**0.51%**	**1.80%**	**6.18%**	
144	34.52549	-81.17112	300	-0.94%	0.86%	**142+05.96**	44.04	-0.9967	-4.3644	144.5	**-1.74%**	**-7.63%**	**-5.63%**	**0.60%**	**1.80%**	**6.23%**	
145	34.52545	-81.1711	300	-0.94%	0.86%	**142+21.71**	28.29	-0.9488	-4.1412	144.5	**-1.66%**	**-7.24%**	**-5.24%**	**0.69%**	**1.80%**	**5.93%**	
146	34.52541	-81.1711	300	-0.94%	0.86%	**142+36.27**	13.73	-0.9236	-4.0009	144.5	**-1.61%**	**-6.99%**	**-4.99%**	**0.78%**	**1.80%**	**5.77%**	
Sag VC ends at 142+50						**3+00.00**											
147	34.52536	-81.17108				**142+55.44**		-0.8404	-4.0389	144.5	**-1.47%**	**-7.06%**	**-5.06%**				HORIZONTAL CURVE
148	34.52532	-81.17107				**142+70.30**		-0.7906	-4.248	144.5	**-1.38%**	**-7.43%**	**-5.43%**				
								....									
169	34.52442	-81.1707				**146+18.49**		-0.4828	-4.3466	146	**-0.84%**	**-7.60%**	**-5.60%**				
170	34.52438	-81.17068				**146+34.24**		-0.5336	-4.4018	146.75	**-0.93%**	**-7.70%**	**-5.70%**				
PT is at 146+36.5676																	
171	34.52434	-81.17064				**146+53.14**		-0.5608	-4.4535	147	**-0.98%**	**-7.79%**	**-5.79%**	**0.86%**		**6.65%**	TANGENT SECTION
172	34.52429	-81.17061				**146+73.45**		-0.4835	-4.3697	147	**-0.84%**	**-7.64%**	**-5.64%**	**0.86%**		**6.50%**	
173	34.52425	-81.17056				**146+94.40**		-0.403	-4.1622	147.25	**-0.70%**	**-7.28%**	**-5.28%**	**0.86%**		**6.14%**	
174	34.5242	-81.17053				**147+14.72**		-0.3135	-4.0017	147	**-0.55%**	**-7.00%**	**-5.00%**	**0.86%**		**5.86%**	
								....									
196	34.52329	-81.16969				**151+34.07**		-0.3198	-4.3722	146	**-0.56%**	**-7.65%**	**-5.65%**	**0.86%**		**6.51%**	
197	34.52325	-81.16964				**151+55.01**		-0.2775	-4.4579	146	**-0.48%**	**-7.80%**	**-5.80%**	**0.86%**		**6.66%**	
198	34.52321	-81.1696				**151+73.91**		-0.2787	-4.2351	146	**-0.49%**	**-7.41%**	**-5.41%**	**0.86%**		**6.27%**	
199	34.52317	-81.16956				**151+92.80**		-0.2353	-4.054	146	**-0.41%**	**-7.09%**	**-5.09%**	**0.86%**		**5.95%**	
Sag VC starts at 152+00																	
200	34.52314	-81.1695	300	0.86%	2.36%	**152+13.92**	286.08	-0.2398	-4.1612	146	**-0.42%**	**-7.28%**	**-5.28%**	**0.93%**	**1.50%**	**6.21%**	SAG VERTICAL CURVE
201	34.5231	-81.16945	300	0.86%	2.36%	**152+34.87**	265.13	-0.3503	-4.2503	145.75	**-0.61%**	**-7.43%**	**-5.43%**	**1.03%**	**1.50%**	**6.47%**	
202	34.52307	-81.1694	300	0.86%	2.36%	**152+53.47**	246.53	-0.4113	-4.3083	145.75	**-0.72%**	**-7.53%**	**-5.53%**	**1.13%**	**1.50%**	**6.66%**	
203	34.52303	-81.16935	300	0.86%	2.36%	**152+74.41**	225.59	-0.2735	-4.4381	145.5	**-0.48%**	**-7.76%**	**-5.76%**	**1.23%**	**1.50%**	**6.99%**	
								....									
210	34.52279	-81.16897	300	0.86%	2.36%	**154+19.16**	80.84	-0.3584	-3.3372	145.75	**-0.63%**	**-5.83%**	**-3.83%**	**1.96%**	**1.50%**	**5.79%**	
211	34.52275	-81.16891	300	0.86%	2.36%	**154+42.36**	57.64	-0.2885	-3.1372	145.75	**-0.50%**	**-5.48%**	**-3.48%**	**2.07%**	**1.50%**	**5.55%**	
212	34.52272	-81.16885	300	0.86%	2.36%	**154+63.48**	36.52	-0.2671	-2.8624	145.75	**-0.47%**	**-5.00%**	**-3.00%**	**2.18%**	**1.50%**	**5.18%**	
213	34.52269	-81.1688	300	0.86%	2.36%	**154+82.08**	17.92	-0.2345	-2.7259	146	**-0.41%**	**-4.76%**	**-2.76%**	**2.27%**	**1.50%**	**5.03%**	

ID	Longitude (deg)	Latitude (deg)	L = Length of curve	G1	G2	DOT Stationing	Distance from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
214	34.522663	-81.16874				**155+03.19**		-0.20336	-2.7618	146	**-0.35%**	**-4.82%**	**-2.82%**	**2.36%**		**5.18%**	TANGENT SECTION
215	34.522636	-81.16868				**155+22.68**		-0.23148	-2.8549	146	**-0.40%**	**-4.99%**	**-2.99%**	**2.36%**		**5.35%**	
216	34.522606	-81.16862				**155+43.79**		-0.344962	-2.8306	146	**-0.60%**	**-4.94%**	**-2.94%**	**2.36%**		**5.30%**	
217	34.522579	-81.16856				**155+64.91**		-0.396667	-2.6383	146	**-0.69%**	**-4.61%**	**-2.61%**	**2.36%**		**4.97%**	
218	34.522552	-81.1685				**155+86.02**		-0.42292	-2.4883	146	**-0.74%**	**-4.35%**	**-2.35%**	**2.36%**		**4.71%**	
219	34.522526	-81.16843				**156+08.33**		-0.44332	-2.4253	146	**-0.77%**	**-4.24%**	**-2.24%**	**2.36%**		**4.60%**	
220	34.522499	-81.16837				**156+29.44**		-0.36404	-2.2417	146	**-0.64%**	**-3.91%**	**-1.91%**	**2.36%**		**4.27%**	
221	34.522472	-81.1683				**156+53.19**		-0.346769	-1.9228	146	**-0.61%**	**-3.36%**	**-1.36%**	**2.36%**		**3.72%**	
222	34.522446	-81.16825				**156+69.92**		-0.312167	-1.6666	146	**-0.54%**	**-2.91%**	**-0.91%**	**2.36%**		**3.27%**	
223	34.522423	-81.16818				**156+93.66**		-0.35092	-1.491	146.25	**-0.61%**	**-2.60%**	**-0.60%**	**2.36%**		**2.96%**	
Crest VC starts at 157+00																	
224	34.522396	-81.16812	500	2.36%	-2.08%	**157+13.14**	486.86	-0.43604	-1.2396	146.25	**-0.76%**	**-2.16%**	**-0.16%**	**2.24%**	**-4.44%**	**2.41%**	CREST VERTICAL CURVE
225	34.522373	-81.16805	500	2.36%	-2.08%	**157+36.89**	463.11	-0.479346	-0.8898	146.25	**-0.84%**	**-1.55%**	**0.45%**	**2.03%**	**-4.44%**	**1.59%**	
226	34.522347	-81.16798	500	2.36%	-2.08%	**157+59.20**	440.80	-0.561792	-0.6934	146.25	**-0.98%**	**-1.21%**	**0.79%**	**1.83%**	**-4.44%**	**1.04%**	
227	34.52232	-81.16792	500	2.36%	-2.08%	**157+80.31**	419.69	-0.50328	-0.6958	146.25	**-0.88%**	**-1.21%**	**0.79%**	**1.65%**	**-4.44%**	**0.86%**	
								....									
243	34.521927	-81.16689	500	2.36%	-2.08%	**161+22.84**	77.16	-1.45856	0.61964	146.5	**-2.55%**	**1.08%**	**3.08%**	**-1.39%**	**-4.44%**	**4.48%**	
244	34.521904	-81.16682	500	2.36%	-2.08%	**161+46.59**	53.41	-1.45988	0.43128	146.5	**-2.55%**	**0.75%**	**2.75%**	**-1.61%**	**-4.44%**	**4.36%**	
245	34.521877	-81.16676	500	2.36%	-2.08%	**161+66.07**	33.93	-1.446154	0.39623	146.25	**-2.52%**	**0.69%**	**2.69%**	**-1.78%**	**-4.44%**	**4.47%**	
246	34.521851	-81.16669	500	2.36%	-2.08%	**161+89.82**	10.18	-1.549542	0.39429	146.5	**-2.70%**	**0.69%**	**2.69%**	**-1.99%**	**-4.44%**	**4.68%**	
Crest VC ends at 162+00						**5+00.00**											
247	34.521828	-81.16663				**162+09.30**		-1.67808	0.37124	146.25	**-2.93%**	**0.65%**	**2.65%**	**-2.08%**		**4.73%**	TANGENT SECTION
248	34.521801	-81.16656				**162+33.04**		-1.93064	0.4972	146.25	**-3.37%**	**0.87%**	**2.87%**	**-2.08%**		**4.95%**	
249	34.521778	-81.1665				**162+52.53**		-1.98284	0.6472	146.25	**-3.46%**	**1.13%**	**3.13%**	**-2.08%**		**5.21%**	
250	34.521751	-81.16644				**162+73.64**		-2.07308	0.61592	146	**-3.62%**	**1.08%**	**3.08%**	**-2.08%**		**5.16%**	
								....									
261	34.521484	-81.16572				**165+12.29**		-2.31468	0.74536	144.25	**-4.04%**	**1.30%**	**3.30%**	**-2.08%**		**5.38%**	
262	34.521461	-81.16565				**165+34.59**		-2.446115	0.62442	144.25	**-4.27%**	**1.09%**	**3.09%**	**-2.08%**		**5.17%**	
263	34.521435	-81.16559				**165+55.71**		-2.321458	0.70596	144.25	**-4.05%**	**1.23%**	**3.23%**	**-2.08%**		**5.31%**	
264	34.521412	-81.16552				**165+78.01**		-2.234923	0.78396	144	**-3.90%**	**1.37%**	**3.37%**	**-2.08%**		**5.45%**	
PC starts at 165+97.161						**3+97.00**											
265	34.521389	-81.16546				**165+97.50**		-2.1874	0.71116	144	**-3.82%**	**1.24%**	**3.24%**				HORIZONTAL CURVE
266	34.521362	-81.16539				**166+21.24**		-2.16912	0.64952	144	**-3.78%**	**1.13%**	**3.13%**				
								....									
289	34.520798	-81.16389				**171+19.10**		-2.150667	0.78417	141	**-3.75%**	**1.37%**	**3.37%**				

ID	Longitude (deg)	Latitude (deg)	L = Length of curve	G1	G2	DOT Stationing	Distance from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
Sag VC starts at 171+42.8																	
291	34.5207	-81.1638	300	-2.08%	-1.38%	**171+62.52**	280.28	-2.341	0.64228	140.75	**-4.08%**	**1.12%**	**3.12%**	**-2.03%**	**0.70%**	**5.16%**	HORIZONTAL AND SAG VERTICAL CURVE
292	34.5207	-81.1637	300	-2.08%	-1.38%	**171+83.63**	259.17	-2.3452	0.43396	140.5	**-4.09%**	**0.76%**	**2.76%**	**-1.98%**	**0.70%**	**4.74%**	
293	34.5207	-81.1636	300	-2.08%	-1.38%	**172+03.12**	239.68	-2.3064	0.42679	140.5	**-4.02%**	**0.74%**	**2.74%**	**-1.94%**	**0.70%**	**4.68%**	
294	34.5207	-81.1636	300	-2.08%	-1.38%	**172+25.42**	217.38	-2.3108	0.5358	140.5	**-4.03%**	**0.94%**	**2.94%**	**-1.89%**	**0.70%**	**4.82%**	
								....									
301	34.5205	-81.1631	300	-2.08%	-1.38%	**173+79.24**	63.56	-2.4054	0.56264	139.5	**-4.20%**	**0.98%**	**2.98%**	**-1.53%**	**0.70%**	**4.51%**	
302	34.5205	-81.163	300	-2.08%	-1.38%	**174+00.36**	42.44	-2.5138	0.59876	139.5	**-4.39%**	**1.05%**	**3.05%**	**-1.48%**	**0.70%**	**4.52%**	
303	34.5205	-81.163	300	-2.08%	-1.38%	**174+22.66**	20.14	-2.3343	0.6872	139.5	**-4.07%**	**1.20%**	**3.20%**	**-1.43%**	**0.70%**	**4.63%**	
304	34.5204	-81.1629	300	-2.08%	-1.38%	**174+42.15**	0.65	-2.1115	0.85668	139.25	**-3.68%**	**1.50%**	**3.50%**	**-1.38%**	**0.70%**	**4.88%**	
Sag VC ends at 174+42.8						**3+00.00**											
305	34.5204	-81.1628				**174+65.89**		-2.1925	1.09267	139	**-3.83%**	**1.91%**	**3.91%**				HORIZONTAL CURVE
306	34.5204	-81.1628				**174+87.01**		-2.2373	1.15978	139	**-3.90%**	**2.02%**	**4.02%**				
								....									
315	34.5202	-81.1622				**176+80.18**		-2.1942	1.98148	138	**-3.83%**	**3.46%**	**5.46%**				
316	34.5201	-81.1621				**177+02.49**		-2.2382	2.21768	138	**-3.91%**	**3.87%**	**5.87%**				
PT is at 177+14.1609																	
317	34.5201	-81.1621				**177+23.60**		-2.2725	2.33264	138	**-3.97%**	**4.07%**	**6.07%**	**-1.38%**		**7.45%**	TANGENT SECTION
318	34.5201	-81.162				**177+43.09**		-2.2735	2.27342	137.75	**-3.97%**	**3.97%**	**5.97%**	**-1.38%**		**7.35%**	
319	34.5201	-81.1619				**177+66.83**		-2.285	2.09304	137.75	**-3.99%**	**3.65%**	**5.65%**	**-1.38%**		**7.03%**	
320	34.52	-81.1619				**177+87.95**		-2.2847	1.85504	137.75	**-3.99%**	**3.24%**	**5.24%**	**-1.38%**		**6.62%**	
								....									
336	34.5195	-81.1609				**181+34.03**		-2.3952	3.90284	136	**-4.18%**	**6.82%**	**8.82%**	**-1.38%**		**10.20%**	
337	34.5195	-81.1609				**181+55.15**		-2.3462	3.86852	136	**-4.09%**	**6.76%**	**8.76%**	**-1.38%**		**10.14%**	
338	34.5195	-81.1608				**181+78.36**		-2.2326	3.9584	136	**-3.90%**	**6.92%**	**8.92%**	**-1.38%**		**10.30%**	
339	34.5194	-81.1607				**181+96.96**		-2.0044	3.8544	136	**-3.50%**	**6.74%**	**8.74%**	**-1.38%**		**10.12%**	
Sag VC starts at 182+00																	
340	34.5194	-81.1607	600	-1.38%	1.20%	**182+20.17**	579.83	-1.9748	3.29856	136	**-3.45%**	**5.76%**	**7.76%**	**-1.29%**	**2.58%**	**9.06%**	SAG VERTICAL CURVE
341	34.5194	-81.1606	600	-1.38%	1.20%	**182+41.28**	558.72	-2.0154	3.12176	135.75	**-3.52%**	**5.45%**	**7.45%**	**-1.20%**	**2.58%**	**8.66%**	
342	34.5193	-81.1606	600	-1.38%	1.20%	**182+62.40**	537.60	-1.9613	3.31428	135.75	**-3.42%**	**5.79%**	**7.79%**	**-1.11%**	**2.58%**	**8.90%**	
343	34.5193	-81.1605	600	-1.38%	1.20%	**182+83.34**	516.66	-1.9784	3.41328	135.75	**-3.45%**	**5.96%**	**7.96%**	**-1.02%**	**2.58%**	**8.99%**	
								....									
364	34.5185	-81.1594	600	-1.38%	1.20%	**187+35.94**	64.06	-0.76	1.71528	135.75	**-1.33%**	**2.99%**	**4.99%**	**0.92%**	**2.58%**	**4.07%**	
365	34.5184	-81.1593	600	-1.38%	1.20%	**187+54.84**	45.16	-0.6477	1.59458	136	**-1.13%**	**2.78%**	**4.78%**	**1.01%**	**2.58%**	**3.78%**	
366	34.5184	-81.1593	600	-1.38%	1.20%	**187+78.04**	21.96	-0.577	1.5548	136	**-1.01%**	**2.71%**	**4.71%**	**1.11%**	**2.58%**	**3.61%**	
367	34.5183	-81.1592	600	-1.38%	1.20%	**187+96.94**	3.06	-0.5658	1.65016	136	**-0.99%**	**2.88%**	**4.88%**	**1.19%**	**2.58%**	**3.69%**	

ID	Longitude (deg)	Latitude (deg)	L = Length of curve	G1	G2	DOT Stationing	Dist. from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
368	34.518303	-81.159195				**188+22.59**		-0.55344	1.75332	136	**-0.97%**	**3.06%**	**5.06%**	**1.20%**		**3.86%**	TANGENT SECTION
369	34.518261	-81.159149				**188+41.48**		-0.51524	1.67872	136	**-0.90%**	**2.93%**	**4.93%**	**1.20%**		**3.73%**	
370	34.518219	-81.159103				**188+62.43**		-0.67171	1.44125	136.25	**-1.17%**	**2.52%**	**4.52%**	**1.20%**		**3.32%**	
371	34.518177	-81.15905				**188+83.38**		-0.78904	1.23808	136.5	**-1.38%**	**2.16%**	**4.16%**	**1.20%**		**2.96%**	
								....									
389	34.517414	-81.15818				**192+68.14**		-0.68208	1.32062	138.5	**-1.19%**	**2.31%**	**4.31%**	**1.20%**		**3.11%**	
390	34.517372	-81.158134				**192+89.09**		-0.74288	1.24179	138.75	**-1.30%**	**2.17%**	**4.17%**	**1.20%**		**2.97%**	
391	34.517326	-81.158089				**193+07.98**		-0.69136	1.20588	138.75	**-1.21%**	**2.10%**	**4.10%**	**1.20%**		**2.90%**	
392	34.517284	-81.158035				**193+31.61**		-0.64888	1.322	138.5	**-1.13%**	**2.31%**	**4.31%**	**1.20%**		**3.11%**	
Crest VC starts at 193+50																	
393	34.517242	-81.157997	400	1.20%	-0.36%	**193+50.50**	399.50	-0.7044	1.42916	138.5	**-1.23%**	**2.49%**	**4.49%**	**1.20%**	**-1.56%**	**3.30%**	CREST VERTICAL CURVE
394	34.517197	-81.157944	400	1.20%	-0.36%	**193+73.71**	376.29	-0.696	1.32919	138.5	**-1.21%**	**2.32%**	**4.32%**	**1.11%**	**-1.56%**	**3.21%**	
395	34.517155	-81.157898	400	1.20%	-0.36%	**193+95.53**	354.47	-0.62384	1.28352	138.5	**-1.09%**	**2.24%**	**4.24%**	**1.02%**	**-1.56%**	**3.22%**	
396	34.517109	-81.15786	400	1.20%	-0.36%	**194+14.43**	335.57	-0.60767	1.37163	138.75	**-1.06%**	**2.39%**	**4.39%**	**0.95%**	**-1.56%**	**3.45%**	
								....									
408	34.516598	-81.15728	400	1.20%	-0.36%	**196+69.97**	80.03	-0.9405	1.16365	139.75	**-1.64%**	**2.03%**	**4.03%**	**-0.05%**	**-1.56%**	**4.08%**	
409	34.516556	-81.157234	400	1.20%	-0.36%	**196+90.91**	59.09	-0.97017	1.313	139.75	**-1.69%**	**2.29%**	**4.29%**	**-0.13%**	**-1.56%**	**4.42%**	
410	34.51651	-81.157181	400	1.20%	-0.36%	**197+14.54**	35.46	-0.99612	1.36412	139.75	**-1.74%**	**2.38%**	**4.38%**	**-0.22%**	**-1.56%**	**4.60%**	
411	34.516464	-81.157135	400	1.20%	-0.36%	**197+36.36**	13.64	-1.0642	1.31676	139.75	**-1.86%**	**2.30%**	**4.30%**	**-0.31%**	**-1.56%**	**4.61%**	H&C VC
Crest VC ends at 197+50						**4+00.00**											
412	34.516426	-81.157082				**197+57.48**		-1.15164	1.34444	140	**-2.01%**	**2.35%**	**4.35%**				HORIZONTAL CURVE
413	34.516384	-81.157043				**197+79.30**		-1.14812	1.25032	140	**-2.00%**	**2.18%**	**4.18%**				
								....									
436	34.515388	-81.15593				**202+72.57**		-1.95288	1.44427	138.75	**-3.41%**	**2.52%**	**4.52%**				
437	34.515347	-81.155876				**202+93.52**		-1.96904	1.46538	138.5	**-3.44%**	**2.56%**	**4.56%**				
Crest VC starts at 203+00																	
438	34.515301	-81.155838	400	0.36%	-1.62%	**203+15.34**	384.66	-2.00319	1.58158	138.25	**-3.50%**	**2.76%**	**4.76%**	**0.28%**	**-1.98%**	**4.48%**	HORIZONTAL AND CREST VERTICAL CURVE
439	34.515255	-81.155777	400	0.36%	-1.62%	**203+40.99**	359.01	-1.99592	1.67792	138.25	**-3.48%**	**2.93%**	**4.93%**	**0.16%**	**-1.98%**	**4.77%**	
440	34.515217	-81.155739	400	0.36%	-1.62%	**203+57.25**	342.75	-1.99204	1.52485	138	**-3.48%**	**2.66%**	**4.66%**	**0.08%**	**-1.98%**	**4.59%**	
441	34.515171	-81.155685	400	0.36%	-1.62%	**203+80.87**	319.13	-1.95273	1.41608	138	**-3.41%**	**2.47%**	**4.47%**	**-0.04%**	**-1.98%**	**4.51%**	
								....									
445	34.514999	-81.155495	400	0.36%	-1.62%	**204+67.54**	232.46	-1.74204	1.45468	137.75	**-3.04%**	**2.54%**	**4.54%**	**-0.47%**	**-1.98%**	**5.01%**	
446	34.514954	-81.155441	400	0.36%	-1.62%	**204+91.16**	208.84	-1.67748	1.42152	137.75	**-2.93%**	**2.48%**	**4.48%**	**-0.59%**	**-1.98%**	**5.07%**	
447	34.514915	-81.155388	400	0.36%	-1.62%	**205+09.77**	190.23	-1.7368	1.4156	137.75	**-3.03%**	**2.47%**	**4.47%**	**-0.68%**	**-1.98%**	**5.15%**	
448	34.514874	-81.15535	400	0.36%	-1.62%	**205+31.59**	168.41	-1.87896	1.47908	137.75	**-3.28%**	**2.58%**	**4.58%**	**-0.79%**	**-1.98%**	**5.37%**	
PT is at 205+43.6672						**2+68.00**											
449	34.514828	-81.155289	400	0.36%	-1.62%	**205+54.80**	145.20	-1.94292	1.44631	137.75	**-3.39%**	**2.52%**	**4.52%**	**-0.90%**	**-1.98%**	**5.43%**	CREST VERTICAL CURVE
450	34.514786	-81.155251	400	0.36%	-1.62%	**205+73.70**	126.30	-1.97424	1.18868	137.5	**-3.45%**	**2.07%**	**4.07%**	**-0.99%**	**-1.98%**	**5.07%**	
451	34.51474	-81.155205	400	0.36%	-1.62%	**205+97.32**	102.68	-1.96192	0.87638	137.25	**-3.42%**	**1.53%**	**3.53%**	**-1.11%**	**-1.98%**	**4.64%**	
452	34.514702	-81.155151	400	0.36%	-1.62%	**206+18.27**	81.73	-1.98992	0.70435	137	**-3.47%**	**1.23%**	**3.23%**	**-1.22%**	**-1.98%**	**4.44%**	
453	34.514656	-81.155106	400	0.36%	-1.62%	**206+37.16**	62.84	-1.94344	0.61668	137	**-3.39%**	**1.08%**	**3.08%**	**-1.31%**	**-1.98%**	**4.39%**	
454	34.514614	-81.155052	400	0.36%	-1.62%	**206+62.81**	37.19	-1.87967	0.33071	136.75	**-3.28%**	**0.58%**	**2.58%**	**-1.44%**	**-1.98%**	**4.01%**	

Table A-12: 12-9-06 Run 1 on SCDOT Test Road Grade and Cross-Slope Analysis Spreadsheet

ID	Longitude (deg)	Latitude (deg)	L = Len. of curve	G1	G2	DOT Stationing	Dist. from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
12	**-81.1713**	**34.53091**				**122+15.34**		1.0426	0.19496	133.00	**1.82%**	**0.34%**	**2.34%**	**2.72%**		**0.38%**	TANGENT SECTION
13	-81.171303	34.5309105				**122+15.34**		1.11044	0.1886	133.25	**1.94%**	**0.33%**	**2.33%**	**2.72%**		**0.39%**	
14	-81.171303	34.5309029				**122+18.98**		1.10116	0.22872	133.00	**1.92%**	**0.40%**	**2.40%**	**2.72%**		**0.32%**	
15	-81.171303	34.5308952				**122+18.98**		1.0414	0.21856	133.25	**1.82%**	**0.38%**	**2.38%**	**2.72%**		**0.34%**	
								....									
32	-81.171272	34.5307312				**122+85.33**		0.437667	-0.367375	135.00	**0.76%**	**-0.64%**	**1.36%**	**2.72%**		**1.36%**	
33	-81.171272	34.5307198				**122+88.97**		0.422208	-0.392125	135.25	**0.74%**	**-0.68%**	**1.32%**	**2.72%**		**1.40%**	
34	-81.171288	34.5307121				**122+96.01**		0.410192	-0.381385	135.00	**0.72%**	**-0.67%**	**1.33%**	**2.72%**		**1.39%**	
35	-81.171288	34.5307007				**122+99.65**		0.399875	-0.395333	135.25	**0.70%**	**-0.69%**	**1.31%**	**2.72%**		**1.41%**	
Crest VC starts at 123+00																	
36	-81.171288	34.5306931	500	2.72%	-4.70%	**123+03.28**	496.72	0.36116	-0.4076	135.25	**0.63%**	**-0.71%**	**1.29%**	**2.67%**	**-7.42%**	**1.38%**	CREST VERTICAL CURVE
37	-81.171288	34.5306816	500	2.72%	-4.70%	**123+06.92**	493.08	0.281769	-0.470115	135.25	**0.49%**	**-0.82%**	**1.18%**	**2.62%**	**-7.42%**	**1.44%**	
38	-81.171288	34.530674	500	2.72%	-4.70%	**123+10.56**	489.44	0.284792	-0.558417	135.75	**0.50%**	**-0.97%**	**1.03%**	**2.56%**	**-7.42%**	**1.54%**	
39	-81.171288	34.5306664	500	2.72%	-4.70%	**123+10.56**	489.44	0.250923	-0.603038	135.75	**0.44%**	**-1.05%**	**0.95%**	**2.56%**	**-7.42%**	**1.62%**	
								....									
105	-81.171227	34.5294228	500	2.72%	-4.70%	**127+71.07**	28.93	0.78772	-2.29704	142.25	**1.37%**	**-4.01%**	**-2.01%**	**-4.27%**	**-7.42%**	**2.26%**	
106	-81.171227	34.5293999	500	2.72%	-4.70%	**127+78.34**	21.66	0.81544	-2.287	142.25	**1.42%**	**-3.99%**	**-1.99%**	**-4.38%**	**-7.42%**	**2.38%**	
107	-81.171227	34.529377	500	2.72%	-4.70%	**127+85.62**	14.38	0.85564	-2.29508	142.25	**1.49%**	**-4.01%**	**-2.01%**	**-4.49%**	**-7.42%**	**2.48%**	
108	-81.171227	34.5293541	500	2.72%	-4.70%	**127+96.54**	3.46	0.90824	-2.27984	142.50	**1.59%**	**-3.98%**	**-1.98%**	**-4.65%**	**-7.42%**	**2.67%**	
Crest VC ends at 128+00																	
109	-81.171227	34.5293312				**128+03.82**		1.034	-2.25696	142.50	**1.80%**	**-3.94%**	**-1.94%**	**-4.70%**		**2.76%**	TANGENT SECTION
110	-81.171227	34.5293083				**128+11.10**		1.155375	-2.247375	142.50	**2.02%**	**-3.92%**	**-1.92%**	**-4.70%**		**2.78%**	
111	-81.171227	34.5292854				**128+18.38**		1.23032	-2.281	142.50	**2.15%**	**-3.98%**	**-1.98%**	**-4.70%**		**2.72%**	
112	-81.171227	34.5292625				**128+29.29**		1.254615	-2.230192	142.50	**2.19%**	**-3.89%**	**-1.89%**	**-4.70%**		**2.81%**	
								....									
120	-81.171227	34.5290756				**128+94.80**		1.28825	-1.960583	143.00	**2.25%**	**-3.42%**	**-1.42%**	**-4.70%**		**3.28%**	
121	-81.171219	34.5290527				**129+06.12**		1.17004	-1.95096	142.75	**2.04%**	**-3.41%**	**-1.41%**	**-4.70%**		**3.29%**	
122	-81.171219	34.5290299				**129+13.40**		1.04464	-1.92268	142.50	**1.82%**	**-3.36%**	**-1.36%**	**-4.70%**		**3.34%**	
123	-81.171211	34.529007				**129+21.28**		0.96964	-1.91856	142.50	**1.69%**	**-3.35%**	**-1.35%**	**-4.70%**		**3.35%**	
PC starts at 129+21.3885																	
Sag VC starts at 129+24.4																	
124	-81.171211	34.5289803	300	-4.70%	3.08%	**129+32.20**	292.20	0.89544	-1.92052	142.50	**1.56%**	**-3.35%**	**-1.35%**	**-4.50%**	**7.78%**	**3.14%**	HORIZONTAL AND SAG VERTICAL CURVE
125	-81.171204	34.5289574	300	-4.70%	3.08%	**129+40.07**	284.33	0.861111	-1.925148	142.75	**1.50%**	**-3.36%**	**-1.36%**	**-4.29%**	**7.78%**	**2.93%**	
126	-81.171211	34.5289307	300	-4.70%	3.08%	**129+51.40**	273.00	0.88488	-1.92212	143.00	**1.54%**	**-3.36%**	**-1.36%**	**-4.00%**	**7.78%**	**2.64%**	
127	-81.171211	34.528904	300	-4.70%	3.08%	**129+62.32**	262.08	0.898792	-1.93225	143.25	**1.57%**	**-3.37%**	**-1.37%**	**-3.72%**	**7.78%**	**2.34%**	
								....									
152	-81.171204	34.5282898	300	-4.70%	3.08%	**131+86.92**	37.48	0.560833	-1.2005	142.75	**0.98%**	**-2.10%**	**-0.10%**	**2.11%**	**7.78%**	**2.20%**	
153	-81.171204	34.5282631	300	-4.70%	3.08%	**131+97.84**	26.56	0.511115	-1.115962	142.75	**0.89%**	**-1.95%**	**0.05%**	**2.39%**	**7.78%**	**2.34%**	
154	-81.171196	34.5282364	300	-4.70%	3.08%	**132+05.12**	19.28	0.407458	-1.079083	142.75	**0.71%**	**-1.88%**	**0.12%**	**2.58%**	**7.78%**	**2.46%**	
155	-81.171196	34.5282097	300	-4.70%	3.08%	**132+16.03**	8.37	0.435	-1.095115	142.75	**0.76%**	**-1.91%**	**0.09%**	**2.86%**	**7.78%**	**2.77%**	
Sag VC ends at 132+24.4																	

ID	Longitude (deg)	Latitude (deg)	L = Len. of curve	G1	G2	DOT Stationing	Dist. from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
156	-81.171196	34.52818				**132+26.95**		0.51529	-1.0823	142.50	**0.90%**	**-1.89%**	**0.11%**				HORIZONTAL CURVE
157	-81.171196	34.52816				**132+34.23**		0.58735	-1.1341	142.50	**1.03%**	**-1.98%**	**0.02%**				
								....									
169	-81.171196	34.52784				**133+50.69**		1.44881	-0.93	142.25	**2.53%**	**-1.62%**	**0.38%**				
170	-81.171196	34.52781				**133+61.60**		1.51192	-0.7292	142.25	**2.64%**	**-1.27%**	**0.73%**				
Crest VC starts at 133+70																	
171	-81.171196	34.52778	400	3.08%	-0.94%	**133+72.52**	397.48	1.35804	-0.6203	142.00	**2.37%**	**-1.08%**	**0.92%**	**3.05%**	**-4.02%**	**2.14%**	HORIZONTAL AND CREST VERTICAL CURVE
172	-81.171196	34.52775	400	3.08%	-0.94%	**133+83.44**	386.56	1.09848	-0.6576	142.00	**1.92%**	**-1.15%**	**0.85%**	**2.94%**	**-4.02%**	**2.09%**	
173	-81.171196	34.52772	400	3.08%	-0.94%	**133+94.36**	375.64	0.98158	-0.629	142.00	**1.71%**	**-1.10%**	**0.90%**	**2.84%**	**-4.02%**	**1.93%**	
174	-81.171196	34.52769	400	3.08%	-0.94%	**134+05.27**	364.73	0.90927	-0.6638	142.00	**1.59%**	**-1.16%**	**0.84%**	**2.73%**	**-4.02%**	**1.88%**	
								....									
204	-81.171165	34.52681	400	3.08%	-0.94%	**137+26.94**	43.06	0.78427	-0.815	142.25	**1.37%**	**-1.42%**	**0.58%**	**-0.51%**	**-4.02%**	**1.08%**	
205	-81.171158	34.52678	400	3.08%	-0.94%	**137+38.26**	31.74	0.60792	-0.8815	142.25	**1.06%**	**-1.54%**	**0.46%**	**-0.62%**	**-4.02%**	**1.08%**	
206	-81.171158	34.52675	400	3.08%	-0.94%	**137+49.18**	20.82	0.44	-0.9688	142.25	**0.77%**	**-1.69%**	**0.31%**	**-0.73%**	**-4.02%**	**1.04%**	
207	-81.171158	34.52672	400	3.08%	-0.94%	**137+60.10**	9.90	0.22016	-1.0296	142.25	**0.38%**	**-1.80%**	**0.20%**	**-0.84%**	**-4.02%**	**1.04%**	
Crest VC ends at 137+70																	
208	-81.171158	34.52669				**137+71.02**		-0.00916	-1.0552	142.25	**-0.02%**	**-1.84%**	**0.16%**				HORIZONTAL CURVE
209	-81.171158	34.52666				**137+81.93**		-0.18892	-1.1016	142.25	**-0.33%**	**-1.92%**	**0.08%**				
								....									
223	-81.17115	34.52624				**139+35.19**		-2.39392	-1.2533	143.25	**-4.18%**	**-2.19%**	**-0.19%**				
224	-81.171143	34.52621				**139+46.51**		-2.48525	-1.2899	143.50	**-4.34%**	**-2.25%**	**-0.25%**				
Sag VC starts at 139+50																	
225	-81.17115	34.52617	300	-0.94%	0.86%	**139+61.38**	288.62	-2.6042	-1.3708	144.25	**-4.54%**	**-2.39%**	**-0.39%**	**-0.87%**	**1.80%**	**0.48%**	HORIZONTAL AND SAG VERTICAL CURVE
226	-81.17115	34.52614	300	-0.94%	0.86%	**139+72.30**	277.70	-2.65363	-1.3808	145.00	**-4.63%**	**-2.41%**	**-0.41%**	**-0.81%**	**1.80%**	**0.40%**	
227	-81.17115	34.5261	300	-0.94%	0.86%	**139+86.85**	263.15	-2.69152	-1.3825	145.00	**-4.70%**	**-2.41%**	**-0.41%**	**-0.72%**	**1.80%**	**0.31%**	
228	-81.17115	34.52607	300	-0.94%	0.86%	**139+97.77**	252.23	-2.77223	-1.2688	144.50	**-4.84%**	**-2.21%**	**-0.21%**	**-0.65%**	**1.80%**	**0.44%**	
								....									
245	-81.171074	34.52552	300	-0.94%	0.86%	**142+01.92**	48.08	-4.66896	-0.9231	144.50	**-8.14%**	**-1.61%**	**0.39%**	**0.57%**	**1.80%**	**0.18%**	
246	-81.171066	34.52548	300	-0.94%	0.86%	**142+16.47**	33.53	-4.64512	-0.9162	144.25	**-8.10%**	**-1.60%**	**0.40%**	**0.66%**	**1.80%**	**0.26%**	
247	-81.171066	34.52545	300	-0.94%	0.86%	**142+27.39**	22.61	-4.59321	-0.8674	143.75	**-8.01%**	**-1.51%**	**0.49%**	**0.72%**	**1.80%**	**0.24%**	
248	-81.171051	34.52542	300	-0.94%	0.86%	**142+39.86**	10.14	-4.46092	-0.8698	143.75	**-7.78%**	**-1.52%**	**0.48%**	**0.80%**	**1.80%**	**0.32%**	
Sag VC ends at 142+50																	
249	-81.171036	34.52539				**142+51.19**		-4.48204	-0.8248	143.75	**-7.81%**	**-1.44%**	**0.56%**				HORIZONTAL CURVE
250	-81.171028	34.52536				**142+62.51**		-4.56242	-0.6966	143.50	**-7.95%**	**-1.22%**	**0.78%**				
								....									
280	-81.170654	34.52446				**146+14.03**		-4.76636	-0.5417	142.25	**-8.31%**	**-0.95%**	**1.05%**				
281	-81.170631	34.52443				**146+26.50**		-4.75769	-0.6272	142.25	**-8.29%**	**-1.09%**	**0.91%**				
PT is at 146+36.5676																	

ID	Longitude (deg)	Latitude (deg)	L = Len. of curve	G1	G2	DOT Stationing	Dist. from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
282	-81.170616	34.524399				**146+37.82**		-4.75379	-0.61775	142.50	-8.29%	-1.08%	0.92%	0.86%		0.06%	TANGENT SECTION
283	-81.170601	34.524372				**146+50.29**		-4.80684	-0.6884	142.25	-8.38%	-1.20%	0.80%	0.86%		0.06%	
284	-81.170586	34.524345				**146+58.17**		-4.81708	-0.6966	142.25	-8.40%	-1.22%	0.78%	0.86%		0.08%	
285	-81.170563	34.524315				**146+75.30**		-4.78236	-0.66152	142.25	-8.34%	-1.15%	0.85%	0.86%		0.01%	
								....									
330	-81.169586	34.523258				**151+67.52**		-5.15188	-0.4904	141.50	-8.98%	-0.86%	1.14%	0.86%		0.28%	
331	-81.169563	34.523235				**151+79.13**		-5.07572	-0.48088	141.75	-8.85%	-0.84%	1.16%	0.86%		0.30%	
332	-81.16954	34.523212				**151+91.60**		-4.99608	-0.4232	141.75	-8.71%	-0.74%	1.26%	0.86%		0.40%	
333	-81.169525	34.52319				**151+99.47**		-5.0018	-0.40688	142.00	-8.72%	-0.71%	1.29%	0.86%		0.43%	
Sag VC starts at 152+00																	
334	-81.169495	34.523167	300	0.86%	2.36%	**152+13.55**	286.45	-5.071	-0.3228	141.75	-8.84%	-0.56%	1.44%	0.93%	1.50%	0.51%	SAG VERTICAL CURVE
335	-81.169479	34.523148	300	0.86%	2.36%	**152+21.43**	278.57	-5.18325	-0.3655	141.75	-9.03%	-0.64%	1.36%	0.97%	1.50%	0.39%	
336	-81.169441	34.523129	300	0.86%	2.36%	**152+35.50**	264.50	-5.20552	-0.42908	141.50	-9.07%	-0.75%	1.25%	1.04%	1.50%	0.21%	
337	-81.169418	34.523109	300	0.86%	2.36%	**152+44.95**	255.05	-5.20004	-0.550346	141.75	-9.06%	-0.96%	1.04%	1.08%	1.50%	0.05%	
								....									
357	-81.168861	34.522755	300	0.86%	2.36%	**154+62.86**	37.14	-3.83948	-0.5244	143.00	-6.70%	-0.92%	1.08%	2.17%	1.50%	1.09%	
358	-81.168839	34.522743	300	0.86%	2.36%	**154+69.90**	30.10	-3.71212	-0.47936	143.00	-6.47%	-0.84%	1.16%	2.21%	1.50%	1.05%	
359	-81.168808	34.522724	300	0.86%	2.36%	**154+81.50**	18.50	-3.54448	-0.48496	143.00	-6.18%	-0.85%	1.15%	2.27%	1.50%	1.11%	
360	-81.16877	34.522709	300	0.86%	2.36%	**154+94.09**	5.91	-3.47313	-0.479458	143.25	-6.06%	-0.84%	1.16%	2.33%	1.50%	1.17%	
Sag VC ends at 155+00																	
361	-81.168739	34.522694				**155+05.69**		-3.48976	-0.43268	143.50	-6.09%	-0.76%	1.24%	2.36%		1.12%	TANGENT SECTION
362	-81.168716	34.522678				**155+12.73**		-3.5446	-0.41556	143.50	-6.18%	-0.73%	1.27%	2.36%		1.09%	
363	-81.168678	34.522663				**155+26.81**		-3.58012	-0.494231	143.50	-6.24%	-0.86%	1.14%	2.36%		1.22%	
364	-81.168648	34.522644				**155+38.41**		-3.58825	-0.499083	143.50	-6.26%	-0.87%	1.13%	2.36%		1.23%	
								....									
375	-81.168289	34.522495				**156+59.32**		-2.68519	-0.516615	143.75	-4.68%	-0.90%	1.10%	2.36%		1.26%	
376	-81.168251	34.52248				**156+73.39**		-2.50276	-0.51284	143.75	-4.37%	-0.90%	1.10%	2.36%		1.26%	
377	-81.168221	34.522465				**156+85.00**		-2.4032	-0.49428	144.00	-4.19%	-0.86%	1.14%	2.36%		1.22%	
378	-81.16819	34.522453				**156+94.74**		-2.285	-0.504917	144.00	-3.99%	-0.88%	1.12%	2.36%		1.24%	
Crest VC starts at 157+00																	
379	-81.168159	34.522442	500	2.36%	-2.08%	**157+04.48**	495.52	-2.11704	-0.562852	144.00	-3.69%	-0.98%	1.02%	2.32%	-4.44%	1.30%	CREST VERTICAL CURVE
380	-81.168121	34.522427	500	2.36%	-2.08%	**157+17.07**	482.93	-1.96869	-0.598115	144.00	-3.44%	-1.04%	0.96%	2.21%	-4.44%	1.25%	
381	-81.168083	34.522419	500	2.36%	-2.08%	**157+29.65**	470.35	-1.82826	-0.632913	143.75	-3.19%	-1.10%	0.90%	2.10%	-4.44%	1.20%	
382	-81.168053	34.522408	500	2.36%	-2.08%	**157+39.40**	460.60	-1.65835	-0.674423	143.75	-2.89%	-1.18%	0.82%	2.01%	-4.44%	1.19%	
								....									
420	-81.166809	34.521931	500	2.36%	-2.08%	**161+60.17**	39.83	0.464885	-1.6355	145.00	0.81%	-2.86%	-0.86%	-1.73%	-4.44%	0.87%	
421	-81.166771	34.521915	500	2.36%	-2.08%	**161+72.76**	27.24	0.46788	-1.60832	144.75	0.82%	-2.81%	-0.81%	-1.84%	-4.44%	1.03%	
422	-81.16674	34.521904	500	2.36%	-2.08%	**161+84.36**	15.64	0.43596	-1.6358	144.75	0.76%	-2.86%	-0.86%	-1.94%	-4.44%	1.09%	
423	-81.166695	34.521893	500	2.36%	-2.08%	**161+99.86**	0.14	0.34908	-1.5724	144.50	0.61%	-2.75%	-0.75%	-2.08%	-4.44%	1.33%	
Crest VC ends at 162+00																	

ID	Longitude (deg)	Latitude (deg)	L = Len. of curve	G1	G2	DOT Stationing	Dist. from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
424	-81.16666	34.5219				**162+09.60**		0.29308	-1.760417	144.50	**0.51%**	**-3.07%**	**-1.07%**	**-2.08%**		**1.01%**	TANGENT SECTION
425	-81.16663	34.5219				**162+19.34**		0.32252	-1.78392	144.50	**0.56%**	**-3.11%**	**-1.11%**	**-2.08%**		**0.97%**	
426	-81.1666	34.5219				**162+29.08**		0.35164	-1.84308	144.50	**0.61%**	**-3.22%**	**-1.22%**	**-2.08%**		**0.86%**	
427	-81.16656	34.5218				**162+43.16**		0.37344	-2.0072	144.50	**0.65%**	**-3.50%**	**-1.50%**	**-2.08%**		**0.58%**	
....																	
455	-81.16562	34.5215				**165+58.94**		0.81308	-2.551208	142.50	**1.42%**	**-4.46%**	**-2.46%**	**-2.08%**		**0.38%**	
456	-81.16559	34.5215				**165+67.98**		0.89704	-2.49372	142.25	**1.57%**	**-4.36%**	**-2.36%**	**-2.08%**		**0.28%**	
457	-81.16556	34.5215				**165+79.58**		0.94808	-2.36292	142.00	**1.65%**	**-4.13%**	**-2.13%**	**-2.08%**		**0.05%**	
458	-81.16552	34.5215				**165+92.17**		0.89812	-2.33492	142.00	**1.57%**	**-4.08%**	**-2.08%**	**-2.08%**		**0.00%**	
PC starts at 165+97.161																	
459	-81.16549	34.5214				**166+03.77**		0.78844	-2.34292	142.00	**1.38%**	**-4.09%**	**-2.09%**				HORIZONTAL CURVE
460	-81.16545	34.5214				**166+16.36**		0.74236	-2.31116	142.00	**1.30%**	**-4.04%**	**-2.04%**				
....																	
506	-81.16393	34.5208				**171+25.66**		0.80071	-2.272583	139.25	**1.40%**	**-3.97%**	**-1.97%**				
507	-81.16389	34.5208				**171+39.74**		0.81296	-2.3148	139.25	**1.42%**	**-4.04%**	**-2.04%**				
Sag VC starts at 171+42.8																	
508	-81.16386	34.5208	300	-2.08%	-1.38%	**171+49.48**	293.32	0.79632	-2.28852	139.00	**1.39%**	**-4.00%**	**-2.00%**	**-2.06%**	**0.70%**	**0.07%**	HORIZONTAL AND SAG VERTICAL CURVE
509	-81.16383	34.5208	300	-2.08%	-1.38%	**171+59.22**	283.58	0.78573	-2.251	139.00	**1.37%**	**-3.93%**	**-1.93%**	**-2.04%**	**0.70%**	**0.11%**	
510	-81.1638	34.5208	300	-2.08%	-1.38%	**171+70.83**	271.97	0.81564	-2.23552	139.00	**1.42%**	**-3.90%**	**-1.90%**	**-2.01%**	**0.70%**	**0.11%**	
511	-81.16376	34.5208	300	-2.08%	-1.38%	**171+83.41**	259.39	0.78112	-2.28208	139.00	**1.36%**	**-3.99%**	**-1.99%**	**-1.99%**	**0.70%**	**0.00%**	
....																	
531	-81.16311	34.5205	300	-2.08%	-1.38%	**174+01.41**	41.39	0.68513	-2.540417	137.00	**1.20%**	**-4.44%**	**-2.44%**	**-1.48%**	**0.70%**	**0.96%**	
532	-81.16308	34.5205	300	-2.08%	-1.38%	**174+11.16**	31.64	0.7305	-2.525577	137.00	**1.27%**	**-4.41%**	**-2.41%**	**-1.45%**	**0.70%**	**0.96%**	
533	-81.16304	34.5205	300	-2.08%	-1.38%	**174+23.74**	19.06	0.72163	-2.582583	136.75	**1.26%**	**-4.51%**	**-2.51%**	**-1.42%**	**0.70%**	**1.09%**	
534	-81.16301	34.5205	300	-2.08%	-1.38%	**174+33.49**	9.31	0.7402	-2.6684	136.75	**1.29%**	**-4.66%**	**-2.66%**	**-1.40%**	**0.70%**	**1.26%**	
Sag VC ends at 174+42.8																	
535	-81.16297	34.5205				**174+47.56**		0.78524	-2.53292	136.50	**1.37%**	**-4.42%**	**-2.42%**				HORIZONTAL CURVE
536	-81.16294	34.5205				**174+57.30**		0.8944	-2.45312	136.50	**1.56%**	**-4.28%**	**-2.28%**				
....																	
558	-81.16222	34.5202				**176+98.42**		2.23127	-2.180077	134.50	**3.89%**	**-3.81%**	**-1.81%**				
559	-81.16219	34.5202				**177+08.16**		2.31258	-2.229208	134.50	**4.04%**	**-3.89%**	**-1.89%**				
PT is at 177+14.1609																	
560	-81.16216	34.5202				**177+19.77**		2.42123	-2.233308	134.50	**4.22%**	**-3.90%**	**-1.90%**	**-1.38%**		**0.52%**	TANGENT SECTION
561	-81.16212	34.5202				**177+32.35**		2.56913	-2.26475	134.50	**4.48%**	**-3.95%**	**-1.95%**	**-1.38%**		**0.57%**	
562	-81.16209	34.5201				**177+43.96**		2.72154	-2.276962	134.50	**4.75%**	**-3.98%**	**-1.98%**	**-1.38%**		**0.60%**	
563	-81.16206	34.5201				**177+53.70**		2.851	-2.310458	134.50	**4.97%**	**-4.03%**	**-2.03%**	**-1.38%**		**0.65%**	
....																	
600	-81.16089	34.5196				**181+64.82**		4.35463	-2.384708	132.75	**7.59%**	**-4.16%**	**-2.16%**	**-1.38%**		**0.78%**	
601	-81.16086	34.5196				**181+76.42**		4.36584	-2.42544	132.50	**7.61%**	**-4.24%**	**-2.24%**	**-1.38%**		**0.86%**	
602	-81.16082	34.5195				**181+90.50**		4.36535	-2.447885	132.50	**7.61%**	**-4.27%**	**-2.27%**	**-1.38%**		**0.89%**	
603	-81.1608	34.5195				**181+97.54**		4.4032	-2.36948	132.25	**7.68%**	**-4.14%**	**-2.14%**	**-1.38%**		**0.76%**	

ID	Longitude (deg)	Latitude (deg)	L = Len. of curve	G1	G2	DOT Stationing	Dist. from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
Sag VC starts at 182+00																	
604	-81.16077	34.51951	600	-1.38%	1.20%	**182+09.14**	590.86	4.59616	-2.26524	132.00	**8.01%**	**-3.96%**	**-1.96%**	**-1.34%**	**2.58%**	**0.61%**	
605	-81.16074	34.51949	600	-1.38%	1.20%	**182+20.74**	579.26	4.75308	-2.23664	132.00	**8.29%**	**-3.91%**	**-1.91%**	**-1.29%**	**2.58%**	**0.61%**	
606	-81.16071	34.51948	600	-1.38%	1.20%	**182+30.49**	569.51	4.70776	-2.10988	131.75	**8.21%**	**-3.68%**	**-1.68%**	**-1.25%**	**2.58%**	**0.44%**	
607	-81.16068	34.51946	600	-1.38%	1.20%	**182+42.09**	557.91	4.47992	-2.06128	131.75	**7.81%**	**-3.60%**	**-1.60%**	**-1.20%**	**2.58%**	**0.40%**	
608	-81.16065	34.51944	600	-1.38%	1.20%	**182+53.69**	546.31	4.26668	-2.04484	131.50	**7.44%**	**-3.57%**	**-1.57%**	**-1.15%**	**2.58%**	**0.42%**	SAG VERTICAL CURVE
								....									
656	-81.15937	34.51852	600	-1.38%	1.20%	**187+68.67**	31.33	2.53868	-0.67988	130.00	**4.43%**	**-1.19%**	**0.81%**	**1.07%**	**2.58%**	**0.25%**	
657	-81.15936	34.51851	600	-1.38%	1.20%	**187+73.39**	26.61	2.448107	-0.71107	129.50	**4.27%**	**-1.24%**	**0.76%**	**1.09%**	**2.58%**	**0.33%**	
658	-81.15932	34.51849	600	-1.38%	1.20%	**187+87.47**	12.53	2.2405	-0.59113	129.25	**3.91%**	**-1.03%**	**0.97%**	**1.15%**	**2.58%**	**0.18%**	
659	-81.1593	34.51847	600	-1.38%	1.20%	**187+96.92**	3.08	2.12596	-0.5188	128.75	**3.71%**	**-0.91%**	**1.09%**	**1.19%**	**2.58%**	**0.09%**	
Sag VC ends at 188+00																	
660	-81.15927	34.51845				**188+08.52**		2.07856	-0.47244	128.25	**3.63%**	**-0.82%**	**1.18%**	**1.20%**		**0.02%**	
661	-81.15926	34.51843				**188+16.40**		2.04332	-0.41752	127.50	**3.57%**	**-0.73%**	**1.27%**	**1.20%**		**0.07%**	
662	-81.15923	34.51841				**188+28.00**		2.01256	-0.44732	127.50	**3.51%**	**-0.78%**	**1.22%**	**1.20%**		**0.02%**	
663	-81.15921	34.51839				**188+37.45**		1.968455	-0.43655	127.50	**3.43%**	**-0.76%**	**1.24%**	**1.20%**		**0.04%**	
								....									TANGENT SECTION
705	-81.15818	34.51746				**193+05.45**		1.5675	-0.57235	131.00	**2.74%**	**-1.00%**	**1.00%**	**1.20%**		**0.20%**	
706	-81.15816	34.51743				**193+17.92**		1.576261	-0.61691	131.00	**2.75%**	**-1.08%**	**0.92%**	**1.20%**		**0.28%**	
707	-81.15813	34.51741				**193+29.53**		1.531167	-0.72371	131.00	**2.67%**	**-1.26%**	**0.74%**	**1.20%**		**0.46%**	
708	-81.1581	34.51739				**193+41.13**		1.529538	-0.73662	131.25	**2.67%**	**-1.29%**	**0.71%**	**1.20%**		**0.49%**	
Crest VC starts at 193+50																	
709	-81.15807	34.51737	400	1.20%	-0.36%	**193+52.73**	397.27	1.5452	-0.67684	131.50	**2.70%**	**-1.18%**	**0.82%**	**1.19%**	**-1.56%**	**0.37%**	
710	-81.15806	34.51734	400	1.20%	-0.36%	**193+64.06**	385.94	1.563704	-0.67741	132.25	**2.73%**	**-1.18%**	**0.82%**	**1.15%**	**-1.56%**	**0.33%**	
711	-81.15804	34.51731	400	1.20%	-0.36%	**193+76.53**	373.47	1.51768	-0.64652	132.50	**2.65%**	**-1.13%**	**0.87%**	**1.10%**	**-1.56%**	**0.22%**	
712	-81.15802	34.5173	400	1.20%	-0.36%	**193+83.57**	366.43	1.568833	-0.66721	133.00	**2.74%**	**-1.16%**	**0.84%**	**1.07%**	**-1.56%**	**0.23%**	CREST VERTICAL CURVE
713	-81.15799	34.51728	400	1.20%	-0.36%	**193+95.17**	354.83	1.553385	-0.704	132.75	**2.71%**	**-1.23%**	**0.77%**	**1.02%**	**-1.56%**	**0.25%**	
								....									
742	-81.15727	34.51664	400	1.20%	-0.36%	**197+16.05**	33.95	0.9282	-0.8654	134.75	**1.62%**	**-1.51%**	**0.49%**	**-0.23%**	**-1.56%**	**0.72%**	
743	-81.15725	34.51661	400	1.20%	-0.36%	**197+28.52**	21.48	1.03056	-0.91004	135.25	**1.80%**	**-1.59%**	**0.41%**	**-0.28%**	**-1.56%**	**0.69%**	
PC starts at 197+34.3193																	
744	-81.15724	34.51659	400	1.20%	-0.36%	**197+36.40**	13.60	1.129333	-0.93121	135.75	**1.97%**	**-1.63%**	**0.37%**	**-0.31%**	**-1.56%**	**0.68%**	H&C VC
745	-81.15723	34.51657	400	1.20%	-0.36%	**197+44.28**	5.72	1.193038	-0.92769	135.75	**2.08%**	**-1.62%**	**0.38%**	**-0.34%**	**-1.56%**	**0.72%**	
Crest VC ends at 197+50																	

ID	Longitude (deg)	Latitude (deg)	L = Len. of curve	G1	G2	DOT Stationing	Dist. from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
746	-81.1572	34.51655				**197+55.88**		1.23188	-0.901	136.00	**2.15%**	**-1.57%**	**0.43%**				HORIZONTAL CURVE
....																	
793	-81.15601	34.5155				**202+86.36**		1.2992	-1.876	135.00	**2.27%**	**-3.28%**	**-1.28%**				
794	-81.15598	34.51548				**202+97.96**		1.29736	-1.888	134.75	**2.26%**	**-3.30%**	**-1.30%**				
Crest VC starts at 203+00																	
795	-81.15594	34.51546	400	0.36%	-1.62%	**203+12.04**	387.96	1.38483	-1.876	134.50	**2.42%**	**-3.28%**	**-1.28%**	**0.30%**	**-1.98%**	**1.58%**	HORIZONTAL AND CREST VERTICAL CURVE
796	-81.15592	34.51544	400	0.36%	-1.62%	**203+21.49**	378.51	1.42685	-1.937	134.50	**2.49%**	**-3.38%**	**-1.38%**	**0.25%**	**-1.98%**	**1.64%**	
797	-81.15589	34.51542	400	0.36%	-1.62%	**203+33.09**	366.91	1.49558	-1.9	134.25	**2.61%**	**-3.32%**	**-1.32%**	**0.20%**	**-1.98%**	**1.51%**	
798	-81.15587	34.5154	400	0.36%	-1.62%	**203+42.54**	357.46	1.49777	-1.94	134.00	**2.61%**	**-3.39%**	**-1.39%**	**0.15%**	**-1.98%**	**1.54%**	
....																	
812	-81.15555	34.51507	400	0.36%	-1.62%	**204+99.10**	200.90	1.5986	-1.735	135.00	**2.79%**	**-3.03%**	**-1.03%**	**-0.63%**	**-1.98%**	**0.40%**	
813	-81.15552	34.51505	400	0.36%	-1.62%	**205+10.71**	189.29	1.5996	-1.725	135.00	**2.79%**	**-3.01%**	**-1.01%**	**-0.68%**	**-1.98%**	**0.33%**	
814	-81.15549	34.51503	400	0.36%	-1.62%	**205+22.31**	177.69	1.61035	-1.711	135.00	**2.81%**	**-2.99%**	**-0.99%**	**-0.74%**	**-1.98%**	**0.25%**	
815	-81.15547	34.515	400	0.36%	-1.62%	**205+34.78**	165.22	1.57428	-1.711	135.00	**2.75%**	**-2.99%**	**-0.99%**	**-0.80%**	**-1.98%**	**0.18%**	
PT is at 205+43.6672																	
816	-81.15544	34.51498	400	0.36%	-1.62%	**205+46.39**	153.61	1.53167	-1.705	135.00	**2.67%**	**-2.98%**	**-0.98%**	**-0.86%**	**-1.98%**	**0.12%**	CREST VERTICAL CURVE
817	-81.15542	34.51497	400	0.36%	-1.62%	**205+53.42**	146.58	1.4625	-1.649	135.00	**2.55%**	**-2.88%**	**-0.88%**	**-0.89%**	**-1.98%**	**0.01%**	
818	-81.15539	34.51494	400	0.36%	-1.62%	**205+67.60**	132.40	1.42865	-1.663	135.00	**2.49%**	**-2.90%**	**-0.90%**	**-0.96%**	**-1.98%**	**0.06%**	
819	-81.15536	34.51492	400	0.36%	-1.62%	**205+79.20**	120.80	1.39488	-1.706	135.00	**2.43%**	**-2.98%**	**-0.98%**	**-1.02%**	**-1.98%**	**0.04%**	
....																	
826	-81.15518	34.51477	400	0.36%	-1.62%	**206+57.69**	42.31	1.036	-1.966	135.00	**1.81%**	**-3.43%**	**-1.43%**	**-1.41%**	**-1.98%**	**0.02%**	
827	-81.15517	34.51475	400	0.36%	-1.62%	**206+65.57**	34.43	0.89196	-1.89	135.00	**1.56%**	**-3.30%**	**-1.30%**	**-1.45%**	**-1.98%**	**0.15%**	
828	-81.15514	34.51472	400	0.36%	-1.62%	**206+79.74**	20.26	0.77969	-1.922	135.00	**1.36%**	**-3.36%**	**-1.36%**	**-1.52%**	**-1.98%**	**0.16%**	
829	-81.15511	34.5147	400	0.36%	-1.62%	**206+91.35**	8.65	0.66117	-1.932	134.75	**1.15%**	**-3.37%**	**-1.37%**	**-1.58%**	**-1.98%**	**0.20%**	
Crest VC ends at 207+00																	

Table A-13: 12-9-06 Run 2 on SCDOT Test Road Grade and Cross-Slope Analysis Spreadsheet

ID	Longitude (deg)	Latitude (deg)	L = Length of curve	G1	G2	DOT Stationing	Distance from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
23	**-81.1713**	**34.531**				**122+15.34**		0.75056	0.27236	139.75	**1.31%**	**0.48%**	**2.48%**	**2.72%**		**0.24%**	TANGENT SECTION
24	-81.17127	34.5309				**122+22.62**		0.5966	0.1502	140.25	**1.04%**	**0.26%**	**2.26%**	**2.72%**		**0.46%**	
25	-81.17127	34.53088				**122+29.90**		0.604192	0.11204	140.5	**1.05%**	**0.20%**	**2.20%**	**2.72%**		**0.52%**	
26	-81.17127	34.53087				**122+33.54**		0.5555	0.10033	140	**0.97%**	**0.18%**	**2.18%**	**2.72%**		**0.54%**	
								....									
31	-81.17126	34.53078				**122+67.37**		0.21032	-0.2112	139.5	**0.37%**	**-0.37%**	**1.63%**	**2.72%**		**1.09%**	
32	-81.17126	34.53076				**122+74.65**		0.06768	-0.3159	139.5	**0.12%**	**-0.55%**	**1.45%**	**2.72%**		**1.27%**	
33	-81.17126	34.53074				**122+81.93**		0.02212	-0.4218	139.75	**0.04%**	**-0.74%**	**1.26%**	**2.72%**		**1.46%**	
34	-81.17126	34.5307				**122+96.49**		-0.03276	-0.6142	142.5	**-0.06%**	**-1.07%**	**0.93%**	**2.72%**		**1.79%**	
Crest VC starts at 123+00																	
35	-81.17126	34.53069	500	2.72%	-4.70%	123+00.13	499.87	-0.09812	-0.6692	141	**-0.17%**	**-1.17%**	**0.83%**	**2.72%**	**-7.42%**	**1.89%**	CREST VERTICAL CURVE
36	-81.17126	34.53067	500	2.72%	-4.70%	123+07.40	492.60	-0.05731	-0.7258	141	**-0.10%**	**-1.27%**	**0.73%**	**2.61%**	**-7.42%**	**1.88%**	
37	-81.17125	34.53064	500	2.72%	-4.70%	123+18.73	481.27	0.01524	-0.7778	141.75	**0.03%**	**-1.36%**	**0.64%**	**2.44%**	**-7.42%**	**1.80%**	
38	-81.17125	34.53062	500	2.72%	-4.70%	123+26.01	473.99	0.11308	-0.7568	141.75	**0.20%**	**-1.32%**	**0.68%**	**2.33%**	**-7.42%**	**1.66%**	
								....									
85	-81.17123	34.52945	500	2.72%	-4.70%	127+55.30	44.70	0.736231	-2.2813	140.75	**1.28%**	**-3.98%**	**-1.98%**	**-4.04%**	**-7.42%**	**2.05%**	
86	-81.17123	34.52942	500	2.72%	-4.70%	127+66.22	33.78	0.813542	-2.2855	141	**1.42%**	**-3.99%**	**-1.99%**	**-4.20%**	**-7.42%**	**2.21%**	
87	-81.17123	34.52938	500	2.72%	-4.70%	127+80.78	19.22	0.81824	-2.317	141	**1.43%**	**-4.05%**	**-2.05%**	**-4.41%**	**-7.42%**	**2.37%**	
88	-81.17123	34.52935	500	2.72%	-4.70%	127+91.69	8.31	0.82464	-2.2774	141.25	**1.44%**	**-3.98%**	**-1.98%**	**-4.58%**	**-7.42%**	**2.60%**	
Crest VC ends at 128+00																	
89	-81.17123	34.52932				128+02.61		0.98104	-2.2494	141.25	**1.71%**	**-3.93%**	**-1.93%**	**-4.70%**		**2.77%**	TANGENT SECTION
90	-81.17123	34.52929				128+13.53		1.11104	-2.2766	141.25	**1.94%**	**-3.98%**	**-1.98%**	**-4.70%**		**2.72%**	
91	-81.17123	34.52926				128+24.45		1.16148	-2.258	141.25	**2.03%**	**-3.94%**	**-1.94%**	**-4.70%**		**2.76%**	
92	-81.17123	34.52923				128+35.36		1.250826	-2.2169	141.25	**2.18%**	**-3.87%**	**-1.87%**	**-4.70%**		**2.83%**	
								....									
97	-81.17123	34.52909				128+86.31		1.2532	-2.0792	141.5	**2.19%**	**-3.63%**	**-1.63%**	**-4.70%**		**3.07%**	
98	-81.17123	34.52906				128+97.23		1.0886	-2.0712	141.5	**1.90%**	**-3.62%**	**-1.62%**	**-4.70%**		**3.08%**	
99	-81.17123	34.52903				129+08.15		0.89632	-2.0527	141.25	**1.56%**	**-3.58%**	**-1.58%**	**-4.70%**		**3.12%**	
100	-81.17123	34.529				129+19.07		0.827	-2.0405	141.25	**1.44%**	**-3.56%**	**-1.56%**	**-4.70%**		**3.14%**	
PC starts at 129+21.3885 (17+21.3885)																	
Sag VC starts at 129+24.4																	
101	-81.17123	34.52897	300	-4.70%	3.08%	**129+29.98**	294.42	0.787083	-2.0118	141.25	**1.37%**	**-3.51%**	**-1.51%**	**-4.56%**	**7.78%**	**3.04%**	HORIZONTAL AND SAG VERTICAL CURVE
102	-81.17123	34.52894	300	-4.70%	3.08%	**129+40.90**	283.50	0.793962	-1.9652	141.25	**1.39%**	**-3.43%**	**-1.43%**	**-4.27%**	**7.78%**	**2.84%**	
103	-81.17123	34.52891	300	-4.70%	3.08%	**129+51.82**	272.58	0.827417	-1.9603	141	**1.44%**	**-3.42%**	**-1.42%**	**-3.99%**	**7.78%**	**2.57%**	
104	-81.17123	34.52888	300	-4.70%	3.08%	**129+62.74**	261.66	0.79952	-1.946	141	**1.40%**	**-3.40%**	**-1.40%**	**-3.71%**	**7.78%**	**2.31%**	
								....									
126	-81.1712	34.52826	300	-4.70%	3.08%	**131+89.59**	34.81	0.525208	-1.3153	141	**0.92%**	**-2.30%**	**-0.30%**	**2.18%**	**7.78%**	**2.47%**	
127	-81.1712	34.52824	300	-4.70%	3.08%	**131+96.87**	27.53	0.47208	-1.252	141	**0.82%**	**-2.19%**	**-0.19%**	**2.37%**	**7.78%**	**2.55%**	
128	-81.1712	34.52821	300	-4.70%	3.08%	**132+07.79**	16.61	0.460346	-1.195	141	**0.80%**	**-2.09%**	**-0.09%**	**2.65%**	**7.78%**	**2.74%**	
129	-81.1712	34.52818	300	-4.70%	3.08%	**132+18.70**	5.70	0.5406	-1.1527	141	**0.94%**	**-2.01%**	**-0.01%**	**2.93%**	**7.78%**	**2.94%**	
Sag VC ends at 132+24.4																	

ID	Longitude (deg)	Latitude (deg)	L = Length of curve	G1	G2	DOT Stationing	Distance from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
130	-81.171196	34.528152				132+29.62		0.6184231	-1.20585	141	1.08%	-2.10%	-0.10%				HORIZONTAL CURVE
131	-81.171196	34.528126				132+36.90		0.6934583	-1.14542	141	1.21%	-2.00%	0.00%				
								....									
142	-81.171196	34.527817				133+49.72		1.454375	-0.81088	141.5	2.54%	-1.42%	0.58%				
143	-81.171196	34.527786				133+60.63		1.4775769	-0.63996	141.5	2.58%	-1.12%	0.88%				
Crest VC starts at 133+70																	
144	-81.171196	34.52776	400	3.08%	-0.94%	133+71.55	398.45	1.2704583	-0.66767	141.5	2.22%	-1.17%	0.83%	3.06%	-4.02%	2.23%	HORIZONTAL AND CREST VERTICAL CURVE
145	-81.171196	34.527729	400	3.08%	-0.94%	133+82.47	387.53	1.0276538	-0.70854	141.5	1.79%	-1.24%	0.76%	2.95%	-4.02%	2.19%	
146	-81.171188	34.527702	400	3.08%	-0.94%	133+93.79	376.21	0.93372	-0.72632	141.75	1.63%	-1.27%	0.73%	2.84%	-4.02%	2.11%	
147	-81.171196	34.527676	400	3.08%	-0.94%	134+01.67	368.33	0.87412	-0.71948	141.75	1.53%	-1.26%	0.74%	2.76%	-4.02%	2.02%	
148	-81.171196	34.527649	400	3.08%	-0.94%	134+12.59	357.41	0.87156	-0.74052	141.75	1.52%	-1.29%	0.71%	2.65%	-4.02%	1.94%	
								....									
180	-81.171158	34.526764	400	3.08%	-0.94%	137+38.30	31.70	0.5073333	-0.98575	141.5	0.89%	-1.72%	0.28%	-0.62%	-4.02%	0.90%	
181	-81.171158	34.526737	400	3.08%	-0.94%	137+45.58	24.42	0.3418846	-1.05346	141.5	0.60%	-1.84%	0.16%	-0.69%	-4.02%	0.86%	
182	-81.171158	34.526711	400	3.08%	-0.94%	137+56.50	13.50	0.14016	-1.096	141.75	0.24%	-1.91%	0.09%	-0.80%	-4.02%	0.89%	
183	-81.171158	34.526684	400	3.08%	-0.94%	137+67.41	2.59	-0.04012	-1.12824	141.75	-0.07%	-1.97%	0.03%	-0.91%	-4.02%	0.94%	
Crest VC ends at 137+70																	
184	-81.171158	34.526653				137+78.33		-0.13475	-1.13517	142	-0.24%	-1.98%	0.02%				HORIZONTAL CURVE
185	-81.171158	34.526623				137+89.25		-0.187115	-1.10362	142	-0.33%	-1.93%	0.07%				
								....									
199	-81.171158	34.52623				139+31.18		-2.33936	-1.25004	142	-4.08%	-2.18%	-0.18%				
200	-81.17115	34.526203				139+42.50		-2.44696	-1.27988	142.25	-4.27%	-2.23%	-0.23%				
Sag VC starts at 139+50																	
201	-81.17115	34.526173	300	-0.94%	0.86%	**139+53.42**	296.58	-2.56156	-1.2692	142.25	-4.47%	-2.22%	-0.22%	-0.92%	1.80%	0.70%	HORIZONTAL AND SAG VERTICAL CURVE
202	-81.17115	34.526146	300	-0.94%	0.86%	**139+60.70**	289.30	-2.64908	-1.28436	142	-4.62%	-2.24%	-0.24%	-0.88%	1.80%	0.63%	
203	-81.171143	34.526123	300	-0.94%	0.86%	**139+72.03**	277.97	-2.73092	-1.21904	142	-4.76%	-2.13%	-0.13%	-0.81%	1.80%	0.68%	
204	-81.171143	34.526096	300	-0.94%	0.86%	**139+79.30**	270.70	-2.783	-1.20248	142	-4.86%	-2.10%	-0.10%	-0.76%	1.80%	0.67%	
								....									
226	-81.171059	34.525482	300	-0.94%	0.86%	**142+09.12**	40.88	-4.64464	-1.13424	141.75	-8.10%	-1.98%	0.02%	0.61%	1.80%	0.59%	
227	-81.171051	34.525452	300	-0.94%	0.86%	**142+20.45**	29.55	-4.590875	-1.14204	141.75	-8.00%	-1.99%	0.01%	0.68%	1.80%	0.68%	
228	-81.171051	34.525425	300	-0.94%	0.86%	**142+31.37**	18.63	-4.548731	-1.13473	142	-7.93%	-1.98%	0.02%	0.75%	1.80%	0.73%	
229	-81.171036	34.525398	300	-0.94%	0.86%	**142+39.24**	10.76	-4.514808	-1.10315	142	-7.87%	-1.93%	0.07%	0.80%	1.80%	0.72%	
Sag VC ends at 142+50																	
230	-81.171028	34.525372				142+50.57		-4.516826	-1.00313	142	-7.88%	-1.75%	0.25%				HORIZONTAL CURVE
231	-81.171021	34.525345				142+61.90		-4.631154	-0.91523	141.75	-8.07%	-1.60%	0.40%				
								....									
267	-81.170609	34.52441				146+27.64		-4.83604	-0.76044	141.25	-8.43%	-1.33%	0.67%				
268	-81.170601	34.524387				146+35.52		-4.825792	-0.79021	141.25	-8.41%	-1.38%	0.62%				
PT is at 146+36.5676 (34+36.5676)																	

ID	Longitude (deg)	Latitude (deg)	L = Length of curve	G1	G2	DOT Stationing	Distance from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
269	-81.17058	34.52436				146+47.99		-4.87115	-0.8544	141.25	-8.49%	-1.49%	0.51%	0.86%		0.35%	TANGENT SECTION
270	-81.17056	34.52434				146+57.44		-4.89976	-0.8182	141	-8.54%	-1.43%	0.57%	0.86%		0.29%	
271	-81.17054	34.52431				146+69.91		-4.87364	-0.7826	141	-8.50%	-1.37%	0.63%	0.86%		0.23%	
272	-81.17053	34.52429				146+77.78		-4.83792	-0.7482	140.75	-8.43%	-1.31%	0.69%	0.86%		0.17%	
....																	
318	-81.1696	34.52324				151+62.03		-5.13288	-0.6308	143	-8.95%	-1.10%	0.90%	0.86%		0.04%	
319	-81.16957	34.52322				151+73.63		-5.0198	-0.6491	143	-8.75%	-1.13%	0.87%	0.86%		0.01%	
320	-81.16955	34.5232				151+83.08		-4.94885	-0.6396	142.75	-8.63%	-1.12%	0.88%	0.86%		0.02%	
321	-81.16953	34.52319				151+90.12		-4.87738	-0.5913	142.75	-8.50%	-1.03%	0.97%	0.86%		0.11%	
Sag VC starts at 152+00																	
322	-81.1695	34.52317	300	0.86%	2.36%	**152+01.72**	298.28	-4.88844	-0.607	142.75	-8.52%	-1.06%	0.94%	0.87%	1.50%	0.07%	SAG VERTICAL CURVE
323	-81.16948	34.52315	300	0.86%	2.36%	**152+11.17**	288.83	-4.92548	-0.5728	142.75	-8.59%	-1.00%	1.00%	0.92%	1.50%	0.08%	
324	-81.16945	34.52314	300	0.86%	2.36%	**152+20.91**	279.09	-4.9998	-0.6057	142.75	-8.72%	-1.06%	0.94%	0.96%	1.50%	0.02%	
325	-81.16943	34.52312	300	0.86%	2.36%	**152+30.36**	269.64	-4.999	-0.669	142.75	-8.71%	-1.17%	0.83%	1.01%	1.50%	0.18%	
....																	
347	-81.16883	34.52274	300	0.86%	2.36%	**154+61.64**	38.36	-3.92664	-0.6163	144.75	-6.85%	-1.08%	0.92%	2.17%	1.50%	1.24%	
348	-81.1688	34.52272	300	0.86%	2.36%	**154+73.24**	26.76	-3.82016	-0.6241	144.75	-6.66%	-1.09%	0.91%	2.23%	1.50%	1.32%	
349	-81.16877	34.52271	300	0.86%	2.36%	**154+82.98**	17.02	-3.65264	-0.5794	144.75	-6.37%	-1.01%	0.99%	2.27%	1.50%	1.29%	
350	-81.16874	34.5227	300	0.86%	2.36%	**154+92.73**	7.27	-3.48872	-0.5944	144.75	-6.09%	-1.04%	0.96%	2.32%	1.50%	1.36%	
Sag VC ends at 155+00																	
351	-81.16871	34.52268				155+04.33		-3.42728	-0.5653	144.5	-5.98%	-0.99%	1.01%	2.36%		1.35%	TANGENT SECTION
352	-81.16868	34.52267				155+14.07		-3.43379	-0.5499	144.75	-5.99%	-0.96%	1.04%	2.36%		1.32%	
353	-81.16865	34.52266				155+23.81		-3.49992	-0.5073	145	-6.10%	-0.89%	1.11%	2.36%		1.25%	
354	-81.16862	34.52264				155+35.42		-3.55465	-0.5578	145	-6.20%	-0.97%	1.03%	2.36%		1.33%	
....																	
366	-81.16827	34.52247				156+59.38		-2.72378	-0.7526	144	-4.75%	-1.31%	0.69%	2.36%		1.67%	
367	-81.16824	34.52246				156+69.12		-2.55742	-0.734	144	-4.46%	-1.28%	0.72%	2.36%		1.64%	
368	-81.16821	34.52245				156+78.87		-2.4334	-0.7114	144	-4.25%	-1.24%	0.76%	2.36%		1.60%	
369	-81.16818	34.52243				156+90.47		-2.336	-0.6727	144	-4.08%	-1.17%	0.83%	2.36%		1.53%	
Crest VC starts at 157+00																	
370	-81.16815	34.52242	500	2.36%	-2.08%	157+00.21	499.79	-2.25162	-0.6868	144	-3.93%	-1.20%	0.80%	2.36%	-4.44%	1.56%	CREST VERTICAL CURVE
371	-81.16812	34.52241	500	2.36%	-2.08%	157+09.95	490.05	-2.13339	-0.6914	144	-3.72%	-1.21%	0.79%	2.27%	-4.44%	1.48%	
372	-81.16808	34.5224	500	2.36%	-2.08%	157+22.54	477.46	-1.96327	-0.7189	143.75	-3.43%	-1.25%	0.75%	2.16%	-4.44%	1.41%	
373	-81.16805	34.52239	500	2.36%	-2.08%	157+32.28	467.72	-1.8354	-0.7532	143.75	-3.20%	-1.31%	0.69%	2.07%	-4.44%	1.39%	
....																	
414	-81.16676	34.52191	500	2.36%	-2.08%	161+63.30	36.70	0.45416	-1.7391	139.75	0.79%	-3.04%	-1.04%	-1.75%	-4.44%	0.72%	
415	-81.16673	34.5219	500	2.36%	-2.08%	161+73.04	26.96	0.47456	-1.7373	139.75	0.83%	-3.03%	-1.03%	-1.84%	-4.44%	0.81%	
416	-81.16669	34.52188	500	2.36%	-2.08%	161+87.12	12.88	0.44415	-1.7187	139.75	0.78%	-3.00%	-1.00%	-1.97%	-4.44%	0.96%	
417	-81.16666	34.52187	500	2.36%	-2.08%	161+96.86	3.14	0.39432	-1.7133	139.5	0.69%	-2.99%	-0.99%	-2.05%	-4.44%	1.06%	
Crest VC ends at 162+00																	

ID	Longitude (deg)	Latitude (deg)	L = Length of curve	G1	G2	DOT Stationing	Distance from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
418	-81.166634	34.521858				162+06.60		0.29592	-1.70192	139.25	**0.52%**	**-2.97%**	**-0.97%**	**-2.08%**		**1.11%**	TANGENT SECTION
419	-81.166603	34.521847				162+16.35		0.273043	-1.916739	139.25	**0.48%**	**-3.35%**	**-1.35%**	**-2.08%**		**0.73%**	
420	-81.166573	34.521835				162+26.09		0.30908	-1.85776	139	**0.54%**	**-3.24%**	**-1.24%**	**-2.08%**		**0.84%**	
421	-81.166542	34.521824				162+37.69		0.344615	-1.948923	139	**0.60%**	**-3.40%**	**-1.40%**	**-2.08%**		**0.68%**	
								....									
452	-81.165581	34.52145				165+64.40		0.62276	-2.67344	135.5	**1.09%**	**-4.67%**	**-2.67%**	**-2.08%**		**0.59%**	
453	-81.165558	34.521442				165+71.44		0.76675	-2.589042	135.75	**1.34%**	**-4.52%**	**-2.52%**	**-2.08%**		**0.44%**	
454	-81.16552	34.521431				165+84.03		0.78056	-2.47916	136	**1.36%**	**-4.33%**	**-2.33%**	**-2.08%**		**0.25%**	
455	-81.165497	34.521423				165+91.07		0.70472	-2.43936	136.25	**1.23%**	**-4.26%**	**-2.26%**	**-2.08%**		**0.18%**	
PC starts at 165+97.161 (53+97.161)																	
456	-81.165466	34.521416				166+00.10		0.609346	-2.447192	136.25	**1.06%**	**-4.27%**	**-2.27%**				HORIZONTAL CURVE
457	-81.165428	34.5214				166+14.18		0.641333	-2.469042	136.25	**1.12%**	**-4.31%**	**-2.31%**				
								....									
507	-81.163879	34.520824				171+34.30		0.73604	-2.38908	137.25	**1.28%**	**-4.17%**	**-2.17%**				
508	-81.163857	34.520813				171+41.34		0.6892	-2.3696	137.25	**1.20%**	**-4.14%**	**-2.14%**				
Sag VC starts at 171+42.8																	
509	-81.163818	34.520802	300	-2.08%	-1.38%	**171+53.92**	288.88	0.693538	-2.368769	137.25	**1.21%**	**-4.14%**	**-2.14%**	**-2.05%**	**0.70%**	**0.08%**	HORIZONTAL AND SAG VERTICAL CURVE
510	-81.163795	34.52079	300	-2.08%	-1.38%	**171+60.96**	281.84	0.710667	-2.373458	137.5	**1.24%**	**-4.14%**	**-2.14%**	**-2.04%**	**0.70%**	**0.11%**	
511	-81.163765	34.520775	300	-2.08%	-1.38%	**171+75.04**	267.76	0.635923	-2.394385	137.5	**1.11%**	**-4.18%**	**-2.18%**	**-2.00%**	**0.70%**	**0.18%**	
512	-81.163734	34.520763	300	-2.08%	-1.38%	**171+84.78**	258.02	0.56516	-2.52688	137.5	**0.99%**	**-4.41%**	**-2.41%**	**-1.98%**	**0.70%**	**0.43%**	
								....									
533	-81.163078	34.520515	300	-2.08%	-1.38%	**174+04.42**	38.38	0.472923	-2.544808	135.5	**0.83%**	**-4.44%**	**-2.44%**	**-1.47%**	**0.70%**	**0.97%**	
534	-81.163048	34.520504	300	-2.08%	-1.38%	**174+16.03**	26.77	0.435958	-2.532083	135.5	**0.76%**	**-4.42%**	**-2.42%**	**-1.44%**	**0.70%**	**0.98%**	
535	-81.16301	34.520493	300	-2.08%	-1.38%	**174+28.61**	14.19	0.46412	-2.60112	135.25	**0.81%**	**-4.54%**	**-2.54%**	**-1.41%**	**0.70%**	**1.13%**	
536	-81.162987	34.520481	300	-2.08%	-1.38%	**174+35.65**	7.15	0.538115	-2.671615	135	**0.94%**	**-4.67%**	**-2.67%**	**-1.40%**	**0.70%**	**1.27%**	
Sag VC ends at 174+42.8																	
537	-81.162949	34.52047				174+48.24		0.63068	-2.53208	135	**1.10%**	**-4.42%**	**-2.42%**				HORIZONTAL CURVE
538	-81.162926	34.520458				174+55.28		0.75308	-2.49064	135	**1.31%**	**-4.35%**	**-2.35%**				
								....									
561	-81.162216	34.520199				176+94.06		2.00472	-2.2692	133.25	**3.50%**	**-3.96%**	**-1.96%**				
562	-81.162186	34.520187				177+03.80		2.08676	-2.3404	133.25	**3.64%**	**-4.09%**	**-2.09%**				
PT is at 177+14.1609 (65+14.1609)																	
563	-81.162155	34.520172				177+15.41		2.18032	-2.3378	133.25	**3.80%**	**-4.08%**	**-2.08%**	**-1.38%**		**0.70%**	TANGENT SECTION
564	-81.162132	34.520161				177+25.15		2.33836	-2.33432	133.25	**4.08%**	**-4.08%**	**-2.08%**	**-1.38%**		**0.70%**	
565	-81.162102	34.520145				177+34.89		2.5116	-2.37016	133.25	**4.38%**	**-4.14%**	**-2.14%**	**-1.38%**		**0.76%**	
566	-81.162071	34.520134				177+46.50		2.659615	-2.369308	133	**4.64%**	**-4.14%**	**-2.14%**	**-1.38%**		**0.76%**	
								....									
605	-81.160904	34.519569				181+62.34		4.245833	-2.449708	131	**7.40%**	**-4.28%**	**-2.28%**	**-1.38%**		**0.90%**	
606	-81.160873	34.519554				181+73.94		4.26932	-2.43564	131	**7.44%**	**-4.25%**	**-2.25%**	**-1.38%**		**0.87%**	
607	-81.160851	34.519543				181+80.98		4.23652	-2.4772	131.25	**7.39%**	**-4.33%**	**-2.33%**	**-1.38%**		**0.95%**	
608	-81.16082	34.519527				181+90.72		4.20068	-2.44964	131.25	**7.33%**	**-4.28%**	**-2.28%**	**-1.38%**		**0.90%**	

ID	Longitude (deg)	Latitude (deg)	L = Length of curve	G1	G2	DOT Stationing	Distance from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
Sag VC starts at 182+00																	
609	-81.160789	34.51951	600	-1.38%	1.20%	**182+02.33**	597.67	4.28775	-2.38471	131.25	**7.48%**	**-4.16%**	**-2.16%**	**-1.37%**	**2.58%**	**0.79%**	SAG VERTICAL CURVE
610	-81.160759	34.51949	600	-1.38%	1.20%	**182+13.93**	586.07	4.42268	-2.27744	131.5	**7.71%**	**-3.98%**	**-1.98%**	**-1.32%**	**2.58%**	**0.66%**	
611	-81.160736	34.51947	600	-1.38%	1.20%	**182+23.38**	576.62	4.55804	-2.25756	131.75	**7.95%**	**-3.94%**	**-1.94%**	**-1.28%**	**2.58%**	**0.66%**	
612	-81.160706	34.51945	600	-1.38%	1.20%	**182+34.98**	565.02	4.535808	-2.14881	131.75	**7.91%**	**-3.75%**	**-1.75%**	**-1.23%**	**2.58%**	**0.52%**	
....																	
663	-81.159416	34.51851	600	-1.38%	1.20%	**187+64.18**	35.82	2.406038	-0.75931	131.25	**4.20%**	**-1.33%**	**0.67%**	**1.05%**	**2.58%**	**0.37%**	
664	-81.159393	34.51849	600	-1.38%	1.20%	**187+75.78**	24.22	2.419615	-0.73662	131.5	**4.22%**	**-1.29%**	**0.71%**	**1.10%**	**2.58%**	**0.38%**	
665	-81.15937	34.51847	600	-1.38%	1.20%	**187+85.23**	14.77	2.451652	-0.78191	131.5	**4.28%**	**-1.36%**	**0.64%**	**1.14%**	**2.58%**	**0.50%**	
666	-81.159355	34.51845	600	-1.38%	1.20%	**187+93.11**	6.89	2.396308	-0.77523	131.75	**4.18%**	**-1.35%**	**0.65%**	**1.17%**	**2.58%**	**0.52%**	
Sag VC ends at 188+00																	
667	-81.159325	34.51843				188+07.19		2.236667	-0.75408	131.75	**3.90%**	**-1.32%**	**0.68%**	**1.20%**		**0.52%**	TANGENT SECTION
668	-81.159302	34.51841				188+16.64		2.078808	-0.61892	131.75	**3.63%**	**-1.08%**	**0.92%**	**1.20%**		**0.28%**	
669	-81.159287	34.51839				188+24.51		2.035923	-0.58665	131.5	**3.55%**	**-1.02%**	**0.98%**	**1.20%**		**0.22%**	
670	-81.159256	34.51837				188+36.12		1.9925	-0.59229	131.5	**3.48%**	**-1.03%**	**0.97%**	**1.20%**		**0.23%**	
....																	
716	-81.158211	34.51743				193+12.75		1.268292	-0.57342	133.5	**2.21%**	**-1.00%**	**1.00%**	**1.20%**		**0.20%**	
717	-81.158196	34.51741				193+20.62		1.26892	-0.59388	133.25	**2.21%**	**-1.04%**	**0.96%**	**1.20%**		**0.24%**	
718	-81.158165	34.51739				193+34.70		1.233583	-0.54992	133.5	**2.15%**	**-0.96%**	**1.04%**	**1.20%**		**0.16%**	
719	-81.158142	34.51737				193+44.15		1.25956	-0.62604	133.5	**2.20%**	**-1.09%**	**0.91%**	**1.20%**		**0.29%**	
Crest VC starts at 193+50																	
720	-81.158127	34.51735	400	1.20%	-0.36%	193+52.03	397.97	1.250192	-0.69923	133.5	**2.18%**	**-1.22%**	**0.78%**	**1.19%**	**-1.56%**	**0.41%**	CREST VERTICAL CURVE
721	-81.158096	34.51733	400	1.20%	-0.36%	193+63.63	386.37	1.28288	-0.71972	133.5	**2.24%**	**-1.26%**	**0.74%**	**1.15%**	**-1.56%**	**0.40%**	
722	-81.158073	34.5173	400	1.20%	-0.36%	193+77.80	372.20	1.31956	-0.6726	133.25	**2.30%**	**-1.17%**	**0.83%**	**1.09%**	**-1.56%**	**0.27%**	
723	-81.158058	34.51728	400	1.20%	-0.36%	193+85.68	364.32	1.2908	-0.6322	133.5	**2.25%**	**-1.10%**	**0.90%**	**1.06%**	**-1.56%**	**0.16%**	
....																	
754	-81.157333	34.51664	400	1.20%	-0.36%	197+10.37	39.63	0.929577	-0.80604	135	**1.62%**	**-1.41%**	**0.59%**	**-0.21%**	**-1.56%**	**0.80%**	
755	-81.15731	34.51662	400	1.20%	-0.36%	197+19.82	30.18	0.90232	-0.84548	134.75	**1.57%**	**-1.48%**	**0.52%**	**-0.24%**	**-1.56%**	**0.77%**	
756	-81.15728	34.51661	400	1.20%	-0.36%	197+29.56	20.44	0.96268	-0.89232	134.75	**1.68%**	**-1.56%**	**0.44%**	**-0.28%**	**-1.56%**	**0.72%**	
PC starts at 197+34.3193 (85+34.3193)																	
757	-81.157265	34.51658	400	1.20%	-0.36%	197+42.03	7.97	1.06644	-0.94096	134.25	**1.86%**	**-1.64%**	**0.36%**	**-0.33%**	**-1.56%**	**0.69%**	H&CREST VC
Crest VC ends at 197+50																	

ID	Longitude (deg)	Latitude (deg)	L = Length of curve	G1	G2	DOT Stationing	Distance from end of Curve	Roll (deg)	Pitch (deg)	Altitude (m)	Cross Slope	Grade	+2% Grade	DOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
758	-81.157234	34.516563				197+53.63		1.1324	-0.97324	134.25	1.98%	-1.70%	0.30%				HORIZONTAL CURVE
759	-81.157211	34.516544				197+63.08		1.120962	-0.96742	134.25	1.96%	-1.69%	0.31%				
....																	
810	-81.156021	34.515514				202+92.27		1.194269	-1.78615	139.5	2.08%	-3.12%	-1.12%				
811	-81.155998	34.515495				202+99.31		1.26232	-1.87252	139.5	2.20%	-3.27%	-1.27%				
Crest VC starts at 203+00																	
812	-81.155975	34.515469	400	0.36%	-1.62%	203+11.78	388.22	1.320083	-1.92396	139.5	2.30%	-3.36%	-1.36%	0.30%	-1.98%	1.66%	HORIZONTAL AND CREST VERTICAL CURVE
813	-81.155952	34.515453	400	0.36%	-1.62%	203+23.38	376.62	1.30656	-1.91308	139.25	2.28%	-3.34%	-1.34%	0.24%	-1.98%	1.58%	
814	-81.15593	34.51543	400	0.36%	-1.62%	203+32.83	367.17	1.351889	-1.98993	139	2.36%	-3.47%	-1.47%	0.20%	-1.98%	1.67%	
815	-81.155907	34.515411	400	0.36%	-1.62%	203+42.28	357.72	1.368375	-1.97229	139	2.39%	-3.44%	-1.44%	0.15%	-1.98%	1.59%	
....																	
831	-81.155533	34.51508	400	0.36%	-1.62%	205+10.89	189.11	1.41012	-1.8394	139	2.46%	-3.21%	-1.21%	-0.68%	-1.98%	0.53%	
832	-81.15551	34.515064	400	0.36%	-1.62%	205+20.34	179.66	1.42212	-1.82488	139	2.48%	-3.19%	-1.19%	-0.73%	-1.98%	0.46%	
833	-81.155487	34.515038	400	0.36%	-1.62%	205+29.79	170.21	1.42696	-1.79704	138.75	2.49%	-3.14%	-1.14%	-0.78%	-1.98%	0.36%	
834	-81.155472	34.515018	400	0.36%	-1.62%	205+39.24	160.76	1.39852	-1.74328	138.5	2.44%	-3.04%	-1.04%	-0.82%	-1.98%	0.22%	
PT is at 205+43.6672 (93+43.6672)																	
835	-81.155441	34.514999	400	0.36%	-1.62%	205+50.84	149.16	1.347885	-1.71173	138.5	2.35%	-2.99%	-0.99%	-0.88%	-1.98%	0.11%	CREST VERTICAL CURVE
836	-81.155418	34.51498	400	0.36%	-1.62%	205+60.29	139.71	1.346792	-1.72479	138.5	2.35%	-3.01%	-1.01%	-0.93%	-1.98%	0.08%	
837	-81.155403	34.514961	400	0.36%	-1.62%	205+69.74	130.26	1.284154	-1.65462	138.5	2.24%	-2.89%	-0.89%	-0.98%	-1.98%	0.09%	
838	-81.155373	34.514938	400	0.36%	-1.62%	205+81.34	118.66	1.23112	-1.6548	138.25	2.15%	-2.89%	-0.89%	-1.03%	-1.98%	0.14%	
839	-81.15535	34.514919	400	0.36%	-1.62%	205+90.79	109.21	1.25716	-1.74232	138	2.19%	-3.04%	-1.04%	-1.08%	-1.98%	0.04%	
840	-81.155327	34.514896	400	0.36%	-1.62%	206+00.24	99.76	1.239042	-1.82192	138.25	2.16%	-3.18%	-1.18%	-1.13%	-1.98%	0.05%	
841	-81.155312	34.514877	400	0.36%	-1.62%	206+09.69	90.31	1.25112	-1.8752	138.25	2.18%	-3.27%	-1.27%	-1.17%	-1.98%	0.10%	
842	-81.155281	34.514854	400	0.36%	-1.62%	206+23.86	76.14	1.241885	-1.90762	138	2.17%	-3.33%	-1.33%	-1.24%	-1.98%	0.09%	
843	-81.155258	34.514835	400	0.36%	-1.62%	206+30.90	69.10	1.23875	-1.93029	138	2.16%	-3.37%	-1.37%	-1.28%	-1.98%	0.09%	
844	-81.155235	34.514816	400	0.36%	-1.62%	206+40.35	59.65	1.122	-1.97377	138	1.96%	-3.45%	-1.45%	-1.32%	-1.98%	0.12%	
845	-81.155212	34.514793	400	0.36%	-1.62%	206+54.52	45.48	1.061583	-1.96146	137.75	1.85%	-3.42%	-1.42%	-1.39%	-1.98%	0.03%	
846	-81.15519	34.514774	400	0.36%	-1.62%	206+63.97	36.03	0.9472	-1.99304	137.75	1.65%	-3.48%	-1.48%	-1.44%	-1.98%	0.04%	
847	-81.155167	34.514755	400	0.36%	-1.62%	206+71.01	28.99	0.774192	-1.94492	137.75	1.35%	-3.40%	-1.40%	-1.48%	-1.98%	0.08%	
848	-81.155144	34.514732	400	0.36%	-1.62%	206+85.18	14.82	0.70388	-1.9732	137.25	1.23%	-3.45%	-1.45%	-1.55%	-1.98%	0.10%	
849	-81.155121	34.514709	400	0.36%	-1.62%	206+94.63	5.37	0.61172	-2.03732	137	1.07%	-3.56%	-1.56%	-1.59%	-1.98%	0.04%	
Crest VC ends at 207+00																	

Table A-14: Run 2 on Segment 21 Grade Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	L = Len of curve	G1	G2	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations	Dist from end of Curve	GDOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
	33.9357	**-84.39**	**Segment 21 starting point**														
475	33.935623	-84.38982				1.21935	-1.28946	**2.13%**	**-2.25%**	**-0.25%**	269	197+45.91		2.90%		**3.15%**	TANGENT
Crest VC starts 197+50.00																	
476	33.935631	-84.38979	250	2.90%	-3.92%	0.78596	-1.4972	**1.37%**	**-2.61%**	**-0.61%**	269	197+55.71	244.29	2.74%	-6.82%	**3.36%**	CREST VERTICAL CURVE
477	33.935638	-84.38977	250	2.90%	-3.92%	0.3848	-1.72588	**0.67%**	**-3.01%**	**-1.01%**	269.25	197+62.79	237.21	2.55%	-6.82%	**3.56%**	
478	33.935642	-84.38975	250	2.90%	-3.92%	0.122	-1.65388	**0.21%**	**-2.89%**	**-0.89%**	269.25	197+68.85	231.15	2.38%	-6.82%	**3.27%**	
479	33.935654	-84.38972	250	2.90%	-3.92%	0.27658	-1.99881	**0.48%**	**-3.49%**	**-1.49%**	269.5	197+78.65	221.35	2.12%	-6.82%	**3.61%**	
								....									
493	33.935833	-84.38921	250	2.90%	-3.92%	0.11116	-3.29548	**0.19%**	**-5.76%**	**-3.76%**	267.5	199+49.54	50.46	-2.54%	-6.82%	**1.22%**	
494	33.935841	-84.38918	250	2.90%	-3.92%	0.43256	-3.21304	**0.75%**	**-5.61%**	**-3.61%**	267	199+59.34	40.66	-2.81%	-6.82%	**0.81%**	
495	33.935852	-84.38914	250	2.90%	-3.92%	0.1936	-2.98296	**0.34%**	**-5.21%**	**-3.21%**	266.75	199+72.01	27.99	-3.15%	-6.82%	**0.06%**	
496	33.93586	-84.38909	250	2.90%	-3.92%	-0.2707	-3.02608	**-0.47%**	**-5.29%**	**-3.29%**	266.5	199+87.6	12.40	-3.58%	-6.82%	**0.29%**	
Crest VC ends 200+00																	
497	33.935867	-84.38905				-0.415	-2.97556	**-0.72%**	**-5.20%**	**-3.20%**	266.25	200+00.27		-3.92%		**0.72%**	TANGENT SECTION
498	33.935875	-84.38902				0.16296	-3.13638	**0.28%**	**-5.48%**	**-3.48%**	265.5	200+09.37		-3.92%		**0.44%**	
499	33.935879	-84.38897				0.89842	-2.81404	**1.57%**	**-4.92%**	**-2.92%**	265.25	200+24.97		-3.92%		**1.00%**	
500	33.935886	-84.38892				0.86016	-2.97808	**1.50%**	**-5.20%**	**-3.20%**	264.75	200+40.56		-3.92%		**0.71%**	
								....									
527	33.935978	-84.38771				-0.0794	-2.9334	**-0.14%**	**-5.12%**	**-3.12%**	257.75	204+17.07		-3.92%		**0.79%**	
528	33.935978	-84.38766				0.45167	-2.93	**0.79%**	**-5.12%**	**-3.12%**	258.25	204+32.24		-3.92%		**0.80%**	
529	33.935978	-84.3876				0.80579	-2.77071	**1.41%**	**-4.84%**	**-2.84%**	258.5	204+50.43		-3.92%		**1.08%**	
530	33.935974	-84.38755				0.42035	-2.82139	**0.73%**	**-4.93%**	**-2.93%**	258.5	204+66.03		-3.92%		**0.99%**	
Sag VC starts 204+80.62																	
531	33.935974	-84.3875	200	-3.92%	-183%	0.04535	-2.69238	**0.08%**	**-4.70%**	**-2.70%**	258.75	204+81.2	199.42	-3.91%	2.08%	**1.21%**	SAG VERTICAL CURVE
532	33.935974	-84.38745	200	-3.92%	-183%	0.17287	-2.60591	**0.30%**	**-4.55%**	**-2.55%**	258.75	204+96.36	184.26	-3.75%	2.08%	**1.20%**	
533	33.935978	-84.38741	200	-3.92%	-183%	0.38933	-2.59585	**0.68%**	**-4.53%**	**-2.53%**	259	205+09.03	171.59	-3.62%	2.08%	**1.09%**	
534	33.935989	-84.38736	200	-3.92%	-183%	0.45865	-2.69304	**0.80%**	**-4.70%**	**-2.70%**	259.75	205+24.63	155.99	-3.46%	2.08%	**0.75%**	
								....									
542	33.936035	-84.38698	200	-3.92%	-183%	0.1395	-2.23192	**0.24%**	**-3.90%**	**-1.90%**	258	206+42.25	38.37	-2.23%	2.08%	**0.34%**	
543	33.936043	-84.38694	200	-3.92%	-183%	0.1832	-2.07716	**0.32%**	**-3.63%**	**-1.63%**	257.75	206+54.38	26.24	-2.11%	2.08%	**0.48%**	
544	33.93605	-84.3869	200	-3.92%	-183%	0.04716	-2.04352	**0.08%**	**-3.57%**	**-1.57%**	257.75	206+67.05	13.57	-198%	2.08%	**0.41%**	
545	33.936058	-84.38686	200	-3.92%	-183%	0.09469	-2.08773	**0.17%**	**-3.65%**	**-1.65%**	257.5	206+79.72	0.90	-184%	2.08%	**0.20%**	
Sag VC ends 206+80.62																	
546	33.936062	-84.38681				0.38267	-2.15875	**0.67%**	**-3.77%**	**-1.77%**	257.75	206+94.88		-183%		**0.06%**	TANGENT SECTION
547	33.936069	-84.38677				0.3608	-2.18312	**0.63%**	**-3.81%**	**-1.81%**	258	207+07.55		-183%		**0.02%**	
548	33.936073	-84.38672				0.07364	-2.09504	**0.13%**	**-3.66%**	**-1.66%**	258	207+22.72		-183%		**0.18%**	
549	33.936077	-84.38667				0.087	-2.05204	**0.15%**	**-3.58%**	**-1.58%**	258	207+38.31		-183%		**0.25%**	
								....									
694	33.936726	-84.37994				2.17654	-3.27975	**3.80%**	**-5.73%**	**-3.73%**	250.5	228+16.68		-183%		**1.90%**	
695	33.936729	-84.3799				2.22138	-3.19477	**3.88%**	**-5.58%**	**-3.58%**	250.5	228+28.81		-183%		**1.75%**	
696	33.936733	-84.37987				2.46604	-3.20738	**4.30%**	**-5.60%**	**-3.60%**	250.25	228+37.91		-183%		**1.77%**	
697	33.936737	-84.37983				2.83554	-3.34758	**4.95%**	**-5.85%**	**-3.85%**	250	228+50.58		-183%		**2.02%**	

ID	Latitude (deg)	Longitude (deg)	L = Len of curve	G1	G2	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations	Dist from end of Curve	GDOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
Crest VC starts 228+53.94																	
698	33.936741	-84.379799	200	-1.83%	-3.58%	2.7848	-3.3628	**4.86%**	**-5.88%**	**-3.88%**	250.5	228+59.68	194.26	-1.88%	-1.74%	**1.99%**	CREST VERTICAL CURVE
699	33.936749	-84.379753	200	-1.83%	-3.58%	2.52888	-3.2696	**4.41%**	**-5.71%**	**-3.71%**	250.5	228+75.28	178.66	-2.02%	-1.74%	**1.69%**	
700	33.936752	-84.379723	200	-1.83%	-3.58%	2.602	-3.4493	**4.54%**	**-6.03%**	**-4.03%**	250.75	228+84.38	169.56	-2.10%	-1.74%	**1.93%**	
701	33.936764	-84.379692	200	-1.83%	-3.58%	2.8678	-3.0502	**5.00%**	**-5.33%**	**-3.33%**	250.75	228+94.18	159.76	-2.18%	-1.74%	**1.14%**	
								....									
717	33.936832	-84.379272	200	-1.83%	-3.58%	3.04176	-3.7267	**5.31%**	**-6.51%**	**-4.51%**	250.25	230+26.31	27.63	-3.34%	-1.74%	**1.18%**	
718	33.936836	-84.37925	200	-1.83%	-3.58%	3.18744	-3.6996	**5.56%**	**-6.47%**	**-4.47%**	250.25	230+33.38	20.56	-3.40%	-1.74%	**1.07%**	
719	33.936836	-84.379234	200	-1.83%	-3.58%	2.84184	-3.6003	**4.96%**	**-6.29%**	**-4.29%**	250.25	230+39.45	14.49	-3.45%	-1.74%	**0.84%**	
720	33.93684	-84.379211	200	-1.83%	-3.58%	2.94696	-3.7838	**5.14%**	**-6.61%**	**-4.61%**	250.25	230+45.52	8.42	-3.50%	-1.74%	**1.11%**	
Crest VC ends at 230+53.94																	
721	33.936844	-84.379181				3.13448	-3.9467	**5.47%**	**-6.90%**	**-4.90%**	250.5	230+54.62		-3.58%		**1.32%**	TANGENT SECTION
722	33.936848	-84.379166				3.20728	-3.6378	**5.59%**	**-6.36%**	**-4.36%**	250.25	230+59.35		-3.58%		**0.78%**	
723	33.936848	-84.37915				3.6068	-3.6246	**6.29%**	**-6.33%**	**-4.33%**	250.25	230+65.42		-3.58%		**0.76%**	
724	33.936852	-84.379128				3.60328	-3.5937	**6.28%**	**-6.28%**	**-4.28%**	250.25	230+71.49		-3.58%		**0.70%**	
								....									
734	33.936871	-84.378967				2.907875	-3.5327	**5.07%**	**-6.17%**	**-4.17%**	250	231+22.03		-3.58%		**0.60%**	
735	33.936878	-84.378952				2.90084	-3.5902	**5.06%**	**-6.27%**	**-4.27%**	250	231+29.11		-3.58%		**0.70%**	
736	33.936878	-84.378937				3.067083	-3.5903	**5.35%**	**-6.27%**	**-4.27%**	250	231+32.14		-3.58%		**0.70%**	
737	33.936878	-84.378922				3.169538	-3.5994	**5.53%**	**-6.29%**	**-4.29%**	249.75	231+38.21		-3.58%		**0.71%**	
Sag VC starts 231+40.38																	
738	33.936882	-84.378914	200	-3.58%	-1.20%	3.212958	-3.6096	**5.60%**	**-6.31%**	**-4.31%**	250	231+41.24	199.14	-3.57%	2.38%	**0.74%**	SAG VERTICAL CURVE
739	33.936882	-84.378906	200	-3.58%	-1.20%	3.360654	-3.683	**5.86%**	**-6.44%**	**-4.44%**	249.75	231+41.24	199.14	-3.57%	2.38%	**0.87%**	
740	33.936882	-84.378891	200	-3.58%	-1.20%	3.394792	-3.7598	**5.92%**	**-6.57%**	**-4.57%**	249.75	231+47.31	193.07	-3.50%	2.38%	**1.08%**	
741	33.936882	-84.378883	200	-3.58%	-1.20%	3.462192	-3.7843	**6.04%**	**-6.61%**	**-4.61%**	249.75	231+50.34	190.04	-3.46%	2.38%	**1.15%**	
								....									
800	33.936909	-84.378601	200	-3.58%	-1.20%	1.794458	-2.5041	**3.13%**	**-4.37%**	**-2.37%**	248.75	233+17.06	23.32	-1.47%	2.38%	**0.90%**	
801	33.936909	-84.378578	200	-3.58%	-1.20%	1.454385	-2.3082	**2.54%**	**-4.03%**	**-2.03%**	248.5	233+23.13	17.25	-1.40%	2.38%	**0.63%**	
802	33.936913	-84.378555	200	-3.58%	-1.20%	1.223458	-2.197	**2.14%**	**-3.84%**	**-1.84%**	248.75	233+29.2	11.18	-1.33%	2.38%	**0.51%**	
803	33.936913	-84.37854	200	-3.58%	-1.20%	0.98308	-2.0338	**1.72%**	**-3.55%**	**-1.55%**	248.75	233+35.26	5.12	-1.26%	2.38%	**0.29%**	
Sag VC ends 233+40.38																	
804	33.936913	-84.378517				0.67888	-2.0469	**1.18%**	**-3.57%**	**-1.57%**	248.5	233+41.33		-1.20%		**0.38%**	TANGENT SECTION
805	33.936916	-84.378502				0.390407	-1.6683	**0.68%**	**-2.91%**	**-0.91%**	248.5	233+48.4		-1.20%		**0.28%**	
806	33.936916	-84.378479				-0.10842	-1.6465	**-0.19%**	**-2.87%**	**-0.87%**	248.5	233+54.47		-1.20%		**0.32%**	
807	33.936916	-84.378464				-0.10788	-0.7895	**-0.19%**	**-1.38%**	**0.62%**	248.5	233+60.53		-1.20%		**1.82%**	
808	33.936916	-84.378448				-0.53876	-0.2374	**-0.94%**	**-0.41%**	**1.59%**	248.5	233+63.57		-1.20%		**2.78%**	
809	33.93692	-84.378433				-1.05512	-0.1314	**-1.84%**	**-0.23%**	**1.77%**	248.5	233+69.63		-1.20%		**2.97%**	
810	33.93692	-84.378403				-0.35092	-0.2845	**-0.61%**	**-0.50%**	**1.50%**	248.5	233+78.73		-1.20%		**2.70%**	
811	33.936924	-84.378387				0.0444	-1.3944	**0.08%**	**-2.43%**	**-0.43%**	248.5	233+81.77		-1.20%		**0.76%**	
812	33.936924	-84.378357				0.23796	-1.7096	**0.42%**	**-2.98%**	**-0.98%**	248.5	233+90.87		-1.20%		**0.21%**	
813	33.936924	-84.378342				0.39656	-2.0636	**0.69%**	**-3.60%**	**-1.60%**	248.25	233+96.93		-1.20%		**0.41%**	
814	33.936924	-84.378319				0.609542	-2.1127	**1.06%**	**-3.69%**	**-1.69%**	248	234+03.		-1.20%		**0.49%**	
	33.937	**-84.3783**	**Segment 21 ending point**														

Table A-15: Run 4 on Segment 21 Grade Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	L = Len of curve	G1	G2	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations	Dist from end of Curve	GDOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
Crest VC starts 197+50.00																	
	33.9357	**-84.3898**	**Segment 21 starting point**														
570	33.935688	-84.389816	250	2.90%	-3.92%	1.12988	-2.76108	**1.97%**	**-4.82%**	**-2.82%**	264	198+31.41	168.59	0.68%	-6.82%	**3.50%**	CREST VERTICAL CURVE
571	33.935696	-84.389793	250	2.90%	-3.92%	0.73004	-2.94592	**1.27%**	**-5.15%**	**-3.15%**	264.25	198+41.21	158.79	0.41%	-6.82%	**3.56%**	
572	33.935703	-84.389763	250	2.90%	-3.92%	0.5246	-3.0646	**0.92%**	**-5.35%**	**-3.35%**	264	198+50.31	149.69	0.16%	-6.82%	**3.52%**	
573	33.935707	-84.389748	250	2.90%	-3.92%	0.46763	-3.11863	**0.82%**	**-5.45%**	**-3.45%**	263.75	198+55.04	144.96	0.03%	-6.82%	**3.48%**	
								...	...								
584	33.935795	-84.389412	250	2.90%	-3.92%	0.96628	-4.58412	**1.69%**	**-8.02%**	**-6.02%**	261.25	199+63.92	36.08	-2.93%	-6.82%	**3.08%**	
585	33.935806	-84.389381	250	2.90%	-3.92%	1.12032	-5.03212	**1.96%**	**-8.81%**	**-6.81%**	261.25	199+75.57	24.43	-3.25%	-6.82%	**3.55%**	
586	33.935818	-84.389343	250	2.90%	-3.92%	1.16484	-5.18044	**2.03%**	**-9.07%**	**-7.07%**	261.25	199+88.24	11.76	-3.60%	-6.82%	**3.47%**	
587	33.935825	-84.389313	250	2.90%	-3.92%	1.05584	-5.03064	**1.84%**	**-8.80%**	**-6.80%**	261.5	199+98.04	1.96	-3.86%	-6.82%	**2.94%**	
Crest VC ends 200+00																	
588	33.935833	-84.389275				0.92724	-4.87008	**1.62%**	**-8.52%**	**-6.52%**	261.25	200+10.17		-3.92%		**2.60%**	TANGENT SECTION
589	33.935841	-84.389229				0.96504	-4.74142	**1.68%**	**-8.29%**	**-6.29%**	261.25	200+22.84		-3.92%		**2.38%**	
590	33.935852	-84.389191				1.27813	-4.85904	**2.23%**	**-8.50%**	**-6.50%**	261	200+35.51		-3.92%		**2.58%**	
591	33.935856	-84.38916				1.54838	-4.53192	**2.70%**	**-7.93%**	**-5.93%**	261.25	200+45.31		-3.92%		**2.01%**	
								...	...								
621	33.936024	-84.387894				0.99673	-3.31331	**1.74%**	**-5.79%**	**-3.79%**	258	204+38.99		-3.92%		**0.13%**	
622	33.936028	-84.387856				1.22032	-3.32084	**2.13%**	**-5.80%**	**-3.80%**	257.75	204+48.79		-3.92%		**0.11%**	
623	33.936035	-84.387802				1.21927	-3.37842	**2.13%**	**-5.90%**	**-3.90%**	258.25	204+67.35		-3.92%		**0.01%**	
624	33.936039	-84.387764				0.9626	-3.51352	**1.68%**	**-6.14%**	**-4.14%**	258.25	204+79.48		-3.92%		**0.22%**	
Sag VC starts 204+80.62																	
625	33.936039	-84.387711	200	-3.92%	-1.83%	0.97028	-3.607	**1.69%**	**-6.30%**	**-4.30%**	258.5	204+94.65	185.97	-3.77%	2.08%	**0.53%**	SAG VERTICAL CURVE
626	33.936039	-84.387665	200	-3.92%	-1.83%	1.37564	-3.50128	**2.40%**	**-6.12%**	**-4.12%**	258.75	205+09.81	170.81	-3.61%	2.08%	**0.51%**	
627	33.936043	-84.387619	200	-3.92%	-1.83%	1.71128	-3.30476	**2.99%**	**-5.77%**	**-3.77%**	258.75	205+21.94	158.68	-3.49%	2.08%	**0.29%**	
628	33.93605	-84.387573	200	-3.92%	-1.83%	1.42512	-3.2758	**2.49%**	**-5.72%**	**-3.72%**	259	205+37.54	143.08	-3.32%	2.08%	**0.40%**	
								...	...								
635	33.936077	-84.38726	200	-3.92%	-1.83%	1.7842	-3.15296	**3.11%**	**-5.51%**	**-3.51%**	260.75	206+32.97	47.65	-2.33%	2.08%	**1.18%**	
636	33.936085	-84.387222	200	-3.92%	-1.83%	1.46384	-3.28264	**2.55%**	**-5.74%**	**-3.74%**	261	206+45.1	35.52	-2.20%	2.08%	**1.53%**	
637	33.936089	-84.387169	200	-3.92%	-1.83%	1.12156	-3.17356	**1.96%**	**-5.54%**	**-3.54%**	261.25	206+60.7	19.92	-2.04%	2.08%	**1.50%**	
638	33.936092	-84.387131	200	-3.92%	-1.83%	1.03608	-3.0626	**1.81%**	**-5.35%**	**-3.35%**	261.25	206+72.83	7.79	-1.91%	2.08%	**1.44%**	
Sag VC ends 206+80.62																	
639	33.9361	-84.387077				1.09396	-2.98417	**1.91%**	**-5.21%**	**-3.21%**	261.25	206+88.43		-1.83%		**1.38%**	TANGENT SECTION
640	33.936104	-84.387039				1.09768	-2.91196	**1.92%**	**-5.09%**	**-3.09%**	261.5	207+00.56		-1.83%		**1.25%**	
641	33.936108	-84.387001				1.08472	-2.79028	**1.89%**	**-4.87%**	**-2.87%**	262	207+13.23		-1.83%		**1.04%**	
642	33.936111	-84.386955				1.11804	-2.68738	**1.95%**	**-4.69%**	**-2.69%**	262.5	207+25.36		-1.83%		**0.86%**	
								...	...								
792	33.936787	-84.38018				1.426	-2.86314	**2.49%**	**-5.00%**	**-3.00%**	255.25	228+17.9		-1.83%		**1.17%**	
793	33.93679	-84.380142				1.2532	-2.95724	**2.19%**	**-5.17%**	**-3.17%**	254.75	228+30.03		-1.83%		**1.33%**	
794	33.93679	-84.380112				1.02359	-3.03593	**1.79%**	**-5.30%**	**-3.30%**	254.5	228+39.13		-1.83%		**1.47%**	
795	33.936798	-84.380074				0.91083	-2.98708	**1.59%**	**-5.22%**	**-3.22%**	254.5	228+51.8		-1.83%		**1.38%**	

ID	Latitude (deg)	Longitude (deg)	L = Len of curve	G1	G2	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations	Dist from end of Curve	GDOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
Crest VC starts 228+53.94																	
796	33.936802	-84.380043	200	-1.83%	-3.58%	0.80728	-3.07968	**1.41%**	**-5.38%**	**-3.38%**	254.5	228+60.9	193.04	-1.89%	-1.74%	**1.49%**	
797	33.93681	-84.380005	200	-1.83%	-3.58%	0.765692	-3.21996	**1.34%**	**-5.63%**	**-3.63%**	254.5	228+73.57	180.37	-2.00%	-1.74%	**1.62%**	
798	33.936813	-84.379974	200	-1.83%	-3.58%	0.827792	-3.10108	**1.44%**	**-5.42%**	**-3.42%**	254.25	228+82.67	171.27	-2.08%	-1.74%	**1.33%**	
799	33.936817	-84.379944	200	-1.83%	-3.58%	0.984346	-3.13396	**1.72%**	**-5.48%**	**-3.48%**	254	228+92.47	161.47	-2.17%	-1.74%	**1.31%**	CREST VERTICAL CURVE
								....									
825	33.936886	-84.379494	200	-1.83%	-3.58%	1.2234	-3.29812	**2.14%**	**-5.76%**	**-3.76%**	253.25	230+37.95	15.99	-3.44%	-1.74%	**0.32%**	
826	33.93689	-84.379486	200	-1.83%	-3.58%	1.169375	-3.22171	**2.04%**	**-5.63%**	**-3.63%**	253.5	230+37.95	15.99	-3.44%	-1.74%	**0.19%**	
827	33.93689	-84.379471	200	-1.83%	-3.58%	1.15634	-3.12704	**2.02%**	**-5.46%**	**-3.46%**	253.63	230+44.01	9.93	-3.49%	-1.74%	**0.03%**	
828	33.93689	-84.379456	200	-1.83%	-3.58%	0.946885	-3.17342	**1.65%**	**-5.54%**	**-3.54%**	253.25	230+47.05	6.89	-3.52%	-1.74%	**0.03%**	
Crest VC ends at 230+53.94																	
829	33.936897	-84.37944				0.842083	-3.22375	**1.47%**	**-5.63%**	**-3.63%**	253.25	230+54.12		-3.58%		**0.05%**	
830	33.936897	-84.379433				0.821885	-3.23662	**1.43%**	**-5.65%**	**-3.65%**	253	230+57.16		-3.58%		**0.08%**	
831	33.936897	-84.379417				0.618481	-3.21419	**1.08%**	**-5.62%**	**-3.62%**	252.75	230+60.19		-3.58%		**0.04%**	
832	33.936897	-84.379402				0.573583	-3.17317	**1.00%**	**-5.54%**	**-3.54%**	252.75	230+66.25		-3.58%		**0.03%**	TANGENT SECTION
								....									
840	33.93692	-84.37925				-0.27148	-3.12508	**-0.47%**	**-5.46%**	**-3.46%**	252.25	231+14.46		-3.58%		**0.12%**	
841	33.936924	-84.379219				-0.2544	-3.09648	**-0.44%**	**-5.41%**	**-3.41%**	252.25	231+23.56		-3.58%		**0.17%**	
842	33.936928	-84.379204				-0.15472	-3.19424	**-0.27%**	**-5.58%**	**-3.58%**	252	231+30.64		-3.58%		**0.00%**	
843	33.936932	-84.379173				0.001769	-3.20135	**0.00%**	**-5.59%**	**-3.59%**	252	231+39.74		-3.58%		**0.01%**	
Sag VC starts 321+40.38																	
844	33.936932	-84.37915	200	-3.58%	-1.20%	0.090167	-3.20917	**0.16%**	**-5.61%**	**-3.61%**	252	231+45.8	194.58	-3.51%	2.38%	**0.09%**	
845	33.936935	-84.37912	200	-3.58%	-1.20%	0.10912	-3.23368	**0.19%**	**-5.65%**	**-3.65%**	252	231+55.61	184.77	-3.40%	2.38%	**0.25%**	
846	33.936935	-84.379097	200	-3.58%	-1.20%	0.12044	-3.22492	**0.21%**	**-5.63%**	**-3.63%**	252	231+61.67	178.71	-3.32%	2.38%	**0.31%**	
847	33.936935	-84.379074	200	-3.58%	-1.20%	-0.027885	-3.17442	**-0.05%**	**-5.55%**	**-3.55%**	252	231+70.77	169.61	-3.22%	2.38%	**0.33%**	SAG VERTICAL CURVE
								....									
862	33.936981	-84.378624	200	-3.58%	-1.20%	-0.41032	-2.6464	**-0.72%**	**-4.62%**	**-2.62%**	252.5	233+09.9	30.48	-1.56%	2.38%	**1.06%**	
863	33.936981	-84.378601	200	-3.58%	-1.20%	-0.34144	-2.49444	**-0.60%**	**-4.36%**	**-2.36%**	252.5	233+15.97	24.41	-1.49%	2.38%	**0.87%**	
864	33.936985	-84.378571	200	-3.58%	-1.20%	-0.01388	-2.61056	**-0.02%**	**-4.56%**	**-2.56%**	252.25	233+25.77	14.61	-1.37%	2.38%	**1.19%**	
865	33.936989	-84.37854	200	-3.58%	-1.20%	0.2002	-2.49084	**0.35%**	**-4.35%**	**-2.35%**	252	233+34.87	5.51	-1.26%	2.38%	**1.09%**	
Sag VC ends 233+40.38																	
866	33.936989	-84.37851				0.0892	-2.18336	**0.16%**	**-3.81%**	**-1.81%**	251.75	233+43.97		-1.20%		**0.62%**	
867	33.936989	-84.378471				-0.37908	-1.43312	**-0.66%**	**-2.50%**	**-0.50%**	251.5	233+56.1		-1.20%		**0.69%**	
868	33.936996	-84.378441				-0.778385	-0.34762	**-1.36%**	**-0.61%**	**1.39%**	251.25	233+65.9		-1.20%		**2.59%**	TANGENT SECTION
869	33.936989	-84.37841				-0.8436	-0.5976	**-1.47%**	**-1.04%**	**0.96%**	251	233+75.7		-1.20%		**2.15%**	
870	33.936989	-84.37838				-0.0196	-1.54028	**-0.03%**	**-2.69%**	**-0.69%**	251.5	233+84.8		-1.20%		**0.51%**	
871	33.936989	-84.378349				0.650042	-2.05517	**1.13%**	**-3.59%**	**-1.59%**	251.75	233+93.9		-1.20%		**0.39%**	
872	33.936989	-84.378319				0.92256	-2.49028	**1.61%**	**-4.35%**	**-2.35%**	251.75	234+03.		-1.20%		**1.15%**	
	33.937	**-84.3783**	**Segment 21 ending point**														

Table A-16: Run 1 on Segment 42 Grade Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	L = Len of curve	G1	G2	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Opp Dir Travel	Altitude (m)	Stations	Dist from end of Curve	GDOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
	33.86253	-84.4775	Segment 42 ending point															
771	33.8626785	-84.47748	740.00	9.51%	0.53%	0.35888	-8.5563	0.63%	-15.05%	-13.05%	13.05%	276	187+20.	709.96	9.15%	-8.98%	3.90%	CREST
772	33.8626556	-84.4775	740.00	9.51%	0.53%	0.2016	-8.5877	0.35%	-15.10%	-13.10%	13.10%	276	187+10.52	719.44	9.26%	-8.98%	3.84%	VERTICAL
773	33.8626289	-84.47752	740.00	9.51%	0.53%	0.12864	-8.683	0.22%	-15.27%	-13.27%	13.27%	275.25	186+98.03	731.93	9.41%	-8.98%	3.86%	CURVE
Crest VC Ends 186+89.96																		
774	33.8626061	-84.47755				-0.02168	-8.5459	-0.04%	-15.03%	-13.03%	13.03%	275	186+86.37		9.51%		3.52%	
775	33.8625794	-84.47757				-0.32084	-8.2495	-0.56%	-14.50%	-12.50%	12.50%	274.75	186+73.88		9.51%		2.99%	
776	33.8625565	-84.47759				-0.64648	-8.3178	-1.13%	-14.62%	-12.62%	12.62%	274.5	186+64.4		9.51%		3.11%	
777	33.8625298	-84.47762				-0.395	-8.4734	-0.69%	-14.90%	-12.90%	12.90%	274	186+50.19		9.51%		3.39%	TANGENT
								....										SECTION
792	33.8621521	-84.47798				-0.62108	-8.3504	-1.08%	-14.68%	-12.68%	12.68%	269.75	184+72.19		9.51%		3.17%	
793	33.8621254	-84.478				-0.91664	-8.2374	-1.60%	-14.48%	-12.48%	12.48%	269.5	184+62.71		9.51%		2.97%	
794	33.8621025	-84.47803				-1.0172	-8.0972	-1.78%	-14.23%	-12.23%	12.23%	269	184+48.49		9.51%		2.72%	
795	33.8620796	-84.47805				-1.04488	-7.9302	-1.82%	-13.93%	-11.93%	11.93%	268.75	184+39.01		9.51%		2.42%	
Sag VC Starts 184+36.90																		
796	33.8620529	-84.47808	1060.00	-8.63%	9.51%	-1.1944	-7.8694	-2.08%	-13.82%	-11.82%	11.82%	268.25	184+24.8	12.10	9.30%	18.14%	2.52%	
797	33.8620262	-84.4781	1060.00	-8.63%	9.51%	-1.35858	-8.0235	-2.37%	-14.10%	-12.10%	12.10%	267.75	184+15.32	21.58	9.14%	18.14%	2.95%	
798	33.8620071	-84.47813	1060.00	-8.63%	9.51%	-1.48973	-7.9832	-2.60%	-14.02%	-12.02%	12.02%	267.25	184+03.66	33.24	8.94%	18.14%	3.08%	
799	33.8619804	-84.47815	1060.00	-8.63%	9.51%	-1.53036	-7.793	-2.67%	-13.69%	-11.69%	11.69%	266.75	183+91.17	45.73	8.73%	18.14%	2.96%	SAG
								....										VERTICAL
879	33.8598137	-84.47969	1060.00	-8.63%	9.51%	0.555346	1.87327	0.97%	3.27%	5.27%	-5.27%	258.5	174+25.45	1011.45	-7.80%	18.14%	2.53%	CURVE
880	33.8597908	-84.47972	1060.00	-8.63%	9.51%	0.87056	1.89596	1.52%	3.31%	5.31%	-5.31%	259.75	174+13.8	1023.10	-8.00%	18.14%	2.69%	
881	33.8597679	-84.47976	1060.00	-8.63%	9.51%	0.92816	2.2214	1.62%	3.88%	5.88%	-5.88%	261.25	173+99.64	1037.26	-8.24%	18.14%	2.36%	
882	33.8597412	-84.47978	1060.00	-8.63%	9.51%	0.40456	2.08704	0.71%	3.64%	5.64%	-5.64%	261.5	173+87.15	1049.75	-8.46%	18.14%	2.81%	
Sag VC Ends 173+76.0																		
883	33.8597221	-84.47981				0.028538	2.06165	0.05%	3.60%	5.60%	-5.60%	262.25	173+75.49		-8.63%		3.03%	
884	33.8597031	-84.47985				-0.08265	2.16512	-0.14%	3.78%	5.78%	-5.78%	262.75	173+61.33		-8.63%		2.85%	
885	33.8596764	-84.47987				-0.10809	2.34165	-0.19%	4.09%	6.09%	-6.09%	263.25	173+51.85		-8.63%		2.54%	
886	33.8596611	-84.4799				-0.04907	2.44781	-0.09%	4.27%	6.27%	-6.27%	263.5	173+40.19		-8.63%		2.36%	TANGENT
								....										SECTION
905	33.8591805	-84.48039				-0.13112	3.10708	-0.23%	5.43%	7.43%	-7.43%	270	171+05.85		-8.63%		1.20%	
906	33.8591538	-84.48041				-0.07132	3.11392	-0.12%	5.44%	7.44%	-7.44%	270.5	170+93.36		-8.63%		1.19%	
907	33.8591194	-84.48043				-0.19288	3.20819	-0.34%	5.61%	7.61%	-7.61%	271	170+80.87		-8.63%		1.03%	
908	33.8590889	-84.48044				-0.47154	3.20833	-0.82%	5.61%	7.61%	-7.61%	271	170+69.54		-8.63%		1.03%	
Crest VC Ends 170+66.24																		
909	33.8590546	-84.48045	630	9.06%	-8.63%	-0.58271	3.39408	-1.02%	5.93%	7.93%	-7.93%	271.75	170+54.67	11.57	-8.31%	-17.69%	0.38%	
910	33.8590241	-84.48047	630	9.06%	-8.63%	-0.45873	3.36892	-0.80%	5.89%	7.89%	-7.89%	272.25	170+42.18	24.06	-7.96%	-17.69%	0.07%	
911	33.8589897	-84.48049	630	9.06%	-8.63%	-0.23217	3.42391	-0.41%	5.98%	7.98%	-7.98%	273.5	170+29.69	36.55	-7.60%	-17.69%	0.38%	
912	33.8589554	-84.4805	630	9.06%	-8.63%	-0.07782	3.40594	-0.14%	5.95%	7.95%	-7.95%	274.25	170+18.36	47.88	-7.29%	-17.69%	0.66%	CREST
								....										VERTICAL
949	33.8575401	-84.4807	630	9.06%	-8.63%	0.707208	-4.6541	1.23%	-8.14%	-6.14%	6.14%	279	164+93.6	572.64	7.45%	-17.69%	1.31%	CURVE
950	33.857502	-84.48071	630	9.06%	-8.63%	0.912	-4.8647	1.59%	-8.51%	-6.51%	6.51%	279	164+78.74	587.50	7.87%	-17.69%	1.36%	
951	33.8574638	-84.48071	630	9.06%	-8.63%	0.537033	-5.0498	0.94%	-8.84%	-6.84%	6.84%	278.75	164+64.18	602.06	8.28%	-17.69%	1.44%	
952	33.8574181	-84.48071	630	9.06%	-8.63%	0.247458	-5.3933	0.43%	-9.44%	-7.44%	7.44%	277.75	164+49.62	616.62	8.68%	-17.69%	1.24%	

ID	Latitude (deg)	Longitude (deg)	L = Len of curve	G1	G2	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Opp Dir Travel	Altitude (m)	Stations	Dist from end of Curve	GDOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
Crest VC Starts 164+36.24																		
953	33.85738	-84.48071				0.1062	-5.5728	0.19%	-9.76%	-7.76%	7.76%	276.5	164+35.07		9.06%		1.30%	TANGENT SECTION
954	33.85734	-84.48071				0.11038	-5.7779	0.19%	-10.12%	-8.12%	8.12%	275.75	164+20.51		9.06%		0.94%	
955	33.8573	-84.48072				0.41246	-6.1174	0.72%	-10.72%	-8.72%	8.72%	275	164+05.64		9.06%		0.34%	
956	33.85726	-84.48072				0.70563	-6.3026	1.23%	-11.04%	-9.04%	9.04%	274.25	163+91.09		9.06%		0.02%	
									....									
966	33.85686	-84.48078				1.29136	-7.0715	2.25%	-12.41%	-10.41%	10.41%	269.5	162+43.61		9.06%		1.35%	
967	33.85682	-84.48079				1.36817	-7.1905	2.39%	-12.62%	-10.62%	10.62%	269	162+28.74		9.06%		1.56%	
968	33.85677	-84.48079				1.30116	-7.1214	2.27%	-12.49%	-10.49%	10.49%	268.75	162+10.55		9.06%		1.43%	
969	33.85674	-84.48079				0.9228	-6.8274	1.61%	-11.97%	-9.97%	9.97%	268	161+99.63		9.06%		0.91%	
Sag VC Ends 161+86.84																		
970	33.85669	-84.48079	650	-4.39%	9.06%	0.89504	-6.8051	1.56%	-11.93%	-9.93%	9.93%	267.5	161+81.44	5.40	8.95%	13.45%	0.99%	SAG VERTICAL CURVE
971	33.85665	-84.4808	650	-4.39%	9.06%	1.24956	-6.8659	2.18%	-12.04%	-10.04%	10.04%	267.25	161+66.57	20.27	8.64%	13.45%	1.40%	
972	33.85662	-84.4808	650	-4.39%	9.06%	1.47565	-6.817	2.58%	-11.95%	-9.95%	9.95%	267.25	161+55.65	31.19	8.41%	13.45%	1.54%	
973	33.85658	-84.4808	650	-4.39%	9.06%	1.47195	-6.8224	2.57%	-11.96%	-9.96%	9.96%	266	161+41.1	45.74	8.11%	13.45%	1.85%	
									....									
1012	33.85524	-84.48148	650	-4.39%	9.06%	-0.43276	-0.1927	-0.76%	-0.34%	1.66%	-1.66%	259.75	155+91.18	595.66	-3.27%	13.45%	1.60%	
1013	33.85521	-84.48151	650	-4.39%	9.06%	-0.48432	-0.0708	-0.85%	-0.12%	1.88%	-1.88%	260	155+76.97	609.87	-3.56%	13.45%	1.68%	
1014	33.85518	-84.48154	650	-4.39%	9.06%	-0.5685	0.1549	-0.99%	0.27%	2.27%	-2.27%	260.25	155+62.75	624.09	-3.86%	13.45%	1.58%	
1015	33.85515	-84.48158	650	-4.39%	9.06%	-0.842	0.2552	-1.47%	0.45%	2.45%	-2.45%	260.25	155+46.42	640.42	-4.19%	13.45%	1.75%	
Sag VC Starts 155+36.84																		
1016	33.85512	-84.48161				-0.88375	0.5564	-1.54%	0.97%	2.97%	-2.97%	260.5	155+32.2		-4.39%		1.42%	TANGENT SECTION
1017	33.85509	-84.48164				-0.85464	0.564	-1.49%	0.98%	2.98%	-2.98%	261	155+17.98		-4.39%		1.41%	
1018	33.85506	-84.48167				-1.05276	0.6258	-1.84%	1.09%	3.09%	-3.09%	261.5	155+03.77		-4.39%		1.30%	
1019	33.85503	-84.4817				-1.12984	0.7131	-1.97%	1.24%	3.24%	-3.24%	262	154+89.55		-4.39%		1.15%	
1020	33.855	-84.48173				-0.87713	0.7565	-1.53%	1.32%	3.32%	-3.32%	262.25	154+75.33		-4.39%		1.07%	
1021	33.85497	-84.48177				-0.61984	0.6512	-1.08%	1.14%	3.14%	-3.14%	262.5	154+59.		-4.39%		1.25%	
1022	33.85494	-84.4818				-0.5332	0.6669	-0.93%	1.16%	3.16%	-3.16%	263	154+44.78		-4.39%		1.23%	
Crest VC Ends 154+43.73																		
1023	33.85492	-84.48182	480	8.92%	-4.39%	-0.48436	0.9599	-0.85%	1.68%	3.68%	-3.68%	263.25	154+35.31	8.42	-4.16%	-13.32%	0.48%	CREST VERTICAL CURVE
1024	33.85489	-84.48185	480	8.92%	-4.39%	-0.65152	1.1624	-1.14%	2.03%	4.03%	-4.03%	263.5	154+21.09	22.64	-3.76%	-13.32%	0.27%	
1025	33.85485	-84.48187	480	8.92%	-4.39%	-0.78992	0.8383	-1.38%	1.46%	3.46%	-3.46%	263.75	154+05.32	38.41	-3.33%	-13.32%	0.14%	
1026	33.85483	-84.4819	480	8.92%	-4.39%	-0.6762	0.7321	-1.18%	1.28%	3.28%	-3.28%	263.75	153+93.66	50.07	-3.00%	-13.32%	0.28%	
									....									
1055	33.85381	-84.48208	480	8.92%	-4.39%	-1.13473	-5.096	-1.98%	-8.92%	-6.92%	6.92%	263.5	150+06.63	437.10	7.73%	-13.32%	0.82%	
1056	33.85378	-84.48207	480	8.92%	-4.39%	-1.13724	-5.3004	-1.98%	-9.28%	-7.28%	7.28%	263.25	149+95.3	448.43	8.05%	-13.32%	0.77%	
1057	33.85374	-84.48206	480	8.92%	-4.39%	-0.816	-5.608	-1.42%	-9.82%	-7.82%	7.82%	263	149+80.43	463.30	8.46%	-13.32%	0.64%	
1058	33.8537	-84.48204	480	8.92%	-4.39%	-0.19446	-5.8703	-0.34%	-10.28%	-8.28%	8.28%	262.5	149+64.66	479.07	8.90%	-13.32%	0.62%	
Crest VC Starts 149+63.73																		
1059	33.85366	-84.48203				-0.02521	-6.237	-0.04%	-10.93%	-8.93%	8.93%	262.25	149+49.79		8.92%		0.00%	TANGENT SECTION
1060	33.85363	-84.48201				-0.21536	-6.4401	-0.38%	-11.29%	-9.29%	9.29%	262.25	149+37.3		8.92%		0.36%	
1061	33.85359	-84.48199				-0.13154	-6.61	-0.23%	-11.59%	-9.59%	9.59%	262	149+21.53		8.92%		0.66%	
1062	33.85355	-84.48198				0.32859	-6.7749	0.57%	-11.88%	-9.88%	9.88%	261.75	149+06.66		8.92%		0.96%	
1063	33.85352	-84.48196				0.79643	-7.0793	1.39%	-12.42%	-10.42%	10.42%	261.5	148+94.17		8.92%		1.49%	
1064	33.85348	-84.48195				1.05544	-7.2607	1.84%	-12.74%	-10.74%	10.74%	261	148+79.3		8.92%		1.82%	
1065	33.85344	-84.48193				1.04008	-7.305	1.82%	-12.82%	-10.82%	10.82%	260.5	148+63.52		8.92%		1.89%	
1066	33.85341	-84.48191				1.18488	-7.448	2.07%	-13.07%	-11.07%	11.07%	260	148+51.03		8.92%		2.15%	
	33.8524	**-84.481**	**Segment 42 starting point**															

Table A-17: Run 3 on Segment 42 Grade Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	L = Len of curve	G1	G2	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Opp Dir Travel	Altitude (m)	Stations	Dist from end of Curve	GDOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
	33.8625	**-84.477**	**Segment 42 ending point**															
830	33.86267	-84.47748	740.00	9.51%	0.53%	-1.9301	-7.69275	**-3.37%**	**-13.51%**	**-11.51%**	11.51%	273.5	187+20.	709.96	9.15%	-8.98%	**2.36%**	CREST VERTICAL CURVE
831	33.86264	-84.4775	740.00	9.51%	0.53%	-1.8511	-7.84615	**-3.23%**	**-13.78%**	**-11.78%**	11.78%	273.25	187+07.51	722.45	9.30%	-8.98%	**2.48%**	
832	33.86262	-84.47752	740.00	9.51%	0.53%	-1.94	-7.723	**-3.39%**	**-13.56%**	**-11.56%**	11.56%	272.75	186+98.03	731.93	9.41%	-8.98%	**2.15%**	
Crest VC Ends 186+89.96																		
833	33.86259	-84.47754				-2.1608	-7.61511	**-3.77%**	**-13.37%**	**-11.37%**	11.37%	272.5	186+85.54		9.51%		**1.86%**	TANGENT SECTION
834	33.86257	-84.47756				-2.3478	-7.38376	**-4.10%**	**-12.96%**	**-10.96%**	10.96%	272.25	186+76.06		9.51%		**1.45%**	
835	33.86254	-84.47758				-2.1984	-7.53852	**-3.84%**	**-13.23%**	**-11.23%**	11.23%	272	186+63.57		9.51%		**1.72%**	
836	33.86251	-84.47759				-2.1849	-7.6577	**-3.81%**	**-13.45%**	**-11.45%**	11.45%	271.75	186+52.24		9.51%		**1.94%**	
								....										
850	33.86214	-84.47791				-3.1333	-8.00916	**-5.47%**	**-14.07%**	**-12.07%**	12.07%	266.25	184+83.78		9.51%		**2.56%**	
851	33.86212	-84.47794				-3.2075	-7.98856	**-5.60%**	**-14.03%**	**-12.03%**	12.03%	265.5	184+72.12		9.51%		**2.52%**	
852	33.86209	-84.47797				-3.2198	-7.82176	**-5.62%**	**-13.74%**	**-11.74%**	11.74%	265.25	184+57.9		9.51%		**2.23%**	
853	33.86206	-84.47799				-3.0735	-7.78992	**-5.36%**	**-13.68%**	**-11.68%**	11.68%	264.75	184+45.41		9.51%		**2.17%**	
Sag VC Starts 184+36.90																		
854	33.86204	-84.47801	1060.00	-8.63%	9.51%	-3.1426	-7.76844	**-5.48%**	**-13.64%**	**-11.64%**	11.64%	264.5	184+35.93	0.97	9.49%	18.14%	**2.15%**	SAG VERTICAL CURVE
855	33.86201	-84.47803	1060.00	-8.63%	9.51%	-3.1512	-7.75028	**-5.50%**	**-13.61%**	**-11.61%**	11.61%	264.25	184+23.44	13.46	9.28%	18.14%	**2.33%**	
856	33.86198	-84.47806	1060.00	-8.63%	9.51%	-2.8725	-7.67879	**-5.01%**	**-13.48%**	**-11.48%**	11.48%	264	184+09.23	27.67	9.04%	18.14%	**2.45%**	
857	33.86196	-84.47808	1060.00	-8.63%	9.51%	-2.5034	-7.71231	**-4.37%**	**-13.54%**	**-11.54%**	11.54%	263.75	183+99.75	37.15	8.87%	18.14%	**2.67%**	
								....										
928	33.85978	-84.47972	1060.00	-8.63%	9.51%	-1.5452	1.05052	**-2.70%**	**1.83%**	**3.83%**	-3.83%	260.75	174+22.82	1014.08	-7.85%	18.14%	**4.01%**	
929	33.85976	-84.47976	1060.00	-8.63%	9.51%	-1.8722	1.18324	**-3.27%**	**2.07%**	**4.07%**	-4.07%	261.25	174+08.66	1028.24	-8.09%	18.14%	**4.02%**	
930	33.85973	-84.4798	1060.00	-8.63%	9.51%	-2.1644	1.0118	**-3.78%**	**1.77%**	**3.77%**	-3.77%	261.5	173+92.34	1044.56	-8.37%	18.14%	**4.60%**	
931	33.85971	-84.47983	1060.00	-8.63%	9.51%	-2.3167	1.071	**-4.04%**	**1.87%**	**3.87%**	-3.87%	262	173+80.68	1056.22	-8.57%	18.14%	**4.70%**	
Sag VC Ends 173+76.0																		
932	33.85969	-84.47987				-2.1725	1.26071	**-3.79%**	**2.20%**	**4.20%**	-4.20%	262.25	173+66.52		-8.63%		**4.43%**	TANGENT SECTION
933	33.85966	-84.4799				-1.906	1.3684	**-3.33%**	**2.39%**	**4.39%**	-4.39%	262.75	173+52.3		-8.63%		**4.24%**	
934	33.85964	-84.47994				-1.8773	1.46404	**-3.28%**	**2.56%**	**4.56%**	-4.56%	263.25	173+38.14		-8.63%		**4.08%**	
935	33.85962	-84.47998				-1.8631	1.56438	**-3.25%**	**2.73%**	**4.73%**	-4.73%	263.75	173+23.99		-8.63%		**3.90%**	
951	33.85917	-84.48042				-0.3126	2.93988	**-0.55%**	**5.14%**	**7.14%**	-7.14%	270.75	171+08.79		-8.63%		**1.50%**	
952	33.85914	-84.48043				-0.3266	3.11622	**-0.57%**	**5.44%**	**7.44%**	-7.44%	271	170+97.46		-8.63%		**1.19%**	
953	33.85911	-84.48045				-0.477	3.32115	**-0.83%**	**5.80%**	**7.80%**	-7.80%	271.5	170+84.97		-8.63%		**0.83%**	
954	33.85907	-84.48046				-0.6789	3.57132	**-1.18%**	**6.24%**	**8.24%**	-8.24%	271.75	170+70.1		-8.63%		**0.39%**	
Crest VC Ends 170+66.24																		
955	33.85904	-84.48048	630	9.06%	-8.63%	-0.634	3.71768	**-1.11%**	**6.50%**	**8.50%**	-8.50%	272.25	170+57.61	8.63	-8.39%	-17.69%	**0.11%**	CREST VERTICAL CURVE
956	33.85901	-84.48049	630	9.06%	-8.63%	-0.4049	3.877	**-0.71%**	**6.78%**	**8.78%**	-8.78%	272.5	170+46.28	19.96	-8.07%	-17.69%	**0.71%**	
957	33.85898	-84.48051	630	9.06%	-8.63%	-0.0848	4.09004	**-0.15%**	**7.15%**	**9.15%**	-9.15%	273	170+33.78	32.46	-7.72%	-17.69%	**1.43%**	
958	33.85894	-84.48053	630	9.06%	-8.63%	0.1206	4.189	**0.21%**	**7.32%**	**9.32%**	-9.32%	273.75	170+18.01	48.23	-7.28%	-17.69%	**2.05%**	
								....										
993	33.85752	-84.4807	630	9.06%	-8.63%	-0.4264	-2.98942	**-0.74%**	**-5.22%**	**-3.22%**	3.22%	280	164+94.53	571.71	7.42%	-17.69%	**4.20%**	
994	33.85748	-84.48071	630	9.06%	-8.63%	-0.462	-3.23317	**-0.81%**	**-5.65%**	**-3.65%**	3.65%	280.25	164+79.66	586.58	7.84%	-17.69%	**4.19%**	
995	33.85743	-84.48071	630	9.06%	-8.63%	-0.6265	-3.55592	**-1.09%**	**-6.21%**	**-4.21%**	4.21%	280.5	164+61.46	604.78	8.35%	-17.69%	**4.14%**	
996	33.85738	-84.48072	630	9.06%	-8.63%	-0.7376	-3.925	**-1.29%**	**-6.86%**	**-4.86%**	4.86%	280.5	164+43.02	623.22	8.87%	-17.69%	**4.01%**	

ID	Latitude (deg)	Longitude (deg)	L = Len of curve	G1	G2	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Opp Dir Travel	Altitude (m)	Stations	Dist from end of Curve	GDOT Profile Sheet Grade	A = G2-G1	abs (error)	Details
Crest VC Starts 164+36.24																		
997	33.857338	-84.480728				-0.693538	-4.209769	**-1.21%**	**-7.36%**	**-5.36%**	5.36%	280.25	164+28.15		9.06%		**3.70%**	
998	33.857292	-84.480736				-0.254	-4.5821	**-0.44%**	**-8.01%**	**-6.01%**	6.01%	280.25	164+09.7		9.06%		**3.05%**	
999	33.857246	-84.480736				0.0987	-4.8507	**0.17%**	**-8.49%**	**-6.49%**	6.49%	279.75	163+95.15		9.06%		**2.57%**	
1000	33.857201	-84.480743				0.315538	-5.103269	**0.55%**	**-8.93%**	**-6.93%**	6.93%	279	163+76.95		9.06%		**2.13%**	TANGENT SECTION
								....										
1008	33.856831	-84.480782				0.415182	-5.566591	**0.72%**	**-9.75%**	**-7.75%**	7.75%	272.5	162+41.24		9.06%		**1.31%**	
1009	33.856785	-84.480782				0.581	-5.624538	**1.01%**	**-9.85%**	**-7.85%**	7.85%	271.5	162+23.05		9.06%		**1.21%**	
1010	33.856739	-84.480789				0.255875	-5.30625	**0.45%**	**-9.29%**	**-7.29%**	7.29%	270.75	162+08.18		9.06%		**1.77%**	
1011	33.856693	-84.480789				-0.166769	-5.230923	**-0.29%**	**-9.16%**	**-7.16%**	7.16%	270	161+89.98		9.06%		**1.90%**	
Sag VC Ends 161+86.84																		
1012	33.856644	-84.480789	650	-4.39%	9.06%	0.08304	-5.33696	**0.14%**	**-9.34%**	**-7.34%**	7.34%	269.5	161+71.79	15.05	8.75%	13.45%	**1.41%**	
1013	33.856602	-84.480797	650	-4.39%	9.06%	0.787542	-5.425833	**1.37%**	**-9.50%**	**-7.50%**	7.50%	268.75	161+56.92	29.92	8.44%	13.45%	**0.94%**	
1014	33.856556	-84.480804	650	-4.39%	9.06%	0.992625	-5.405375	**1.73%**	**-9.46%**	**-7.46%**	7.46%	268	161+42.37	44.47	8.14%	13.45%	**0.68%**	
1015	33.85651	-84.480804	650	-4.39%	9.06%	0.874654	-5.382654	**1.53%**	**-9.42%**	**-7.42%**	7.42%	267.5	161+24.17	62.67	7.76%	13.45%	**0.34%**	SAG VERTICAL CURVE
								....										
1052	33.855202	-84.481522	650	-4.39%	9.06%	-182972	-183072	**-3.19%**	**-3.20%**	**-1.20%**	1.20%	263	155+79.61	607.23	-3.51%	13.45%	**4.70%**	
1053	33.855171	-84.481552	650	-4.39%	9.06%	-2.012125	-1.591917	**-3.51%**	**-2.78%**	**-0.78%**	0.78%	263	155+65.39	621.45	-3.80%	13.45%	**4.58%**	
1054	33.855145	-84.481583	650	-4.39%	9.06%	-2.29252	-147868	**-4.00%**	**-2.58%**	**-0.58%**	0.58%	263.25	155+51.17	635.67	-4.09%	13.45%	**4.68%**	
1055	33.85511	-84.481613	650	-4.39%	9.06%	-2.306423	-1.1505	**-4.02%**	**-2.01%**	**-0.01%**	0.01%	263.5	155+36.95	649.89	-4.39%	13.45%	**4.40%**	
Sag VC Starts 155+36.84																		
1056	33.85508	-84.481651				-2.147308	-1.110808	**-3.75%**	**-1.94%**	**0.06%**	-0.06%	263.5	155+20.62		-4.39%		**4.33%**	
1057	33.855049	-84.481682				-19868	-100172	**-3.47%**	**-1.75%**	**0.25%**	-0.25%	263.5	155+06.41		-4.39%		**4.14%**	
1058	33.855019	-84.481712				-168132	-0.90464	**-2.93%**	**-1.58%**	**0.42%**	-0.42%	263.5	154+92.19		-4.39%		**3.97%**	TANGENT SECTION
1059	33.854988	-84.481743				-147976	-0.92324	**-2.58%**	**-1.61%**	**0.39%**	-0.39%	263.5	154+77.97		-4.39%		**4.00%**	
1060	33.854958	-84.481773				-144848	-10434	**-2.53%**	**-1.82%**	**0.18%**	-0.18%	263.5	154+63.75		-4.39%		**4.21%**	
1061	33.854927	-84.481796				-143544	-0.71068	**-2.51%**	**-1.24%**	**0.76%**	-0.76%	263.75	154+49.54		-4.39%		**3.63%**	
Crest VC Ends 154+43.73																		
1062	33.854889	-84.481827	480	8.92%	-4.39%	-129516	-0.45112	**-2.26%**	**-0.79%**	**1.21%**	-1.21%	264.25	154+32.36	11.37	-4.08%	-13.32%	**2.86%**	
1063	33.854858	-84.481857	480	8.92%	-4.39%	-136628	-0.58628	**-2.38%**	**-1.02%**	**0.98%**	-0.98%	264.5	154+18.15	25.58	-3.68%	-13.32%	**2.70%**	
1064	33.85482	-84.481888	480	8.92%	-4.39%	-1322391	-0.681261	**-2.31%**	**-1.19%**	**0.81%**	-0.81%	264.75	154+00.98	42.75	-3.21%	-13.32%	**2.39%**	
1065	33.854786	-84.481911	480	8.92%	-4.39%	-1191704	-0.721333	**-2.08%**	**-1.26%**	**0.74%**	-0.74%	264.75	153+88.48	55.25	-2.86%	-13.32%	**2.12%**	CREST VERTICAL CURVE
								....										
1089	33.853825	-84.482086	480	8.92%	-4.39%	-1232542	-2.99125	**-2.15%**	**-5.23%**	**-3.23%**	3.23%	264	150+20.45	423.28	7.35%	-13.32%	**4.13%**	
1090	33.853786	-84.482079	480	8.92%	-4.39%	-126656	-3.26972	**-2.21%**	**-5.71%**	**-3.71%**	3.71%	264	150+09.11	434.62	7.67%	-13.32%	**3.95%**	
1091	33.853741	-84.482071	480	8.92%	-4.39%	-1112577	-3.540769	**-1.94%**	**-6.19%**	**-4.19%**	4.19%	263.5	149+90.67	453.06	8.18%	-13.32%	**3.99%**	
1092	33.853703	-84.482048	480	8.92%	-4.39%	-0.6745	-3.69875	**-1.18%**	**-6.46%**	**-4.46%**	4.46%	263.25	149+74.9	468.83	8.61%	-13.32%	**4.15%**	
Crest VC Starts 149+63.73																		
1093	33.853661	-84.482033				-0.61128	-3.98884	**-1.07%**	**-6.97%**	**-4.97%**	4.97%	263.25	149+59.13		8.92%		**3.95%**	
1094	33.853619	-84.482018				-0.83304	-4.1358	**-1.45%**	**-7.23%**	**-5.23%**	5.23%	262.75	149+44.26		8.92%		**3.69%**	
1095	33.85358	-84.482002				-0.761444	-4.187148	**-1.33%**	**-7.32%**	**-5.32%**	5.32%	262.5	149+28.48		8.92%		**3.60%**	
1096	33.853539	-84.481979				-0.365545	-4.322591	**-0.64%**	**-7.56%**	**-5.56%**	5.56%	262	149+12.71		8.92%		**3.37%**	TANGENT SECTION
1097	33.853497	-84.481964				-0.021407	-4.529741	**-0.04%**	**-7.92%**	**-5.92%**	5.92%	261.5	148+96.94		8.92%		**3.00%**	
1098	33.853455	-84.481949				-0.061375	-4.583667	**-0.11%**	**-8.02%**	**-6.02%**	6.02%	261	148+78.5		8.92%		**2.91%**	
1099	33.853413	-84.481926				-0.091	-4.553654	**-0.16%**	**-7.96%**	**-5.96%**	5.96%	260.5	148+62.72		8.92%		**2.96%**	
1100	33.853371	-84.481911				0.36276	-4.60008	**0.63%**	**-8.05%**	**-6.05%**	6.05%	260.25	148+46.95		8.92%		**2.88%**	
	33.8524	**-84.4814**	**Segment 42 starting point**															

Table A-18: Run 1 on Segment 9 Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations
	33.878043	**-84.464523**	**Segment 9 ending point**						
4	33.8780365	-84.4645233	-1.1114	4.42884	**-1.94%**	**7.75%**	**9.75%**	272	1+00.
5	33.8780479	-84.4645386	-1.28232	4.16612	**-2.24%**	**7.28%**	**9.28%**	272	1+07.08
6	33.8780556	-84.4645538	-1.2842	4.17632	**-2.24%**	**7.30%**	**9.30%**	272	1+11.82
7	33.878067	-84.4645691	-1.45142	3.88673	**-2.53%**	**6.79%**	**8.79%**	272	1+18.89
8	33.8780747	-84.4645767	-1.53844	3.46708	**-2.68%**	**6.06%**	**8.06%**	271.75	1+21.93
9	33.8780899	-84.4645996	-1.35321	3.28083	**-2.36%**	**5.73%**	**7.73%**	271.75	1+31.41
10	33.8781014	-84.4646149	-1.2228	3.20832	**-2.13%**	**5.61%**	**7.61%**	271.75	1+36.15
11	33.8781052	-84.4646378	-1.33772	3.2652	**-2.33%**	**5.71%**	**7.71%**	271.75	1+45.95
12	33.8781166	-84.464653	-1.32604	3.35523	**-2.31%**	**5.86%**	**7.86%**	271.75	1+50.69
13	33.8781242	-84.4646759	-1.53004	3.49596	**-2.67%**	**6.11%**	**8.11%**	271.75	1+59.8
14	33.8781319	-84.4646988	-1.87504	3.75244	**-3.27%**	**6.56%**	**8.56%**	271.75	1+66.87
15	33.8781357	-84.4647217	-1.91912	4.04668	**-3.35%**	**7.07%**	**9.07%**	271.5	1+73.95
16	33.8781395	-84.4647446	-2.34931	4.10523	**-4.10%**	**7.18%**	**9.18%**	271.75	1+80.02
17	33.8781395	-84.4647751	-2.7445	4.18825	**-4.79%**	**7.32%**	**9.32%**	271.75	1+92.16
18	33.8781433	-84.464798	-3.07752	4.27592	**-5.37%**	**7.48%**	**9.48%**	272	1+98.23
19	33.8781471	-84.4648209	-3.27012	4.16136	**-5.70%**	**7.28%**	**9.28%**	272	2+05.31
20	33.8781471	-84.4648514	-3.31296	4.18752	**-5.78%**	**7.32%**	**9.32%**	271.75	2+14.42
21	33.8781471	-84.4648743	-3.44492	4.29692	**-6.01%**	**7.51%**	**9.51%**	272	2+20.49
22	33.8781433	-84.4649048	-3.31656	4.4256	**-5.79%**	**7.74%**	**9.74%**	272	2+30.29
23	33.8781433	-84.4649353	-2.94228	4.52192	**-5.13%**	**7.91%**	**9.91%**	272	2+42.44
24	33.8781433	-84.4649658	-2.66156	4.61536	**-4.64%**	**8.07%**	**10.07%**	272.25	2+51.54
25	33.8781471	-84.4649887	-2.6065	4.75333	**-4.55%**	**8.32%**	**10.32%**	272.5	2+58.62
26	33.8781471	-84.4650192	-2.46211	4.96115	**-4.30%**	**8.68%**	**10.68%**	272.5	2+67.73
27	33.8781509	-84.4650497	-2.31226	5.11639	**-4.03%**	**8.95%**	**10.95%**	272.5	2+76.83
28	33.8781548	-84.4650879	-2.28019	5.24519	**-3.98%**	**9.18%**	**11.18%**	272.5	2+88.97
29	33.8781548	-84.465126	-2.151	5.35325	**-3.75%**	**9.37%**	**11.37%**	273	3+01.11
30	33.8781509	-84.4651566	-2.01515	5.37167	**-3.52%**	**9.40%**	**11.40%**	273.5	3+10.22
			....						
85	33.87817	-84.467453	-1.17975	3.44425	**-2.06%**	**6.02%**	**8.02%**	271.25	10+15.42
86	33.8781738	-84.4674912	-1.28954	3.50279	**-2.25%**	**6.12%**	**8.12%**	271.25	10+27.56
87	33.8781815	-84.4675293	-1.41483	3.35743	**-2.47%**	**5.87%**	**7.87%**	271.25	10+40.23
88	33.8781853	-84.4675751	-1.78333	3.23452	**-3.11%**	**5.65%**	**7.65%**	271.25	10+55.84
89	33.8781891	-84.4676209	-2.26046	3.13225	**-3.94%**	**5.47%**	**7.47%**	271.25	10+67.98
90	33.8782005	-84.467659	-2.68162	3.13615	**-4.68%**	**5.48%**	**7.48%**	271.25	10+80.66
91	33.8782044	-84.4677048	-2.9234	3.06524	**-5.10%**	**5.35%**	**7.35%**	271	10+92.8
92	33.8782082	-84.4677506	-3.09056	2.8536	**-5.39%**	**4.98%**	**6.98%**	271	11+08.4
93	33.8782158	-84.4677887	-3.214	2.77912	**-5.61%**	**4.85%**	**6.85%**	271	11+21.08
94	33.8782234	-84.4678345	-3.22317	2.78192	**-5.62%**	**4.86%**	**6.86%**	271.25	11+33.22
95	33.8782311	-84.4678803	-3.05448	2.6726	**-5.33%**	**4.67%**	**6.67%**	271	11+48.83
96	33.8782349	-84.4679184	-2.86762	2.51196	**-5.00%**	**4.39%**	**6.39%**	270.75	11+60.97
97	33.8782425	-84.4679565	-2.78546	2.48775	**-4.86%**	**4.34%**	**6.34%**	270.75	11+73.64
98	33.8782501	-84.4679947	-2.69924	2.53796	**-4.71%**	**4.43%**	**6.43%**	270.75	11+83.45
99	33.8782539	-84.4680481	-2.43656	2.46056	**-4.25%**	**4.30%**	**6.30%**	271	12+01.66
100	33.8782578	-84.4680862	-2.2125	2.37146	**-3.86%**	**4.14%**	**6.14%**	271	12+14.34
101	33.8782654	-84.468132	-2.17424	2.35644	**-3.79%**	**4.12%**	**6.12%**	270.75	12+27.01
102	33.8782692	-84.4681702	-2.38933	2.24196	**-4.17%**	**3.91%**	**5.91%**	270.75	12+39.15
103	33.878273	-84.4682159	-2.85896	2.19	**-4.99%**	**3.82%**	**5.82%**	271	12+54.33
104	33.8782768	-84.4682617	-3.16867	2.562	**-5.53%**	**4.47%**	**6.47%**	271	12+67.
105	33.8782768	-84.4682999	-2.70128	2.66968	**-4.71%**	**4.66%**	**6.66%**	270.75	12+79.15
106	33.8782806	-84.4683533	-1.98419	2.44715	**-3.46%**	**4.27%**	**6.27%**	271	12+94.32
107	33.8782845	-84.4683914	-1.695	2.23092	**-2.96%**	**3.90%**	**5.90%**	271.25	13+06.46
108	33.8782845	-84.4684448	-1.78288	2.02977	**-3.11%**	**3.54%**	**5.54%**	271.25	13+21.64
	33.878271	**-84.468465**	**Segment 9 starting point**						

Table A-19: Run 2 on Segment 14 Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations
	33.84545	**-84.4004**	**Segment 14 starting Point**						
125	33.8454056	-84.400452	1.627815	-1.2586296	**2.84%**	**-2.20%**	**-0.20%**	254	1+00.
126	33.8454018	-84.400414	1.894667	-1.1771667	**3.31%**	**-2.05%**	**-0.05%**	253.75	1+12.68
127	33.8453941	-84.400368	2.319231	-1.3234231	**4.05%**	**-2.31%**	**-0.31%**	253.75	1+25.36
128	33.8453865	-84.400322	2.54876	-1.39104	**4.45%**	**-2.43%**	**-0.43%**	254	1+40.54
129	33.8453827	-84.400291	2.427708	-1.4371667	**4.24%**	**-2.51%**	**-0.51%**	254.25	1+50.35
130	33.8453751	-84.400253	2.11696	-1.42532	**3.69%**	**-2.49%**	**-0.49%**	254.5	1+62.5
131	33.8453674	-84.400215	2.0712	-1.58052	**3.61%**	**-2.76%**	**-0.76%**	254.75	1+72.31
132	33.845356	-84.400177	2.25492	-1.70912	**3.93%**	**-2.98%**	**-0.98%**	255	1+84.99
133	33.8453484	-84.400139	2.30432	-1.73768	**4.02%**	**-3.03%**	**-1.03%**	255	1+97.66
134	33.8453407	-84.400101	2.164577	-1.9058077	**3.78%**	**-3.33%**	**-1.33%**	255	2+10.34
135	33.8453293	-84.400063	2.082577	-2.0360769	**3.63%**	**-3.56%**	**-1.56%**	255	2+23.02
136	33.8453293	-84.400024	2.328783	-2.1314348	**4.06%**	**-3.72%**	**-1.72%**	255	2+35.17
137	33.8453217	-84.399986	2.55525	-2.2643571	**4.46%**	**-3.95%**	**-1.95%**	255.5	2+44.98
138	33.8453217	-84.399956	2.735125	-2.25725	**4.77%**	**-3.94%**	**-1.94%**	255.5	2+54.09
139	33.8453178	-84.399918	2.81768	-2.20148	**4.92%**	**-3.84%**	**-1.84%**	255.75	2+66.23
140	33.845314	-84.399872	2.845958	-2.2532083	**4.97%**	**-3.93%**	**-1.93%**	256	2+81.85
141	33.8453064	-84.399834	2.805417	-2.270375	**4.89%**	**-3.96%**	**-1.96%**	256	2+93.99
142	33.8453026	-84.399803	2.8638	-2.26236	**5.00%**	**-3.95%**	**-1.95%**	255.75	3+03.8
143	33.8452988	-84.399765	2.986115	-2.3695769	**5.21%**	**-4.14%**	**-2.14%**	255.75	3+12.91
144	33.845295	-84.399727	2.935391	-2.3762609	**5.12%**	**-4.15%**	**-2.15%**	255.5	3+25.59
145	33.8452835	-84.399689	2.9194	-2.47168	**5.09%**	**-4.32%**	**-2.32%**	255.25	3+38.27
146	33.8452721	-84.399658	3.10448	-2.6066	**5.42%**	**-4.55%**	**-2.55%**	255	3+48.08
147	33.8452606	-84.399612	3.314567	-2.5306333	**5.78%**	**-4.42%**	**-2.42%**	254.75	3+63.69
....									
246	33.8440285	-84.396149	2.978643	-1.8714643	**5.20%**	**-3.27%**	**-1.27%**	249	15+26.95
247	33.8440208	-84.396118	3.18213	-1.8753043	**5.55%**	**-3.27%**	**-1.27%**	249	15+36.76
248	33.8440132	-84.39608	3.40796	-1.86104	**5.94%**	**-3.25%**	**-1.25%**	249	15+49.44
249	33.8440132	-84.39605	3.540444	-1.8007037	**6.18%**	**-3.14%**	**-1.14%**	249	15+58.55
250	33.8440018	-84.396019	3.60828	-1.76016	**6.29%**	**-3.07%**	**-1.07%**	249.5	15+68.36
251	33.8439941	-84.395988	3.42216	-1.75076	**5.97%**	**-3.06%**	**-1.06%**	249.75	15+78.17
252	33.8439865	-84.39595	3.405292	-1.7451667	**5.94%**	**-3.05%**	**-1.05%**	250	15+90.32
253	33.8439865	-84.39592	3.655462	-1.6139231	**6.38%**	**-2.82%**	**-0.82%**	250	15+99.43
254	33.8439789	-84.395889	3.973333	-1.6360417	**6.93%**	**-2.86%**	**-0.86%**	250	16+09.23
255	33.8439789	-84.395851	3.848292	-1.7657917	**6.71%**	**-3.08%**	**-1.08%**	249.75	16+21.38
256	33.8439865	-84.395821	3.554	-1.8375	**6.20%**	**-3.21%**	**-1.21%**	250	16+31.19
257	33.8439865	-84.39579	3.444917	-1.9229583	**6.01%**	**-3.36%**	**-1.36%**	250.25	16+40.3
258	33.8439865	-84.395752	3.416	-1.83032	**5.96%**	**-3.20%**	**-1.20%**	250.5	16+52.45
259	33.8439865	-84.395721	3.215654	-1.6945	**5.61%**	**-2.96%**	**-0.96%**	251	16+61.56
260	33.8439751	-84.395691	3.17672	-1.7176	**5.54%**	**-3.00%**	**-1.00%**	251	16+71.37
261	33.8439751	-84.39566	3.23308	-1.77888	**5.64%**	**-3.11%**	**-1.11%**	251	16+80.48
262	33.8439751	-84.395622	3.2034	-1.81688	**5.59%**	**-3.17%**	**-1.17%**	250.75	16+92.62
263	33.8439751	-84.395592	3.190808	-1.8135769	**5.57%**	**-3.17%**	**-1.17%**	251	17+01.73
264	33.8439751	-84.395561	3.19325	-1.7135	**5.57%**	**-2.99%**	**-0.99%**	251.25	17+10.84
265	33.8439751	-84.395531	3.103208	-1.59275	**5.41%**	**-2.78%**	**-0.78%**	251.25	17+19.95
266	33.8439751	-84.3955	3.109	-1.58748	**5.42%**	**-2.77%**	**-0.77%**	251.25	17+29.06
267	33.8439751	-84.395477	3.145192	-1.5809615	**5.49%**	**-2.76%**	**-0.76%**	251.25	17+35.13
268	33.8439789	-84.395447	3.164478	-1.494	**5.52%**	**-2.61%**	**-0.61%**	251	17+44.24
269	33.8439865	-84.395409	2.88616	-1.30208	**5.04%**	**-2.27%**	**-0.27%**	251	17+56.92
270	33.8439865	-84.395378	2.39308	-1.32856	**4.18%**	**-2.32%**	**-0.32%**	250.75	17+66.03
271	33.8439941	-84.395355	2.37537	-1.7411852	**4.14%**	**-3.04%**	**-1.04%**	250.75	17+72.1

Table A-20: Run 3 on Segment 15 Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations
	33.841684	**-84.384589**	**Segment 15 ending point**						
743	33.84175491	-84.38458252	2.28816	-3.06632	**3.99%**	**-5.36%**	**-3.36%**	258.25	1+00.
744	33.84177017	-84.38461304	2.38236	-2.59372	**4.16%**	**-4.53%**	**-2.53%**	258	1+11.66
745	33.84178925	-84.38463593	2.598	-2.77652	**4.53%**	**-4.85%**	**-2.85%**	257.5	1+23.32
746	33.84180832	-84.38465881	2.59744	-2.99604	**4.53%**	**-5.23%**	**-3.23%**	257.25	1+32.8
747	33.84182358	-84.38467407	2.63533	-2.621167	**4.60%**	**-4.58%**	**-2.58%**	257.25	1+37.54
748	33.84183884	-84.38470459	2.34336	-2.53464	**4.09%**	**-4.43%**	**-2.43%**	257	1+49.2
749	33.8418541	-84.38473511	1.897	-2.544583	**3.31%**	**-4.44%**	**-2.44%**	256.75	1+61.88
750	33.84186935	-84.384758	1.58554	-2.56825	**2.77%**	**-4.49%**	**-2.49%**	256.25	1+71.36
751	33.84188843	-84.38478851	1.67264	-2.6004	**2.92%**	**-4.54%**	**-2.54%**	256	1+83.02
752	33.8419075	-84.3848114	1.69108	-2.59168	**2.95%**	**-4.53%**	**-2.53%**	255.75	1+92.5
753	33.84192657	-84.38484192	1.53264	-2.60236	**2.67%**	**-4.55%**	**-2.55%**	255.5	2+04.16
754	33.84194946	-84.38486481	1.24386	-2.418379	**2.17%**	**-4.22%**	**-2.22%**	254	2+13.64
755	33.84196091	-84.38489532	1.14487	-2.371652	**2.00%**	**-4.14%**	**-2.14%**	254	2+26.32
756	33.84196854	-84.38492584	1.1118	-2.34772	**1.94%**	**-4.10%**	**-2.10%**	254.25	2+36.13
757	33.8419838	-84.38494873	1.04577	-2.381364	**1.83%**	**-4.16%**	**-2.16%**	254.5	2+43.21
758	33.84199524	-84.38498688	1.37359	-2.370966	**2.40%**	**-4.14%**	**-2.14%**	254.5	2+57.37
759	33.84201431	-84.3850174	1.81108	-2.33975	**3.16%**	**-4.09%**	**-2.09%**	254.75	2+67.18
760	33.84202957	-84.38504791	2.04967	-2.293	**3.58%**	**-4.00%**	**-2.00%**	254.75	2+78.84
761	33.84205246	-84.3850708	2.04015	-2.232769	**3.56%**	**-3.90%**	**-1.90%**	255.25	2+88.31
762	33.84207153	-84.38510132	1.94411	-2.151222	**3.39%**	**-3.76%**	**-1.76%**	254.75	2+99.97
763	33.84209061	-84.38513184	2.03028	-2.15408	**3.54%**	**-3.76%**	**-1.76%**	255.25	3+11.63
764	33.84211731	-84.38516235	2.32726	-2.465696	**4.06%**	**-4.31%**	**-2.31%**	255	3+25.85
765	33.8421402	-84.38518524	2.58685	-2.438269	**4.51%**	**-4.26%**	**-2.26%**	255.5	3+37.51
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1005	33.84408951	-84.39426422	1.98876	-1.89284	**3.47%**	**-3.30%**	**-1.30%**	260.5	33+99.76
1006	33.84408569	-84.39430237	1.56481	-1.855808	**2.73%**	**-3.24%**	**-1.24%**	260.75	34+11.91
1007	33.84407806	-84.39434052	1.466	-1.856292	**2.56%**	**-3.24%**	**-1.24%**	260.25	34+24.59
1008	33.84407425	-84.3943634	1.51327	-1.721923	**2.64%**	**-3.01%**	**-1.01%**	260	34+31.67
1009	33.84408569	-84.39441681	1.911	-1.631167	**3.33%**	**-2.85%**	**-0.85%**	259.5	34+51.28
1010	33.84409332	-84.39446259	1.98438	-1.373885	**3.46%**	**-2.40%**	**-0.40%**	259	34+63.43
1011	33.84410095	-84.39450836	1.9986	-1.23884	**3.49%**	**-2.16%**	**-0.16%**	258.75	34+79.04
1012	33.84410477	-84.39454651	2.11396	-1.238083	**3.69%**	**-2.16%**	**-0.16%**	258.75	34+91.19
1013	33.84410477	-84.39458466	2.34262	-1.050731	**4.09%**	**-1.83%**	**0.17%**	258.75	35+00.3
1014	33.84410095	-84.3946228	2.21071	-0.99975	**3.86%**	**-1.75%**	**0.25%**	258.5	35+12.45
1015	33.84410095	-84.39466095	2.22338	-1.037958	**3.88%**	**-1.81%**	**0.19%**	258.75	35+24.59
1016	33.8441124	-84.39471436	2.4489	-1.028933	**4.27%**	**-1.80%**	**0.20%**	259.25	35+40.2
1017	33.84408569	-84.39472198	2.82629	-1.071	**4.93%**	**-1.87%**	**0.13%**	261	35+48.09
1018	33.84407806	-84.39476013	3.07238	-1.0725	**5.36%**	**-1.87%**	**0.13%**	262.25	35+60.77
1019	33.84407425	-84.39478302	2.95552	-1.0388	**5.16%**	**-1.81%**	**0.19%**	263.25	35+67.85
1020	33.84406662	-84.39481354	2.96045	-0.9329	**5.16%**	**-1.63%**	**0.37%**	264	35+76.96
1021	33.84406281	-84.39485168	2.508	-0.918731	**4.38%**	**-1.60%**	**0.40%**	263.5	35+89.64
1022	33.84405899	-84.3948822	2.48296	-0.84616	**4.33%**	**-1.48%**	**0.52%**	263.75	35+98.75
1023	33.84406662	-84.39492798	2.65216	-0.90888	**4.63%**	**-1.59%**	**0.41%**	264	36+14.36
1024	33.84406662	-84.3949585	2.73396	-0.91004	**4.77%**	**-1.59%**	**0.41%**	263.5	36+23.47
1025	33.84407043	-84.39499664	2.73248	-0.83804	**4.77%**	**-1.46%**	**0.54%**	262	36+35.62
1026	33.84407043	-84.39502716	2.88152	-0.828	**5.03%**	**-1.45%**	**0.55%**	262	36+44.73
1027	33.84407043	-84.39508057	3.40704	-0.751038	**5.94%**	**-1.31%**	**0.69%**	262.75	36+59.91
1028	33.84407425	-84.39511871	3.83492	-0.75404	**6.69%**	**-1.32%**	**0.68%**	262.75	36+72.06
1029	33.84407425	-84.39515686	3.97492	-0.76304	**6.93%**	**-1.33%**	**0.67%**	262.75	36+84.2
1030	33.84407425	-84.39518738	4.15308	-0.83236	**7.24%**	**-1.45%**	**0.55%**	262.75	36+93.31
1031	33.84407425	-84.39522552	4.04827	-0.714692	**7.06%**	**-1.25%**	**0.75%**	262.5	37+05.46
1032	33.84407425	-84.39526367	3.98443	-0.870522	**6.95%**	**-1.52%**	**0.48%**	262.25	37+14.57
1033	33.84407043	-84.39530182	4.1268	-0.79396	**7.20%**	**-1.39%**	**0.61%**	262.25	37+26.71
1034	33.84407043	-84.3953476	4.21048	-0.85684	**7.34%**	**-1.50%**	**0.50%**	262.5	37+41.9
1035	33.84406662	-84.39538574	3.96156	-0.88368	**6.91%**	**-1.54%**	**0.46%**	262.75	37+54.04
	33.844049	**-84.395373**	**Segment 15 starting point**						

Table A-21: Run 1 on Segment 16 Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations
	33.84366	**-84.37929**	**Segment 16 ending point**						
363	33.8434601	-84.3792954	3.02634615	-193969231	**5.28%**	**-3.39%**	**-1.39%**	269	1+00.
364	33.8434258	-84.3792801	2.99468182	-188304545	**5.22%**	**-3.29%**	**-1.29%**	268.75	1+12.49
365	33.8433952	-84.3792725	2.99888462	-183496154	**5.23%**	**-3.20%**	**-1.20%**	268	1+23.82
366	33.8433609	-84.3792648	2.996875	-179625	**5.23%**	**-3.14%**	**-1.14%**	267.5	1+38.69
367	33.8433266	-84.3792496	3.10622222	-187222222	**5.42%**	**-3.27%**	**-1.27%**	267.25	1+50.02
368	33.8432999	-84.3792343	3.53016667	-185116667	**6.16%**	**-3.23%**	**-1.23%**	267	1+62.52
369	33.8432732	-84.3792191	3.6308	-155016	**6.33%**	**-2.71%**	**-0.71%**	266.75	1+73.85
370	33.8432427	-84.3792038	3.1972	-18002	**5.58%**	**-3.14%**	**-1.14%**	267.25	1+86.34
371	33.8432083	-84.3791885	2.89903704	-180803704	**5.06%**	**-3.16%**	**-1.16%**	267.5	1+97.67
372	33.8431816	-84.3791809	3.12036	-182664	**5.44%**	**-3.19%**	**-1.19%**	267.75	2+09.
373	33.8431511	-84.3791733	3.28144	-185132	**5.72%**	**-3.23%**	**-1.23%**	267.75	2+20.33
374	33.8431168	-84.3791657	3.38420833	-177116667	**5.90%**	**-3.09%**	**-1.09%**	268	2+31.25
375	33.8430901	-84.3791504	3.49132	-169812	**6.09%**	**-2.96%**	**-0.96%**	268.5	2+43.74
376	33.8430557	-84.3791504	3.58343478	-165491304	**6.25%**	**-2.89%**	**-0.89%**	269	2+54.66
377	33.8430176	-84.3791351	3.73970833	-162858333	**6.52%**	**-2.84%**	**-0.84%**	269	2+69.53
378	33.8429833	-84.3791275	4.00469231	-166257692	**6.98%**	**-2.90%**	**-0.90%**	269.25	2+84.4
379	33.8429451	-84.3791122	4.34046154	-154715385	**7.57%**	**-2.70%**	**-0.70%**	269.25	2+96.89
380	33.8429146	-84.3791046	4.98636	-129664	**8.69%**	**-2.26%**	**-0.26%**	269	3+11.76
381	33.8428841	-84.3790817	5.17530769	-0.75	**9.02%**	**-1.31%**	**0.69%**	268.75	3+24.25
382	33.8428536	-84.3790741	4.16844	-0.2032	**7.27%**	**-0.35%**	**1.65%**	268.75	3+35.58
383	33.8428268	-84.3790741	2.92284	-0.4846	**5.10%**	**-0.85%**	**1.15%**	268.75	3+42.86
384	33.8428001	-84.3790665	2.718	-0.41475	**4.74%**	**-0.72%**	**1.28%**	268.5	3+53.78
385	33.8427696	-84.3790665	3.18236	-0.54216	**5.55%**	**-0.95%**	**1.05%**	268.25	3+64.69
386	33.8427391	-84.3790512	3.553875	-0.53025	**6.20%**	**-0.93%**	**1.07%**	267.75	3+77.19
387	33.8427124	-84.3790436	3.56823077	-0.332	**6.22%**	**-0.58%**	**1.42%**	267.25	3+88.52
388	33.8426781	-84.379036	3.30079167	-0.11275	**5.76%**	**-0.20%**	**1.80%**	266.75	3+99.43
389	33.8426476	-84.379036	2.79764	-0.11344	**4.88%**	**-0.20%**	**1.80%**	267	4+10.35
390	33.842617	-84.3790207	2.367	-0.14384	**4.13%**	**-0.25%**	**1.75%**	267	4+22.84
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540	33.8398285	-84.379776	0.71692	-1.3178	**1.25%**	**-2.30%**	**-0.30%**	262.5	16+22.68
541	33.8398209	-84.379776	0.6652	-1.34	**1.16%**	**-2.34%**	**-0.34%**	262.5	16+26.32
542	33.8398132	-84.3797836	0.74157692	-1.25715385	**1.29%**	**-2.19%**	**-0.19%**	262.75	16+29.96
543	33.8398018	-84.3797989	0.74516667	-1.29258333	**1.30%**	**-2.26%**	**-0.26%**	262.75	16+37.04
544	33.8397942	-84.3797989	0.73316	-1.23716	**1.28%**	**-2.16%**	**-0.16%**	262.75	16+40.68
545	33.8397827	-84.3798065	0.75183333	-1.31366667	**1.31%**	**-2.29%**	**-0.29%**	262.75	16+45.42
546	33.8397675	-84.3798065	0.68311538	-1.28673077	**1.19%**	**-2.25%**	**-0.25%**	262.75	16+49.06
547	33.839756	-84.3798142	0.547375	-1.37116667	**0.96%**	**-2.39%**	**-0.39%**	262.75	16+52.7
548	33.8397446	-84.3798294	0.46592	-1.55088	**0.81%**	**-2.71%**	**-0.71%**	262.5	16+62.18
549	33.8397293	-84.3798294	0.42412	-1.61968	**0.74%**	**-2.83%**	**-0.83%**	263	16+65.81
550	33.8397179	-84.379837	0.39416	-1.69324	**0.69%**	**-2.96%**	**-0.96%**	262.75	16+70.55
551	33.8397026	-84.3798447	0.39628	-1.71616	**0.69%**	**-3.00%**	**-1.00%**	262.75	16+77.83
552	33.839695	-84.3798523	0.52872	-1.85564	**0.92%**	**-3.24%**	**-1.24%**	262.5	16+82.57
553	33.8396759	-84.3798599	0.55144	-1.95268	**0.96%**	**-3.41%**	**-1.41%**	262.75	16+87.31
554	33.8396645	-84.3798599	0.49844	-1.98016	**0.87%**	**-3.46%**	**-1.46%**	263.5	16+94.59
555	33.8396492	-84.3798676	0.50984	-2.0508	**0.89%**	**-3.58%**	**-1.58%**	263.75	16+99.33
556	33.8396378	-84.3798752	0.62565385	-2.03861538	**1.09%**	**-3.56%**	**-1.56%**	263.5	17+04.07
557	33.8396263	-84.3798828	0.64404	-1.9818	**1.12%**	**-3.46%**	**-1.46%**	263.25	17+07.71
558	33.8396149	-84.3798828	0.53876923	-2.03780769	**0.94%**	**-3.56%**	**-1.56%**	263.5	17+14.99
559	33.8396034	-84.3798828	0.6123913	-2.08795652	**1.07%**	**-3.65%**	**-1.65%**	263.75	17+18.62
560	33.839592	-84.3798904	0.86614815	-2.06814815	**1.51%**	**-3.61%**	**-1.61%**	264	17+23.36
561	33.8395805	-84.3798981	1.08332	-2.1324	**1.89%**	**-3.72%**	**-1.72%**	264.25	17+28.1
562	33.8395653	-84.3799057	1.20392	-2.31564	**2.10%**	**-4.04%**	**-2.04%**	264.5	17+32.84
563	33.8395538	-84.3799057	1.69304	-2.3848	**2.95%**	**-4.16%**	**-2.16%**	264.75	17+40.12
	33.839558	**-84.379750**	**Segment 16 starting point**						

Table A-22: Run 2 on Segment 17 Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations
	33.846599	**-84.381765**	**Segment 17 starting point**						
1337	33.84671021	-84.3817749	0.93268	-4.45132	**1.63%**	**-7.78%**	**-5.78%**	249.75	1+00.
1338	33.84674072	-84.38180542	1.156458333	-4.446666667	**2.02%**	**-7.78%**	**-5.78%**	249.75	1+16.33
1339	33.84676743	-84.38182831	1.269	-4.52992	**2.21%**	**-7.92%**	**-5.92%**	249	1+28.82
1340	33.84679413	-84.38185883	1.30425	-4.618125	**2.28%**	**-8.08%**	**-6.08%**	248.5	1+40.48
1341	33.84682465	-84.38188934	1.39876	-4.66904	**2.44%**	**-8.17%**	**-6.17%**	247.75	1+54.7
1342	33.84685516	-84.38191223	1.54128	-4.74052	**2.69%**	**-8.29%**	**-6.29%**	247.25	1+70.47
1343	33.84688187	-84.38193512	1.564846154	-4.810769231	**2.73%**	**-8.42%**	**-6.42%**	246.75	1+82.13
1344	33.84691238	-84.38196564	1.605307692	-4.599346154	**2.80%**	**-8.04%**	**-6.04%**	246	1+96.35
1345	33.84695053	-84.3819809	1.787083333	-4.584708333	**3.12%**	**-8.02%**	**-6.02%**	246.25	2+11.22
1346	33.84698486	-84.38200378	1.592769231	-4.571153846	**2.78%**	**-8.00%**	**-6.00%**	246.25	2+23.71
1347	33.8470192	-84.38201904	1.308125	-4.566541667	**2.28%**	**-7.99%**	**-5.99%**	246	2+39.48
1348	33.84705734	-84.38204193	1.417107143	-4.4865	**2.47%**	**-7.85%**	**-5.85%**	245.75	2+55.26
1349	33.84708786	-84.38206482	1.565583333	-4.379291667	**2.73%**	**-7.66%**	**-5.66%**	245.25	2+67.75
1350	33.84711838	-84.38208771	1.37456	-4.46996	**2.40%**	**-7.82%**	**-5.82%**	244.75	2+81.97
1351	33.84715652	-84.38210297	1.227846154	-4.3915	**2.14%**	**-7.68%**	**-5.68%**	244	2+96.83
1352	33.84718704	-84.38212585	1.10488	-4.30208	**1.93%**	**-7.52%**	**-5.52%**	243.75	3+11.05
1353	33.847229	-84.38213348	0.902	-4.3044	**1.57%**	**-7.53%**	**-5.53%**	244	3+25.61
1354	33.84726715	-84.38215637	1.04248	-4.35392	**1.82%**	**-7.61%**	**-5.61%**	244	3+42.78
1355	33.8473053	-84.38217163	1.516913043	-4.198869565	**2.65%**	**-7.34%**	**-5.34%**	244.25	3+57.65
1356	33.84734726	-84.38217926	1.57396	-4.13844	**2.75%**	**-7.24%**	**-5.24%**	244	3+72.52
1357	33.84738922	-84.38220215	1.33184	-4.43364	**2.32%**	**-7.75%**	**-5.75%**	244	3+88.29
1358	33.84742737	-84.38221741	1.716541667	-4.657166667	**3.00%**	**-8.15%**	**-6.15%**	244	4+04.06
1359	33.84746552	-84.38223267	2.34736	-4.29172	**4.10%**	**-7.50%**	**-5.50%**	244	4+18.93
1360	33.84750366	-84.38225555	2.38896	-4.42708	**4.17%**	**-7.74%**	**-5.74%**	244	4+33.15
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1530	33.85289383	-84.38271332	4.25298	-0.17676	**7.42%**	**-0.31%**	**1.69%**	257.75	24+54.43
1531	33.85289764	-84.38271332	4.39245098	-0.173784314	**7.66%**	**-0.30%**	**1.70%**	257.873	24+58.07
1532	33.85290146	-84.38271332	4.538583333	-0.018958333	**7.91%**	**-0.03%**	**1.97%**	258.25	24+58.07
1533	33.85290909	-84.38272095	4.572346154	0.132807692	**7.97%**	**0.23%**	**2.23%**	258.25	24+62.81
1534	33.8529129	-84.38272095	4.441666667	0.280875	**7.74%**	**0.49%**	**2.49%**	258.5	24+62.81
1535	33.8529129	-84.38272858	4.41656	0.32204	**7.70%**	**0.56%**	**2.56%**	258.5	24+65.84
1536	33.85292053	-84.38272858	4.521423077	0.380269231	**7.88%**	**0.66%**	**2.66%**	258.5	24+69.48
1537	33.85292053	-84.38272095	4.418583333	0.325916667	**7.70%**	**0.57%**	**2.57%**	258.25	24+72.52
1538	33.85292816	-84.38272095	4.155	0.3685	**7.25%**	**0.64%**	**2.64%**	258.25	24+76.16
1539	33.85293579	-84.38272095	4.182	0.2458	**7.29%**	**0.43%**	**2.43%**	258.25	24+79.8
1540	33.85293961	-84.38272095	4.1624	0.42932	**7.26%**	**0.75%**	**2.75%**	258.5	24+79.8
1541	33.85294724	-84.38272095	4.121230769	0.513884615	**7.19%**	**0.90%**	**2.90%**	258.5	24+83.43
1542	33.85295486	-84.38272095	3.93873913	0.480608696	**6.87%**	**0.84%**	**2.84%**	258.75	24+83.43
1543	33.85296631	-84.38272095	3.73804	0.523	**6.52%**	**0.91%**	**2.91%**	258.75	24+90.71
1544	33.85297394	-84.38272095	3.65492	0.45768	**6.37%**	**0.80%**	**2.80%**	258.75	24+90.71
1545	33.8529892	-84.38272095	3.539923077	0.597192308	**6.17%**	**1.04%**	**3.04%**	258.75	24+97.99
1546	33.85300064	-84.38272095	3.168875	0.530666667	**5.53%**	**0.93%**	**2.93%**	258.75	25+0163
1547	33.85301971	-84.38271332	2.973230769	0.544076923	**5.19%**	**0.95%**	**2.95%**	258.75	25+09.51
1548	33.85302734	-84.38271332	2.77388	0.53904	**4.84%**	**0.94%**	**2.94%**	258.5	25+13.15
1549	33.85304642	-84.38270569	2.599730769	0.543730769	**4.54%**	**0.95%**	**2.95%**	258.5	25+20.43
1550	33.85305405	-84.38270569	2.36824	0.48604	**4.13%**	**0.85%**	**2.85%**	259	25+20.43
1551	33.85306931	-84.38269043	2.161608696	0.455391304	**3.77%**	**0.79%**	**2.79%**	259	25+29.91
1552	33.85308075	-84.38269043	1.927384615	0.289807692	**3.36%**	**0.51%**	**2.51%**	259	25+33.55
1553	33.85309601	-84.38269043	1.68516	0.38472	**2.94%**	**0.67%**	**2.67%**	259.5	25+40.83
1554	33.85311127	-84.3826828	1.51232	0.53148	**2.64%**	**0.93%**	**2.93%**	259.75	25+45.57
1555	33.85312653	-84.3826828	1.37075	0.400791667	**2.39%**	**0.70%**	**2.70%**	259.75	25+52.84
	33.853286	**-84.382685**	**Segment 17 ending point**						

Table A-23: Run 3 on Segment 22 Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations
	33.943550	**-84.331613**	**Segment 22 starting point**						
94	33.9434662	-84.331604	2.71244	-1.12536	**4.73%**	**-1.96%**	**0.04%**	286.75	1+00.
95	33.9434357	-84.331573	3.15028	-1.05772	**5.50%**	**-1.85%**	**0.15%**	286.5	1+14.21
96	33.9434128	-84.331558	3.63708	-1.17744	**6.34%**	**-2.06%**	**-0.06%**	286.5	1+25.54
97	33.9433823	-84.331535	3.9188846	-1.08888	**6.83%**	**-1.90%**	**0.10%**	286.5	1+38.03
98	33.9433556	-84.331512	4.0856	-0.92784	**7.12%**	**-1.62%**	**0.38%**	286.5	1+49.68
99	33.9433327	-84.331497	4.3942	-0.93904	**7.66%**	**-1.64%**	**0.36%**	286.5	1+61.01
100	33.943306	-84.331482	4.46668	-0.989	**7.79%**	**-1.73%**	**0.27%**	286.25	1+70.49
101	33.9432793	-84.331459	4.0728519	-0.96085	**7.10%**	**-1.68%**	**0.32%**	286.25	1+82.98
102	33.9432488	-84.331444	3.865375	-1.04113	**6.74%**	**-1.82%**	**0.18%**	286.25	1+95.46
103	33.9432259	-84.331429	4.24612	-1.2064	**7.40%**	**-2.11%**	**-0.11%**	286.25	2+03.35
104	33.9431992	-84.331406	4.44725	-0.93163	**7.75%**	**-1.63%**	**0.37%**	286.25	2+15.84
105	33.9431725	-84.33139	3.9856923	-1.16396	**6.95%**	**-2.03%**	**-0.03%**	286.5	2+28.33
106	33.9431496	-84.331367	3.6645217	-1.2677	**6.39%**	**-2.21%**	**-0.21%**	286.25	2+37.8
107	33.9431191	-84.331352	3.9337308	-1.40435	**6.86%**	**-2.45%**	**-0.45%**	286.5	2+50.29
108	33.9430962	-84.331337	3.9985	-1.48808	**6.97%**	**-2.60%**	**-0.60%**	285.75	2+58.18
109	33.9430656	-84.331314	3.55376	-1.4188	**6.20%**	**-2.48%**	**-0.48%**	285.5	2+72.39
110	33.9430389	-84.331299	2.912625	-1.51167	**5.08%**	**-2.64%**	**-0.64%**	285	2+83.72
111	33.9430161	-84.331291	2.54368	-1.7086	**4.44%**	**-2.98%**	**-0.98%**	284.25	2+91.6
112	33.942997	-84.331268	2.31516	-1.97456	**4.04%**	**-3.45%**	**-1.45%**	284	3+01.08
113	33.9429703	-84.331245	2.1044167	-2.16513	**3.67%**	**-3.78%**	**-1.78%**	283.5	3+13.56
114	33.9429436	-84.331238	2.143	-2.35662	**3.74%**	**-4.12%**	**-2.12%**	283.5	3+24.9
115	33.9429169	-84.331215	2.4234286	-2.50452	**4.23%**	**-4.37%**	**-2.37%**	284	3+36.55
116	33.9428864	-84.3312	2.5042692	-2.78954	**4.37%**	**-4.87%**	**-2.87%**	284.5	3+47.88
117	33.9428558	-84.331177	2.38408	-3.01988	**4.16%**	**-5.28%**	**-3.28%**	285	3+60.37
118	33.942833	-84.331162	2.41084	-3.08308	**4.21%**	**-5.39%**	**-3.39%**	284	3+72.85
119	33.9428062	-84.331139	2.7566	-3.2996	**4.81%**	**-5.77%**	**-3.77%**	284	3+82.33
120	33.9427834	-84.331123	2.9326154	-3.62996	**5.12%**	**-6.34%**	**-4.34%**	284.25	3+94.82
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455	33.9338875	-84.320587	2.509	-1.55192	**4.38%**	**-2.71%**	**-0.71%**	282	50+22.02
456	33.9338646	-84.320541	2.9582	-1.52128	**5.16%**	**-2.66%**	**-0.66%**	282.25	50+40.71
457	33.9338455	-84.320503	2.8944615	-1.4375	**5.05%**	**-2.51%**	**-0.51%**	282.5	50+53.38
458	33.9338265	-84.320465	2.4502381	-1.48486	**4.28%**	**-2.59%**	**-0.59%**	282.25	50+65.03
459	33.9338112	-84.320435	2.133	-1.41204	**3.72%**	**-2.46%**	**-0.46%**	282	50+79.18
460	33.9337959	-84.320404	2.0846786	-1.52704	**3.64%**	**-2.67%**	**-0.67%**	282.5	50+88.98
461	33.933773	-84.320366	1.97744	-1.66092	**3.45%**	**-2.90%**	**-0.90%**	283.25	51+03.19
462	33.933754	-84.320328	1.92188	-1.6738	**3.35%**	**-2.92%**	**-0.92%**	284	51+17.34
463	33.9337463	-84.320297	1.81692	-1.76016	**3.17%**	**-3.07%**	**-1.07%**	284.75	51+26.44
464	33.9337311	-84.320259	1.64812	-1.67548	**2.88%**	**-2.93%**	**-0.93%**	285	51+40.59
465	33.9337196	-84.320229	1.53096	-1.5438	**2.67%**	**-2.70%**	**-0.70%**	284.5	51+50.39
466	33.9337082	-84.320198	1.4962	-1.5006	**2.61%**	**-2.62%**	**-0.62%**	284.25	51+60.19
467	33.9336968	-84.320168	1.5749545	-1.51668	**2.75%**	**-2.65%**	**-0.65%**	284.25	51+69.99
468	33.9336815	-84.320137	1.6307692	-1.45427	**2.85%**	**-2.54%**	**-0.54%**	284.75	51+81.64
469	33.93367	-84.320107	1.7914167	-1.45721	**3.13%**	**-2.54%**	**-0.54%**	285	51+91.44
470	33.9336548	-84.320076	2.0364815	-1.30663	**3.55%**	**-2.28%**	**-0.28%**	284.75	52+03.1
471	33.9336357	-84.320061	2.0631739	-1.35648	**3.60%**	**-2.37%**	**-0.37%**	284.5	52+10.17
472	33.9336243	-84.320023	1.9362414	-1.46803	**3.38%**	**-2.56%**	**-0.56%**	284	52+24.32
473	33.9336166	-84.32	1.47184	-1.52836	**2.57%**	**-2.67%**	**-0.67%**	283.75	52+30.39
474	33.9336052	-84.319969	0.7594583	-1.67408	**1.33%**	**-2.92%**	**-0.92%**	283.75	52+40.19
475	33.9335938	-84.319939	0.6686087	-1.58565	**1.17%**	**-2.77%**	**-0.77%**	283.75	52+51.84
476	33.9335823	-84.319908	0.50372	-1.683	**0.88%**	**-2.94%**	**-0.94%**	283	52+61.64
477	33.9335709	-84.319878	0.361	-1.6376	**0.63%**	**-2.86%**	**-0.86%**	282.25	52+71.44
478	33.9335556	-84.319855	0.5428846	-1.81669	**0.95%**	**-3.17%**	**-1.17%**	282.25	52+81.24
479	33.933548	-84.319824	1.1805	-1.78883	**2.06%**	**-3.12%**	**-1.12%**	281.75	52+91.04
480	33.9335251	-84.319794	2.07684	-1.83524	**3.62%**	**-3.20%**	**-1.20%**	281.75	53+02.69
481	33.9335098	-84.319763	2.5580769	-1.97396	**4.46%**	**-3.45%**	**-1.45%**	281.5	53+14.35
	33.933465	**-84.319767**	**Segment 22 ending point**						

Table A-24: Run 2 on Segment 23 Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations
	33.935068	**-84.349912**	**Segment 23 starting point**						
1571	33.93506622	-84.34994507	2.13804	0.04016	**3.73%**	**0.07%**	**2.07%**	299.75	1+00.
1572	33.93509293	-84.34992981	2.2332963	0.0566296	**3.90%**	**0.10%**	**2.10%**	299.75	1+09.47
1573	33.93511963	-84.34990692	2.2985	0.141	**4.01%**	**0.25%**	**2.25%**	300	1+21.96
1574	33.93514633	-84.34989166	2.3620769	0.1962692	**4.12%**	**0.34%**	**2.34%**	300	1+34.45
1575	33.93517303	-84.34986877	2.21352	0.24876	**3.86%**	**0.43%**	**2.43%**	300.5	1+43.93
1576	33.93519592	-84.34983826	2.11848	0.26	**3.70%**	**0.45%**	**2.45%**	300.75	1+58.14
1577	33.93522644	-84.349823	2.0986923	0.0720385	**3.66%**	**0.13%**	**2.13%**	301.25	1+70.63
1578	33.93524933	-84.34980011	2.13956	0.0672	**3.73%**	**0.12%**	**2.12%**	301.25	1+80.1
1579	33.93527603	-84.34977722	1.992	0.0404	**3.48%**	**0.07%**	**2.07%**	301.5	1+92.59
1580	33.93530655	-84.34976196	1.74188	0.18036	**3.04%**	**0.31%**	**2.31%**	302	2+05.08
1581	33.93533325	-84.34973907	1.70892	0.1674	**2.98%**	**0.29%**	**2.29%**	302.25	2+14.56
1582	33.93535995	-84.34970856	1.74992	0.15636	**3.05%**	**0.27%**	**2.27%**	302.5	2+28.77
1583	33.93539047	-84.3496933	1.7105833	0.163125	**2.99%**	**0.28%**	**2.28%**	302.75	2+41.26
1584	33.93541718	-84.34967804	1.493	0.2148846	**2.61%**	**0.38%**	**2.38%**	303.25	2+52.59
1585	33.93544388	-84.34964752	1.278625	0.2126667	**2.23%**	**0.37%**	**2.37%**	303.75	2+64.24
1586	33.9354744	-84.34963226	1.1996	0.24052	**2.09%**	**0.42%**	**2.42%**	304	2+76.73
1587	33.93550491	-84.34960937	1.25284	0.37772	**2.19%**	**0.66%**	**2.66%**	304	2+89.22
1588	33.93553162	-84.34959412	1.2325769	0.4151923	**2.15%**	**0.72%**	**2.72%**	303.75	3+01.71
1589	33.93556213	-84.34957123	1.2815417	0.4486667	**2.24%**	**0.78%**	**2.78%**	304.25	3+14.2
1590	33.93558884	-84.34954834	1.3924	0.52588	**2.43%**	**0.92%**	**2.92%**	304.5	3+26.69
1591	33.93561935	-84.34953308	1.53332	0.53584	**2.68%**	**0.94%**	**2.94%**	304.75	3+39.18
1592	33.93564606	-84.34951019	1.7681923	0.309	**3.09%**	**0.54%**	**2.54%**	305	3+51.67
1593	33.93567657	-84.34949493	1.98088	0.25428	**3.46%**	**0.44%**	**2.44%**	305	3+64.15
1594	33.93570709	-84.34947968	2.1028333	0.3338333	**3.67%**	**0.58%**	**2.58%**	305	3+75.48
1595	33.9357338	-84.34945679	2.16948	0.44272	**3.79%**	**0.77%**	**2.77%**	304.5	3+84.96
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1965	33.94324112	-84.33837891	-1.27336	-0.76596	**-2.22%**	**-1.34%**	**0.66%**	305	49+45.09
1966	33.94325256	-84.33835602	-1.370692	-0.701308	**-2.39%**	**-1.22%**	**0.78%**	304.75	49+52.16
1967	33.94326782	-84.33833313	-1.366583	-0.788917	**-2.38%**	**-1.38%**	**0.62%**	304.75	49+63.81
1968	33.94328308	-84.33831024	-1.26616	-0.99048	**-2.21%**	**-1.73%**	**0.27%**	304.75	49+70.89
1969	33.94329834	-84.33828735	-1.01336	-0.89856	**-1.77%**	**-1.57%**	**0.43%**	304.5	49+80.36
1970	33.9433136	-84.33825684	-0.80336	-0.97128	**-1.40%**	**-1.70%**	**0.30%**	304	49+90.16
1971	33.94332886	-84.33823395	-0.77384	-1.05824	**-1.35%**	**-1.85%**	**0.15%**	304	50+01.81
1972	33.94334412	-84.33820343	-0.75548	-1.26532	**-1.32%**	**-2.21%**	**-0.21%**	304	50+11.61
1973	33.94335937	-84.33818054	-0.722625	-1.370458	**-1.26%**	**-2.39%**	**-0.39%**	304	50+21.08
1974	33.94337845	-84.33815765	-0.77296	-1.46016	**-1.35%**	**-2.55%**	**-0.55%**	303.75	50+30.56
1975	33.94339371	-84.33812714	-0.94364	-1.63516	**-1.65%**	**-2.85%**	**-0.85%**	303.75	50+40.36
1976	33.94340515	-84.33810425	-1.088615	-1.736346	**-1.90%**	**-3.03%**	**-1.03%**	304	50+52.01
1977	33.94342041	-84.33807373	-1.07364	-1.77928	**-1.87%**	**-3.11%**	**-1.11%**	304	50+61.81
1978	33.94343567	-84.33805847	-0.993577	-1.781462	**-1.73%**	**-3.11%**	**-1.11%**	304	50+69.69
1979	33.94345093	-84.33802795	-0.861043	-1.848435	**-1.50%**	**-3.23%**	**-1.23%**	303.75	50+79.49
1980	33.94346619	-84.33800507	-0.854077	-1.7615	**-1.49%**	**-3.08%**	**-1.08%**	303.75	50+88.97
1981	33.94348526	-84.33797455	-0.95604	-1.71216	**-1.67%**	**-2.99%**	**-0.99%**	303.75	51+03.12
1982	33.94350433	-84.33795929	-1.227115	-1.655577	**-2.14%**	**-2.89%**	**-0.89%**	304	51+07.85
1983	33.94351959	-84.33792877	-1.498	-1.662	**-2.61%**	**-2.90%**	**-0.90%**	304.25	51+19.5
1984	33.94353485	-84.33790588	-1.611375	-1.579458	**-2.81%**	**-2.76%**	**-0.76%**	304.25	51+26.58
1985	33.94355011	-84.33787537	-1.612462	-1.567846	**-2.81%**	**-2.74%**	**-0.74%**	304	51+38.23
1986	33.94356537	-84.33786011	-1.733958	-1.593542	**-3.03%**	**-2.78%**	**-0.78%**	304	51+47.7
1987	33.94358444	-84.33782959	-1.82472	-1.62396	**-3.18%**	**-2.84%**	**-0.84%**	304.25	51+57.5
1988	33.94360352	-84.3378067	-1.7318	-1.70872	**-3.02%**	**-2.98%**	**-0.98%**	304.25	51+66.98
	33.943609	**-84.338026**	**Segment 23 ending point**						

Table A-25: Run 3 on Segment 40 Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations
	33.866335	**-84.466025**	**Segment 40 starting point**						
1	33.86639023	-84.4658661	1.126822	-2.5314	**1.97%**	**-4.42%**	**-2.42%**	255.2	1+00.
2	33.86639023	-84.4658432	2.249962	-2.395846	**3.93%**	**-4.18%**	**-2.18%**	254.5	1+09.11
3	33.86639023	-84.4658356	2.46132	-2.39724	**4.29%**	**-4.19%**	**-2.19%**	253.75	1+09.11
4	33.86639786	-84.4658279	2.26025	-2.39025	**3.94%**	**-4.17%**	**-2.17%**	253.25	1+13.85
5	33.86639786	-84.4658127	2.451167	-2.476125	**4.28%**	**-4.32%**	**-2.32%**	253	1+19.92
6	33.86640167	-84.4657898	2.77952	-2.31532	**4.85%**	**-4.04%**	**-2.04%**	252.75	1+25.99
7	33.86640167	-84.4657745	2.791958	-2.264458	**4.87%**	**-3.95%**	**-1.95%**	252.5	1+32.06
8	33.86640167	-84.4657517	2.73708	-2.3752	**4.78%**	**-4.15%**	**-2.15%**	252.5	1+38.13
9	33.86640549	-84.4657364	2.860033	-2.185333	**4.99%**	**-3.82%**	**-1.82%**	252.5	1+42.87
10	33.8664093	-84.4657135	2.847238	-2.163333	**4.97%**	**-3.78%**	**-1.78%**	253.25	1+51.98
11	33.86641312	-84.4656982	2.63128	-2.099	**4.59%**	**-3.67%**	**-1.67%**	253.25	1+55.01
12	33.86641693	-84.4656754	2.30752	-2.04388	**4.03%**	**-3.57%**	**-1.57%**	253.25	1+62.09
13	33.86641693	-84.4656601	2.171333	-2.008958	**3.79%**	**-3.51%**	**-1.51%**	253	1+68.16
14	33.86642456	-84.4656372	2.128038	-1.776462	**3.71%**	**-3.10%**	**-1.10%**	253	1+74.24
15	33.86642838	-84.4656143	2.098667	-1.643208	**3.66%**	**-2.87%**	**-0.87%**	253	1+84.04
16	33.866436	-84.4655991	1.84076	-1.58824	**3.21%**	**-2.77%**	**-0.77%**	253	1+88.78
17	33.866436	-84.4655762	1.646655	-1.67869	**2.87%**	**-2.93%**	**-0.93%**	253	1+94.85
18	33.86644745	-84.4655609	1.503115	-1.832731	**2.62%**	**-3.20%**	**-1.20%**	254.5	2+01.93
19	33.86645508	-84.4655457	1.4857	-1.8214	**2.59%**	**-3.18%**	**-1.18%**	255.5	2+06.67
20	33.86646271	-84.4655304	1.682889	-2.023407	**2.94%**	**-3.53%**	**-1.53%**	256.5	2+12.74
21	33.86648178	-84.4654999	1.595125	-1.980292	**2.78%**	**-3.46%**	**-1.46%**	251	2+24.4
22	33.86648178	-84.4654846	1.339	-1.643379	**2.34%**	**-2.87%**	**-0.87%**	250.75	2+30.47
23	33.86648178	-84.4654465	0.896652	-1.69913	**1.56%**	**-2.97%**	**-0.97%**	253.25	2+39.58
24	33.8664856	-84.4654312	0.592792	-1.96775	**1.03%**	**-3.44%**	**-1.44%**	255	2+46.66
25	33.86648941	-84.4654007	0.737577	-2.041962	**1.29%**	**-3.57%**	**-1.57%**	255.5	2+55.76
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300	33.87042999	-84.4577255	-0.571625	-0.381	**-1.00%**	**-0.66%**	**1.34%**	204.25	31+63.91
301	33.87044907	-84.4576874	-0.93532	-0.17588	**-1.63%**	**-0.31%**	**1.69%**	205	31+78.07
302	33.87047577	-84.4576492	-1.054615	-0.221692	**-1.84%**	**-0.39%**	**1.61%**	206	31+94.4
303	33.87049103	-84.4576187	-1.233792	-0.000417	**-2.15%**	**0.00%**	**2.00%**	208.5	32+04.2
304	33.87051392	-84.4575882	-1.47708	0.33296	**-2.58%**	**0.58%**	**2.58%**	210.25	32+15.86
305	33.87052917	-84.4575501	-1.553692	0.640654	**-2.71%**	**1.12%**	**3.12%**	211.75	32+30.02
306	33.87054825	-84.4575119	-1.76872	1.01112	**-3.09%**	**1.76%**	**3.76%**	213	32+44.17
307	33.87057495	-84.4574814	-2.399792	1.077	**-4.19%**	**1.88%**	**3.88%**	213.25	32+55.83
308	33.87059402	-84.457428	-2.7644	1.19084	**-4.82%**	**2.08%**	**4.08%**	213.75	32+72.66
309	33.87062073	-84.4574051	-2.59124	1.2232	**-4.52%**	**2.14%**	**4.14%**	213.75	32+85.16
310	33.87064743	-84.4573669	-2.25708	1.4586	**-3.94%**	**2.55%**	**4.55%**	213.75	33+01.48
311	33.87067413	-84.4573288	-2.09076	1.71008	**-3.65%**	**2.99%**	**4.99%**	214	33+15.64
312	33.87069702	-84.4572983	-1.69764	2.00676	**-2.96%**	**3.50%**	**5.50%**	214.5	33+29.86
313	33.87071991	-84.4572754	-1.25616	2.19264	**-2.19%**	**3.83%**	**5.83%**	214.75	33+39.34
314	33.87074661	-84.4572449	-1.163593	2.273259	**-2.03%**	**3.97%**	**5.97%**	214.75	33+55.66
315	33.87076569	-84.4572144	-1.216292	2.110333	**-2.12%**	**3.68%**	**5.68%**	214.75	33+67.32
316	33.87079239	-84.4571915	-0.90044	2.28556	**-1.57%**	**3.99%**	**5.99%**	214.75	33+76.8
317	33.87081146	-84.457161	-0.46388	2.65808	**-0.81%**	**4.64%**	**6.64%**	214.75	33+88.46
318	33.87083435	-84.4571457	-0.5314	2.4744	**-0.93%**	**4.32%**	**6.32%**	214.75	33+96.34
319	33.87085342	-84.4571152	-0.85092	2.32388	**-1.49%**	**4.06%**	**6.06%**	214.75	34+08.
320	33.8708725	-84.4570999	-0.770167	2.535917	**-1.34%**	**4.43%**	**6.43%**	215.5	34+17.48
321	33.87089157	-84.4570847	-0.235846	2.470654	**-0.41%**	**4.31%**	**6.31%**	215.75	34+26.95
322	33.87091064	-84.4570541	0.23864	2.3076	**0.42%**	**4.03%**	**6.03%**	215.75	34+38.61
323	33.87092972	-84.4570313	0.442808	2.555731	**0.77%**	**4.46%**	**6.46%**	215.75	34+48.09
324	33.87094498	-84.457016	0.534	2.641333	**0.93%**	**4.61%**	**6.61%**	215.75	34+52.83
325	33.87096405	-84.4569931	0.55192	2.8028	**0.96%**	**4.90%**	**6.90%**	215.5	34+64.49
326	33.87097931	-84.4569855	0.538417	2.979292	**0.94%**	**5.20%**	**7.20%**	215.25	34+71.76
327	33.87099075	-84.4569702	0.548368	2.924316	**0.96%**	**5.11%**	**7.11%**	215	34+78.84
	33.871300	**-84.456482**	**Segment 40 ending point**						

Table A-26: Run 2 on Segment 41 Analysis Spreadsheet

ID	Latitude (deg)	Longitude (deg)	Roll (deg)	Pitch (deg)	Cross Slope	Grade	+2% Grade	Altitude (m)	Stations
	33.865492	**-84.476693**	**Segment 41 starting point**						
571	33.86513519	-84.47669983	1.66167	-1.55525	**2.90%**	**-2.72%**	**-0.72%**	283	1+00.
572	33.86516953	-84.47668457	1.62636	-1.48108	**2.84%**	**-2.59%**	**-0.59%**	283.25	1+12.49
573	33.86520004	-84.47668457	1.58	-1.388542	**2.76%**	**-2.42%**	**-0.42%**	283.25	1+23.41
574	33.86523056	-84.47667694	1.59332	-1.44844	**2.78%**	**-2.53%**	**-0.53%**	283.25	1+34.33
575	33.86526108	-84.47666931	1.52396	-1.50172	**2.66%**	**-2.62%**	**-0.62%**	283.25	1+45.66
576	33.86529541	-84.47666931	1.41504	-1.5284	**2.47%**	**-2.67%**	**-0.67%**	283	1+60.21
577	33.86532974	-84.47665405	1.43696	-1.414542	**2.51%**	**-2.47%**	**-0.47%**	283	1+72.7
578	33.86536026	-84.47665405	1.82188	-1.14268	**3.18%**	**-1.99%**	**0.01%**	283	1+83.62
579	33.86539459	-84.47664642	2.38044	-0.52748	**4.15%**	**-0.92%**	**1.08%**	283.25	1+94.54
580	33.86542892	-84.47663879	2.59432	-0.32156	**4.53%**	**-0.56%**	**1.44%**	283	2+09.41
581	33.86545944	-84.47663116	2.48428	-0.21644	**4.33%**	**-0.38%**	**1.62%**	283	2+20.74
582	33.86549759	-84.47662354	2.35862	-0.267154	**4.12%**	**-0.47%**	**1.53%**	283	2+35.61
583	33.86553192	-84.47661591	2.33209	-0.100174	**4.07%**	**-0.17%**	**1.83%**	283.25	2+46.52
584	33.86556244	-84.47660828	2.5907	0.511815	**4.52%**	**0.89%**	**2.89%**	283.5	2+57.85
585	33.86560059	-84.47660065	2.76126	0.62287	**4.82%**	**1.09%**	**3.09%**	283.5	2+72.72
586	33.8656311	-84.47659302	2.90704	-0.03	**5.07%**	**-0.05%**	**1.95%**	283.75	2+84.05
587	33.86566925	-84.47658539	3.08113	-0.034167	**5.37%**	**-0.06%**	**1.94%**	284	2+98.61
588	33.86569977	-84.47657776	3.16008	1.226269	**5.51%**	**2.14%**	**4.14%**	284	3+09.94
589	33.8657341	-84.47657776	2.62707	0.528148	**4.58%**	**0.92%**	**2.92%**	284.5	3+20.86
590	33.86576843	-84.47657013	2.49033	-1.555625	**4.35%**	**-2.72%**	**-0.72%**	284.75	3+35.73
591	33.86580276	-84.4765625	2.69264	-1.64072	**4.70%**	**-2.86%**	**-0.86%**	285	3+47.06
592	33.86584091	-84.47654724	2.76044	-0.88816	**4.82%**	**-1.55%**	**0.45%**	285	3+61.93
593	33.86587524	-84.47653961	2.58431	-0.477923	**4.51%**	**-0.83%**	**1.17%**	285	3+76.8
594	33.86590576	-84.47653961	2.43348	-0.57124	**4.25%**	**-1.00%**	**1.00%**	285	3+87.71
595	33.86594391	-84.47653198	2.14052	-0.64584	**3.74%**	**-1.13%**	**0.87%**	285	3+99.04
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745	33.87125778	-84.47455597	2.2478	-3.47172	**3.92%**	**-6.07%**	**-4.07%**	263.25	25+09.86
746	33.87129593	-84.47455597	2.20828	-3.36604	**3.85%**	**-5.88%**	**-3.88%**	263.5	25+24.41
747	33.87134171	-84.47454834	1.98	-3.44772	**3.46%**	**-6.02%**	**-4.02%**	263.75	25+39.28
748	33.87137985	-84.47453308	2.26208	-3.7178	**3.95%**	**-6.50%**	**-4.50%**	263.75	25+55.05
749	33.87142181	-84.47453308	2.6434	-4.02236	**4.61%**	**-7.03%**	**-5.03%**	264	25+69.61
750	33.87146378	-84.47453308	2.33464	-4.21772	**4.07%**	**-7.37%**	**-5.37%**	263.75	25+84.16
751	33.87150574	-84.47453308	1.95776	-4.27992	**3.42%**	**-7.48%**	**-5.48%**	263.75	26+02.36
752	33.8715477	-84.47452545	2.28268	-4.38216	**3.98%**	**-7.66%**	**-5.66%**	263.75	26+16.91
753	33.87158966	-84.47452545	2.73176	-4.64672	**4.77%**	**-8.13%**	**-6.13%**	263.5	26+31.47
754	33.87162781	-84.47452545	2.69176	-4.69164	**4.70%**	**-8.21%**	**-6.21%**	263.25	26+46.03
755	33.87166977	-84.47452545	2.5182	-5.19864	**4.39%**	**-9.10%**	**-7.10%**	263	26+60.58
756	33.87170792	-84.47453308	2.43816	-5.39076	**4.25%**	**-9.44%**	**-7.44%**	262.75	26+75.14
757	33.87174988	-84.47453308	2.18412	-5.52364	**3.81%**	**-9.67%**	**-7.67%**	262.5	26+89.69
758	33.87178802	-84.47453308	1.83592	-5.47408	**3.20%**	**-9.58%**	**-7.58%**	262	27+04.25
759	33.87182617	-84.47453308	1.7515	-5.733708	**3.06%**	**-10.04%**	**-8.04%**	261.5	27+18.8
760	33.87186432	-84.47453308	2.06412	-6.12944	**3.60%**	**-10.74%**	**-8.74%**	261.25	27+29.72
761	33.87190247	-84.47453308	2.33788	-6.188	**4.08%**	**-10.84%**	**-8.84%**	261	27+44.28
762	33.87194061	-84.47453308	2.21241	-6.398889	**3.86%**	**-11.21%**	**-9.21%**	260.75	27+58.83
763	33.87198257	-84.47454834	2.01904	-6.752043	**3.52%**	**-11.84%**	**-9.84%**	260.25	27+74.6
764	33.87202072	-84.47454834	2.00115	-7.082778	**3.49%**	**-12.43%**	**-10.43%**	260	27+89.16
765	33.87205505	-84.47454834	2.00604	-7.073957	**3.50%**	**-12.41%**	**-10.41%**	259.75	28+03.71
766	33.8720932	-84.47454834	2.29752	-7.159222	**4.01%**	**-12.56%**	**-10.56%**	259.5	28+14.63
767	33.87213516	-84.47455597	3.04817	-7.211522	**5.32%**	**-12.65%**	**-10.65%**	259.25	28+33.08
768	33.87217331	-84.47455597	3.61685	-7.492037	**6.31%**	**-13.15%**	**-11.15%**	259	28+43.99
769	33.87220764	-84.47455597	3.68158	-7.283958	**6.42%**	**-12.78%**	**-10.78%**	258.75	28+58.55
770	33.8722496	-84.47455597	3.664	-7.225808	**6.39%**	**-12.68%**	**-10.68%**	258.5	28+73.11
771	33.87228775	-84.47455597	3.66958	-7.304417	**6.40%**	**-12.82%**	**-10.82%**	258.25	28+87.66
772	33.8723259	-84.47455597	3.51281	-7.273808	**6.13%**	**-12.76%**	**-10.76%**	257.75	29+02.22
	33.872305	**-84.474654**	**Segment 41 ending point**						

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