FINAL REPORT

DESIGN GUIDELINES FOR HIGHWAY RAILROAD GRADE CROSSING PROFILES IN FLORIDA

Contract No. BC 352-15

By

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16. Abstract

The goal of this research project can be generally described as the revision of the current Florida Department of Transportation (FDOT) manual on profile evaluation of grade crossings, including the development of computer tool(s) for evaluating existing profiles and use for design by professionals such as roadway designers, inspectors, and railroad flagmen. The seriousness of the problems posed by the potential hang-up of low ground clearance vehicles at highway-railroad grade crossings, and the need for research efforts, is supported by prior accident reports and reports on research efforts, in addition to the results of a questionnaire survey conducted among state agencies and railroad companies. The research team made considerable effort to utilize the laser profilometer in collecting 3-D profile elevation data. Modifying an existing ICC profilometer to enable collection of three-profile data, detailed profile data were collected at 28 grade crossings throughout central Florida. It was observed, after much analyses, involving a detailed comparison to the rod and staff leveling data, that the profilometer data would not yield a true ground elevation data, unless the profilometer is properly configured and the technology further studied to yield the desired results. Alternative methods to obtaining ground elevations, though not as low-cost productive, are suggested.

Some basic geometric design criteria for highway railroad grade crossings were presented, and a methodology was developed for evaluating highway railroad grade crossings, developing vertical crest and sag curves, to prevent hang-up of low clearance vehicles, based on the required approach tangents and the existing slope of the railway tracks plane. Recommendations on changes to existing FDOT design guidelines are presented, along with the development of a new comprehensive profile documentation form, to assist inspectors in performing field evaluations of grade crossings for the potential of hangup. A comprehensive computer software was written and compiled in Microsoft Visual Basic 6.0, to serve as design and rehabilitation aids, for evaluation of hang-up potential of low clearance vehicles at highway railroad grade crossings. Also available are Microsoft Excel Tools for performing simple hang-up evaluations. An overall review of hump crossings in Florida indicated that that many of the critical crossing, in terms of potential hang-up by low clearance vehicles, are located near roadway intersections or a roadway curve, and all these crossing indicate some rail maintenance resulting in asphalt buildup on the tracks. Finally, a simple demonstration was presented on the use of Geographic Information System (GIS) for network routing along roadways with grade crossings, using a suggested rating of hang-up potential, and also considering other roadway attributes such as the time and distance of travel.

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METRIC CONVERSIONS

$$\text{ft} \times 0.3048 = \text{m}$$

$$\text{ft}^2 \times 0.09290 = \text{m}^2$$

$$\text{yd}^2 \times 0.000008361 = \text{m}^2$$

$$\text{yd}^3 \times 0.7646 = \text{m}^3$$

DISCLAIMER

The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the Florida Department of Transportation (FDOT) or the U.S. Department of Transportation (USDOT), and Federal Highway Administration (FHWA).

The contents of this report are provided as findings of a research and not as design manuals for highway railroad grade crossings. The authors would not be liable for any crossings designed based on the findings in this report.

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EXECUTIVE SUMMARY

The problem posed by potential hang-up of low ground clearance vehicles at highway-railroad grade crossings was presented, including the justification for the Florida Department of Transportation, to sponsor a study to investigate the problem. Pertinent literature and records were discussed, including prior accident reports and research efforts. A questionnaire survey was conducted among state agencies and railroad companies, with the results indicating the seriousness of the problem and the need for research efforts to address the issues.

The research team made considerable effort to utilize the laser profilometer in collecting 3-D profile elevation data that would be useful for evaluating the potential of hang-up by low clearance vehicles as they traverse at-grade rail crossings. Modifying an existing ICC profilometer, to enable collection of three-profile data (along the traditional two wheel paths and additional center path of vehicle), detailed profile data were collected at 28 grade crossings throughout central Florida. It was observed, after much analyses, involving a detailed comparison to the rod and staff leveling data at a few crossings, that the profilometer data would not yield a true ground elevation data, unless the profilometer is properly configured and the technology further studied, to yield the desired results. Alternative methods to obtaining ground elevations, though not as low-cost productive as the profilometer, would include the following: the Rotary Laser Level; Laser Rangefinder; 3-D Scanner; Global Positioning Systems (GPS); As-Built Construction Drawings; Aerial surveys, GIS and Contour Maps; and 3-D Digital Photography.

Attempts were also made at vehicle classification, with emphasis on low ground clearance vehicles, for traffic surveys conducted at three sites in Florida. It was observed that at two rural locations in Florida, the traffic stream has between five and six percent of low clearance vehicles, while an urban location indicated almost 10 percent. Dimensions of low clearance vehicles were not obtained in this study primarily due to restrictions from doing this at the FDOTs weigh stations. It is assumed therefore that FDOT would adopt the documented work by the Eck et al. (2002) at West Virginia University, done for the West Virginia Department of Transportation, using vehicle dimensions to develop an FHWA's classification for clearance vehicles, as discussed in this report.

Some basic geometric design criteria for highway railroad grade crossings were presented, reviewing many existing design documents that are available, discussing the horizontal and vertical alignment requirements, as well as the cross sections, pullout lanes, traffic islands, roadside design, and crossing surface. Also discussed are specific guidelines relevant to the design and maintenance of high profile grade crossings. These criteria and guidelines form the basis of the methodology, developed in this research, for evaluating the potential of hang-up at a grade crossing, by a low ground clearance vehicle.

Based primarily on ramp breakover angle due to design low clearance vehicles, a methodology was developed for evaluating highway railroad grade crossings. Vertical crest and sag curves were developed, to prevent hangup of low clearance vehicles, based on the required approach

tangents and the existing slope of the railway tracks plane. Recommendations on changes to existing FDOT design guidelines are presented, along with illustrative geometric analyses of sample grade crossings in Florida, and some illustrative design aids in form of a table and a chart. Using the methodology developed, the FDOT's inspection form was modified into a new more comprehensive profile documentation form, to assist inspectors in performing field evaluations of grade crossings for the potential of hangup. A comprehensive computer software was written and compiled in Microsoft Visual Basic 6.0, to serve as design and rehabilitation aids, for evaluation of hang-up potential of low clearance vehicles at highway railroad grade crossings. Also available are Microsoft Excel Tools for performing simple hangup evaluations. An overall review of hump crossings in Florida is presented, in terms of the following attributes: nearness to roadway intersections; nearness to roadway cures; asphalt buildup on rail tracks; vertical sag location; number of tracks; and superelevation of the tracks. It was observed that many of the critical crossing, in terms of potential hangup by low clearance vehicles, are located near roadway intersections or a roadway curve, and all these crossing indicate some rail maintenance resulting in asphalt buildup on the tracks.

Finally, a simple demonstration was presented on the use of Geographic Information System (GIS) for network routing along roadways with grade crossings, using a suggested rating of hangup potential, and also considering other roadway attributes such as the time and distance of travel.

1. Research Background

Many roadway designers are becoming concerned by the inability of certain types of grade crossing profiles to safely accommodate some vehicles' geometric characteristics. The need for suitable design guidelines has motivated a research project, with the findings being presented in this report. This section of the report presents the current status of knowledge both in terms of research activities and industry practice in the design and maintenance of grade crossings, to address primarily, the issue of vehicle hang-up on the railroad tracks.

1.1 Introduction and Research Objectives

Florida Department of Transportation, herein referred to as FDOT or the Department, has experienced several collisions between trains and vehicles that were stuck on highway railroad grade crossings. These collisions resulted in high property, equipment, and user costs, as well as injuries to individuals and contamination to the environment. FDOT developed a manual in 1984 for the purpose of evaluating the roadway profiles and for profile design evaluation. The 1984 manual, "Field and Office Manual for Profile Surveys of Highway - Rail At-Grade Crossings on Existing Paved Roadways," [FDOT 1984] is limited in use for optimum profiles based on location of the rails as points of measure, and it does not include additional elements such as surface material outside of the rail that has contributed to vehicle hang-up. The goal of this research project can be generally described as the revision of the current FDOT manual, including the development of computer tool(s) for evaluating existing profiles and use for design by professionals such as roadway designers, inspectors, and railroad flagmen.

Designs of roadway facilities have in the past considered length, height, and weight of a typical design vehicle as identified by AASHTO roadway design policy. The rationale has been to accommodate varying vehicle types in vertical and horizontal alignment and also to ensure that the road infrastructure so designed is capable of handling the traffic loading imposed on them. Little attention has been paid to vehicles' ground–clearance as a design element. The reasons for this may differ from state to state but some of the possible causes could be that there have been few low clearance vehicles (LCV) in the traffic stream in recent past to warrant their consideration in design. Another reason could be that there may have been few reported incidences where low clearance vehicles, because of their ground clearance deficiency, have contributed to the accidents and thus raise issues of safety. The review of literature showed that limited research exists on this subject and therefore no substantial data exist on vehicle hang-ups on high-profile roads even though this is a growing problem. The problem of low clearance vehicles getting stuck on high–profile roadways like railroad grade crossings, bridges, and on roadway with high crowns has been reported across the US [NTSB 1987, 1997, 2002].

Low clearance vehicles include limousines, trucks with trailers, car carriers, and equipment trucks. These vehicles are increasingly using the roads and this development raises concern for road authorities and the motoring public who may be inconvenienced by a low–ground clearance vehicle getting stuck on the road and even causing a crash due to a deficiency in the ground clearance. With the increase in low–ground clearance vehicles in the traffic stream, the problem of low–clearance vehicles should receive considerable attention for most highway authorities. Road design should not only consider length, height, weight, sight distances, readability, and adequate drainage of a typical design vehicle in their design, but, should also incorporate ground clearance to provide for the low clearance vehicles. This becomes imperative especially for cities or areas that have a hilly topography. The ITE information report [ITE 2001] explains that the presence of vertical curvatures at grade crossings may potentially affect motorists in several ways including drivers concentrating on looking in the lateral position instead of watching for oncoming traffic in situations when they encounter elevated tracks with steep approach grades. The report explains that such distractions increase chances for collisions, as the drivers in such situations are unable to adequately watch for approaching trains at the grade crossing. Other safety problems at grade crossings include steep approach (down) grades in which drivers may have difficulties slowing down, as they require greater breaking efforts to safely come to a stop. The steep approach grades have the potential for increasing collisions especially on snow or ice covered crossing surfaces [ITE 2001].

There have been reports of accidents at rail–highway grade crossings in Florida, including the following cases: on Old Kings Road in Jacksonville, Florida on February 5, 1997[NTSB 1997], at Glendale California on January 28, 2000 [NTSB 2001], and at Intercession City, Florida on November 30, 1993 and also on November 17, 2000 [NTSB 2002]. On the Intercession City accident in 2000, National Transportation Safety Board (NTSB) determined that the probable cause of the collision, which involved Amtrak train 97, and a tractor-combination vehicle was the failure of the Kissimmee Utility Authority, its construction contractors and subcontractors, and the motor carrier to provide for the safe passage of the load over the grade crossing. The NTSB also concluded that had the Florida Department of Transportation included language on the permit explaining that low–clearance, slow–moving vehicles are required to notify the railroad before crossing, the accident might have been avoided. NTSB investigations revealed that circumstances under which the two accidents happened on this road were similar. NTSB advice to Kissimmee Utility Authority was that they needed notification on scheduled crossings of low–clearance, slow moving and wide loads to help them provide safe passage of these vehicles. The Department indicated that the language is provided as an addition to the permit but the private company providing the permit did not include the information.

In the Glendale accident, a tractor-combination vehicle, operated by Mercury Transportation, Inc. was transporting through four States, to an oil refinery unit. It was reported in NTBS [2001], that the vehicle missed a turn in its planned route, went over a highway-railroad grade crossing, tried to turn around, and then got stuck on the railroad tracks. Less than two minutes after getting stuck, a Metrolink commuter train collided with the vehicle. There were minor injuries to the train occupants, with the total accident damages estimated to be over $2 million.

In the Jacksonville accident, the National Railroad Passenger Corporation (Amtrak) train P098, the Silver Metro, while operating over CSX Transportation (CSXT) tracks, struck a tractor-semi trailer combination at Old Kings Road, which was stuck on the road. The locomotive and four leading cars were derailed. This accident happened when the truck driver attempted to turn his vehicle around near the grade crossing on Old Kings Road. The driver stated that in the process of turning around, the semi trailer hung on the crossing, and the drive wheels left the pavement and lost traction. Damages arising from this accident were estimated at over $1.4 million.

a. View Along Roadway

b. View Along Rail Tracks

Figure 1.1 Photographs Of Highway-Railroad Grade Crossing For The Intercession City Accident In 2000 [Source: NTSB 2002]

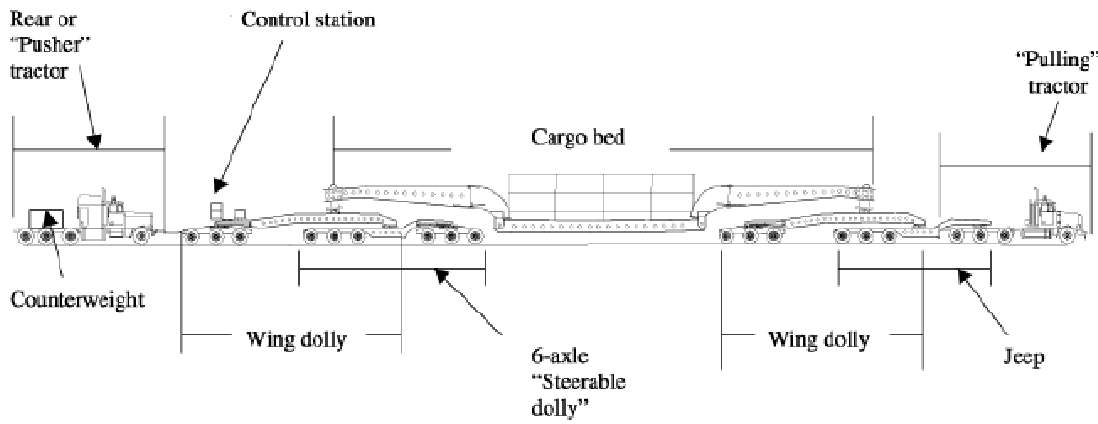

Figure 1.2 Diagram Of Accident Vehicle In The Intercession City Accident In 2000 [Source: NTSB 2002]

It is possible that many of the highway-railroad grade crossing accidents that have occurred but are unnoticed by FDOT due to little or no data being kept on such incidences. The poor data management arises because the operation of highway-railway grade crossings is within the railroad company authority and not FDOT. This therefore makes it difficult to check on the operation and safety of the railroad grade crossing. Accidents that have occurred at highway railroad–grade crossing have made some states to develop guidelines and or warning signs on high profile roads. The Florida Department of Transportation has done significant work in making driving on high–profile roads safer. A program that has been undertaken has included a survey to encourage coordination between government and the rail industry in construction and maintenance of grade crossings. The survey also looked at measures to identify grade crossings that are unsafe and cannot accommodate low–ground clearance vehicles.

Low clearance vehicles do have other operational problems other than hang–ups and crashes. Although there is limited literature existing to suggest that delays happen due to hang-ups of low–ground clearance vehicles, it is reasonable to state that vehicles queuing behind a low clearance vehicle stuck on the grade crossing may be a real problem. Over the years, accidents related to low clearance vehicles have occurred in Florida and several other states across the US, raising concern with FDOT and thus the need for a study to determine the extent of the problem.

To address this problem, FDOT is sponsored this research, to ascertain the magnitude of the problem of hang–up of low clearance vehicles on highway-railroad grade crossings and develop design guidelines, with the following primary objectives: (i) Revise the existing Department's manual "Field and Office Manual for Profile Surveys of Highway-Rail At-Grade Crossings on Existing Paved Roadways"; (ii) Develop a simple computer tool(s) for roadway designers, inspectors, railroad flagmen, etc., to evaluate existing highway railroad grade crossings for potential hang-up problems, i.e. model the profile of sample grade crossings and develop procedure(s) and tool(s) that can be used to check whether a given class of vehicle can safely traverse a high–profile grade crossing; and

(iii) Develop a simple computer tool(s) for the Department's Permitting Office to evaluate oversized and over-length vehicles in relation to proposed routes.

1.2. Literature Review

High profile crossings as described by the ITE [2001]'s information report, are those crossings at which there is an unusually abrupt change in the level of the road surface as it crosses the tracks. High profiles may exist as a result of poor design practice, or, as a result of track maintenance practices that raises the grade crossing elevation. In certain cases lack of maintenance can cause the track to deteriorate, developing a hump. A review of literature shows that there is limited research work that exists on low clearance vehicles and their operation on high profile roads. In cases where the problems of low–ground clearance have been recognized, data on the accidents or incidences were these low clearance vehicles have been involved, was collected. A few publications that have been done on this subject include Eck [1997], Eck and Kang [1991,1992], McConnell W.A [1958], and Bauer L.A [1958]. Other reports include the US Department of Transportation study done by a Grade Crossing Task Force [USDOT 1996], the Institute of Transportation Engineers (ITE) Report [ITE 2001], and various accident reports written by the National Transportation Safety Board (NTSB), involving low clearance vehicles stuck on highway-railroad grade crossings [NTSB 1984, 1997, 2001 and 2002].

Eck et al. [1991] and Eck [1997] gave an overview of the problems of hang-ups associated with low ground clearance vehicles on highway railroad grade crossings. The authors in their literature search found that little research work exists on hang–ups. Eck et al. [1991] explains that early work that was done on the subject of hang–ups have included McConnell [1958] and Bauer [1958]. Early work on this subject has also included the American Railway Engineering Association's Manual for Railway Engineering, and geometric design guidelines from the American Association of Highways and Transportation Officials (AASHTO).

The AASHTO design policy [2001] states that:

> *To prevent drivers of low-clearance vehicles from becoming caught on the tracks, the crossing surface should be at the same plane as the top of the rails for a distance of 0.6 m [2ft] outside the rails. The surface of the highway should also not be more than 75 mm [3 inches] higher or lower than the top of the nearest rail at a point 9 m [30 ft] from the rail unless track superelevation makes a different level appropriate.*

The above practice was incorporated in the 2001 policy to review the previous guidelines that recommended a maximum surface elevation of 3 inches higher or 3 inches lower than the top of the nearest rail. The use of uniform 3 inches according to current research appears to mitigate most problems related to high profile roads. Many states have adopted the AASHTO recommended practice with little or no modifications.

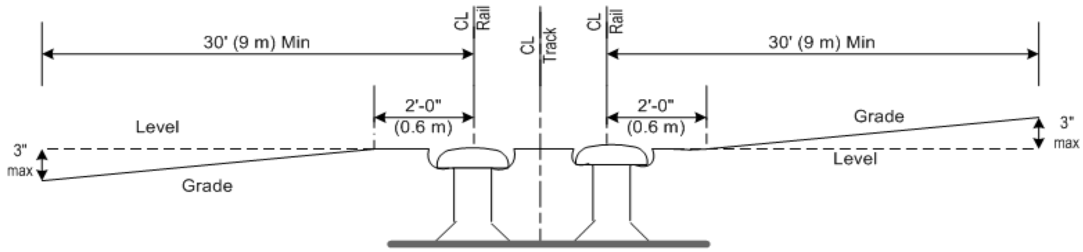

Figure 1.3. Grade Crossing Maximum Approach Grades [Source: AASHTO 2001]

Eck and Kang [1992] in their work also developed software called HANGUP. HANGUP was developed with appropriate graphics and animation for checking whether a given class of vehicles can safely negotiate a particular highway-railroad grade crossing profile. Various categories of low clearance vehicles were identified in this research, including low–boy equipment trailers, car carriers, double drop van trailers, and cars/trucks with trailers. Results obtained from running this program included specific crossings and alignments. Design criteria profiles were explained for the classes of vehicles likely to encounter problems at given grade crossings. Table 1.1 shows some of the results from the computer run from this study, indicating that vehicles with long wheelbases require high ground clearance in order to avoid hang–ups.

The results shown in this table are site specific. The results may differ if used for another location. Eck and Kang [1991] explained that this model while providing a useful guide in redesign of a road profile could still be improved to suit its use in all highway scenarios. The authors explained that HANGUP is currently a two-dimensional tool and pointed out that it can be more versatile if improved to three-dimensional. In concluding this study, some of the cardinal points raised by the authors include: (i) the need for consideration of low clearance vehicles in highway operations including the permitting for oversized vehicles; and (ii) the development of specific design criteria for highway vertical alignment at highway- railroad grade crossings.

Eck and Kang [1992] studied and compared HANGUP with various available road design standards. The authors presented results on some existing standards –AASHTO design standards, the American Railway Engineering Association (AREA) method, and the ITE design standards. The overhang dragging problems that vehicles experience on sag curves was also studied. The results of this study showed that the AREA method was found to accommodate most low clearance vehicles. The results that are obtained in a format similar to Table 1.1 show that a 24 ft wheelbase vehicle will not hang up until the ground clearance drops below 8 inches.

Table 1.1: Automatic–Mode Output Of HANGUP For Redesign Of Example Crossing In Huntington, West VA [Extracted from Eck et al. (1991)]

Wheel Base (ft)	Ground Clearance (in)									
	1	2	3	4	5	6	7	8	9	10
10	1	1	1	0	0	0	0	0	0	0
11	1	1	1	0	0	0	0	0	0	0
12	1	1	1	0	0	0	0	0	0	0
13	1	1	1	1	0	0	0	0	0	0
14	1	1	1	1	0	0	0	0	0	0
15	1	1	1	1	0	0	0	0	0	0
16	1	1	1	1	1	0	0	0	0	0
17	1	1	1	1	1	0	0	0	0	0
18	1	1	1	1	1	0	0	0	0	0
19	1	1	1	1	1	1	0	0	0	0
20	1	1	1	1	1	1	0	0	0	0
21	1	1	1	1	1	1	0	0	0	0
22	1	1	1	1	1	1	1	0	0	0
23	1	1	1	1	1	1	1	0	0	0
24	1	1	1	1	1	1	1	0	0	0
25	1	1	1	1	1	1	1	1	0	0
26	1	1	1	1	1	1	1	1	0	0
27	1	1	1	1	1	1	1	1	0	0
28	1	1	1	1	1	1	1	1	1	0
29	1	1	1	1	1	1	1	1	1	0
30	1	1	1	1	1	1	1	1	1	1
31	1	1	1	1	1	1	1	1	1	1
32	1	1	1	1	1	1	1	1	1	1
33	1	1	1	1	1	1	1	1	1	1
34	1	1	1	1	1	1	1	1	1	1
35	1	1	1	1	1	1	1	1	1	1
36	1	1	1	1	1	1	1	1	1	1
37	1	1	1	1	1	1	1	1	1	1
38	1	1	1	1	1	1	1	1	1	1
39	1	1	1	1	1	1	1	1	1	1
40	1	1	1	1	1	1	1	1	1	1

1→ Hang up 0 → Safe

It was recommended that HANGUP be used in low–ground clearance design. The general design standards formulated to accommodate low clearance vehicles on vertical alignment provide (in the form of tables and figures) recommended profiles for cross–sections at intersections and vertical alignment of driveways. Listed below are some of the authors' design considerations and conclusions:

a. To eliminate hang–up incidents at high–profile roadways, the rate of change of grade on crest vertical curves should be constant (i.e., a parabolic curve).
b. All interstates and primary highways should accommodate the design low-ground clearance vehicle.
c. All secondary highways and local roads that can not meet the design standard should provide an advance warning sign advising of the potential clearance problem.
d. A detour route or turning space on a relatively level area, which does not interrupt through traffic, must also be provided for low–ground clearance vehicles in advance of the crossing.

e. Weigh stations should measure wheelbases and ground clearance under static conditions for vehicles whose ability to negotiate high–profile roadways appear questionable.
f. On existing roadway profiles, surface maintenance is very important. Pavement patches or pavement defects can lead to hang–ups for certain low–ground clearance vehicles.
g. Grade changes of more than 2.3 percent on each side of the crossing leave the potential for low–clearance vehicles to become stuck.
h. If two roadways intersect, grade difference at the intersection should be less than or equal to 4.6 percent, which is the maximum slope rate for the standard low–clearance vehicle.

McConnell [1958] looked at the trends in car specific dimensions of interest relative to under clearance, including, wheelbase, angle of approach and departure, minimum ground clearance and the break over angle (Figure 1.4). He looked at these dimensions and how they changed for a ten-year period (1948–1958). This study considered both domestic and foreign cars. McConnell conclusions from this study were that the overhang on short wheelbase vehicles was critical to the vehicles performance on a sag or hump. He explained that a sag vertical curve radius, which is less than 90 feet, would pose problems for short passenger cars to traverse; for a long car, the radius of 80 ft will be troublesome. McConnell recommends no more than 6.5 percent change in slope between any two successful 5 ft chords. The minimum standards recommended for use in design of driveway profiles are:

a. Sag vertical curve–75 ft minimum radius
b. Crest vertical curve–45 ft radius.

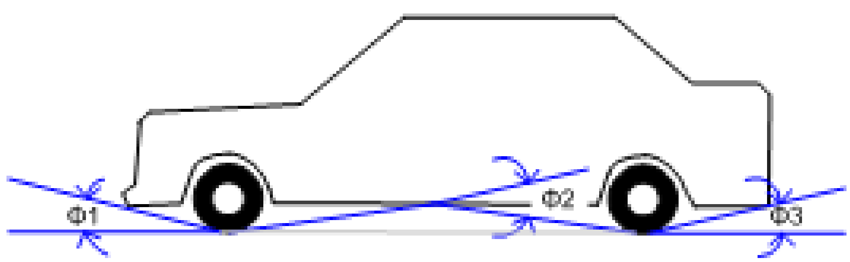

Figure 1.4: Angle of Approach (Φ1), Angle of Departure (Φ3), and Ramp Break over Angle (Φ2) [Source: McConnell 1958]

Bauer [1958] also studied the dimensions of under clearance, wheelbase, overhang and the overall length of a particular car, which he modeled. Bauer focused on connections of driveways in suburban areas, where a connection involves ascending or descending profiles into and out of properties. The author used a manual procedure where he cut a model car using a piece of cardboard, which had the same scale as the road profile to determine trouble spots. From this study, he recommends some profiles as shown in Figure 1.5, indicating that when the driveway ascends steeply from the back of the walk into the owner's property, the ascent for the first 5 ft back of the walk should not be more than 10 in., or at the rate of 16 percent, or otherwise the car will tilt too much before it crosses the walk and the bumper will strike the "ribbon walk" at the break in grade. For the descending slope, the descent should not be more than 2.5 in., or 4 percent, in the first 5 ft from the back edge of walk and not more than 9 in., or 15 percent, in the next 5 ft. .

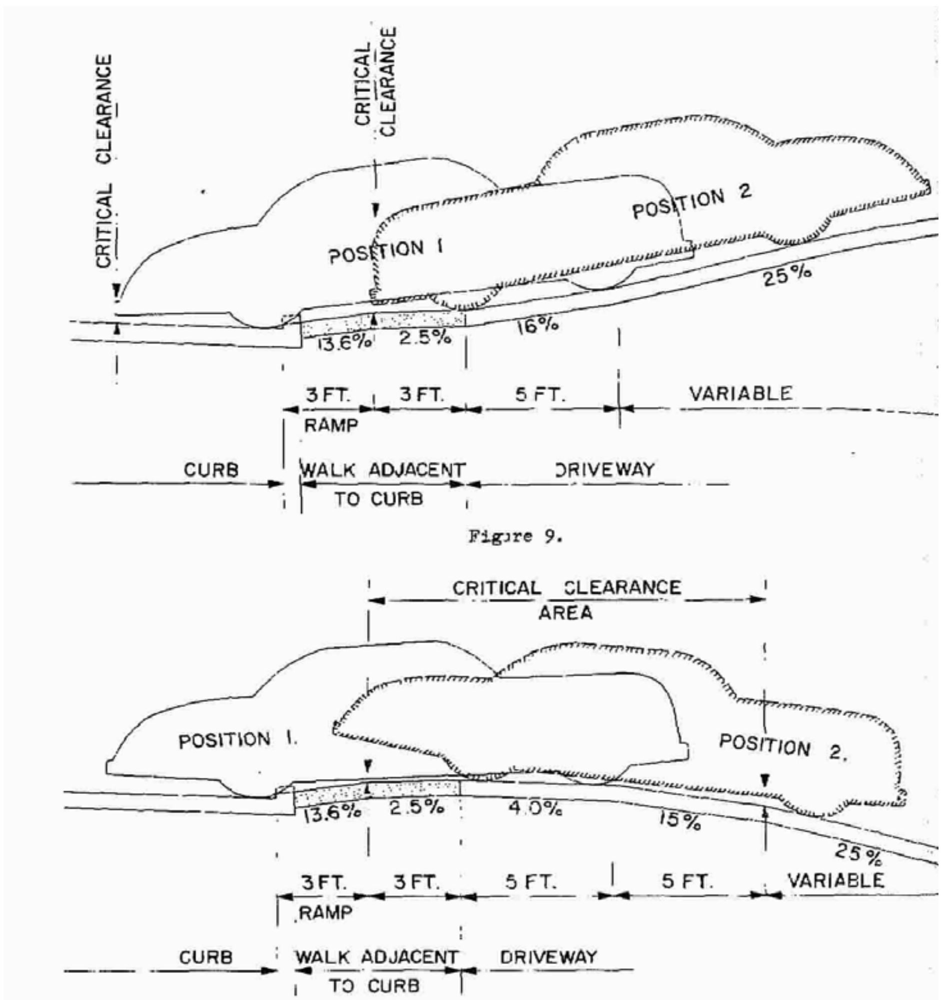

Figure 1.5. Profiles Proposed For Ascending And Descending Slopes [Source: Bauer 1958]

The maximum permissible descent recommended is 1 ft in the first 10 ft and maximum permissible grade on both profile changes is 25 percent. This study also proposed the provision of 2 inches margin of safety to the underclearance to accommodate the downward thrust that cars experience when applying brakes and also when traversing the varying roadway profile

The US Department of Transportation report [USDOT 2001] explains that the problems related to hang up are not only associated with design but may also be broken down into to four categories: vehicles, crossing design, crossing maintenance, and grade crossing problems. Low–ground clearance vehicles have a higher risk of being stuck on the railroad grade crossing and the ground clearance specifications are not standardized except for vehicles like tank trucks, piggyback trailers, etc. Vehicle manufacturers do not have minimum specified ground clearance but build vehicles as specified by shippers and operators.

Vertical alignment is equally a very difficult issue to manage because of the complexities that are involved especially during construction. Even when designs account for the low ground clearance, the actual construction of the road profile may prove difficult when the field construction crewmembers want to adopt convenient and or economical practices, instead of establishing the specified curvature, the consideration of two design standards for railroad crossing (i.e., for railway engineering and roadway engineering) also make the construction and maintenance process difficult. The American Railway Engineering Association (AREA) in the Manual provides the guidelines for construction of railroads for Railway Engineering. Road construction guidelines are provided by AASHTO design policy.

Highway-railroad grade crossings may not receive periodic maintenance on some roadways that are under the jurisdiction of the cities and counties. The grade crossing requires adequate maintenance to maintain the original grade but because of the problems of inadequate resources and lack of coordination between the railway authorities and road authorities, this is not always achievable. Another setback in the proper maintenance of the grade crossing occurs when the tracks are raised by the railroad agencies; typically the state standards expected for the adjoining roadway standards are not enforced.

Advance warning about low ground clearance and the eventual detouring of motorists that have low–ground clearance vehicles, and therefore cannot cross the grade crossing has been applied inconsistently. In Florida however, the state intends on measuring all suspect crossing profiles and have signs placed on those that are problematic for low–ground clearance vehicles. A standard advanced warning sign has already been developed. Work still needs to be done on educating the motorists on the specifics of this sign. The use of the sign certainly can be subjective given that no standards on ground clearance for manufacturing of vehicles exist. It may also be true that most drivers of the low–ground clearance vehicles may not even pay attention to their vehicles ground clearance. Most drivers may not be willing to change routes even where situations dictate so. The motorists have few resources to enable them to comfortably make a choice on which route to take when they encounter a deviation. State road authorities may also need to improve or acquire navigation systems that will assist motorists on alternative routing.

A study in Kansas was recently reported by Mutabazi and Russell [2003], with the objective of developing an effective process for identifying and ranking crossings where there may be a problem with the approach grade profiles. The identification included some physical characteristics of the highway railroad crossing, and a profile of the centerline and edge of roadway of the approaches. Without any emphasis on countermeasures, the research team evaluated the HANGUP software, conducted a questionnaire survey among Kansas counties and states in the country, developed a physical model, and created a protocol for identification of hump crossings with hang-up potentials.

The results of the 79 survey respondents among Kansas's counties are as follows:

- Few counties (13%) have experienced hang-up problems within the last two years, with 48 such incidents.
- Mitigation measures taken for hang-up problems included: closing the road (5%); restraining certain vehicles (5%); installing warning signs (17%); reconstructing roadway approaches (36%); doing nothing (47%); and others (14%) using methods including informing the railroad companies.
- Many (83%) reported their dissatisfaction with railroad companies in solving the hang-up problem.

The survey among the states also revealed some useful results (34 states responding), with the responses indicating the following:

- Most states rate the hang-up problem as not very serious; only one state rate the problem as very serious with 52% ranking it as "almost no problem."
- Hump crossings are usually identified after hang-up incidents; Minnesota has approach grades recorded in their databases; Virginia uses a template to measure crossings; Michigan observes scrape marks on pavement.
- Mitigation measures taken to treat hump crossings include primarily reconstruction of roadway approaches (26 states).
- No scientific method was identified for identifying vehicles with hang-up potential at hump crossings.
- Many states (17) indicated consideration of hump crossings in their highway design manual, with most adopting the AREA/AASHTO guidelines as it is, or with some modifications.

The Kansas research team also developed a physical model, shown below, to simulate a low vehicle's move across a hump crossing, with the hang-up locations recorded during the transition.

Figure 1.6. End View of Kansas Study's Physical Model for Measuring Hang-up [Mutabazi and Russell 2003]

Figure 1.7. Measurement with the Kansas Study's Physical Model [Mutabazi and Russell 2003]

The US Department of Transportation Grade Crossing Safety Task Force [USDOT 2001] recommended that an investigation on the feasibility of developing a nationwide classification system be done to allow for assigning compatibility codes of crossings and vehicles for the purpose of helping low-clearance vehicle operators to avoid getting hung-up on high profile crossings. This will be necessary to avoid adhoc-crossing practices that may be unsafe. In this FDOT research, our discussions with the car carrier manufacturers revealed that most car carrier' operators have the vehicle underclearance ranging between 6 to 10 inches. The maximum allowable clearance that Boydstun Metal Works of Portland, Oregon for instance provides on their car carriers is 10 inches. The car carrier' operators can adjust the underclearance to suit the terrain of their route which is sometimes restricted by underpass clearances that exist. In this research, design guidelines will be provided, including the findings and recommendations, which though common to Florida, will provide a valuable source of information for other states and the nation.

In developing the methodology of this research, some of the relevant literature and studies will once again be discussed, in Chapter 4 of this report. To establish the extent of the problem of potential hang-up by low clearance vehicles on highway-railroad grade crossings, a questionnaire survey was conducted nationally. The process and results are presented in the following section.

1.3. Questionnaire Survey Results

Targeting government agencies and railroad companies, a total of 79 questionnaires were sent out to all of the states in the country. The research team contacted the people both in the roadway design and the railroad offices of state agencies, as they may have diverse views on the problem. Given that the construction and maintenance of the highway-railroad grade crossings involve two different organizations, i.e., the roadway agency and the railroad company, a total of 64 questionnaires were mailed to state transportation departments while 15 were sent to railroad companies. Out of the 79 questionnaires mailed out, 36 have responded to date, with 31 responses being useful for analyses; five responses were left either completely or mostly blank, with comments implying that the problem is not of concern to their agency. Of the 31 useful responses, 20 are responses from the state transportation departments and 11 are from railroad companies. This represents about 31% and 73% response rates for the states and railroad companies respectively. A sample questionnaire is shown in Appendix A as well as the list of responding agencies. The results, as shown in Tables 1.2 and 1.3, and also graphically in Figures 1.8 to 1.11, can be summarized as follows:

- About 55% of all respondents consider the ***problem of vehicle hang-up*** on highway-railroad grade crossing a major operational safety issue, with 60% and 45% of state and railroad companies, respectively, indicating this in the survey responses.
- Many of the agencies have not ***conducted any study*** related to the issue. Only about 23% of the agencies on the overall, comprising eight state agencies and one Railroad Company, indicated that they have either done, or plan to do such study in the future.

- The survey results also indicated that other than the AASHTO design policy in some cases, there is a ***lack of formal guidelines***, specifically addressing low under vehicle clearance issue, during design, construction and maintenance of highway railroad grade crossings. Of the 31 total responses, only one state agency and three railroad companies reported having such a policy, implying that about 87% of all agencies do not have such formal guidelines.
- Only two state agencies reported ***having any software*** (HANGUP) for design and/or evaluation of highway railroad grade crossing profiles.
- On the ***maintenance of grade crossings***, only six respondents (three states and three railroad companies), i.e., about 20% of all responses, stated that they have a regular program to establish a desirable roadway profile at highway railroad grade crossings during such maintenance.
- In suggesting ***the causes of hang-up*** of low ground clearance vehicles at grade crossing, both states and railroad companies equally blames roadway design, and construction methods. The suggestion of maintenance as a cause, including the raising of the railroad crossing either during maintenance or reconstruction, however, was biased, with the states citing this as a cause while only one railroad company did. Materials and track design were cited least, as a cause for hang-up of low ground clearance vehicles at grade crossings. One railroad company indicated lack of attention or carelessness by drivers of those vehicles regarding the existing geometric limitations of the grade crossing. It is interesting to note that from the responses received, over one-third (about 38%) cites road design as a major cause of hang-ups, while about another 35% blames maintenance issues.

Table 1.2. Summary of Survey Among State DOTs and Railroad Companies

Survey Question		Count of Overall Responses (31 Total)		% of Overall Responses (%)		Count of States' Responses Only (20 Total)		% of Responses from States Only		Count of Railroad Companies Responses Only (11 Total)		% of Responses from Railroad Companies Only	
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
1.	Does your agency consider the problem of low under vehicle clearance a major concern in the operational safety of vehicles on highway railroad grade crossings?	17	14	54.8	45.2	12	8	60.0	40.0	5	6	45.5	54.5
2.	Have you conducted any study in the past, have an ongoing study, or immediate future plan to conduct a study, on the problem of low under vehicle clearance at highway railroad grade crossings?	7	24	22.6	77.4	6	14	30.0	70.0	1	10	9.1	90.9
3.	Do you have any guidelines for design, construction and maintenance of highway railroad grade crossings (specifically addressing low under vehicle clearance issues) in your agency, other than the guidelines in the AASHTO design policy?	4	27	12.9	87.1	1	19	5.0	95.0	3	8	27.3	72.7
4.	Do you have a software program that is used for design and/or evaluation of highway railroad grade crossing profiles?	2	29	6.5	93.5	2	18	10.0	90.0	0	11	0.0	100.0
5.	What would you consider as major causes of hang-ups at highway railroad grade crossings due to low under vehicle clearance? Please select all that apply.	Please see the responses in Table 1.2.											
6.	Does your agency have a regular maintenance program to establish a desirable roadway profile at highway railroad grade crossings?	6	25	19.4	80.6	3	17	15.0	85.0	3	8	27.3	72.7

COMMENTS:

Question No. 3: States which have undertaken studies or plan to do in the future, include Ohio, North Carolina, South Carolina, Kansas, Texas, Connecticut, Virginia, and New York.
Question No. 3: Guidelines sent from North Carolina DOT. Railroad Companies were citing the RR design Manual.
Question No. 4: Software available with Kansas & Virginia DOTs (HANGUP).

Table 1.3. Responses On Major Causes Of Hang-ups At Highway Railroad Grade Crossings

Cause of Hang-up (Count of Responses)*	Count of Overall Responses				Percentage of Responses Within Cause Category (Road Design, Materials,..)		Percentage of Responses Within Group (States/Rail Companies)	
	States	Railroad Companies	Total	Percent ages	States	Railroad Companies	States	Railroad Companies
Road Design (18)	9	9	18	37.5	50.0	50.0	26.5	64.3
Materials (1)	1	0	1	2.1	100.0	0.0	2.9	0.0
Construction (7)	4	3	7	14.6	57.1	42.9	11.8	21.4
Maintenance (12)	11	1	12	25.0	91.7	8.3	32.4	7.1
RR Raise at Maintenance (5)	5	0	5	10.4	100.0	0.0	14.7	0.0
Vehicle Design and Driver's Inattention (4)	3	1	4	8.3	75.0	25.0	8.8	7.1
Track Design (1)	1	0	1	2.1	100.0	0.0	2.9	0.0
Total	34	14	48	100.0	NA	NA	100	100

**Multiple answers allowed from each respondent.*

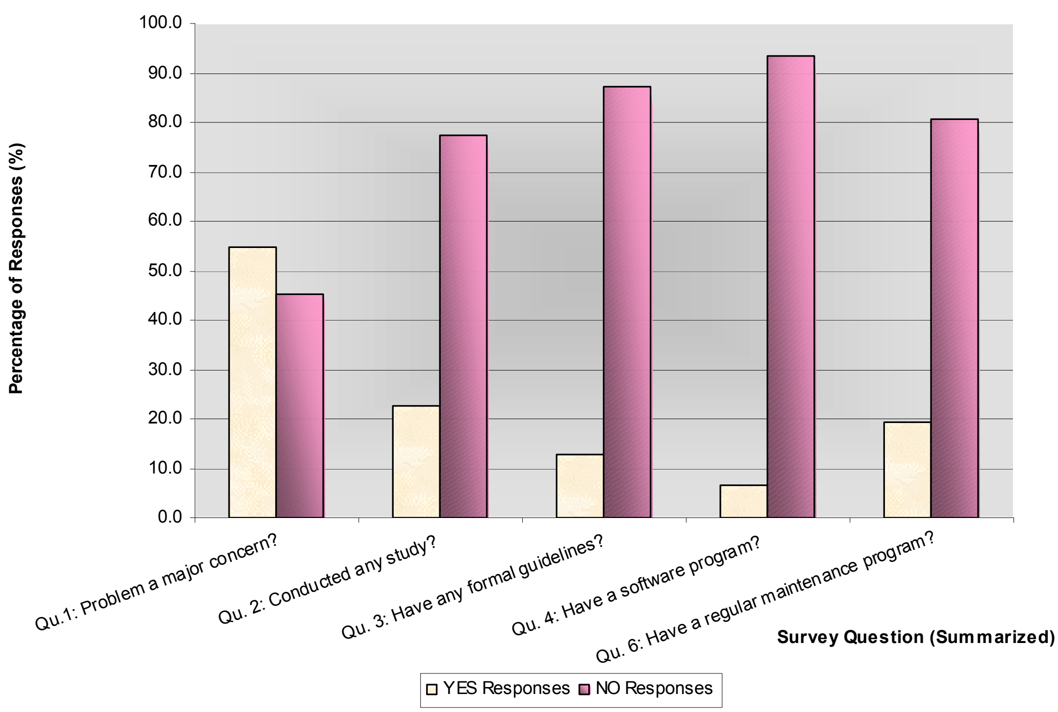

Figure 1.8. Overall Responses To Each Question

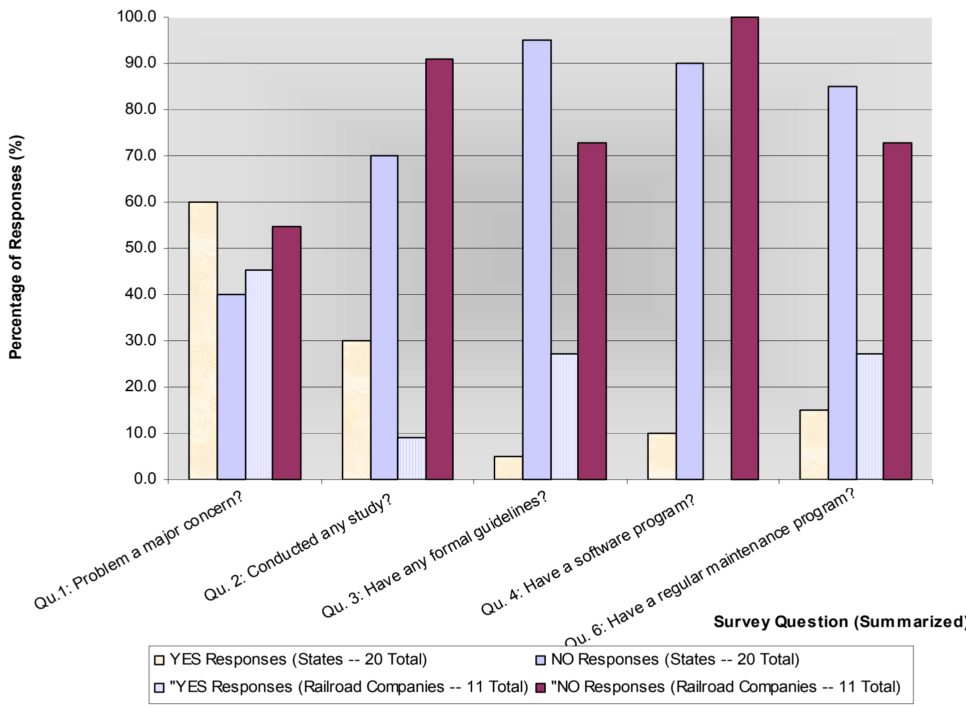

Figure 1.9. State Vs. Railroad Companies' Responses Within Each Survey Question

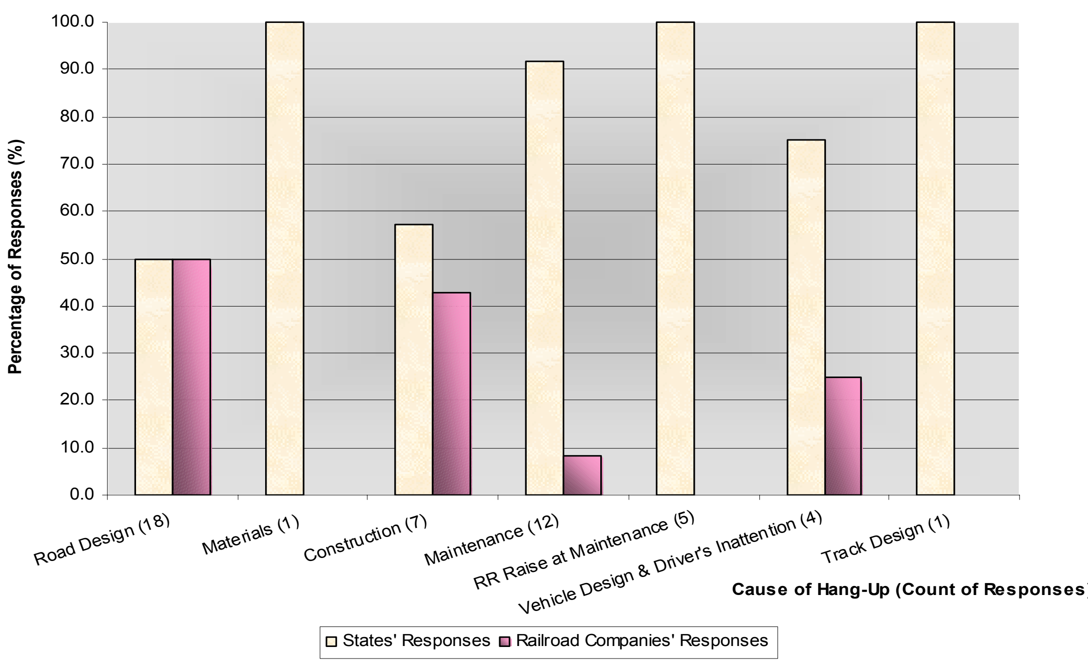

Figure 1.10. State Vs. Railroad Companies' Responses Within Each Suggested Cause of Hang-Up

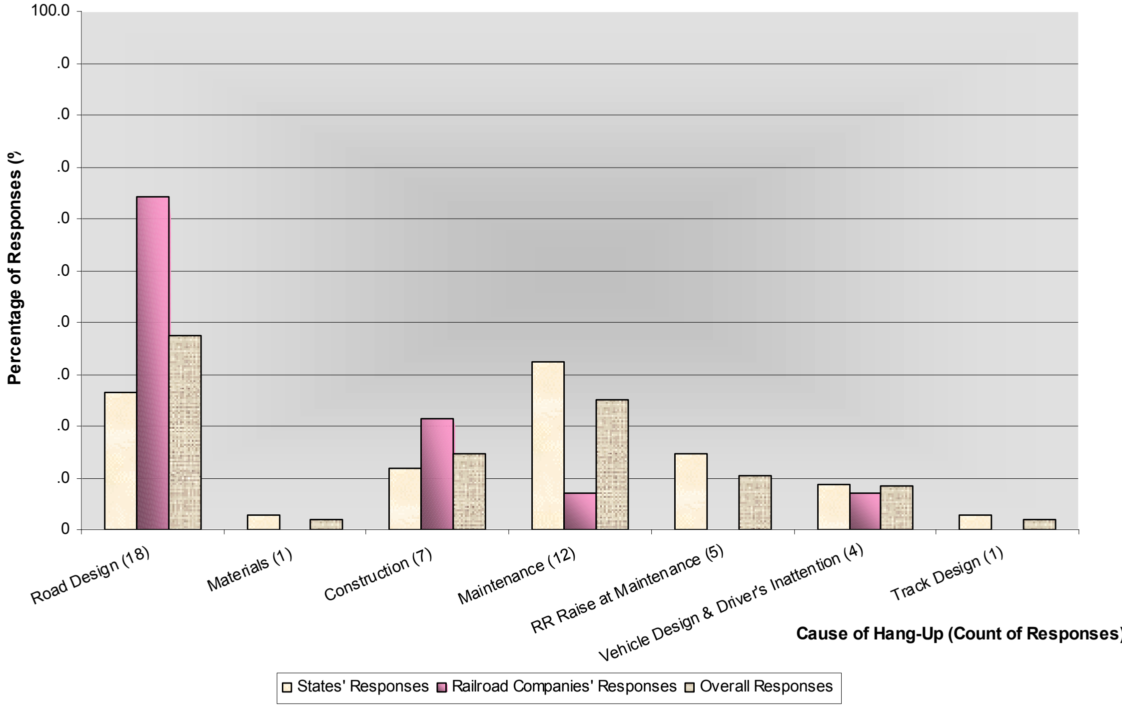

Figure 1.11. Variation in Responses Within Each Group of Responders (State/Railroad Companies) on Suggested Cause of Hang-Up

1.4. Summary

The problem posed by potential hang-up of low ground clearance vehicles at highway-railroad grade crossings, has been presented in this section of the report, including the justification for the Florida Department of Transportation, to sponsor a study to investigate the problem. Pertinent literature and records were discussed, including prior accident reports and research efforts. A questionnaire survey was conducted among state agencies and railroad companies, with the results indicating the seriousness of the problem and the need for research efforts to address the issues.

2. Data Collection

In order to evaluate the vehicle-related factors contributing to vehicle hang up on highway railroad grade crossings, it was necessary to survey common vehicles on Florida roadways and also estimate the proportion of the general traffic that are low clearance vehicles. In addition, existing profiles (elevations) of highway-railroad grade crossings need to be reviewed. This section presents the efforts and results of the data collection effort on traffic classification and grade profile data.

2.1 Reviews And Analyses Of Grade Crossings Profiles

Several grade crossing sites within the research team's local area (Tallahassee, Florida) were first visited to study the extent of the potential problem of hang-up by low clearance vehicles. The sites visited include railroad crossings on Railroad Avenue, Adams Street, Gadsden Street, Sterns Street, and Tower Road. The sites visited reveal the need for classifying the vehicles during the analysis for hang-ups. The condition of the crossings after the crossing had been maintained or rehabilitated by the railroad company was examined for areas, where there appears to be uneven or a rough ride resulting from such work.

Obtaining the existing ground profiles (elevations) at railroad grade crossings is a very important prerequisite for hang-up analysis of low-clearance vehicles. Depending on the type of low clearance vehicle and the crossing the vehicle is traversing, it would be beneficial to check for possible hang-up, using at least three profiles along the vehicle-driving lane. These profiles include the left and right wheel paths, and on the pavement surface along the middle section of the vehicle.

Figure 2.1. Railroad Avenue Grade Crossing showing a Bus Traversing the Tracks

Figure 2.2. Tower Road Grade Crossing

2.1.1 Laser-Based Profilometer Data

The first approach taken under this study was the use of an Inertial Profilometer or Profilograph. This method of measurement was selected based on its low cost production capabilities. The Department's State Materials Office, working with modifications provided by International Cybernetics Corporation (ICC), utilized a High Speed Laser Profilograph that simulates the California Profilograph. Modifications done to the profiler, included replacement of the two existing accelerometers on each side of the equipment platform to withstand the higher "G" forces encountered at highway railroad grade crossings, and the installation of a middle sensor and a high "G" force accelerometer to collect data along a third longitudinal path. The ICC's profiler is designed to evaluate the surface smoothness of pavement, by using an infrared laser and precision accelerometer to obtain profile measurement at speeds up to 65 mph. This was used to obtain profile measurements of 28 selected highway railroad grade crossings in the central Florida area. The output data for each site was converted from an ASCII text format to a Microsoft Excel format before analysis. Based on the data submitted to the research team by the State Materials Office, two-dimensional plots were developed for each site, with 3-D plots demonstrated for one site. Sample results are presented in Figures 2.4 through 2.7.

The traditional (rod and staff) survey leveling was also done at a selected crossing site in Madison, Florida, to verify the data collected by the profilometer at the same site earlier. For this specific site, the profile obtained using the ICC profiler was observed to be completely different from the true ground profile, obtained from the leveling. Further investigation into the data collection process and analysis done by the ICC profilometers, and also making inquiries at ICC, revealed that that ICC profiles are not expected to be same as the true ground profile (please see Figure 2.3). This is primarily because many of the raw data points have been “filtered” out, including the true slope or grade of the road as it is being collected by the profiler. The next effort than was to obtain the raw data as it is collected by the ICC Profiler, before any “filtering.”

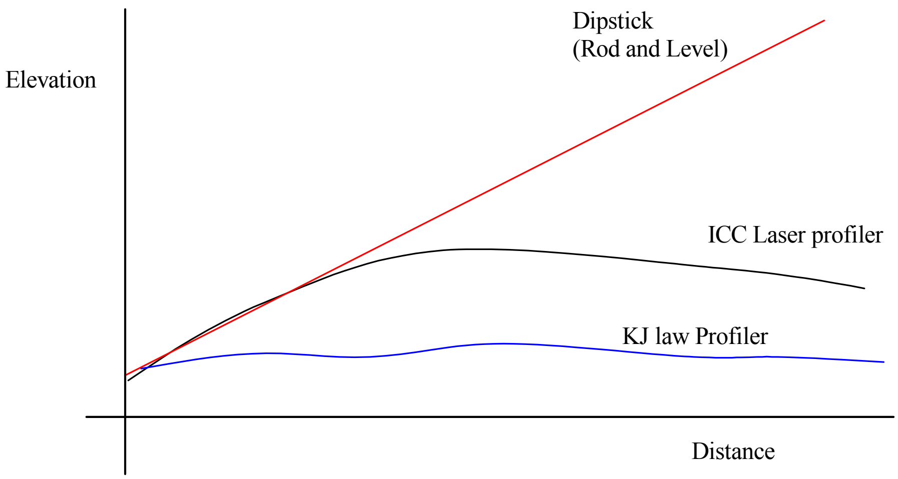

Figure 2.3. Three Profiles Measured With Different Devices [Source: Sayers and Karamihas 1998]

This issue was closely reviewed, to see how the “filter” could be removed, and also if other site data were collected in the raw format. Also, as discussed later in this chapter of the report, there are other suitable methods for collecting profile data at grade crossings, including using a laser-based one-man crew leveling equipment. The laser profilometer data collected on the study are available on the accompanying CD to the report.

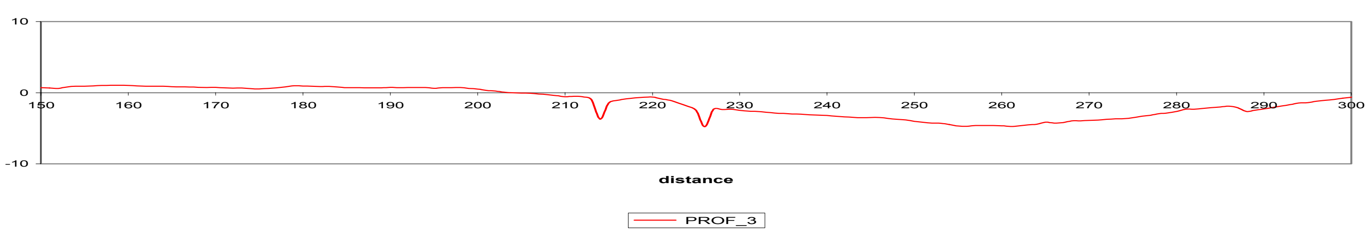

Figure 2.4. Profilograh’s 2-D Surface Profile (Middle Profile 3) for Crossing ID 625013E, S.E. 221st St. (Hawthorne), Madison, Florida (Northbound, Near Rail tracks)

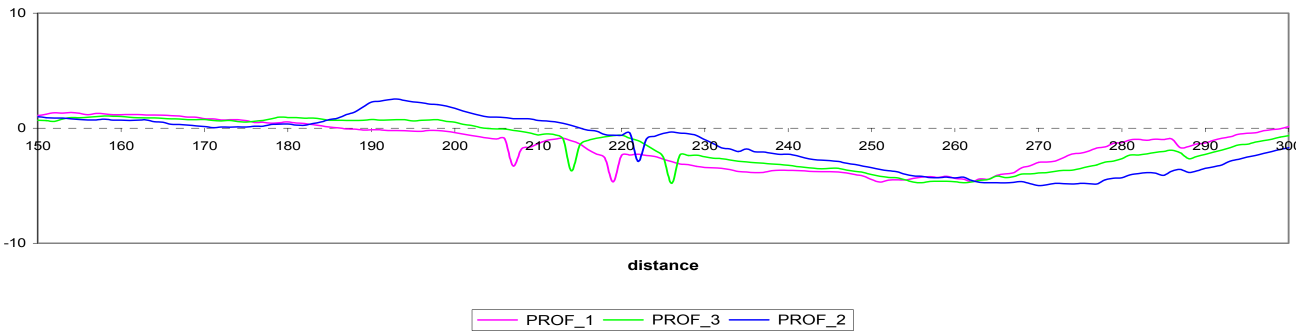

Figure 2.5. Profilograh's 2-D Surface Profile (All Profiles) for Crossing ID 625013E, S.E. 221st St. (Hawthorne), Madison, Florida (Northbound, Near Rail tracks)

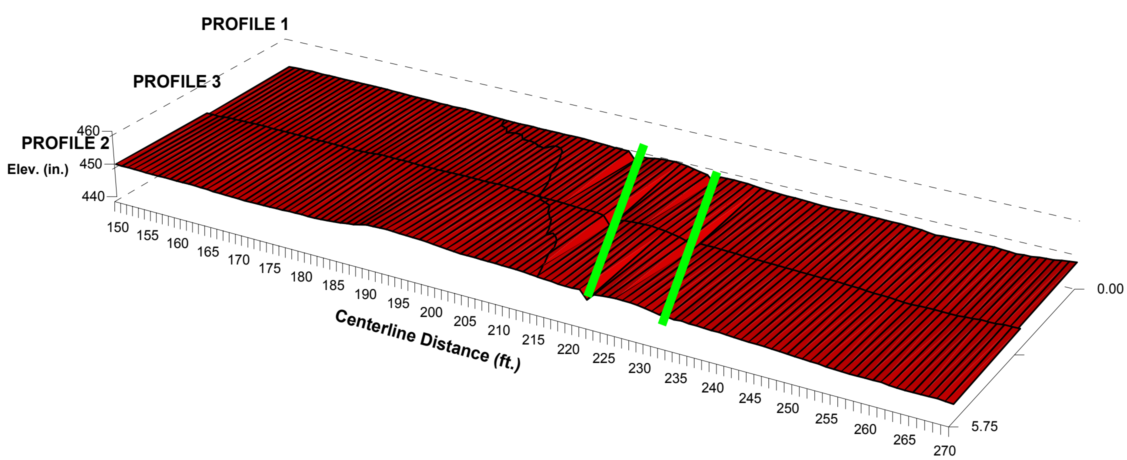

Figure 2.6. Profilograh's 3-D Surface Profile (All Profiles) for Crossing ID 625013E, S.E. 221st St. (Hawthorne), Madison, Florida (Northbound, Near Rail tracks)

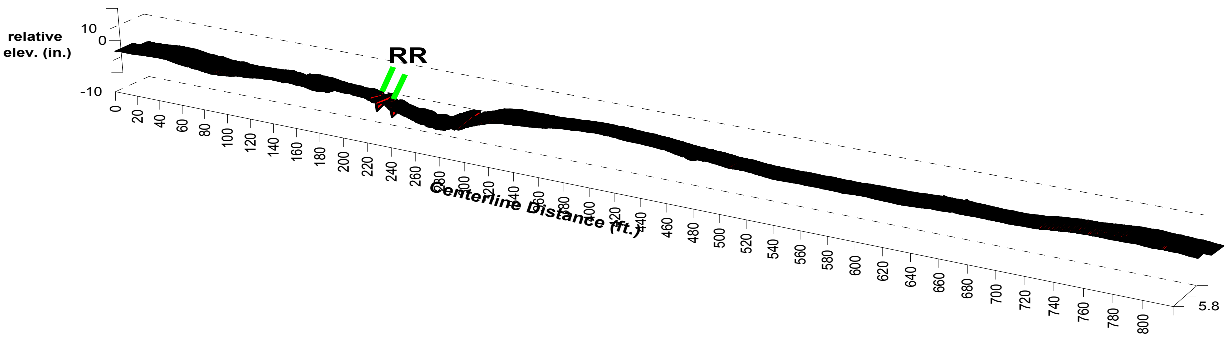

Figure 2.7. Profilograh's 3-D Surface Profile (All Profiles) for Crossing ID 625 013E, S.E. 221st St. (Hawthorne), Madison, Florida (Entire test length)

The raw profilometer data was also reviewed using another tool called *RoadRuf*. This is a computer tool for interpreting profile data for longitudinal road roughness. RoadRuf is a user-friendly package developed to provide profile analyses like the International Roughness Index (IRI) and Ride Number (RN). RoadRuf was developed at the University of Michigan Transportation Research Institute UMTRI) with funding from the Federal Highway Administration (FHWA) under a research project called "Interpretation of Road Roughness Profile Data." IRI and RN algorithms that were developed under RoadRuf included in recently approved ASTM standards for analyzing longitudinal profile. RoadRuf, runs on Intel PC's equipped with Windows 95/NT. Other than being an easy to use tool bin computing IRI and RN, the software also provides a user with advanced analysis capabilities to support research activities. The software includes an interactive X-Y plotter, a spectrum analyzer, and a set of custom filters. All these features can be operated interactively or in a batch-processing mode.

As indicated earlier, the traditional survey method was used to obtain roadway centerline profile at the grade crossing, Crossing No. 625497V on SR 14 in Madison, Florida. Using the RoadRuf, plots were generated for the profiles for the north and south travel directions. Figures 2.8 and 2.9 show plots for the northbound profiles, while figures 2.10 and 2.11 show the southbound profiles. Figures 2.8 and 2.9 can be used to compare for the northbound, the plots for data obtained from laser profilometer in the northbound profile versus plots obtained from traditional survey methods (rod and staff). Figures 2.10 and 2.11 can be similarly used for the southbound profiles. It can be clearly seen that for both directions, these two profiles from the two sources of measurement are different. The graphs are supposed to correspond in elevations changes for specified distances on the profile. This does not seem to be the case for this site in Madison.

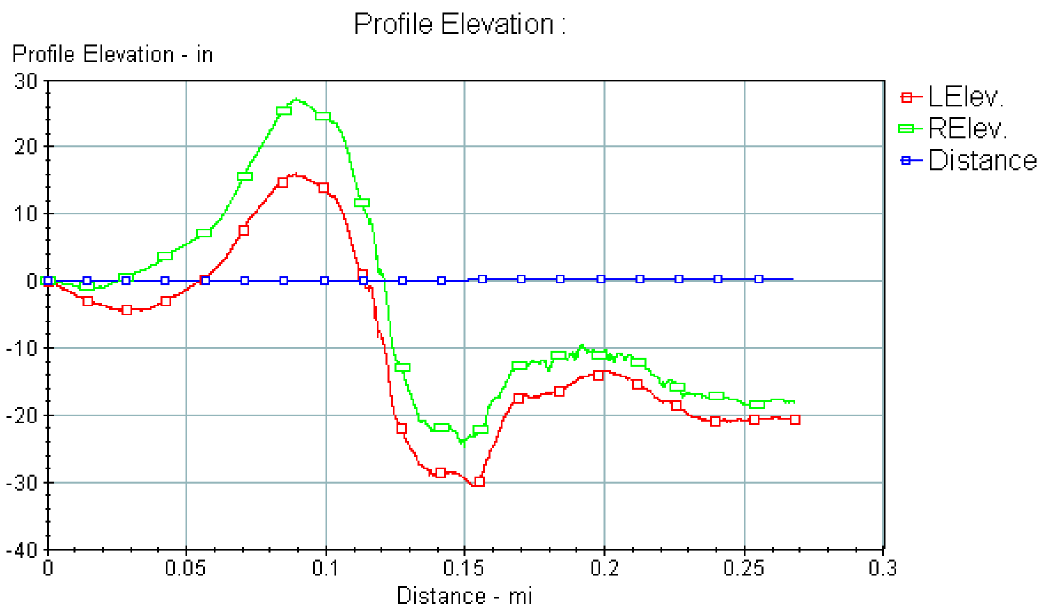

Figure 2.8. RoadRuf's North Direction Plot From Laser Profilometer Data

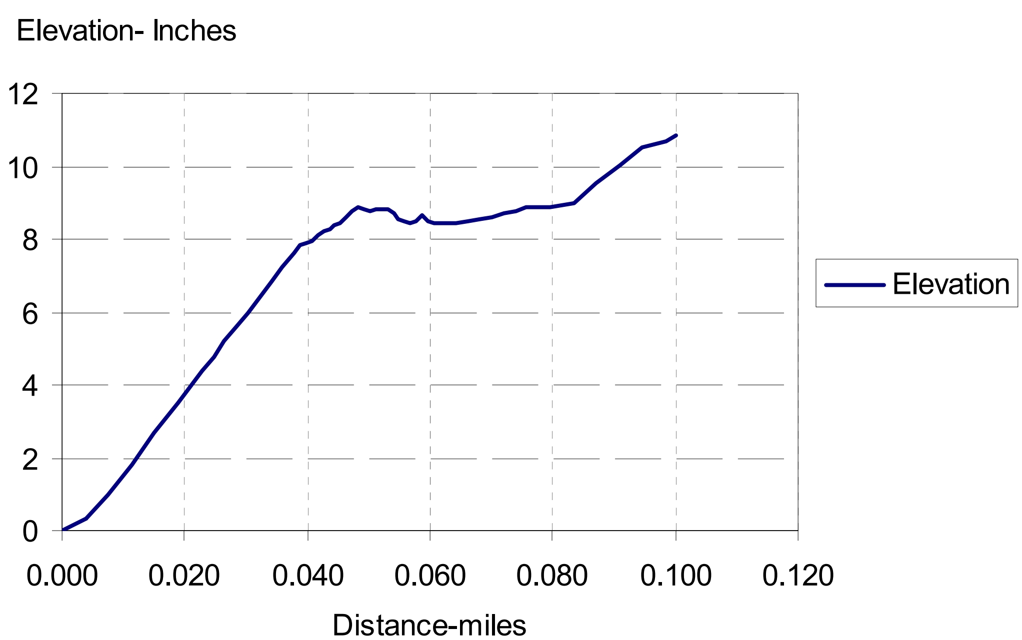

Figure 2.9. North Direction Plot From Traditional Survey Method (Rod And Staff)

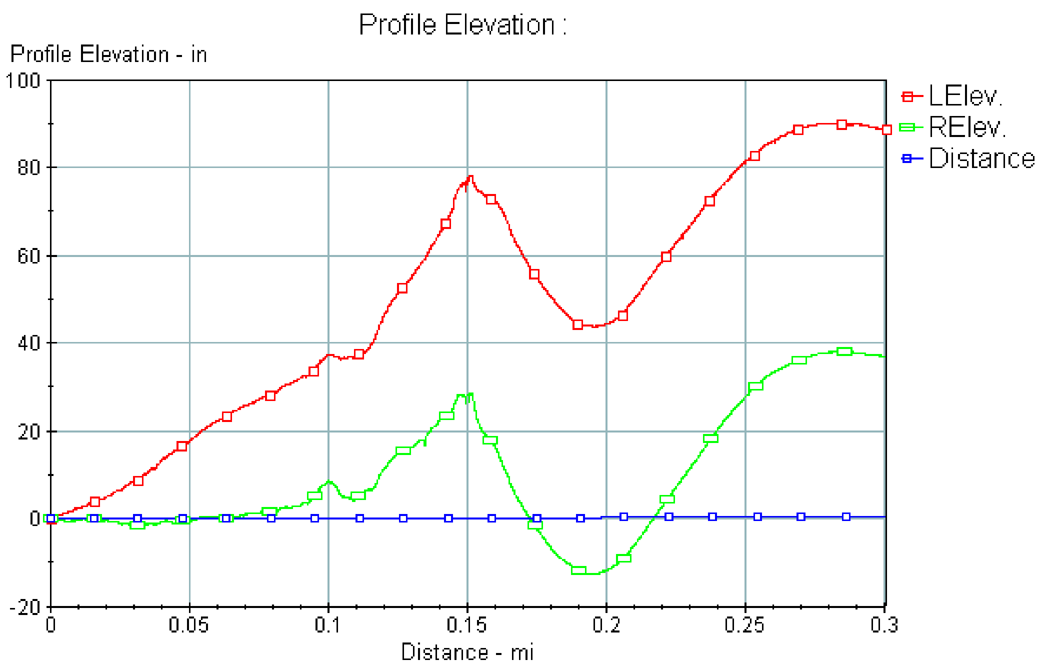

Figure 2.10. RoadRuf's South Direction From Laser Profilometer Data

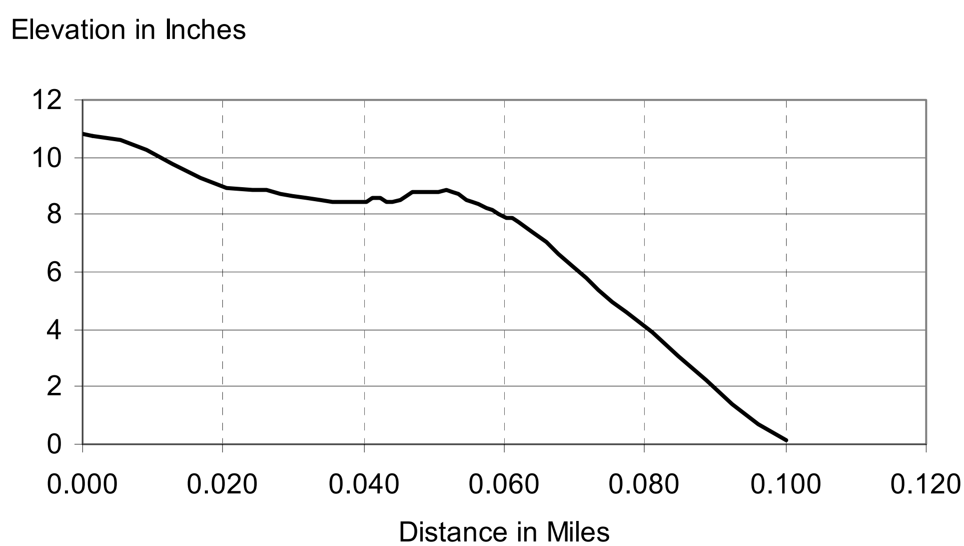

Figure 2.11. South Direction Plot From Traditional Survey Method (rod and staff)

Comparing the plots made for both directions using the two sources of data—it is certain that the data obtained from the profilometer needs further study to understand unexpected plots obtained. It should be noted that the difference is due to when data collection started and ended. There could be other reasons as to why the plots do not give expected results.

2.1.2. Rod and Level Survey Data

With assistance from the FDOT Rails Office in Tallahassee, Florida, and the District Two Office in Lake City, ground elevation data along the roadway centerline was obtained using the traditional survey leveling for five grade crossings in FDOT District Two. The services of surveying consultants were utilized by FDOT District Two to collect profile data at the following crossings:

1. Section Number: 35001 Crossing ID Number 625497V, S.R. 14, in Madison, Madison County, Florida.
2. Section Number: 71003 Crossing ID Number: 620928T, Center Street in Green Cove Springs, Clay County, Florida.
3. Section Number: 71004 Crossing ID Number: 620927L, Martin Luther King Street in Green Cove Springs, Clay County, Florida.
4. Section Number: 71008 Crossing ID Number: 620921V, C.R. 315B North of Green Cove Springs, Clay County, Florida.
5. Section Number: 76001 Crossing ID Number: 621004S, C.R. 308 Outside of Crescent City, Clay County, Florida.

These data were used to further review or “ground truth” the laser profilometer data, for the corresponding crossings. The findings are reported in the following sections, but first, the elevation data from rod and staff level, can be seen in Table 2.1 and Figures 2.12 through 2.16.

Table 2.1. Ground Elevation Data from Selected Grade Crossings (by Crossing IDs)

Station (ft)	625 497V Elevation[a] (ft.)	620 928T Elevation[b] (ft.)	620 927L Elevation[c] (ft.)	620 921V Elevation[d] (ft.)	621 004S Elevation[e] (ft.)
0+00	90.69	98.28	96.47	97.84	94.78
0+20	91.32	98.22	96.40	97.82	94.97
0+40	92.03	98.21	96.43	97.83	95.14
0+60	92.83	98.15	96.40	97.82	95.35
0+80	93.59	98.09	96.32	97.81	95.66
1+00	94.37	98.08	96.22	97.76	96.07
1+20	95.40	97.99	96.11	97.77	96.49
1+30	95.83	98.09	96.03	97.81	96.74
1+40	96.25	98.07	95.95	97.85	96.97
1+50	96.64	98.07	95.87	97.91	97.25
1+60	97.06	98.10	95.87	97.98	97.53
1+70	97.44	98.14	95.90	98.07	97.78
1+80	97.85	98.29	95.94	98.17	98.00
1+90	98.24	98.24	96.03	98.33	98.29
2+00	98.66	98.28	96.23	98.70	98.54
2+05	98.82	98.30	96.35	98.74	98.65
2+10	98.94	98.34	96.45	98.77	98.76
2+15	99.07	98.36	96.55	98.81	98.86
2+20	99.15	98.41	96.66	98.83	98.99
2+25	99.24	98.44	96.80	98.90	99.13
2+30	99.32	98.49	96.95	98.96	99.33
2+35	99.40	98.56	97.13	99.12	99.48
2+40	99.53	98.71	97.43	99.27	99.70
2+45	99.63	98.95	97.79	99.49	99.85
2+50	99.67	99.28	98.17	99.73	99.97
2+55	99.83	99.63	98.75	99.90	99.94
2+60	100.02	99.95	99.31	100.05	99.96
2+65	100.02	100.00	99.81	100.06	100.01
2+70	100.00	99.91	100.05	100.00	99.97
2+75	100.01	99.66	99.98	99.80	99.98
2+80	100.04	99.40	99.79	99.65	99.91
2+85	100.02	99.16	99.56	99.42	99.73
2+90	99.91	98.82	99.22	99.21	99.56
2+95	99.76	98.54	98.87	98.99	99.45
3+00	99.67	98.45	98.44	98.81	99.35
3+05	99.64	98.28	98.28	98.63	99.23
3+10	99.63	98.06	98.02	98.58	99.12
3+15	99.65	97.88	97.81	98.52	98.95
3+20	99.65	97.77	97.60	98.47	98.82
3+25	99.62	97.56	97.41	98.40	98.71
3+30	99.63	97.35	97.25	98.36	98.58
3+40	99.61	96.97	96.99	98.24	98.29
3+50	99.63	96.67	96.79	98.08	98.03
3+60	99.72	96.46	96.69	97.92	97.80
3+70	99.78	96.25	96.62	97.74	97.60
3+80	99.87	96.04	96.57	97.56	97.38
3+90	99.95	95.85	96.52	97.38	97.15
4+00	100.00	95.69	96.47	97.21	96.62
4+20	100.12	95.42	96.32	96.88	96.40
4+40	100.04	95.24	96.17	96.61	95.86
4+60	100.35	95.10	96.00	96.41	95.34
4+80	100.82	95.00	95.85	96.27	94.81
5+00	101.35	94.91	95.73	96.09	94.33
5+10	101.60	94.87	95.67	95.98	94.09
5+20	101.84	94.83	95.62	95.91	93.85
5+28	102.02	94.82	95.57	95.93	93.65

[a] Elevation - 100.00, Assumed on S. Railroad at Road Center Line, at Sta 2+65; Fresh pavement between Sta 0+00 and 1+00.

[b] Elevation - Assumed East Rail 100.00/West Rail 100.02, Road Center Line, at Sta 2+65.

[c] Elevation - Assumed East Rail 100.00/West Rail 99.57, Road Center Line, at Sta 2+65.

[d] Elevation - Assumed East Rail 106.00/West Rail 99.99, Road Center Line, at Sta 2+65.

[e] Elevation (Double Set of Tracks) - Assumed Easterly Most Rail 100.0, West Rail East Side 99.99, East Rail Westerly Side 99.99, Westerly Most Rail 100.01, Road Center Line, at Sta 2+65.

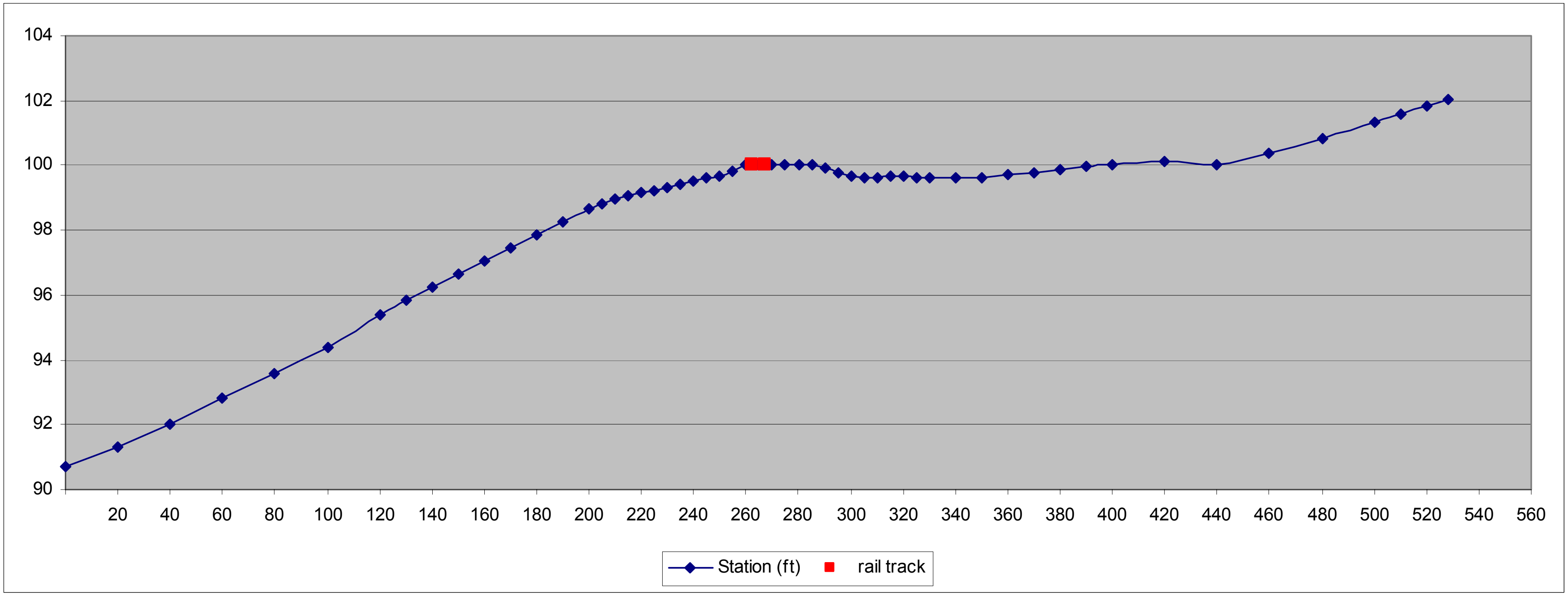

Figure 2.12. Roadway Centerline Elevation Based On Traditional Survey Leveling For Crossing ID Number 625497V, S.R. 14, In Madison, Madison County, Florida.

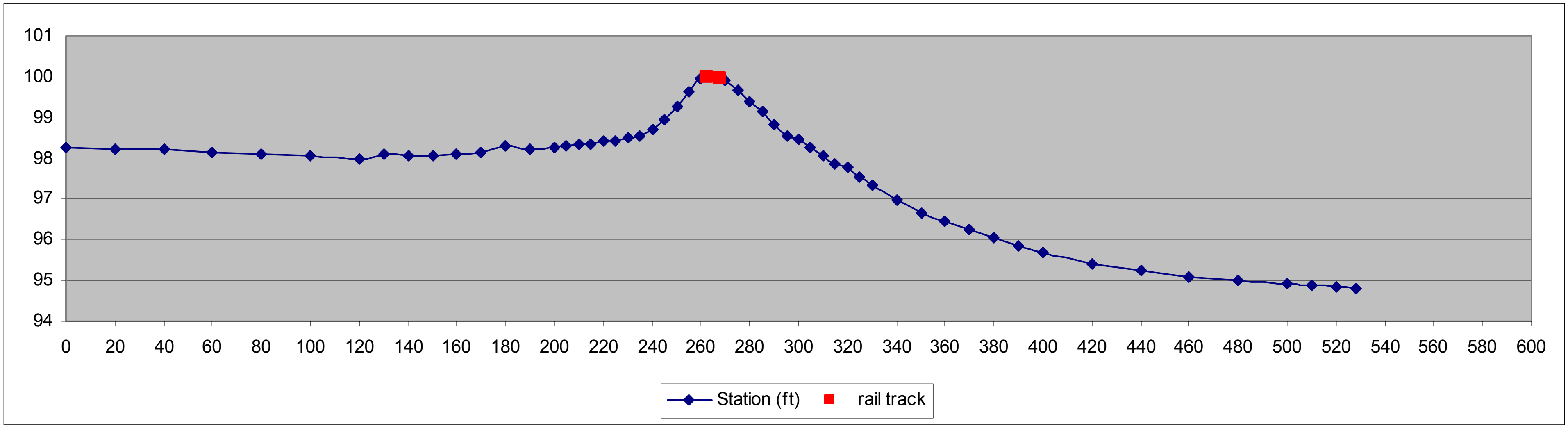

Figure 2.13. Roadway Centerline Elevation Based On Traditional Survey Leveling For Crossing ID Number: 620928T, Center Street In Green Cove Springs, Clay County, Florida

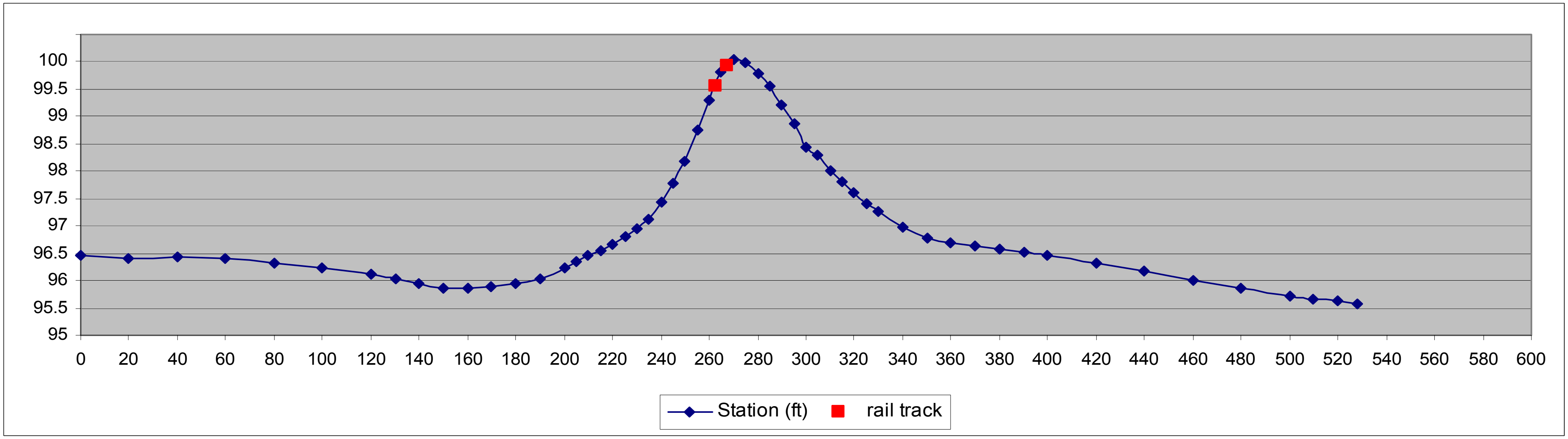

Figure 2.14. Roadway Centerline Elevation Based On Traditional Survey Leveling For Crossing ID Number: 620927L, Martin Luther King Street In Green Cove Springs, Clay County, Florida.

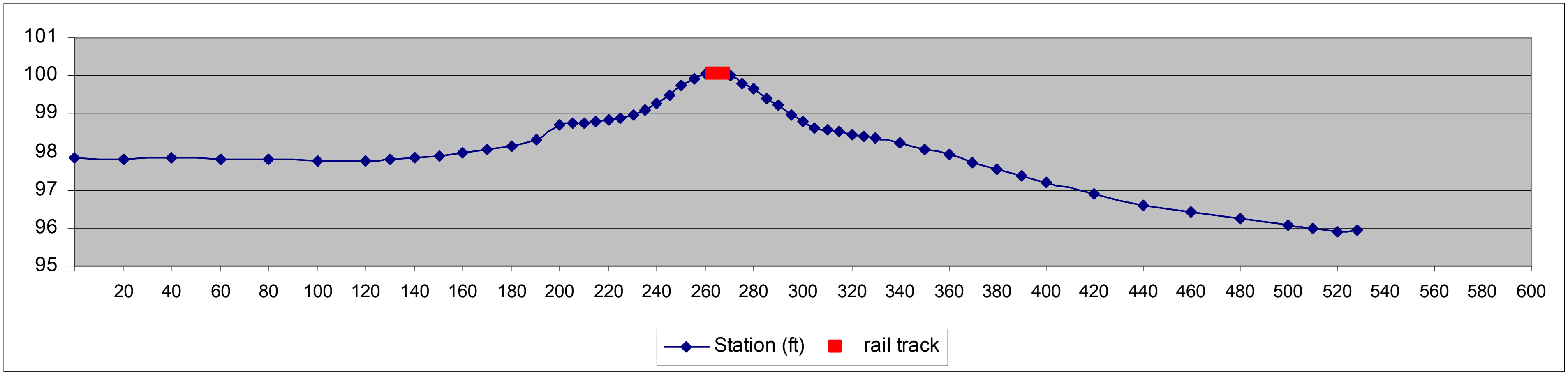

Figure 2.15. Roadway Centerline Elevation Based On Traditional Survey Leveling For Crossing ID Number: 620921V, C.R. 315B North Of Green Cove Springs, Clay County, Florida.

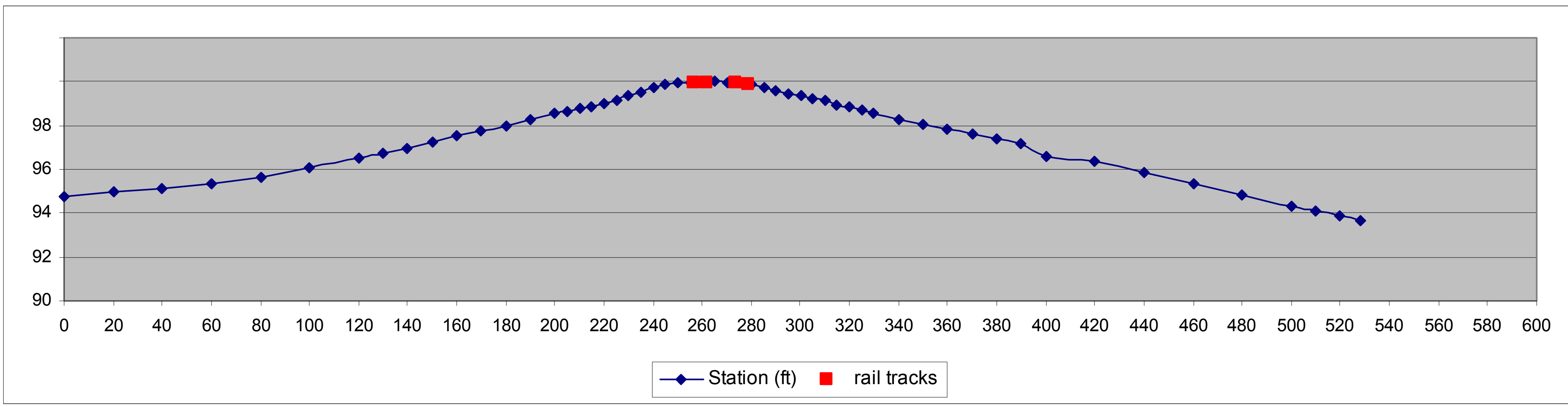

Figure 2.16. Roadway Centerline Elevation Based On Traditional Survey Leveling For Crossing ID Number: 621004S, C.R. 308 Outside Of Crescent City, Clay County, Florida.

Again, using the RoadRuf software, and obtaining a set of the original "raw" profilometer data from ICC, another set of analyses was done to perform "ground truthing," i.e. investigating any correlation between the profilometer data and the rod and staff data. It was difficult to establish the reference points for the profiles and also identify the directions in which the profile data was taken. The "raw" profilometer data showed a data length of about 0.3 mile, while the actual test length was 0.1 mile or 528 ft. A comparison was first done, using the initial 0.1-mile of the profilometer data, before using the entire full length. Also, both possible directions of profiles were considered. The RoadRuf's plots for two sites are shown as follows for the profilometer data. The comparison with the respective rod and staff level plots, shown earlier in the report, indicate no match.

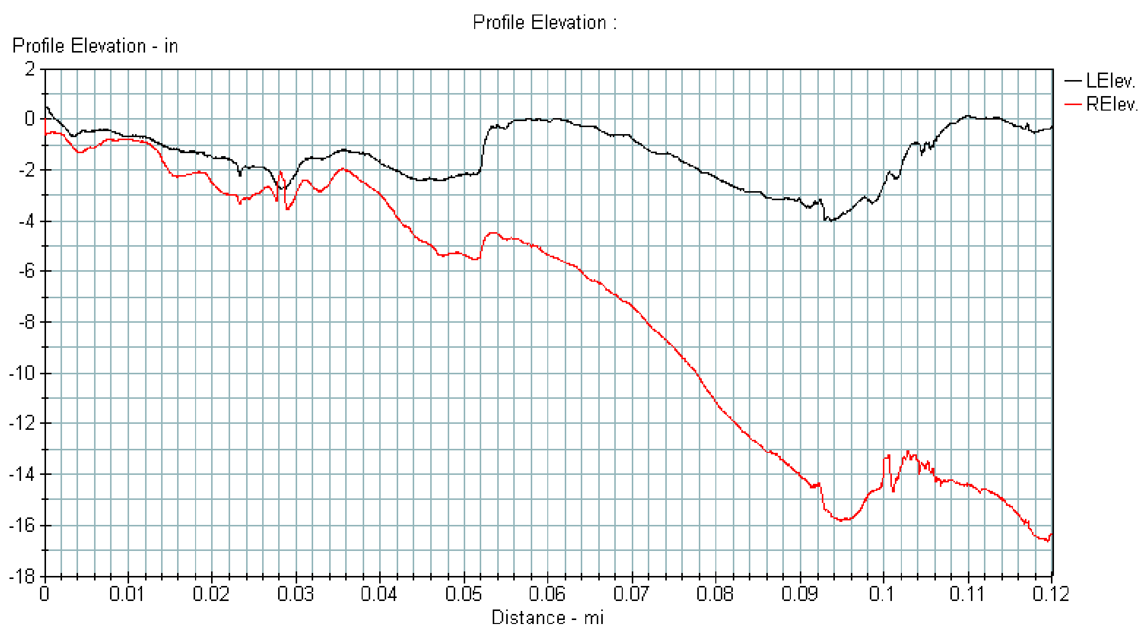

Figure 2.17. RoadRuf's East Direction Profilometer Plot (0.1 Mile) for Crossing ID Number: 620928T, Center Street in Green Cove Springs, Clay County, Florida

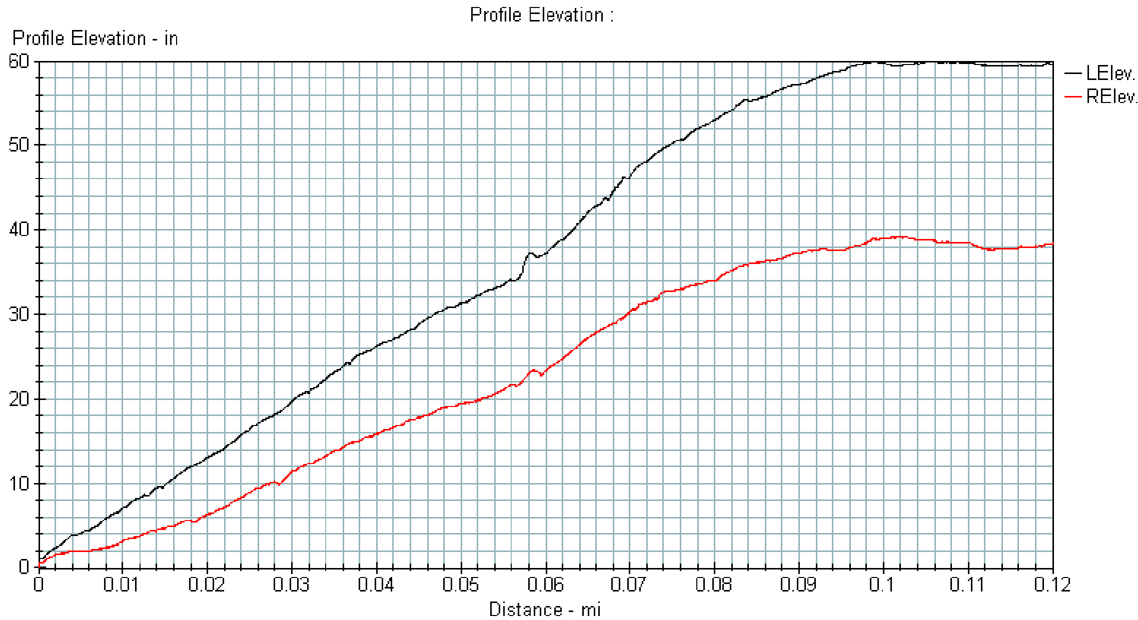

Figure 2.18. RoadRuf's West Direction Profilometer Plot (0.1 Mile) For Crossing ID Number: 620928T, Center Street In Green Cove Springs, Clay County, Florida

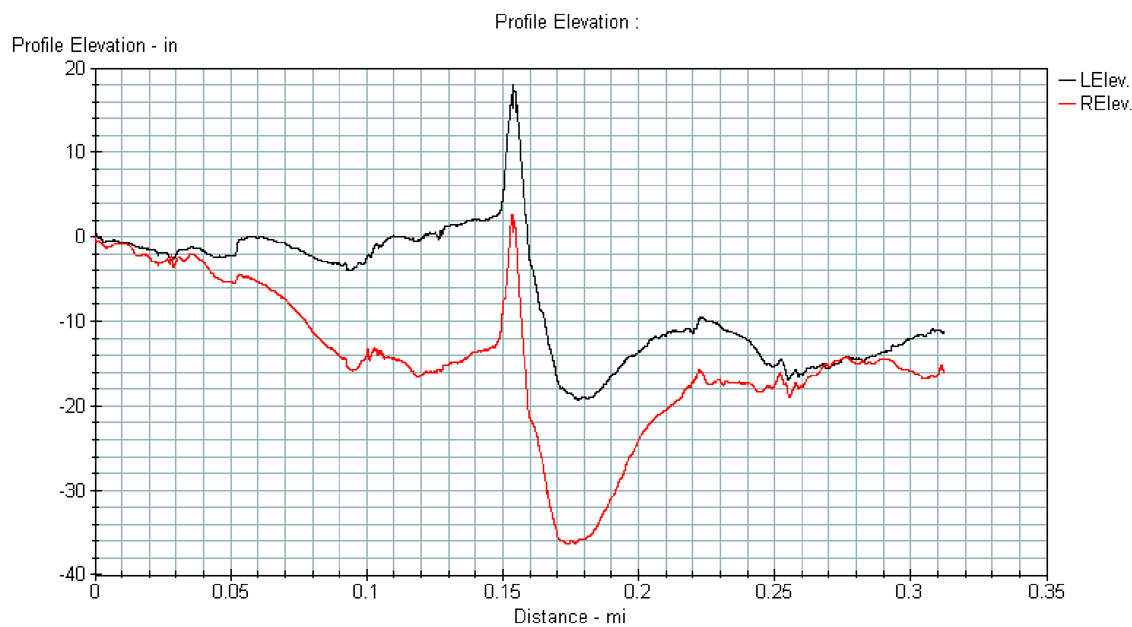

Figure 2.19. RoadRuf's East Direction Profilometer Plot (0.3 Mile) For Crossing ID Number: 620928T, Center Street In Green Cove Springs, Clay County, Florida

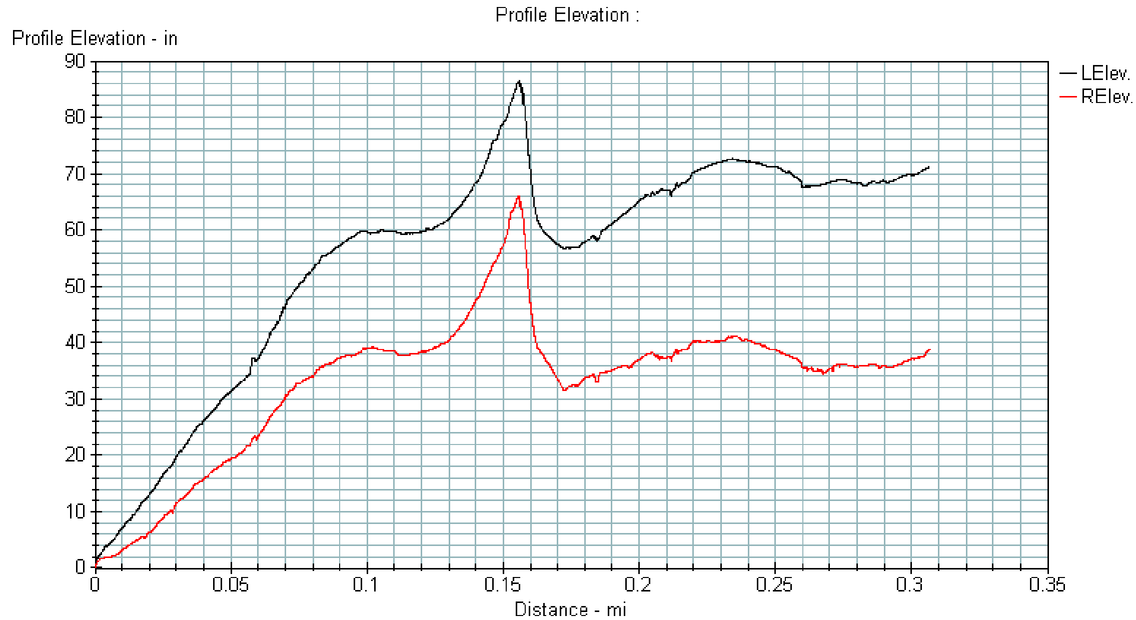

Figure 2.20. RoadRuf's West Direction Profilometer Plot (0.3 Mile) For Crossing ID Number: 620928T, Center Street In Green Cove Springs, Clay County, Florida

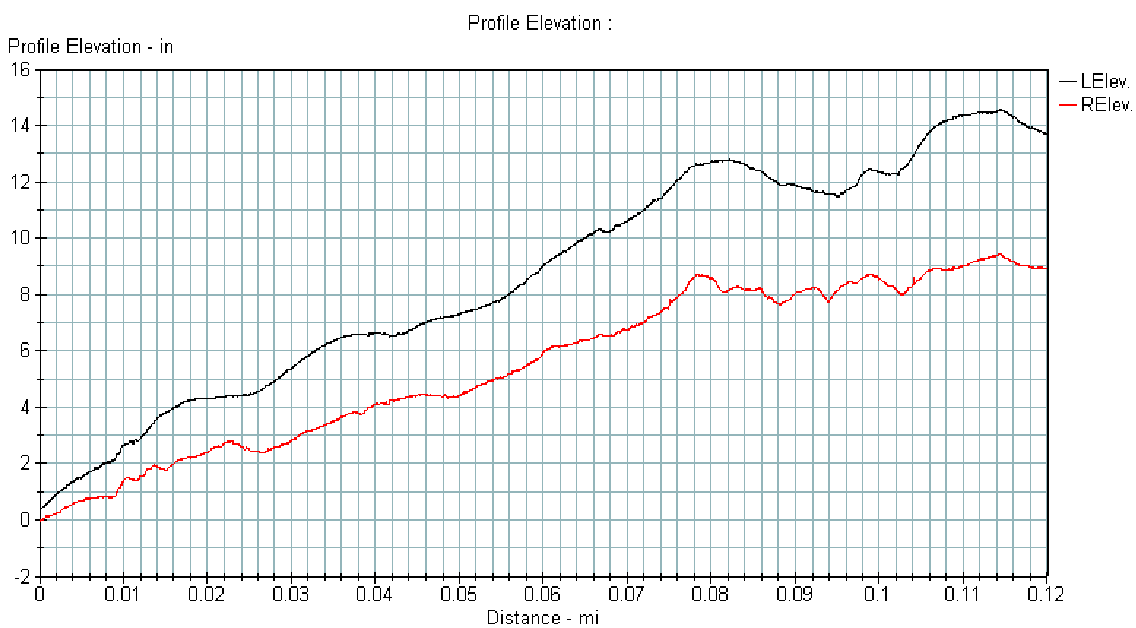

Figure 2.21. RoadRuf's East Direction Profilometer Plot (0.1 Mile) For Crossing ID Number: 620927L, Martin Luther King Street In Green Cove Springs, Clay County, Florida

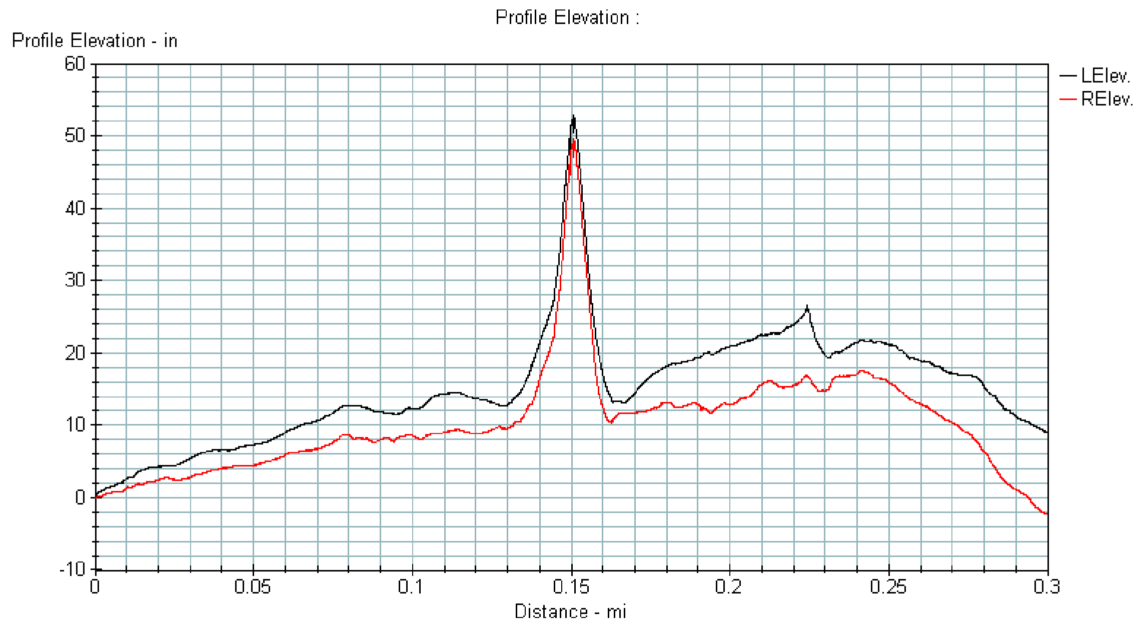

Figure 2.22. RoadRuf's East Direction Profilometer Plot (0.3 Mile) For Crossing ID Number: 620927L, Martin Luther King Street In Green Cove Springs, Clay County, Florida.

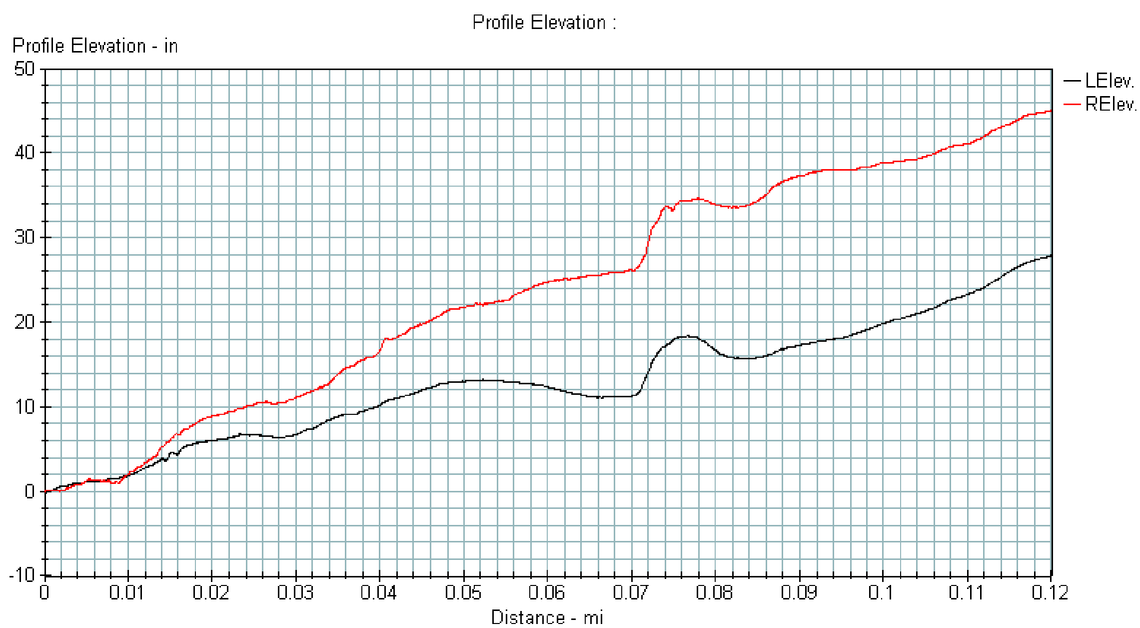

Figure 2.23. RoadRuf's West Direction Profilometer Plot (0.1 Mile) For Crossing ID Number: 620927L, Martin Luther King Street In Green Cove Springs, Clay County, Florida.

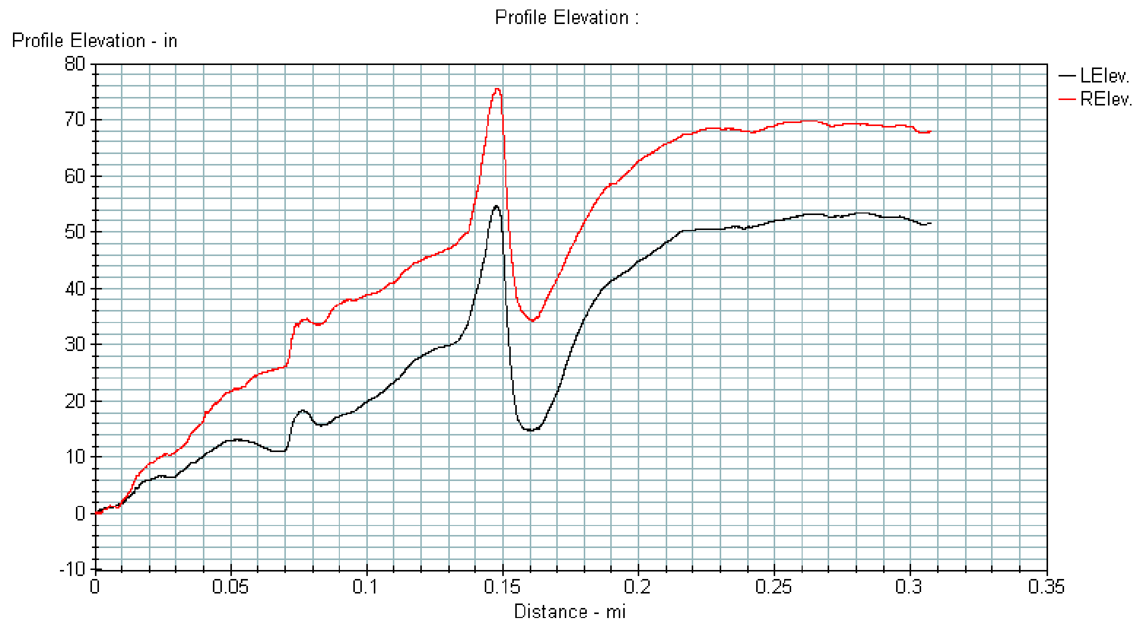

Figure 2.24 RoadRuf's West Direction Profilometer Plot (0.3 Mile) For Crossing ID Number: 620927L, Martin Luther King Street In Green Cove Springs, Clay County, Florida.

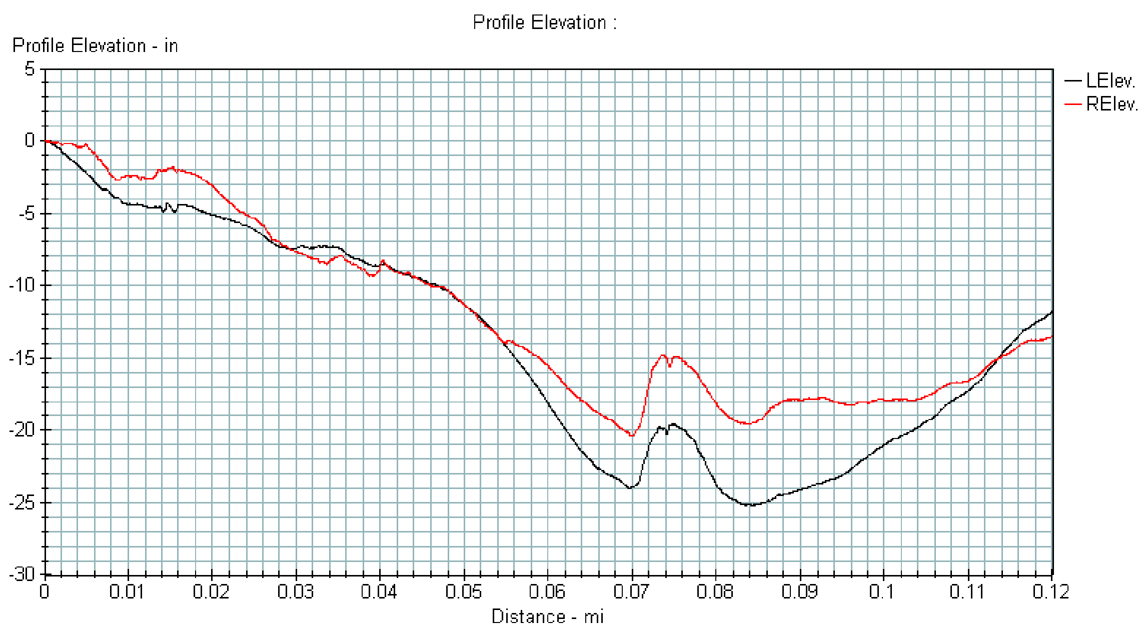

Figure 2.25. RoadRuf's West Direction Profilometer Plot (0.1 Mile - Scale Adjusted) For Crossing ID Number: 620927L, Martin Luther King Street In Green Cove Springs, Clay County, Florida.

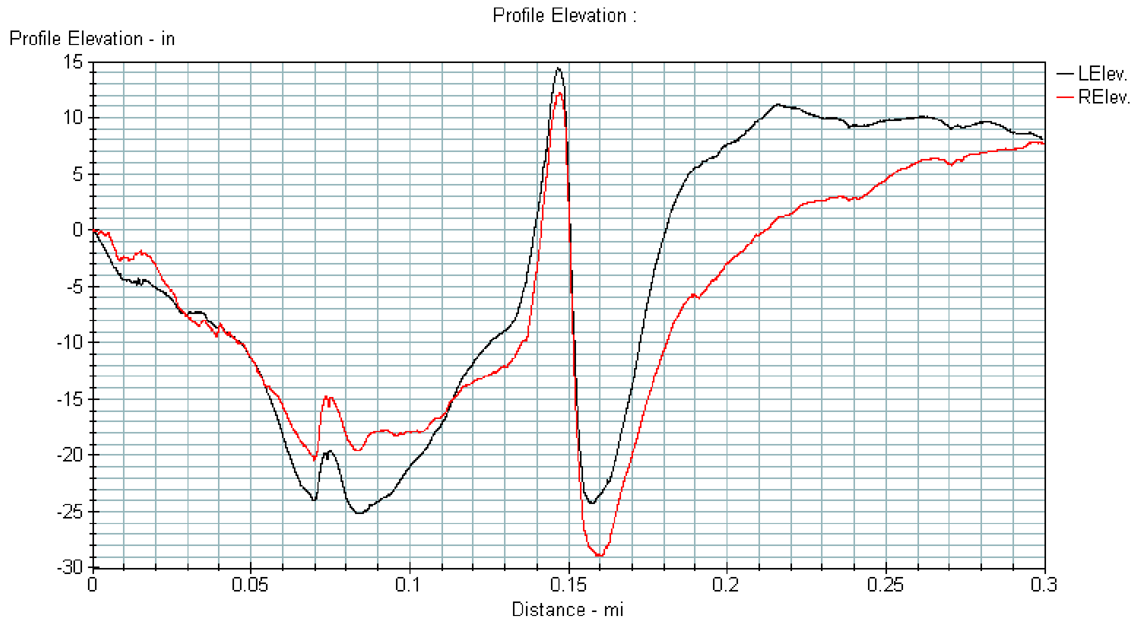

Figure 2.26. RoadRuf's West Direction Profilometer Plot (0.3 Mile- Scale Adjusted) For Crossing ID Number: 620927L, Martin Luther King Street In Green Cove Springs, Clay County, Florida.

Attempts were made to develop statistical regression models between profilometer data and the rod and staff level data, producing empirical equations unique to each site, but not stable enough to be applied to all situations. In other words, the derived equations from one site cannot be validated using data from other sites. Further research and inquiry revealed that it would be very difficult to utilize ICC profilometer data as road ground elevations. Contact were made with the following industry's experts on profilometer: (1) Dr. George Chang of the Transtec Group, developers of FHWA's ProVAL for analyzing profilometer data (similar to the RoadRuf); and (2) Dr. Emmanuel Fernando of the Texas Transportation Institute, College Station, Texas, These inquiries were made informally. Their comments reflect that the rod and level data require long wavelength content at measurement but that high-speed profilers (like ICC's) normally collect data at relatively shorter cut-off wavelength. By adjusting the cut-off wavelength, it may be possible to collect better data, that may resemble the rod and level data after processing, but it will never be the same as the ground elevation data. The detailed processing here would involve getting the raw accelerometer data and laser readings. Another alternative, with data closer to the raw elevation data, is the dipstick profiler (walking profilers) such as the CSC Digital Profilite 300 or ICC's SurfPro but even then you would not get exactly the raw ground elevations (rod and level); using relative benchmark elevations at say every 100 ft. may improve the elevations data, closer to the rod and level data.

2.1.3 Alternative Methods for Profile Data Collection

Two methods have been presented in this section for collecting profile data near at-grade railroad crossings. The traditional survey method is the more realistic option but it is not as productive and also more expensive, on a large quantity scale, compared with the laser profilometer. On the other hand, it is difficult to obtain the ground elevations directly from the profilometer. As possible solutions, the following methods are suggested for collecting profile data near the crossings:

1. ***Rotary Laser-Level:*** Using a one-man crew, the desired locations are first established on the pavement surface, at centerline of roadway, as well as the edge of pavement or edge of travel lanes. Setting up the rotary laser at desired height (of instrument), a graduated rod (staff) with laser detector is moved to each location on the road, and level readings taken. This method is just a little improvement from the traditional level survey but it will be cheaper and faster.

2. ***Laser Rangefinder:*** Using a setup similar to that described above for the Rotary Laser-Level, a laser rangefinder, such as the Impulse Rangefinder, can be set up on a tripod in a fixed location near the crossing. The rangefinder is then sighted on each point on the pavement surface. The relative depths and angles of elevations are shown and recorded for each point, to eventually obtain a profile of the surface.

3. ***3-D Laser Scanner:*** Although very expensive, a 3-D scanner can also be used to capture a 3-D profile of the crossings, but this has to be done in more than one scan, for desired directions, implying more costs.

4. ***Global Positioning Systems (GPS):*** Use of high-precision GPS receivers such as the Real Time Kinematics (RTK) options, can also produce profile data for railroad crossings but the expenses, time, and the exposure to traffic (safety) may be a concern.

5. ***As-Built Construction Drawings:*** Though not frequently updated by the responsible agencies, an as-built profile drawing of the railroad crossing should provide a good source of ground elevations.

6. ***Aerial Survey, GIS, and Contour Maps:*** Typically not of high accuracy, aerial photos may also serve as source of profile data, along with contour maps. Many agencies using Geographic Information Systems (GIS) also have some forms of contour elevations maps. The compromise here is the lack of frequent updating, especially since the railroad companies do maintenance work on the tracks.

7. ***3-D Digital Photography:*** Using complicated processing, digital photography can also be used to generate 3-D elevation data from existing ground surfaces such as the at-grade crossing profiles. It is not expensive but the details and skills required would have to be investigated.

2.2 Traffic Counts And Vehicle Classification

One of the interests of the research team was to estimate what proportion of the overall traffic stream on Florida roadways are actually low-ground clearance vehicles. The activity undertaken involved traffic counts and vehicle classification. Data collection on traffic was done near weigh in motion (truck weight enforcement) station sites, both at White Springs on I-75 North and Flagler on I-95 South. Other sites were considered, throughout the State of Florida, consisting mainly of weigh station sites, rest areas, and urban arterials, with the chosen rural and urban sites reflecting a variation in functional class and geographical location. A high volume of trucks recorded on the weigh stations was considered necessary. Table 2.2 shows the three survey sites with information on approximate truck percentages as compiled on the FDOT FTI 2001 CD. Assuming the low ground clearance vehicles are in the FHWA/FDOT vehicle classes 4, 5, and 6, an estimate was made of expected proportion of low ground clearance vehicles in the traffic streams (Table 2.2).

Table 2.2. Vehicle Survey Sites

Location	Approx. Location	FTI Station	AADT	Truck Factor	Est. % of Low Clear. Vehicles
White Springs I-75S	Hamilton	320235	29,000	34.74	4
Flagler I-75N	Flagler/Daytona Beach	730255	53,500	16.61	3
SR 15/ Union Street	200 E. of Main Street, Jacksonville	725056	26,500	5.28	N/A

Data on ground clearance of vehicles were planned to be collected in three dimensions for front, rear and wheelbase. Collection of field data on the total traffic volume and classification was carried out using a denominator tally board (Figure 2.27). Counters were mounted on hand-held clipboards and used to record the traffic counts in the vehicle classes of autos, motorcycles, trucks, recreation vehicles, car carriers, motorcoaches, lowboys, double drop vans, etc.

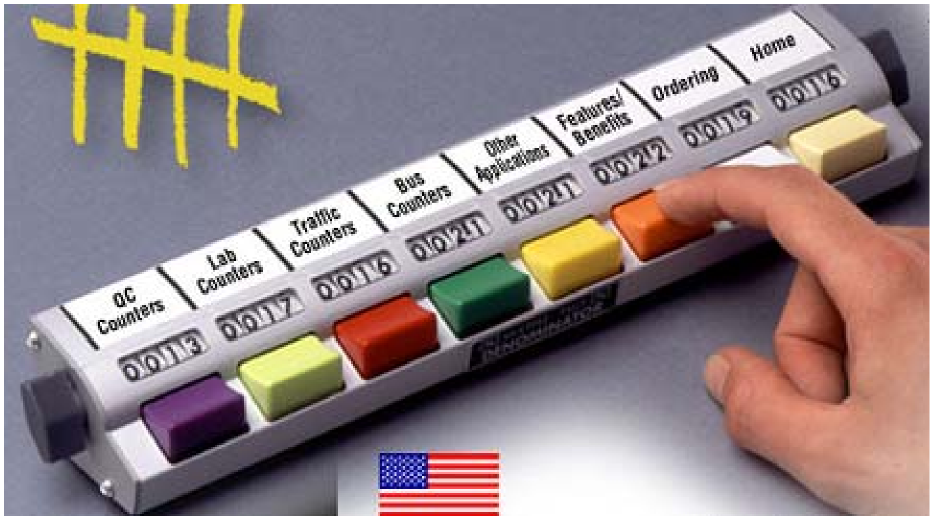

Figure 2.27. Denominator Tally Counter

2.2.1 White Springs I-75 Location

This site is near the FDOT's Weigh-In-Motion (WIM) Weight Enforcement Station in White Springs, located in Hamilton County, north of Lake City, Florida. This weigh station is located 0.2 miles NW of southeast of SR - 51. The data on the FDOT's Traffic CD of 2001, as shown in Table 2.2, has an AADT of 29,000 veh/day and a Truck Factor of 34.74%, with an estimated four (4) percent of low ground clearance vehicles. In comparison, traffic counts conducted for one week at this site indicated that five (5) percent of the total traffic stream were low ground clearance vehicles, and that the Truck Factor is 25.19 percent.

2.2.2 Flagler I-95 Location

The Flagler WIM Weight Enforcement Station is located in Flagler County, south of Jacksonville, Florida, between St Augustine and Daytona Beach. Data was collected at a site close to the Flagler weigh station, located on I-95. The data on the FDOT's Traffic CD of 2001, as shown in Table 2.2, stated that this site has an AADT of 53,500 veh/day and a Truck Factor of 16.61%, with an estimated three (3) percent of low ground clearance vehicles. In comparison, traffic counts conducted for one week at this site indicated that six (6) percent of the total traffic stream were low ground clearance vehicles, and that the Truck Factor is 10.70 percent.

2.2.3. SR15 (Union Street), Jacksonville Location

This site on SR 15, milepost 0.036, is located in Jacksonville, Duval County. Initial data on the site from the 2002 traffic CD (Site # 725056, one way, 200' east of Main street, data collected in 2001) indicated that this site has an AADT of 26,500 veh/day and a Truck factor of 5.28 percent. A spot check on the traffic count conducted on Union Street on September 17, 2003, between 8: 00 am and 1:00 pm showed 9.42 percent of the traffic stream being low clearance vehicles. This high figure can be attributed to a number of reasons, including the fact that Union Street serves a lot of buses (low clearance vehicles) for the Jacksonville Transportation Authority, with a bus station located on the street.

2.3 Summary

The research team's effort has been presented in this chapter, on data collection for 3-D profile data near at-grade crossings, in addition to vehicle classification. Much effort was expended on utilizing the laser profilometer to collect elevation data that would be useful for evaluating the potential of hang-up by low clearance vehicles as they traverse at-grade crossings. Modifying an existing ICC profilometer to enable collection of three-profile data (along the traditional two wheel paths and additional center path of vehicle), detailed profile data were collected at 28 grade crossings throughout central Florida. It was observed, after much analyses, involving a detailed comparison to the rod and staff leveling data, that the profilometer data would not yield a true ground elevation data, unless the profilometer is properly configured and the technology further studied, to yield the desired results. Alternative methods to obtaining ground elevations, though not as low-cost productive as the profilometer, include the following: the Rotary Laser Level; Laser Rangefinder; 3-D Laser Scanner; Global Positioning Systems (GPS); As-Built Construction Drawings; Aerial surveys, GIS and Contour Maps; and 3-D Digital Photography.

Some results are also presented on vehicle classification, with emphasis on low ground clearance vehicles, for traffic surveys conducted at three sites in Florida. It was observed that each of the traffic streams at two rural locations has between five and six percent of low clearance vehicles, while an urban location has almost 10 percent. Dimensions of low clearance vehicles were not obtained in this study primarily due to restrictions from doing this at the FDOT's weigh stations. It is assumed therefore that FDOT would adopt the documented work by the Eck et al (2002) using vehicle dimensions to develop an FHWA's classification for clearance vehicles, as discussed later in Chapter 4 of this report.

Table 2.3. White Springs I-75 Traffic Count Summary

Vehicle Summary Sheet: White Springs I-75															
Date	Time	Autos	Motorcycles	Trucks	Recreation vehicles	Passenger vehicle and trailer-Private use	Passenger vehicle and trailer-Commercial use	Car Carriers	Low Boy	Single Unit Transit Bus	Motorcoach	Motorhomes	Double Drop Trailer	Minibus	Other LCVs
3-Nov-03	8:12 to 12:14pm	2,256	8	891	56	118	12	8	24	4	3	0	6	32	1
3-Nov-03	1:15 to 5:15 pm	2,132	5	1182	30	124	28	11	34	0	0	0	19	54	2
4-Nov-03	8:21 to 12:23pm	1,978	4	1002	48	71	24	20	28	3	0	0	22	51	0
4-Nov-03	1:00 to 5:00 pm	1,936	3	1168	41	112	16	13	18	3	0	0	17	41	0
5-Nov-03	8:10 to 12:45 pm	2,070	0	1309	67	99	17	20	12	1	4	0	11	104	19
5-Nov-03	1:00 to 2:45 pm	1,024	0	620	26	48	12	11	8	0	1	0	4	27	6
6-Nov-03	8:16 to 12:20pm	2,460	0	1260	44	102	21	24	16	0	1	0	12	91	5
6-Nov-03	1:00 to 5:00 pm	2,040	2	1414	62	83	16	19	18	2	4	0	14	59	3
7-Nov-03	8:18 to 12:20pm	2,113	1	1312	59	84	20	14	14	4	2	0	9	74	7
7-Nov-03	12:40 to 3:40 pm	1,630	0	814	24	49	11	9	9	2	1	0	6	31	5
8-Nov-03	8:30 to 12:30pm	4,019	7	695	55	115	20	18	7	1	5	0	3	81	23
8-Nov-03	1:00 to 5:00 pm	2,880	4	615	48	75	15	11	7	2	8	0	3	49	12
9-Nov-03	8:30 to 10:40 pm	1,484	3	162	25	50	7	38	4	0	0	0	5	38	0
9-Nov-03	11:10 to 5:00 pm	7,451	7	948	263	364	31	10	25	0	13	3	17	176	17
Total		**35,473**	**44**	**13,392**	**848**	**1,494**	**250**	**226**	**224**	**22**	**42**	**3**	**148**	**908**	**100**
Total Vehicles															**53,174**
Percent per Category		66.71	0.08	25.19	1.59	2.81	0.47	0.43	0.42	0.04	0.08	0.01	0.28	1.71	0.19
LCV Percent															8.02
LCV Percent(Adjusted)															5.21

Table 2.4. Flagler I-95 Traffic Count Summary

Vehicle Summary Sheet: Flagler Site on I-95																
Date	Time	Autos	Motorcycles	Trucks	Recreation vehicles	Passenger vehicle and trailer-Private use	Passenger vehicle and trailer-Commercial use	Car Carriers	Low Boy	Single Unit Transit Bus	Motorcoach	Motorhomes	Double Drop Trailer	Minibus	Other LCVs
10-Nov-03	8:30 to 12:30 pm	5,232	3	742	196	105	36	53	32	2	7	11	48	68	29
10-Nov-03	1:50 to 5:50 pm	5,067	2	814	169	98	48	62	23	0	6	9	38	56	20
11-Nov-03	7:45 to 11:45 pm	5,320	1	718	202	113	53	65	38	4	9	7	47	72	29
11-Nov-03	1:00 to 5:00 pm	4,994	0	753	154	102	62	57	37	6	11	0	34	84	14
12-Nov-03	7:40 to 11:42 pm	5,004	2	871	183	83	32	71	39	0	0	7	32	52	39
12-Nov-03	1:00 to 5:02 pm	4,288	1	889	142	86	44	59	32	4	7	9	20	57	21
13-Nov-03	7:32 to 11:32 pm	5,412	0	1002	214	102	36	54	28	7	13	2	34	73	14
13-Nov-03	1:20 to 5:20 pm	4,892	2	749	189	99	39	61	33	4	0	0	37	66	30
14-Nov-03	7:30 to 11:30 pm	5,241	4	794	207	118	52	56	32	4	7	7	39	71	26
14-Nov-03	12:30 to 4:30 pm	5,163	0	741	198	103	34	49	37	4	7	4	43	64	11
15-Nov-03	8:17 to 12:17pm	5,684	5	504	112	72	26	27	20	2	3	4	9	40	20
15-Nov-03	12:52 to 4:52 pm	6,758	35	389	93	70	0	21	11	3	8	2	15	16	7
16-Nov-03	8:45 to 12:45 pm	6,579	23	468	125	35	27	23	15	1	10	0	14	18	3
16-Nov-03	11:10 to 5:00 pm	6,964	39	577	128	56	19	21	14	4	22	0	19	30	14
Total		**76,598**	**117**	**10,011**	**2,312**	**1,242**	**508**	**679**	**391**	**45**	**110**	**62**	**429**	**767**	**277**
Total Vehicles															**93,548**
Percent per Category		81.88	0.13	10.70	2.47	1.33	0.54	0.73	0.42	0.05	0.12	0.07	0.46	0.82	0.30
LCV Percent															7.29
LCV Percent(Adjusted)															5.96

Table 2.5. Union Duval Traffic Count

ehicle Summary Sheet: Union-Duval in Jacksonville (urban Site), Time 8:00 am to 2:45pm														
Autos	Motorcycles	Vans & Pickups	Trucks	Recreation vehicles	Fire Trucks	Beverage Truck	Garbage Truck	Passenger vehicle & trailer-Private use	Passenger vehicle & trailer-Commercial use	Single Unit Transit Bus	Motorcoach	Schoolbus	Low Boy	Minibus
4,821	2	1,797	296	1	8	2	13	53	17	181	303	32	14	154
Percentages per Category (total vehicle count 7,694)														
62.66	0.03	23.36	3.85	0.01	0.10	0.03	0.17	0.69	0.22	2.35	3.94	0.42	0.18	2.00
Low clearance vehicles percentage														9.42

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3. Geometric Design Considerations

Provision of adequate sight distances, including limitations by physical obstructions on the roadway or tracks, is a major objective in the geometric design of the crossings. While the scope of this study is on high-profile or hump crossings, this section presents the general considerations of design issues of grade crossings in terms of sight distances, horizontal alignment, and vertical alignment. FHWA (1986), AASHTO (1994), and ITE (2001) provided the basis for most of the materials discussed here. The FDOT's Manual Of Minimum Uniform Standards For Design, Construction, and Maintenance For Streets And Highways or Florida "Green book" (2002), in its Chapter 7, encourages the elimination of grade crossings, with preference for grade separations, but it recommends using the roadway geometric design principles, in general for grade crossings.

3.1 Sight Distances

Well-designed transportation facilities consider geometric and design speed requirements, including the following three types of sight distances:

1. Sight distance along the highway ahead of a grade crossing;
2. Line of sight across the approach "sight triangle" usually due to an obstruction; and
3. Distance along the track(s) in either direction for a vehicle stopped at the crossing to safely clear.

The sight triangle is illustrated in Figure 3.1. AASHTO 1994 "Green book" provides more details on determining safe speeds and available sight distances at grade crossings. The sight distance ahead of the crossing is greatly influenced by both the horizontal and vertical alignments, along with intersecting highways and driveways near the grade crossings. Measures should be taken to minimize horizontal and vertical curvatures at grade crossings. Sight triangles should be considered at grade crossings with passive traffic control devices and consider all obstructions over 42 inches high. Along the track, sight distance should allow a driver of a vehicle stopped at the crossing, to see both ways and adjust its speed accordingly. Illinois established an administrative code and statutes to ensure a clear right-of-way on the tracks for at least 300 ft. from the crossing. The Florida "Green book" (2002) provides some useful guidelines, as shown in Figure 3.1, similar to the AASHTO "Green book," on considering sight distances for geometric design of railroad grade crossings.

3.2 Horizontal Alignment Criteria

Many of the existing documents available advised that it is preferable that the highway intersects the tracks at a right angle. There should be no roadway intersections or driveways nearby. Horizontal and vertical alignment of the approach highways, along with that of the rail track itself, should not adversely affect the decision-making of pedestrian or vehicle drivers trying to traverse the grade crossing. Designers should avoid locating grade crossings on highway and track curves, particularly sharp curves, and track superelevations that are opposite to the grade of the highway. Skewed crossings constitute potential sight distance and safety problems for vehicle drivers. The Florida "Green book" limited the angle of skew to 70 degrees, discourages the use of horizontal curves and superelevation at grade crossings.

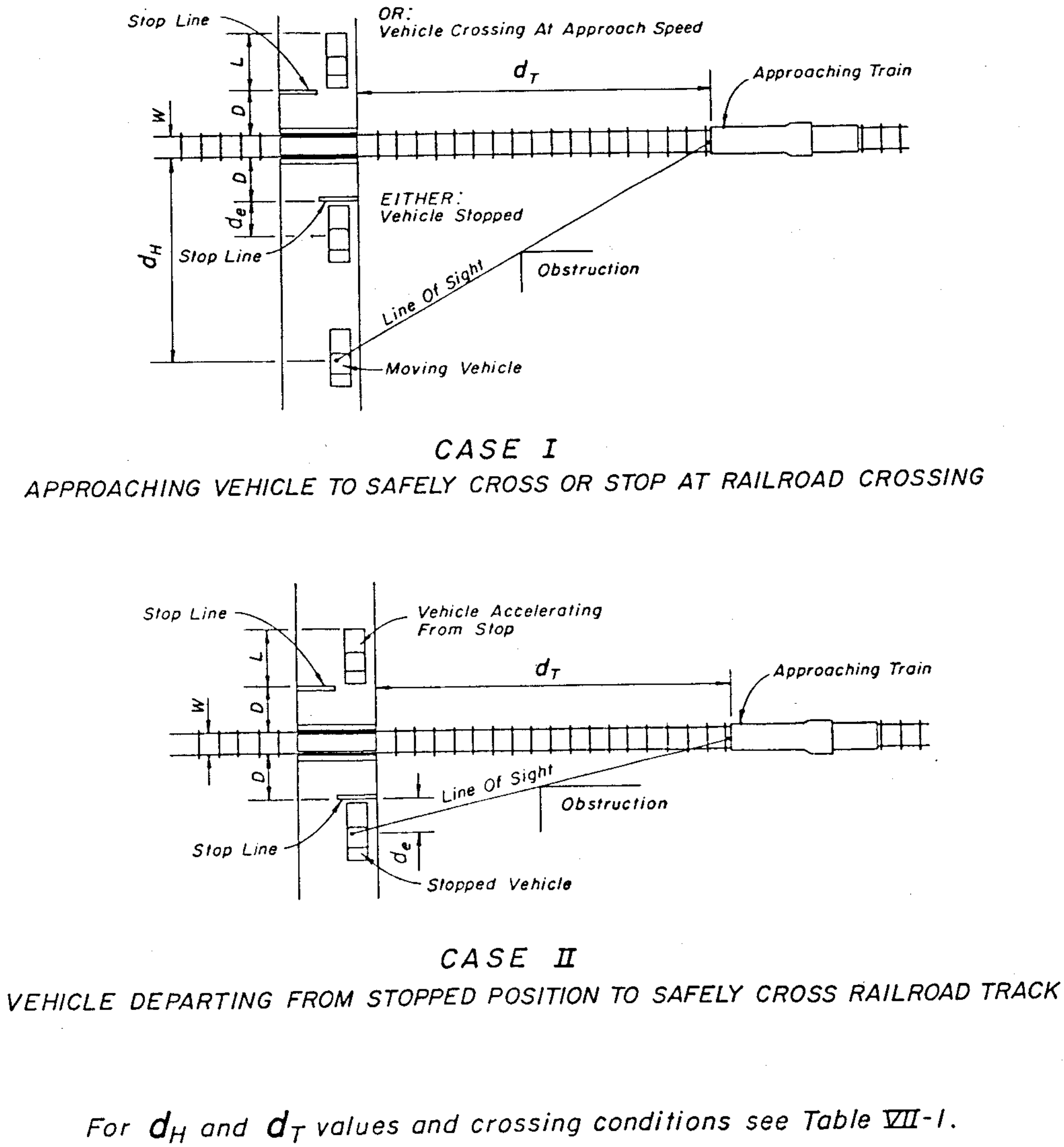


Figure 3.1 Visibility Triangle at Railroad Grade Crossings [Source: FDOT "Greenbook" 2002]

3.3 Vertical Alignment Criteria

Grade crossings should be constructed with considerations of the following factors: maximum sight distance, optimum rideability, minimum braking and acceleration distances, and adequate drainage. Vertical curves of sufficient length should therefore be provided to ensure adequate view of the crossing. Steep approach grades to the crossing would obstruct proper view of oncoming vehicles, leading to distraction from observation of approaching trains on the tracks. Excessive acceleration times on ascending steep grades and the increased time for braking on the descent approach, creates the potential for collision. Ideally the rail tracks should lie on a same flat plane. Rideability and safety are compromised when multiple tracks, especially superelevated tracks, lie on different elevation planes.

Typically associated with steep approach grades are high-profile or hump grade crossings, which may adversely affect safety and operation of low-clearances vehicles, i.e., vehicles with long wheelbases and low ground clearances. Hump grade crossings result from original construction, typically designed to follow the existing terrain, and using abrupt change in grades near the crossing. Track maintenance also contributes to the formation of hump crossings when the track elevation is raised, and materials, typically asphalt, are added at the roadway railroad crossings to match the new track elevations. An alternative to raising tracks, when tracks settle due to ballast degradation, is to modify the adjacent roadway surfaces to match the new track elevation.

The Florida "Green book" recommends the tracks and highway intersecting on the same plane. In the case of superelevated tracks, the highway's vertical alignment should match the superelevation of the tracks. The profile grade at the crossings should be flat (zero grade) for a minimum distance twice the design speed (feet), with no vertical curvature or a gentle vertical curve, providing adequate sight distance.

3.4 Existing Guidelines for High-Profile Grade Crossings

Compared with other design components of a highway or railroad tracks, the design of highway-railroad grade intersections has not been formalized through adequate design guidelines or manuals. As indicated in Section 1 of this report, the results of the survey questionnaire also confirm this. Some of the existing guidelines are summarized here.

3.4.1 FDOT's Profile Survey Manual (1984)

The manual was established for field data collection on elevations at grade crossings, classifying a crossing profile by type and scheme, and performing office analysis to determine if a crossing will accommodate low-clearance vehicles.

Tables were created showing maximum relative elevation values, for specific configurations that will accommodate low clearance vehicles meeting the Florida Statutes on low clearances. Disclaimers were also indicated on the use of the tables for design purposes. The FDOT 1984 method developed tables and figures for some defined profile types. The application of the tables and figures involves matching the profile's field-measured distance and relative elevation values, with the values indicated in the tables. If one or more of the elevation values exceeds the table values, then the crossing will not accommodate the low clearance vehicle meeting statute clearances.

3.4.2 AASHTO Criteria, ITE Criteria and FDOT's Standard Index 560 (2002)

Based on recent revisions, the FDOT 's design recommendations for crossing profiles shown in Standard Index 560, is shown in Figure 3.2 below, and is quoted as follows:

> *"To prevent low-clearance vehicles from becoming caught on the tracks, the crossing surface should be of the same plane as the top of the rails for a distance of 2 feet outside the rails. The surface of the highway should also not be more than 3 inches higher or lower than the top of the nearest rail at a point 30 feet from rail unless track superelevation makes a different level appropriate. Vertical curves should be used to traverse from the highway grade to a level plane at the elevation of the rails. Rails that are superelevated, or a roadway approach that is not level, will necessitate a site specific analysis for rail clearances."*

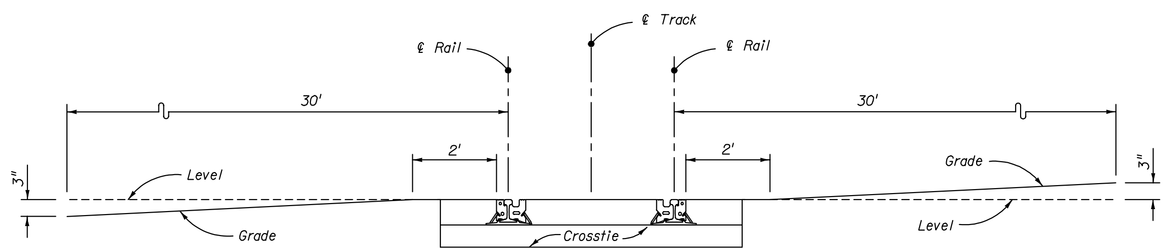


Figure 3.2. FDOT Standard Index No. 560 (2002): Railroad Crossings

Both the most recent AASHTO and The Institute of Transportation Engineers (ITE)'s Geometric design criteria for vertical profiles at grade crossings were adapted by FDOT and developed as the FDOT Standard Index 560 just described above. The FDOT's January 2003 Plans Preparation Manual (PPM), Revised January 1, 2004, Volume I - Design Criteria and Process, (Topic # 625-000-007) does not address at-grade crossings in detail, but does makes reference to the FDOT Standard Index No. 560.

3.4.3 FDOT's Rail Manual (2000)

The Rail Manual, Topic No. 725-080-002, March 2000, is one of several sources providing information on Rail topics. The manual also provide information on crossing profiles with the pertinent sections stated as follows:

> *"It is preferable for the highway alignment to intersect the railroad track at or close to a right angle. When a highway railroad grade crossing involve two (2) or more tracks, the top of the roadway surface will be brought to the same plane as the railroad tracks. The surface of the roadway will be the same plane as the top of rails for a distance of two (2) feet outside the rails for either multiple or single track highway railroad grade crossings. The top of rail plane will be connected with the grade line of the highway in each direction by vertical curves of such length so as to meet riding conditions and sight distances that are normally applied. It is desirable that the profiles of the highway not exceed ....3 in. above or 6 in. lower ....at 50 ft. from the nearest rail, measured at a right angle.... may not be*

possible at superelevated tracks. Profile survey manual of 1984 may be used to check final results… Traffic signings…. Provide adequate drainage (reference to FDOT Drainage Manual, Topic 625-040-001)…"

3.4.4 Florida Statute Section 316.170: Moving Heavy Equipment at Railroad Grade Crossings

Established as part of the regulations for motor vehicle laws commonly violated at grade crossing in Florida, the statute provided the following:

1. *No person shall operate or move any crawler-type tractor, steam shovel, derrick, or roller or any equipment or structure having a normal operating speed of 10 or less MPH or a vertical body or load clearance of less than ½ inch per foot of the distance between any two adjacent axles or in any event of less than 9 inches, measured above the level surface of a roadway, upon or across any tracks at a railroad grade crossing without first complying with this section.*

2. *Notice of such intended crossing shall be given to a station agent or other proper authority of the railroad, and a reasonable time shall be given to the railroad to provide protection at the crossing.*

3. *The person operating or moving any such vehicle or equipment shall first stop the same not less than 15 feet nor more than 50 feet from the nearest rail of the railroad and while so stopped shall listen and look in both directions along the track for any approaching train,…. and shall not proceed until the crossing can be made safely.*

4. *No such crossing shall be made when warning is being given by automatic signal or crossing gates or a flagger or otherwise of the immediate approach of a railroad train or car. If a flagger is provided by the railroad, movement over the crossing shall be under his or her direction.*

According to other materials distributed by the Department, some additional situations that may invoke the requirement of Section 316.170, Florida Statute include but are not limited to the following:

> *"Heavy, wide, and/or long vehicles with/without loads; Transporting loads requiring more that one drive unit; Articulated vehicles and trailers combinations; Vehicles caring sensitive loads; Vehicles caring loads with a high center of gravity; Multiple tracks; Skew angle of the roadway in relation to the track; Up hill grade; Roadway profile on both sides of the crossing area; Roadway and/or track super elevation/cross slope; Roadway curvature; Roughness of the crossing area; Tire traction in the crossing area; Stability of the roadway surface and roadway shoulder area; Vertical obstacles in the crossing area such as overhead signs and signals, wires, trees limbs, structures, etc.; Lateral obstacles in the crossing area such as signs, traffic signals, poles, trees, structures, roadway curbing, etc.; Multiple turning movements and maneuvers; Heavy rail traffic; and other barriers and obstacles outside the crossing area."*

3.4.5 The AREMA Manual for Railway Engineering

The American Railway Engineering and Maintenance Association (AREMA)'s manual recommends that,

> *"the crossing surface be in the same plane as the top of the rails for a distance of two feet outside of the rails and that the surface of the highway be not more than three inches higher nor six inches lower than the top of the nearest rail at a point 30 feet from the rail unless the track superelevation dictates otherwise."*

3.4.6 The Illinois Commerce Commission

The commission specifies that,

> *"from the outer rail of the outermost track, the road surface should be level for about 24 inches. From there to a distance of 25 feet, a maximum grade not to exceed one percent is specified. From that point to the railroad right-of-way line, the maximum grade is five percent."*

3.4.7 The Southern Pacific Railroad Company

The railroad company recommends that,

> *"for a distance of 20 feet from a point two feet from the nearest rail, the maximum descent should be six inches. From that point for a distance of another 20 feet, the maximum descent should be two feet."*

3.4.8 Public Utilities Commission of California

Based on a General Order No. 72-B (amended 1991), rules were established governing construction standards and maintenance responsibilities at railroad crossings with public streets, roads and highways. Widths of grade crossings, at a specified minimum of 24 ft. in effective roadway measured at right angles to centerline of roadway, were instructed not to be less than the traveled approach, including usable shoulders and sidewalks. Widening of one or both roadway approaches should consider the existing crossing width. Provision of acceleration and deceleration lanes is required as found necessary.

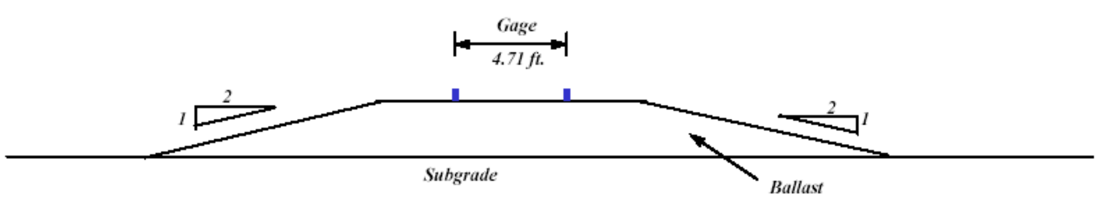
> *"At the time of construction the surface of the highway shall be installed to conform substantially to the plane of the rails for the entire area between the rails and between tracks to lines two (2) feet outside the rails. The alignment and profile of each grade crossing shall be substantially maintained as constructed.*
>
> *"Where crossings involve two or more tracks, the top of the rails for all tracks shall be brought to the same plane where practicable. The surface of the highway shall be at the same plane as the top of rails for a distance of at least two feet outside of rails for either multiple or single-track crossings. The top of rail plane shall be connected with the grade line of the highway each way by vertical curves of such length as is required to provide riding conditions and sight distances normally applied to the highway under*

considerations. Unless special conditions so require, such curvature and/or train speeds, the rails of spur or secondary tracks shall not be substantially superelevated within the limits of the crossing.

"In general, approach grades not in excess of six percent are desirable, but where not reasonably obtainable due to local topographical conditions the gradients in the vicinity of the rails shall be kept as low as feasible."

3.5 Cross Section Elements

The cross section details of both the roadway and railroad are always very different, away from the grade crossing. The crossing would therefore be a composite of these two individual cross sections, requiring modifications of the individual cross sections. Most roadway designers are familiar with the elements of a typical roadway cross section (surfacing, base, subbase, subgrade, travel lanes, shoulder, foreslope, drainage, etc.). Figure 3.3 shows a sketchy illustration of the general tracks cross section away from the crossing, showing the subgrade, track gage, and ballast typically constructed on a 2:1 sideslope. This is will vary depending on the track curvature and right-of-way restrictions. The shoulder-to-shoulder widths of single-track vary from 20 to 26 feet, while the minimum between two sets of tracks sharing common ballast is 15 feet.



(a) Away from the Roadway-Railroad Grade Crossing

(b) At the Roadway-Railroad Grade Crossing

Figure 3.3. Typical Cross Section Elements of Railroad Tracks

The challenge at highway-railroad grade crossings is to modify the cross section of the roadway to support the track surface, where the normal crown pavement of the approach roadway must also match the almost level surface at the crossing. Most of the roadway alignment features are interrupted at the crossing. Drainage consideration at the grade crossing is also very important, particularly the runoff away from the track centerline, which now flows along the roadway. In cases where the approach grade descends towards the crossing, adequate drainage is required to capture and transport the surface runoff. At the crossing, the railroad subgrade's position relative to that of the roadway subgrade is crucial to proper drainage.

The minimum width of a grade crossing should be at least as wide as the width of the approach roadway plus shoulders or sidewalks. The AREMA manual requires an additional 2 ft. to the traveled way, ensuring same number and width of approach roadway lanes. The state of Illinois requires that unless authorized, the minimum width of the grade crossing will be 16 feet.

3.6. Pullout Lanes, Traffic Islands, Roadside Design, and Crossing Surface

In order to avoid traffic delay at the crossing, pullout lanes are necessary for some vehicles which are required to stop at grade crossings. Detailed configurations for these layouts are well described in FHWA (1985) and ITE (2001).

With safety as the priority, the roadside design of the grade crossing is done with provision of shoulders and level roadside for errant vehicles, and the provision of guard rails near the crossing, but avoiding redirection of vehicles (by guard rails) towards the train. Traffic islands may be used to prevent vehicles from going through lowered gates. Details on its design and considerations are presented in FHWA (1985) and ITE (2001). The condition of the highway railroad grade crossing surfacing is also very important. A rough surface may distract the driver as well as adversely affect braking and safe steering of the vehicle.

3.7 Maintenance Criteria: Track Raising

The primary maintenance issue in geometry of crossings relates to track maintenance by railroad companies in raising track elevations at the grade crossings. Repeated track raises, followed by asphalt paving, often result in "hump" profiles.

Existing design criteria for track raises include the West Virginia Division of Highways' criteria which recommends that when a track raise of one inch or more is necessary, the approach pavement should be tapered at a rate of not less than 10 ft. per inch of track rise, and that the pavement immediately adjacent to the outermost rail should be level for a minimum distance of 3 ft. It can also be reasonably assumed that the design criteria described earlier for the Southern Pacific Railroad Company, would apply to the track maintenance, i.e., providing a maximum descent of six inches at 20 feet from at a point that is two feet from the nearest rail.

According to the U.S. DOT/AAR National Railway Highway Crossing Inventory, the majority of crossings are made of asphalt pavement materials. A rough review of Florida's inventory also indicates the same. Whenever track resurfacing or pavement resurfacing projects involves a crossing, measures should be taken to avoid reduction in the serviceability of the crossing. Track raising should be done by maintaining a level surface at the crossing and gradually adjusting the grade lines to be consistent with that of the approach roadway. If more than one track is involved, the modified plane of the entire crossing should be level and all tracks raised to same new elevation. In general, roadway or track resurfacing projects should involve appropriate raising and adjustment of grades.

3.8 Summary

Some basic geometric design criteria for highway railroad grade crossings have been presented in this section. Many existing design documents are available, discussing the horizontal and vertical alignment requirements, as well as the cross sections, pullout lanes, traffic islands, roadside design, and crossing surface. Also discussed were specific guidelines relevant to the design and maintenance of high profile grade crossings. These criteria and guidelines form the basis of the methodology, presented in the next section of this report, for evaluating the potential of hang-up at a grade crossing, by a low ground clearance vehicle.

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4. Research Methodology and Analyses

Many factors influence the geometric design of crossing profiles. With primary focus on accommodating low-clearance vehicles, and preventing hang-up, this section presents the proposed methodology for selecting vertical grades and curves for crossing profiles. The use of a design vehicle is utilized to generate various feasible profiles, safe from potential vehicle hang-ups.

4.1 Vertical Crest Curves

As reported in Eck and Kang (1991), the concept of ramp breakover angle has been mentioned by McConnell (1958) in the evaluation of driveways for possible hang-up by passenger cars. This concept is further illustrated as follows in an application to evaluate possible hang-up of a low clearance vehicle (LCV) at "hump" types of at-grade highway railroad crossings.

Consider the schematic diagram shown below showing the wheelbase of an LCV above a flat ground profile.

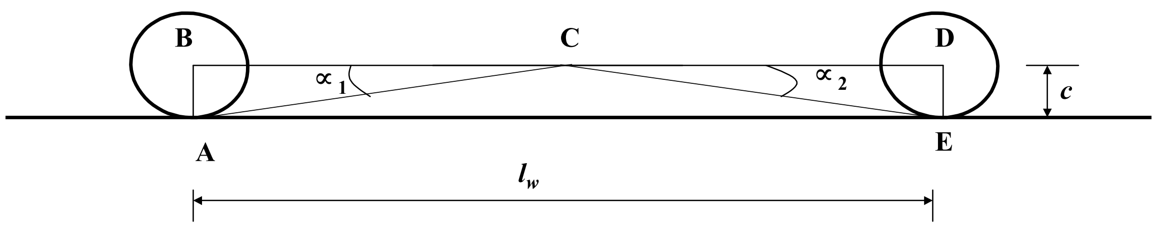


Figure 4.1. Low Clearance Vehicle Wheelbase Above A Flat Ground Surface

From Figure 4.1 above,

Let l_w = Wheelbase length of LCV, wheel to wheel (ft.).
c = Ground clearance of LCV (in.)
α_1 = Angle (degrees) enclosed by a plane joining the nearest rear wheel low point to the lowest point under the LCV, and the flat ground surface.
α_2 = Angle (degrees) enclosed by a plane joining the nearest front wheel low point to the lowest point under the LCV, and the flat ground surface.

Consider again, the situation of an LCV traversing a railroad crossing on one approach, as shown in Figure 4.2. In reality, the intersecting point C will not be a sharp point as shown but will be composed of a short vertical curve as suggested by Eck and Kang (1991). For sake of simplicity let us assume a sharp point in this analysis. Also, it is actually conservative in the evaluation of hang-up by LCVs since the curve point will be lower than the sharp point C.

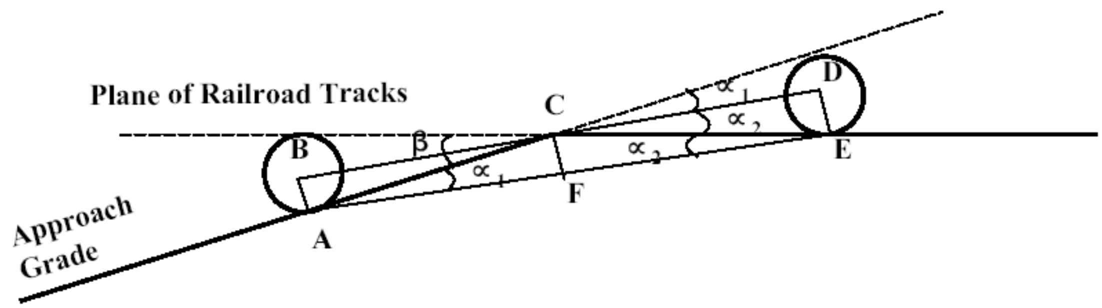


Figure 4.2. The Concept of Breakover Angle for LCV Approaching a Grade Crossing

In this case, a simple analysis of the geometry will indicate that the ramp breakover angle as defined by McConnell (1958), indicated as β in Figure 4.2, is given as

$$\beta = \alpha_1 + \alpha_2$$

The critical situation for hang-up will be as shown in Figure 4.2 where the midpoint of the wheelbase will rest directly on the point C. Then,

$$\alpha_1 = \alpha_2 \text{ or } \propto \quad \text{and, } \beta = 2\propto$$

The ramp breakover angle β therefore describes the critical slope for an approach grade to a railroad crossing, relative to the flat plane of the railroad tracks, or simply, the difference in grades between the two planes. Relative to a flat plane of the rail tracks, the critical grade, G_c is defined as

$$G_c = \tan \beta$$

From the extensive studies by Eck and Kang (1991, 1993, and 2002), it was observed that there is a variety in the pertinent dimensions of LCVs with respect to possible hang-ups at railroad crossings. From these studies, particularly Eck and Kang (1993, 2002), design vehicles were suggested based on statistics and the criticality of the dimensions (Table 4.1). For wheelbase relative to ground clearance, the critical vehicle was the Car Carrier Trailers with a wheel base length of 40 ft. and a ground clearance of 4 in. For front overhang evaluations for hang-up, the critical vehicle is Single Unit Transit Bus with 18 ft. front overhang and 6 in. ground clearance, while the rear overhang critical vehicles are Minibus and Recreation Vehicles, each recorded as 16 ft. rear overhang lengths with 8 in. ground clearance.

As reported in Section 1 of this report, the traffic composition (%) of LCVs at two Interstate locations on Florida roadways were less than 6%, which can be considered low. Moreover, at-grade highway railroad crossings are located on lower functional classes of roadways, typically, with low truck traffic. Information provided in Table 4.1 may suggest that the dimensions of vehicles especially overhang lengths, indicated in the Florida "Green book" are outdated. This may not be the case because low clearance vehicles formed the basis of Table 4.1, and constitute only a small proportion of the typical traffic streams. As such, it may not be justified to increase the existing overhang length values in the Florida "Green Book". At the same time, it may be beneficial to conduct a detailed traffic and vehicle dimension study, in order to update the Florida manuals.

Table 4.1. Design Vehicles for Low Ground Clearance (Eck et al. 2002)

Design Vehicles	Wheel base	Overhang (ft.)		Ground Clearance (in.)			Critical Bay	Ratio of Ground Clearance to Critical Bay (in./ft.)
		Front	Rear	Wheel base	Front	Rear		
Single Unit Trucks:								
Limousine	20	--	--	4	--	--	Wheelbase	0.20
Single Unit Trucks:								
Single Unit Beverage Trucks	24	--	10	6	--	8	Wheelbase	0.25
Articulated Beverage Truck	30	--	--	10	--	--	Wheelbase	0.33
Rear-load Garbage Truck	20	--	12.5	12	--	14	Wheelbase	0.60
Aerial Fire Truck	20	7	12	9	11	10	Wheelbase	0.45
Pumper Fire Truck	22	8	10	7	8	10	Wheelbase	0.32
Buses:								
Minibus	15	--	16	10	--	8	Wheelbase/ Overhang	0.67/0.50
School Bus	23	--	13	7	--	11	Wheelbase/ Overhang	0.30/0.85
Single Unit Transit Bus	25	18	--	8	6	--	Wheelbase/ Overhang	0.32/0.33
Articulated Transit Bus	22/26	--	10	10	--	9	Wheelbase	0.38
Motorcoach	27	7.6	10	7	10	8	Wheelbase	0.26
Trucks:								
Lowboy Trailers < 53 ft	38	--	--	5	--	--	Wheelbase	0.13
Double-drop Trailers	40	--	--	6	--	--	Wheelbase	0.15
Car Carrier Trailers	40	--	14	4	--	6	Wheelbase	0.10
Belly Dump Trailers	40	--	--	11	--	--	Wheelbase	0.28
Recreational Vehicles:								
Passenger Vehicle & Trailer-Private Use	20	--	13	5	--	5	Wheelbase	0.25
Passenger Vehicle & Trailer-Commercial Use	27(24 to hitch)	--	13	7	--	7	Wheelbase	0.26
Recreation vehicles	27	7.8	16	7	6	8	Wheelbase/ Overhang	0.26/0.50

Table 4.2. Design Vehicles for Streets and Highways [FDOT Green Book 2002]

Design Vehicle		Dimension in Feet					
Type	Symbol	Wheelbase	Overhang		Overall Length	Overall Width	Height
			Front	Rear			
Passenger Car	P	11	3	5	19	7	4.25
Single Unit Truck	SU	20	4	6	30	8.5	13.5
Single Unit Bus	BUS	25	7	8	40	8.5	23.5
Articulated Bus	A-BUS	18+24=42	8.5	9.5	60	8.5	10.5
Motor Home	MH	20	4	6	30	8	---
Car & Camper Trailer	P/T	11+5+18=34**	3	10	49	8	---
Car & Boat Trailer	P/B	11+5+15=31**	3	8	42	8	---
Semi-Trailer Combination, Intermediate	WB-40	13+27=40	4	6	50	8.5	13.5
Semi-Trailer Combination, Large	WB-50	20+30=50	3	2	55	8.5	13.5
Semi-Trailer Combination, Combination	WB-60	9.7+20+9.4*+20.9=60	2	3	65	8.5	13.5

*Distance between rear wheels of front trailer and front wheels of rear trailer.
**Distance between rear wheels of trailer and front wheels of car.

Table 4.3. Dimensions (feet) for Design Vehicles for Intersections Highways [FDOT Intersection Design Guide 2002]

Design Vehicle Type	Symbol	Overall			Overhang	
		Height	Width	Length	Front	Rear
Passenger Car	P	4.25	7	19	3	5
Single Unit Truck	SU	11-13.5	8	30	4	6
Intercity Bus	BUS-40	12	8.5	40	6	6.3
Intercity Bus	BUS-45	12	8.5	45	6	8.5
City Transit Bus	CITY-BUS	10.5	8.5	40	7	8
Conventional School Bus	S-BUS 36	10.5	8	35.8	2.5	12
Large School Bus	S-BUS 40	10.5	8	40	7	13
Articulated Bus	A-BUS	11	8.5	60	8.6	10
Intermediate Semi trailer	WB-40	13.5	8	45.5	3	2.5
Intermediate Semi trailer	WB-50	13.5	8.5	55	3	2
Interstate Semi trailer	WB-62*	13.5	8.5	68.5	4	2.5
Interstate Semi trailer	WB-65 or WB-67**	13.5	8.5	73.5	4	4.5-2.5
Double Bottom Semi trailer/Trailer	WB-67D	13.5	8.5	73.3	2.33	3
Triple Semi trailer/Trailers	WB-100T	13.5	8.5	104.8	2.33	3
Turnpike Double Semi trailer/Trailer	WB-109D	13.5	8.5	114	2.33	2.5
Motor Home	MH	12	8	30	4	6
Car and Camper Trailer	P/T	10	8	48.7	3	10
Car and Boat Trailer	P/B	----	8	42	3	8
Motor Home and Boat Trailer	MH/B	12	8	53	4	8

*Design vehicle with 48' trailer as adopted in 1982 STAA (Surface Transportation Assistance Act)
**Design vehicle with 53' trailer as grandfathered in 1982 STAA.

Also, rather than evaluating and posting crossings based on a criterion of satisfying all possible LCVs, it may be sufficient to use the design or critical vehicles described above, as the main criterion of evaluation. In other words, if the crossing can accommodate the design vehicle, then it should not be posted. This also becomes the major factor in developing the design criteria for longitudinal profiles along at-grade highway railroad crossings. For longer and lower LCVs, permits will have to be issued.

As defined earlier, the wheel base critical vehicle is defined by

l_w = 40 ft. and c = 4 in. or 0.33 ft.

$$\begin{aligned}\tan \propto &= c / 0.5\, l_w \\ &= 0.33/(0.5*40) \\ &= 0.0165\end{aligned}$$

$$\begin{aligned}\alpha &= \tan^{-1} [0.0165] \\ &= 0.9495 \text{ degrees}\end{aligned}$$

Ramp breakover angle,

$$\begin{aligned}\beta &= 2 \propto \\ &= 2 * 0.9495 \\ &= 1.8906 \text{ degrees}\end{aligned}$$

Approach Critical Grade or change in grade,

$$G_c = \tan \beta$$
$$= \tan [1.8906]$$
$$= 0.033 \text{ or } 3.33\%$$

This value of critical grade (3.33%) can therefore be established as a major criterion for evaluating or designing profiles for highway railroad grade crossings for possible hang-up of LCVs. Looking closely at Figure 4.2, and assuming critical hang-up situation being the midpoint of the vehicle underside, it could be seen that the available length of the railroad tracks plane should be at least half of the wheelbase length for the critical vehicle.

The plane of the railroad tracks should be flat for at least 20 ft., or half the wheelbase of longer LCVs under a special analysis. If the railroad tracks plane is superelevated, it may require more detailed analysis. If possible, the superelevated plane should be maintained for the longest length possible and then transitioned gradually, again with maximum grade change being 3.33%.

A review of all "hump"-signed crossings in the FDOT RHCI database, indicated that many crossings have approximately 10 ft. available for the flat plane described above. In this case, it is worth it to evaluate a critical situation for LCV hang-up as shown in Figure 4.3 below; the LCV is assumed to hang-up with its midsection completely on the railroad tracks plane. The critical parameter in this situation is the approach grade, indicated by the inclination angle $\propto_1$ or $\propto_2$.

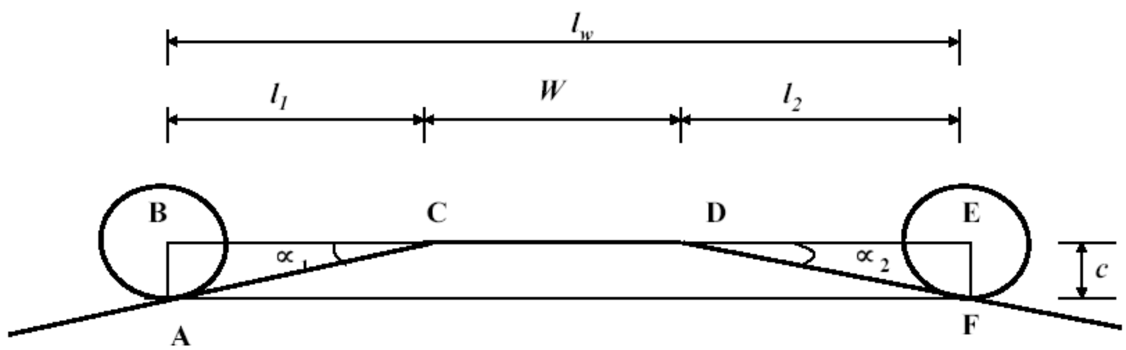


Figure 4.3. The Concept of Breakover Angle for LCV on a Short Grade Crossing

Let us define the following:

W = Length of the railroad tracks plane (ft.).

l_1 = Part of wheelbase length of LCV hanging on the first approach, beyond the railroad tracks plane (ft.).

l_2 = Part of wheelbase length of LCV hanging on the second approach, beyond the railroad tracks plane (ft.).

Using the previous definitions,

LCV wheelbase length, $l_w = l_1 + W + l_2$

Also,

$$l_1 = l_2 = (l_w - W)/2$$

Therefore assuming $W = 10$ ft. (5 ft of track gage + 2 x 2.5 ft of tangent), and design vehicle, with $l_w = 40$ ft. and $c = 0.33$ ft.,

$$l_1 = l_2 = (40 - 10)/2 = 15 \text{ ft.}$$

The approach Critical Grade or change in grade,

$$G_c = \tan \alpha_1 = \tan \alpha_2 = c / l_1 = c / l_2 = 0.33/15 = 0.022 \text{ or } 2.22\%$$

In other words, the approach grade should be less than 2.22% to avoid hang-up by LCVs on railroad crossings with the rail tracks flat plane of about 10 ft. This criterion would equally apply to raising of the rail tracks when asphalt pavement is utilized to taper the new surface to the existing roadway profile. The problem that may be encountered here is in having the adequate tangent length to develop a vertical curve from the rail tracks plane to the approach grade; the tracks' gage of 5 ft. leaves only 2.5 ft. of tangent available.

For an intermediate case of an approaching LCV having just traversed 10 ft. on the tracks plane of a highway railroad grade crossing, as shown in Figure 4.4 a maximum approach slope of 4.4% would be required at this stage of the traverse. The proof is presented in the following paragraph. But the traverse is not complete. This implies that it is necessary to use either the 20 ft. or the 10 ft. track plane options presented above, along with the corresponding approach grade limits.

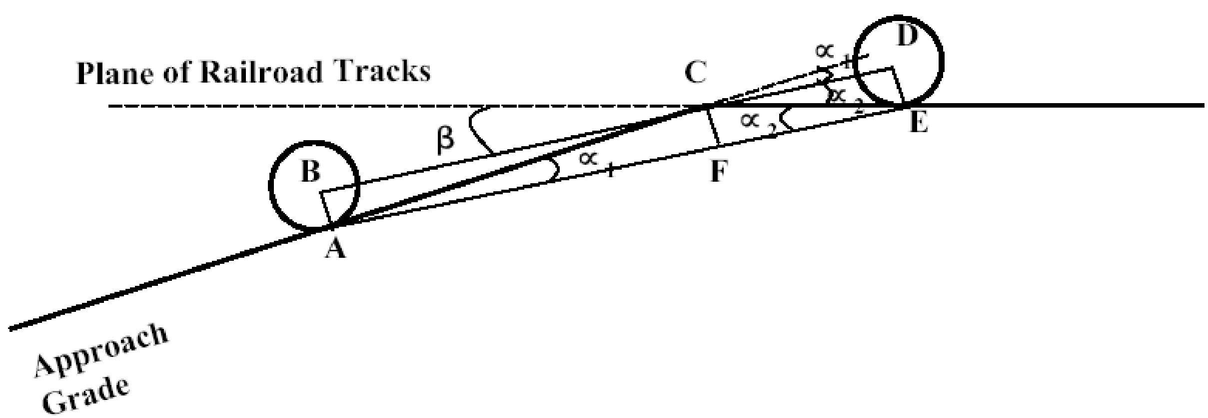


Figure 4.4. The Concept of Breakover Angle for LCV Approaching a Short Grade Crossing

Again, as defined earlier the wheel base critical vehicle is defined by

$l_w = 40$ ft., $l_1 = 30$ ft., $l_2 = 10$ ft., and $c = 4$ in. or 0.33 ft.

$$\alpha_1 = \tan^{-1} [0.33/30] = 0.6302 \text{ deg}$$
$$\alpha_2 = \tan^{-1} [0.33/10] = 1.8901 \text{ deg}$$

Ramp breakover angle,

$$\beta = \alpha_1 + \alpha_2 = 0.6302 + 1.8901 = 2.5203 \text{ deg.}$$

Approach Critical Grade or change in grade,

$G_c = \tan\beta$

$= \tan[2.5203]$

$= 0.044$ *or 4.40%*

The roadway design engineer typically would need to design to meet the immediate profile elevations at the existing railroad crossings. Two alternatives exist. For a 20 ft. flat plane at the crossing, an approach tangent with maximum grade change of 3.33% is recommended. For a 10 ft. flat plane for the crossing, an approach tangent with the maximum grade change of 2.22% is recommended. The difference in option would depend on the adjacent roadway profiles.

Another issue is with fitting vertical curves between the available tangents. Considering that the maximum offset for a 20 ft. vertical curve between two tangents of 3.33% grade difference, is only 1 in. (even less for the 2.22% grade difference), it might be okay to use portion of the tracks plane as a tangent. In many cases, such as with nearby roadway intersections, it may not be convenient to transition from the crossing to a flat grade of 2.22%, to meet an existing steep approach grade.

4.2 Vertical Sag Curves

According to the AASHTO Design Guides, one of the criteria for establishing lengths of sag vertical curves is the headlight sight distance (AASHTO 1994). This criterion states that when a vehicle traverses a sag vertical curve at night, with the headlight beam at a height H above the roadway surface and inclined at an angle δ to the horizontal, the parabolic curve between two straight tangents of algebraic grade difference A (Figure 4.5) can be given as under two situations as follows:

1. Sight distance S is greater than the curve length L:

$$L = 2S - \frac{200(H + S\tan\delta)}{A}$$

2. Sight distance S is less than the curve length L:

$$L = \frac{AS^2}{200(H + S\tan\delta)}$$

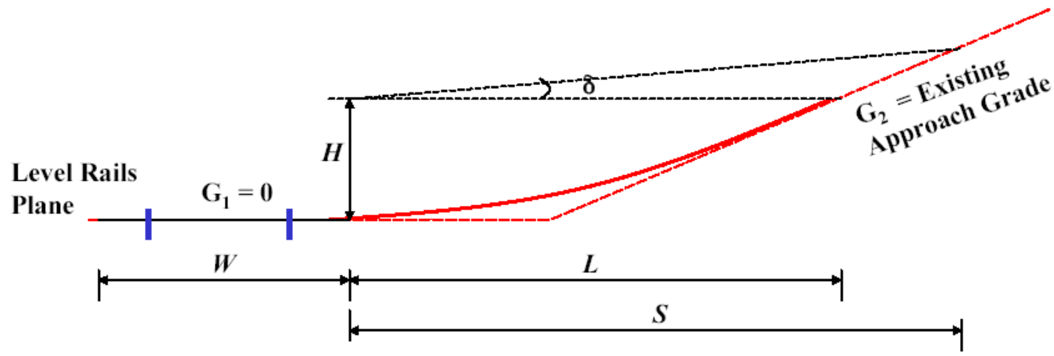


Figure 4.5. AASHTO Design Headlight Beam Criterion for Sag Vertical Curves

In the situation of LCV drag or hang-up on sag vertical curves, these AASHTO equations can be adopted, with the conditions of angle $\delta = 0$ and distances L = S. It should be noted that the headlight height H now becomes the vehicle ground clearance (c), while curve length L is the projected length of vehicle that is susceptible to the hang-up (i.e. the vehicle's front or rear overhang length). The critical curve length or overhang length can then be estimated as

$$L = \frac{200H}{A} = \frac{200c}{A}$$

where,

L	=	Length of a parabolic curve or LCV overhang (ft.)
c	=	Ground clearance of the LCV (in.), when used, should be converted to feet units.
A	=	Algebraic difference between the approach grades (%).

If the first approach grade is designated as G_1 (%), and the other approach grade as G_2 (%), then A is simply the algebraic difference between G_1 and G_2.

For a flat railroad tracks plane, depending on the direction of travel G_1 or $G_2 = 0$. For simplicity sake let us take $G_1 = 0$, then the critical curve length (L) is given as

$$L = \frac{200c}{G_2}$$

Also $G_2 = \dfrac{200c}{L}$

Knowing the ground clearance and the overhang length of a LCV, the critical slope of an approach grade can be estimated for the vertical profile of a highway railroad grade crossing. Using the design vehicles from Eck and Kang (1993) as shown in Table 4.1, the critical vehicle for front overhang is the Single Unit Transit Bus with c = 6 in. and L = 18 ft.
Therefore, assuming a flat plane of railroad tracks, the critical approach grade is estimated as

$$G_2 = \frac{200 \times 0.5}{18} = 5.55\%$$

If we consider a 20 ft. curve length, at the same ground clearance,

$$G_2 = \frac{200 \times 0.5}{20} = 5.00\%$$

This implies that using the design vehicle, hang-up can be avoided if a 20 ft. sag vertical curve is provided with a maximum approach grade of 5%.

For the LCV rear overhang, the critical vehicles are the Minibus and Recreation Vehicles with c = 8 in. and L = 16 ft.

Performing similar calculations as shown above for the front overhang situation for an assumed flat plane of railroad tracks,

$$G_2 = \frac{200 \times 0.67}{16} = 8.38\%$$

Again, if we consider a 20 ft. curve length, at the same ground clearance,

$$G_2 = \frac{200 \times 0.67}{20} = 6.70\%$$

Similar calculations for specific LCV will indicate the unique requirement for the vehicle. For example, a school bus is indicated with measurements L = 13 ft. and c = 11 in. To accommodate this vehicle, a short sag vertical curve of 13 ft. will be adequate, between two approach grades having a maximum algebraic difference of 14.2%. Using 20 ft. curve, the maximum grade difference should be about 9%.

To summarize the design considerations for sag vertical curves for highway railroad grade crossings, it is suggested that a vertical parabolic curve of 20 ft. length connect the flat plane of the railroad tracks, to an approach grade of a maximum value of 5%. Ideally, the entire curve should be located beyond the outermost rail in the direction of the approach grade. In the case of superelevated tracks, the tracks plane becomes a tangent with non-zero grade and t the approach tangents should be adequately provided to develop the curve(s).

4.3 Proposed Vertical Profile Criteria

Currently AASHTO and FDOT recommend a maximum approach grade of 3 in. over 28 ft. (about 1%) for both vertical crest and sag curves for highway railroad grade crossings. For crest vertical curves, a vertical parabolic curve should connect approach grades, each of a maximum value of 3.33%, to the flat plane of the railroad tracks. A 20 ft. minimum length is also desired for the plane of the railroad tracks. Preserving the central 10 ft. of this flat plane, (containing the 5 ft. rail track gages), there is 7.5 ft. available on the outside, on each side of the racks. Ideally, this 7.5 ft. should also be flat on be on the same plane as the central 10 ft. but to incorporate a curve, a 10 ft. tangent can be initiated on each side, from a point 2.5 ft. beyond the outermost rail. This would allow 20 ft. crest vertical curves to be developed, originating from about 2 ft. beyond the outermost rail. For superelevated sections, the vertical curve at the crossing should be developed such that the immediate approach grade’s value is not higher than the difference between 3.3% and the track superelevation in percent.

Based on the methodologies formulated above, a modification of AREA/AASHTO/FDOT recommendations is presented as follows, with the strikeouts and additions highlighted:

> *"To prevent low-clearance vehicles from becoming caught on the tracks, **located on crest vertical curve**, the crossing surface should be of the same plane as the top of the rails for a distance of ~~2~~ **7.5** feet outside the rails. The surface of the highway should also not be more than ~~3~~ 9 inches ~~higher or~~ lower than the top of the nearest rail at a point 30 feet from rail, **measured at right angle thereto**, unless track superelevation makes a different level appropriate. Vertical curves **of 20 ft. lengths** should be used to traverse from the highway grade to a level plane at the elevation of the rails, **ensuring that the change in tangent grades does not exceed 3.33%.** Rails that are superelevated, or a roadway approach that is not level, will necessitate a site specific analysis for rail clearances, **but in most cases, two tangents can be used to fit 20 ft. vertical curve, ensuring that the change in tangent grades does not exceed a value equal to 3.33% plus the rails superelevation rate in percent."***

It should also be noted that ITE (2001) states "..allow 0.3% on area outside rails to prevent sheet flooding on crossing. This implies an approach grade of 3.33% plus the 0.3% or 3.63%. Therefore the recommendations may be modified again as:

> *"To prevent low-clearance vehicles from becoming caught on the tracks, **located on crest vertical curve**, the crossing surface should be of the same plane as the top of the rails for a distance of 2 feet outside the rails**, and then tapered down 0.3% to prevent sheet flooding for the next 5 ft.** The surface of the highway should also not be more than ~~3~~ 10 inches ~~higher or~~ lower than the top of the nearest rail at a point 30 feet from rail, **measured at right angle there to**, unless track superelevation makes a different level appropriate. Vertical curves **of 20 ft. lengths** should be used to traverse from the highway grade to a level plane at the elevation of the rails**, ensuring that the change in tangent grades does not exceed 3.63%.** Rails that are superelevated, or a roadway approach that is not level, will necessitate a site specific analysis for rail clearances, **but in most cases, two tangents can be used to fit 20 ft. vertical curve, ensuring that the change in tangent grades does not exceed a value equal to 3.63% plus the rails superelevation rate in percent."***

The recommendation stated above assumes that 20 ft. flat planes can be obtained for the tracks. In cases of restricted 10 ft. track planes, the following recommendation will hold, assuming the 2.5 ft. beyond rails can be ignored in the case of sheet flooding:

> *"To prevent low-clearance vehicles from becoming caught on the tracks**, located on crest vertical curve**, the crossing surface should be of the same plane as the top of the rails for a distance of 2 feet outside the rails. The surface of the highway should also not be more than ~~3~~ 7.5 inches ~~higher or~~ lower than the top of the nearest rail at a point 30 feet from rail, **measured at right angle there to**, unless track superelevation makes a different level appropriate. Vertical curves **of 20 ft. lengths** should be used to traverse from the highway grade to a level plane at the elevation of the rails, **ensuring that the change in tangent grades does not exceed 3.33%.** Rails that are superelevated, or a roadway approach that is not level, will necessitate a site specific analysis for rail clearances**, but in most cases, two***

> ***tangents can be used to fit 20 ft. vertical curve, ensuring that the change in tangent grades does not exceed a value equal to 3.33% plus the rails superelevation rate in percent."***

For sag vertical curves the recommendations are as follows:

> *"To prevent low-clearance vehicles from becoming caught on the tracks,* ***located on sag vertical curve****, the crossing surface should be of the same plane as the top of the rails for a distance of ~~2~~ 10 feet outside the rails. The surface of the highway should also not be more than ~~3~~ 6 inches higher ~~or lower~~ than the top of the nearest rail at a point ~~30~~ 20 feet from rail,* ***measured at right angle thereto****, unless track superelevation makes a different level appropriate. Vertical curves* ***of 20 ft. lengths*** *should be used to traverse from the highway grade to a level plane at the elevation of the rails****, ensuring that the change in tangent grades does not exceed 5%****. Rails that are superelevated, or a roadway approach that is not level, will necessitate a site specific analysis for rail clearances,* ***but in most cases, two tangents can be used to fit 20 ft. vertical curve, ensuring that the change in tangent grades does not exceed a value equal to 5% plus the rails superelevation rate in percent."***

It should also be noted that hang-up of LCV may occur on roadway sections away from the railroad crossing itself due to the roadway vertical alignment.

The following general steps are recommended in design of crossing profiles:

1. Inspect the existing terrain around grade crossing; decide on the design methods, i.e., preliminary locations of tangents and vertical curves.
2. Establish the various tangents and grades using the ground elevations.
3. Choose curve lengths.
4. Select pertinent points for the vertical curve: PVC, PVI, and PVT, tying the point to existing elevations as much as possible.
5. Calculate the curve elevations.
6. Run the Profile Evaluator Computer Program on the new profile, using the low clearance (design or specific) vehicle.
7. Revise the design as appropriate, suggesting suitable rehabilitation methods.

Two sets of computer programs were written for profile evaluation at grade crossings: one using Microsoft Visual Basic, and another for preliminary evaluation and design considerations, using Microsoft Excel. Suggested design methods are illustrated in the following figures for various situations. First, as illustrated in Figure 4.6, two vertical crest curves and a sag curve can be fitted to the approaches of highway-railroad grade crossing (flat plane), providing a profile that would prevent the hang up of the (design) low clearance vehicle. As later discussed in this section of the report, there are many cases of hump crossings located near a roadway intersection or a roadway curve (illustrated in Figure 4.7). This poses a serious constraint for fitting vertical crest curves where the situation becomes compounded when the tracks are superlelevated. The suggested solution here is to fit a series of vertical curves, ensuring that each time, the algebraic difference in grades is less than 3.33%, as shown in Figures 4.8 and 4.9.

For grade crossings located on sag vertical curves, vertical curves can also be fitted, as shown in Figure 4.10 for a simple flat plane rail track, and that the change in grade is less 5.55%, with proper drainage before the tracks provided. There are also cases of multiple tracks at different elevations. In this case, though the geometry is entirely within the jurisdiction of the railroad company, it suggested that the track separation, between outer rails, be at least 20 ft., and that the slope of the separation area be a maximum of 3.33% (Figure 4.11).

General combination of multiple vertical curves is further illustrated in Figure 4.12, In cases where permanent vertical profile modifications are not possible, the use of portable ramps for the special movement of a load are suggested as illustrated in Figure 4.14. The top elevations of the ramps can be estimated based on the required vertical curves and the tangents. It should be noted that permanent raising of the approach grades to a hump crossing may require short retaining walls if right-of-way is not available, as illustrated in Figure 4.15, for a roadway cross section, near the tracks.

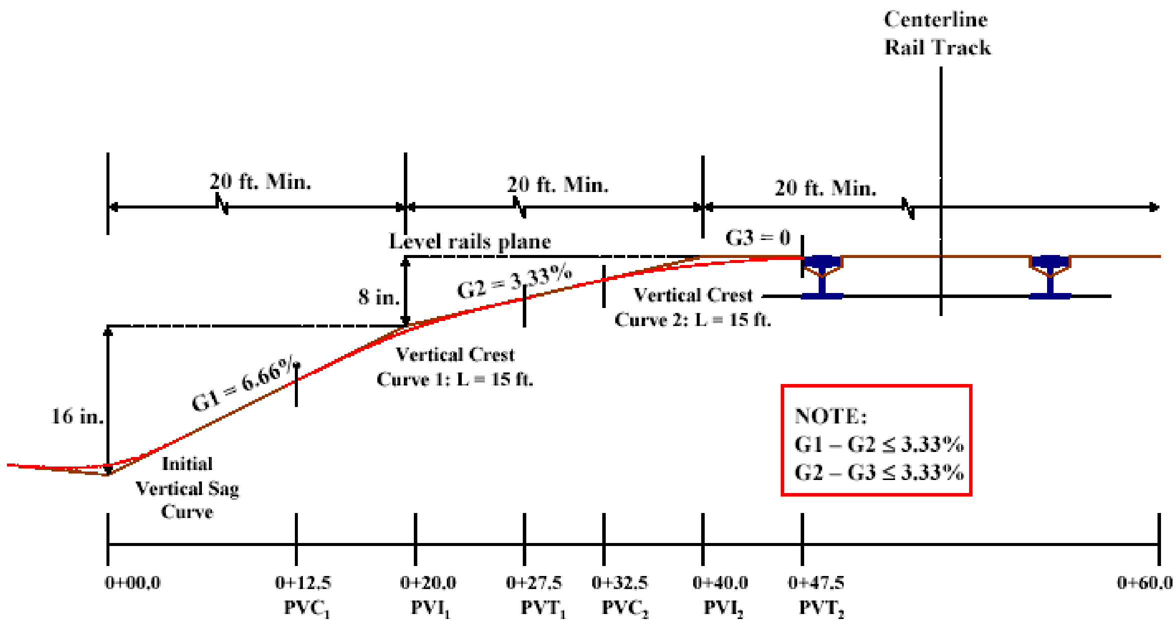


Figure 4.6. Fitting Three Vertical Curves To An Approach To A Railroad Crossing Profile

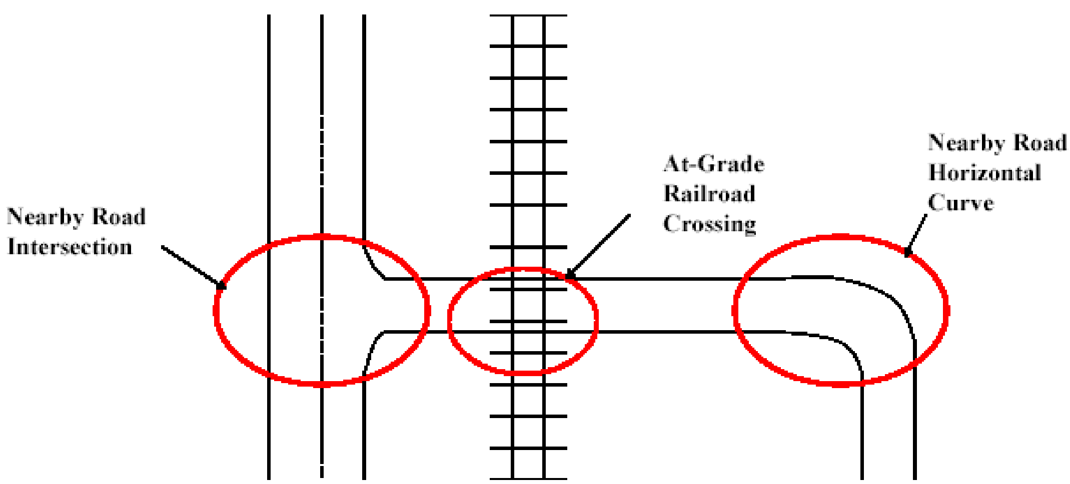


Figure 4.7. Nearby Road Intersections or Curved Roadways at a Railroad Crossing

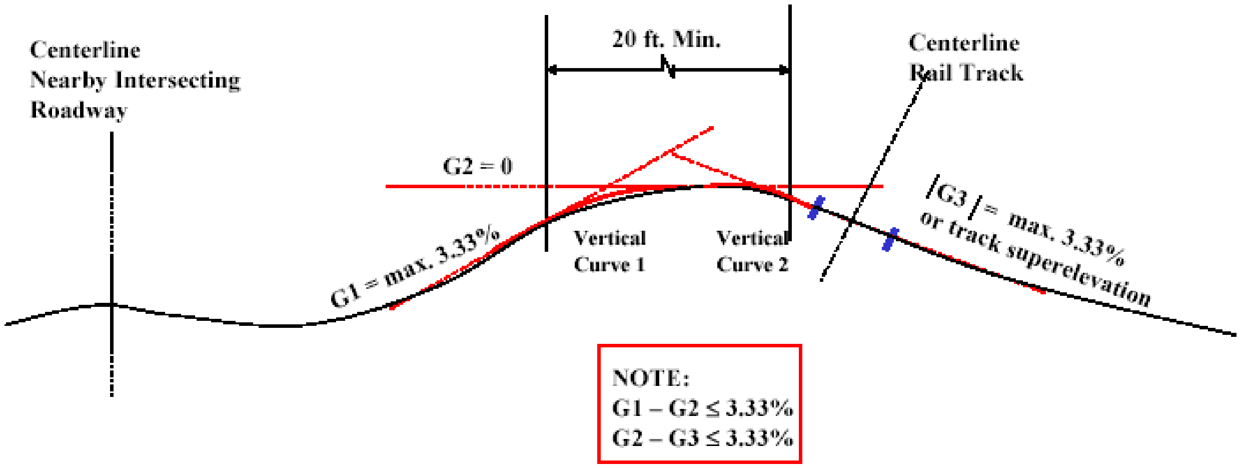


Figure 4.8. Fitting Two Vertical Crest Curves To A Railroad Crossing With Superelevated Tracks.

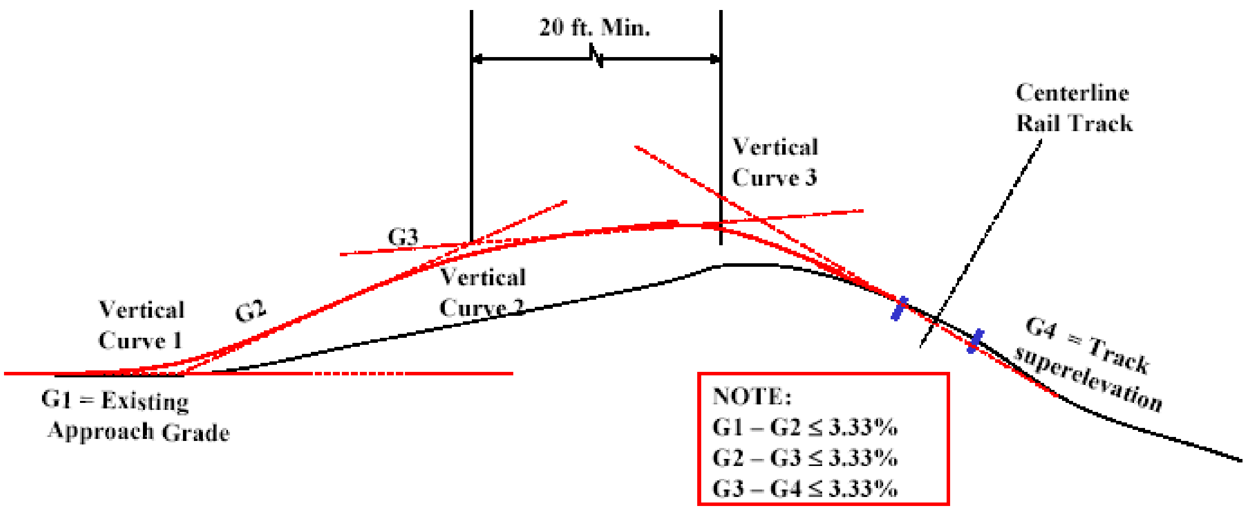


Figure 4.9. Fitting Three Vertical Crest Curves To A Railroad Crossing With Superelevated Tracks.

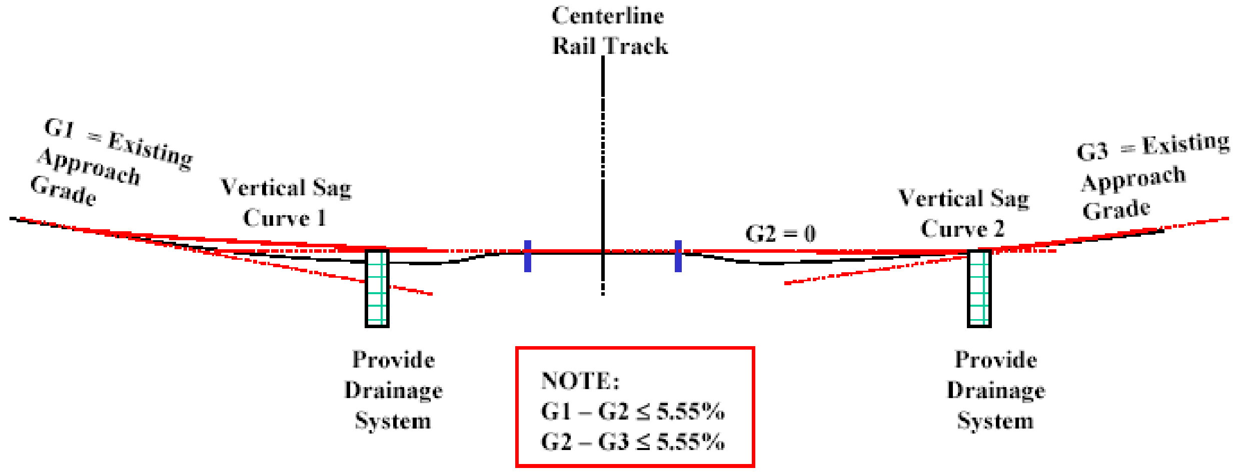


Figure 4.10. Fitting Two Vertical Sag Curves To A Railroad Crossing.

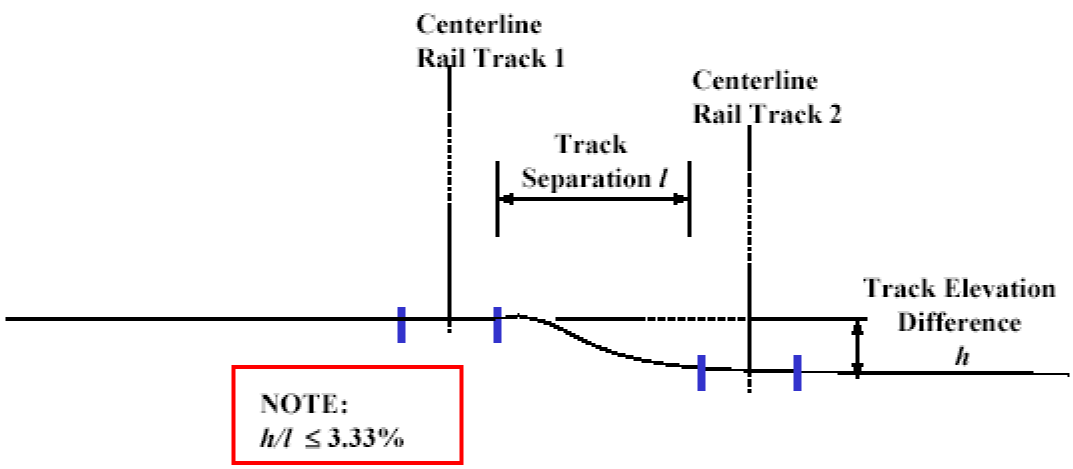


Figure 4.11. Track Separation Profile on Multiple Track Crossings.

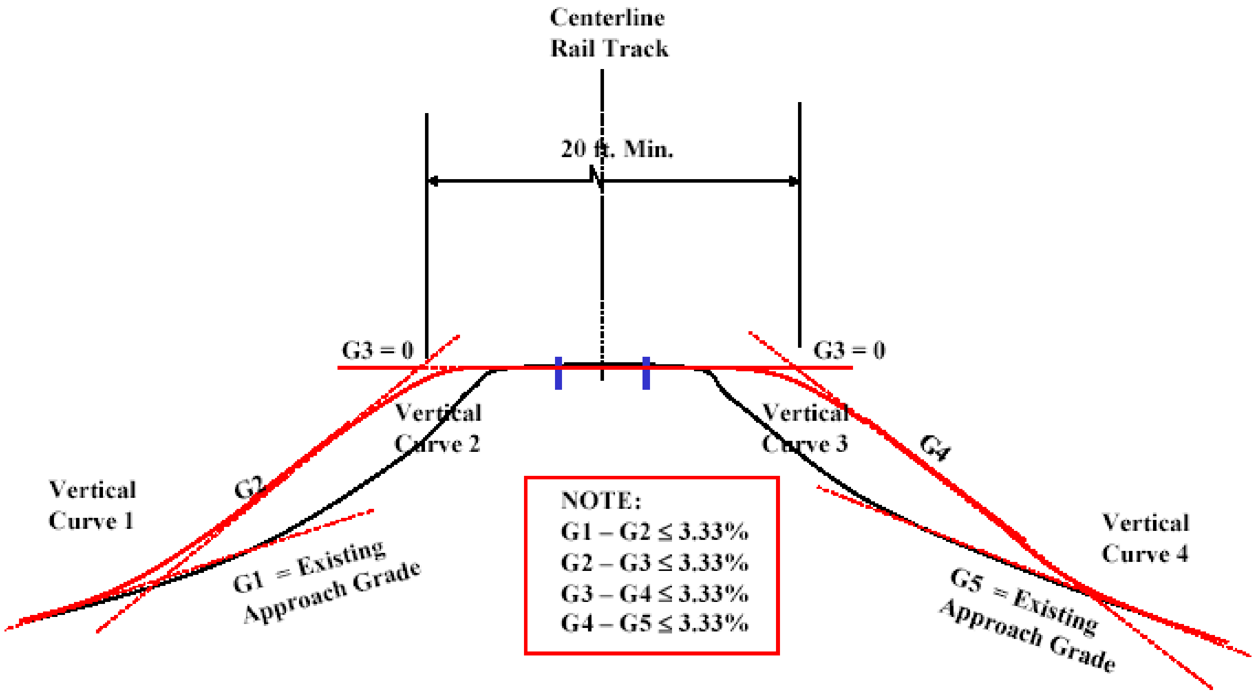


Figure 4.12. Fitting Multiple Vertical Crest Curves to a Railroad Crossing With Flat Plane Tracks.

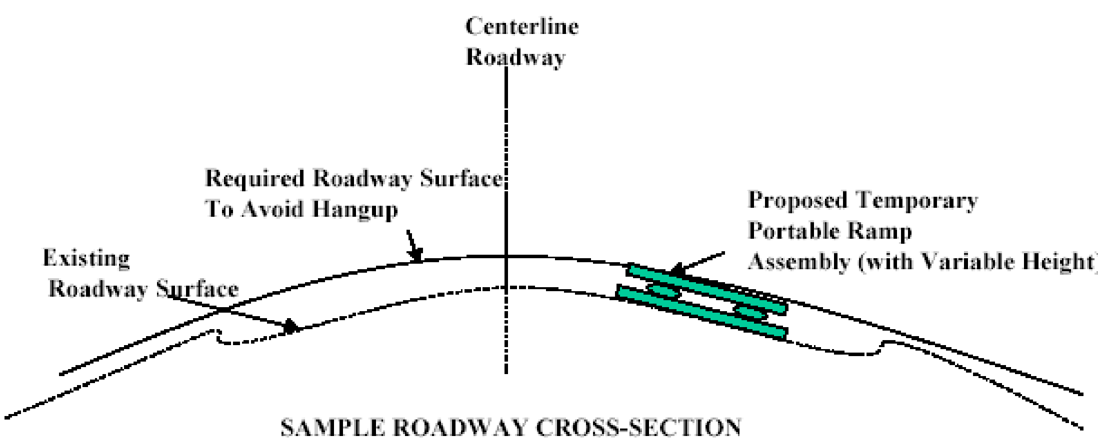


Figure 4.13. Roadway Cross Section near a Grade Crossing: Use of Portable Temporary Ramp.

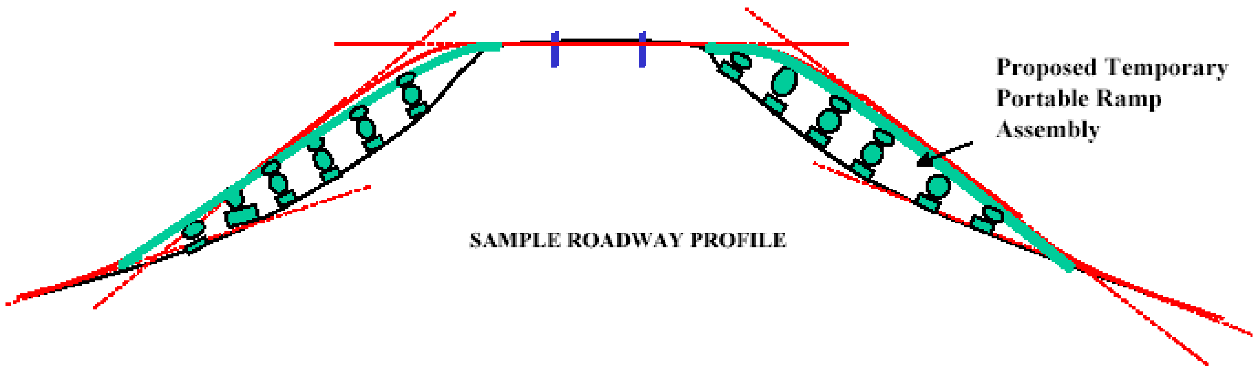


Figure 4.14. Use of Portable Temporary Ramp at Railroad Crossings (Roadway Profile).

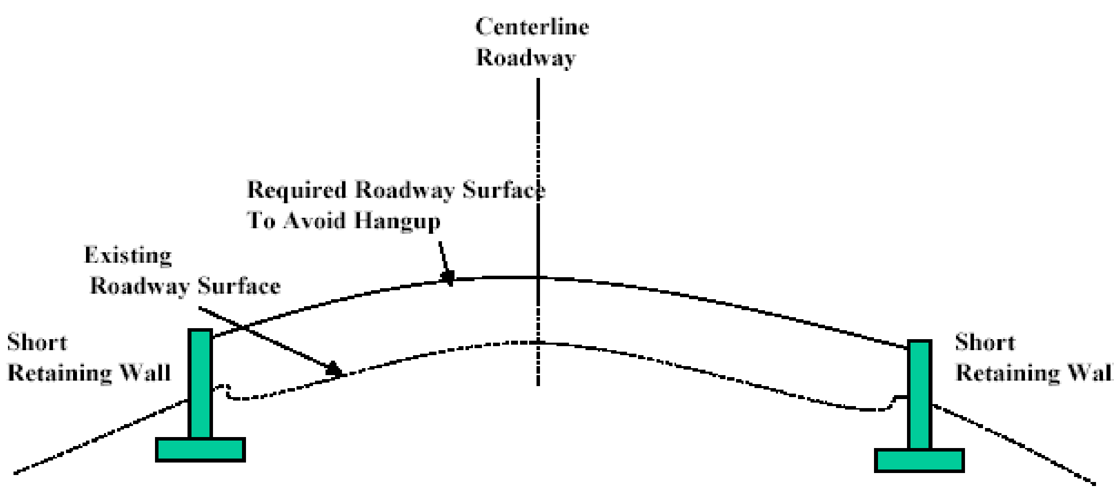


Figure 4.15. Raising Roadway Surface: Roadway Cross-Section Near a Grade Crossing

4.4 Simulation of Low Clearance Vehicles on Profiles

Using Microsoft Excel tools developed under this study, grade crossing profiles at the five locations with surveyed centerline profiles were analyzed for possible hang-up by the design low clearance vehicle.

The required profiles according to some existing design guidelines are shown (e.g., FDOT current guidelines, and AREMA 1993 design guides), in comparison with the proposed profile grade requirements based on the design low clearance vehicle. Crossing No. 625497V (S.R. 14) in Madison is shown in Figure 4.16 during a preliminary analysis where a vertical curve can be conveniently fitted between an approach grade of +4%, to a flat tangent at the tracks plane. Crossing No. 620928T in Clay County (Center Street in Green Cove Springs) is shown in a more detailed analysis (Figure 4.17). This particular crossing will not satisfy any of the design requirements therefore rehabilitation of the profile is needed. The current FDOT design guide requires an almost flat plane as shown. Within 10 ft. of the tracks outermost rails, the AREMA requirement is almost the same as the proposed 10 ft. tracks plane option for design low clearance vehicle (Figure 4.18). Looking at the 20-ft. tracks plane option of the proposed model, the grade requirements are different within about 20 ft. beyond the outermost tracks (Figure 4.19). To prevent hang-up at this crossing, it will be necessary to either provide a temporary ramp or construct a new pavement profile with surface elevations satisfying the profile requirements. In both cases, a new profile will be required, fitting vertical curves as appropriate to match the existing approach and tracks profile. To accomplish this, the 20 ft. tracks plane option is used to illustrate, including the provision of a “piecewise ramp” from 3.33% to 6.66% grades. These “piecewise ramp” elevations can be used to generate vertical curves or build a portable ramp for traversing the grade crossing. Figure 4.21 shows the proposed profile while Figure 4.22 estimates portable ramp elevations at each approach grade.

Similar analyses are shown again in Figures 4.23 to 4.29 for two other grade crossings: Crossing No. 620921V at C.R. 315B North of Green Cove Springs and Crossing No. 621004S at C.R. 308 Outside of Crescent City, both located in Clay County. Table 4.4 presents the sample vertical curve computations for Crossing No. 621004S.

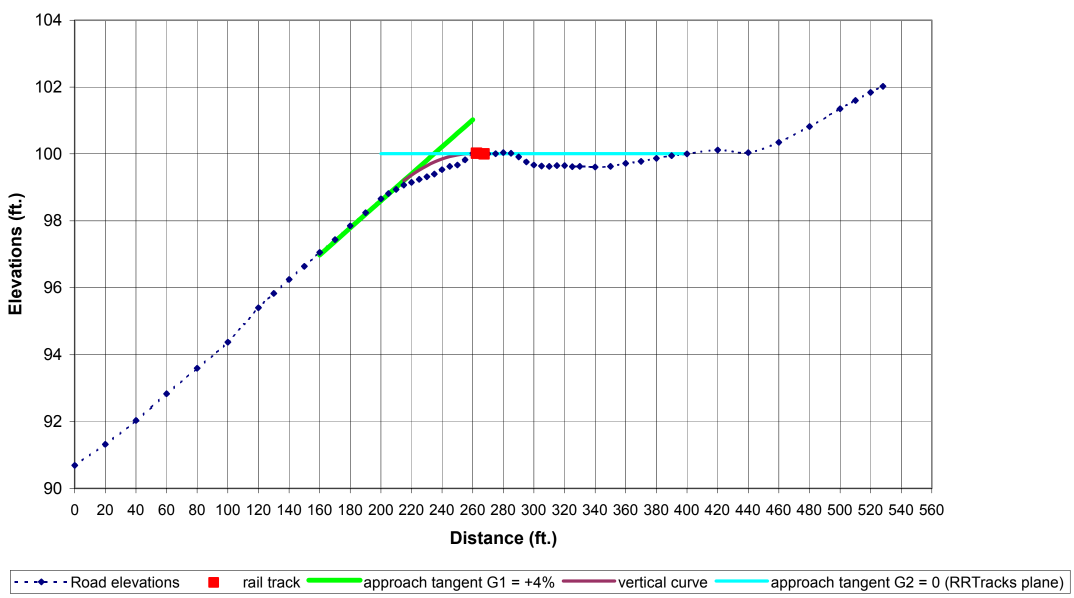


Figure 4.16. Hang-up Rehabilitation Evaluation for Crossing No. 625497V, Madison County, Florida (Rdwy C/L elevations; RR Tracks C/L at approx. 265 ft., Elev. 100 ft.)

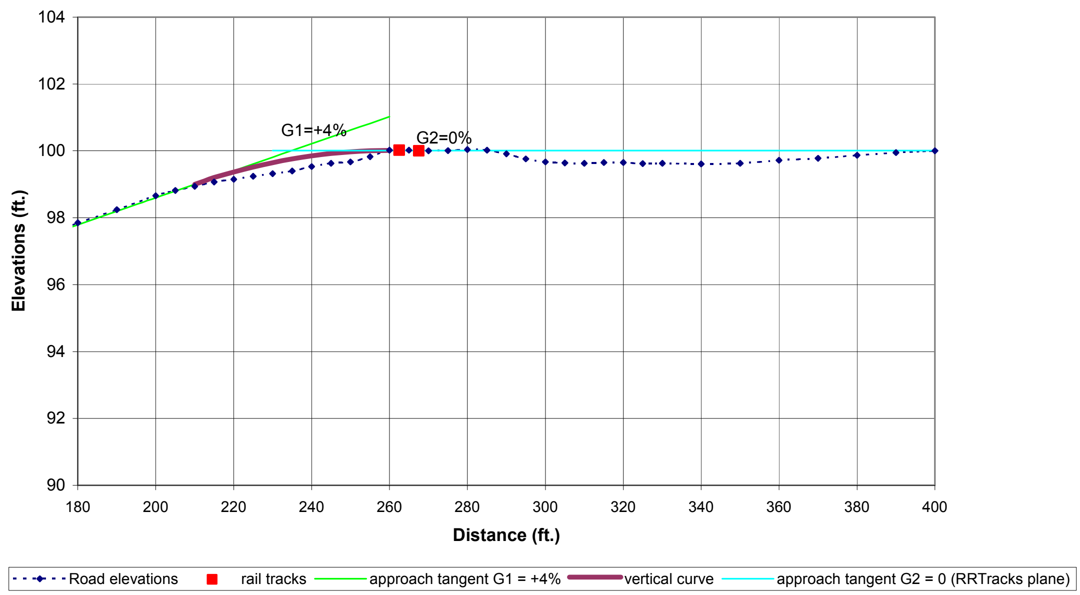


Figure 4.17. Closer View: Hang-up Rehabilitation Evaluation for Crossing No. 625497V, Madison County, Florida

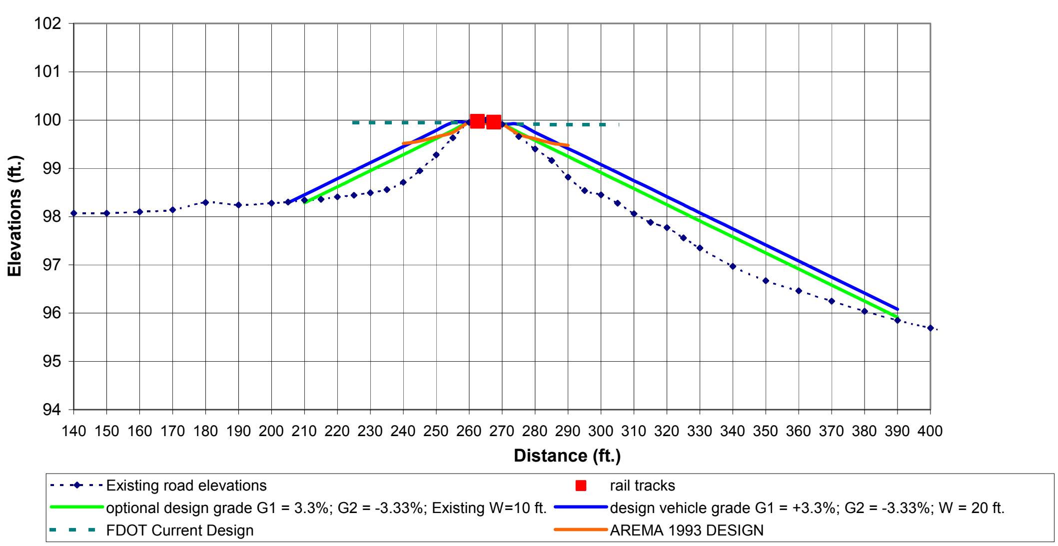


Figure 4.18. Closer View1: Hang-up Rehabilitation Evaluation for Crossing No. 620928T, Clay County, Florida

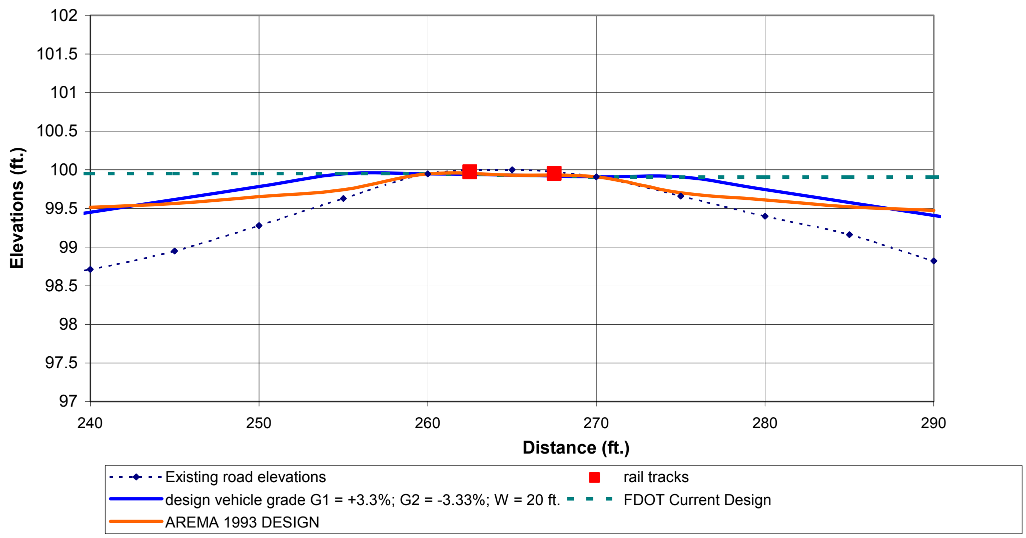


Figure 4.19. Closer View2: Hang-up Rehabilitation Evaluation for Crossing No. 620928T, Clay County, Florida

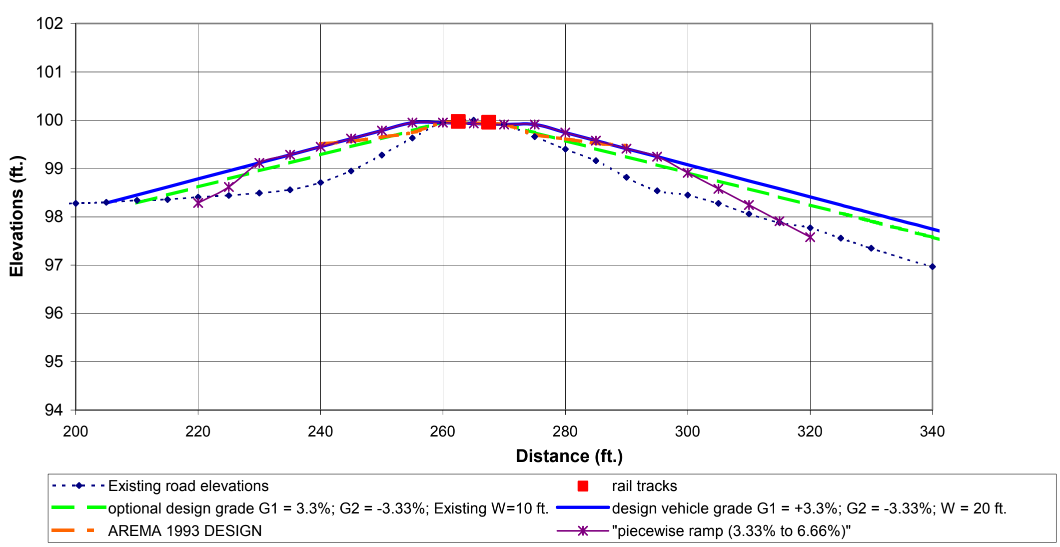


Figure 4.20. Closer View3: Hang-up Rehabilitation Evaluation for Crossing No. 620928T, Clay County, Florida

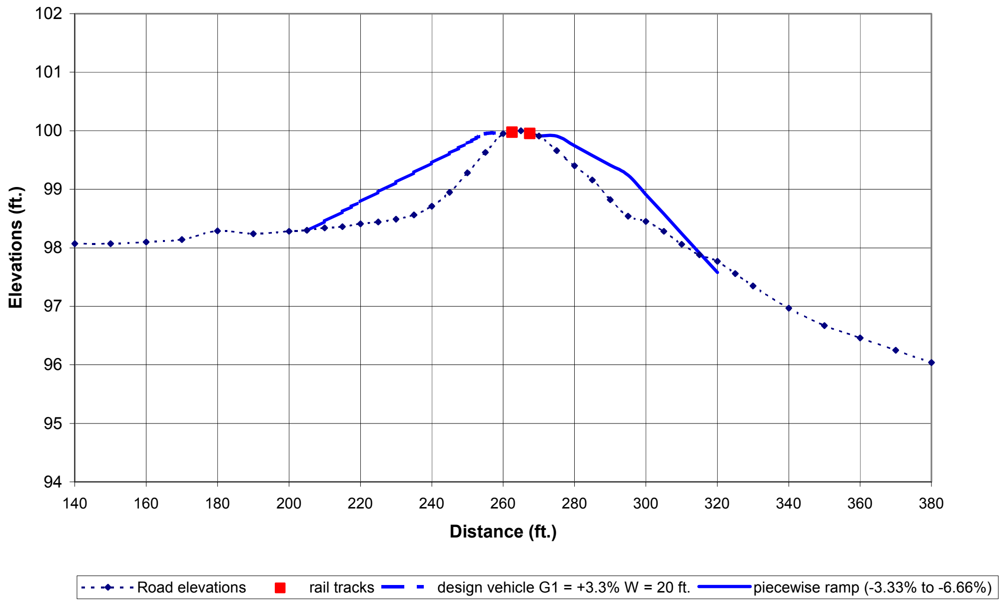


Figure 4.21. Closer View3: Hang-up Rehabilitation Evaluation for Crossing No. 620928T, Clay County, Florida

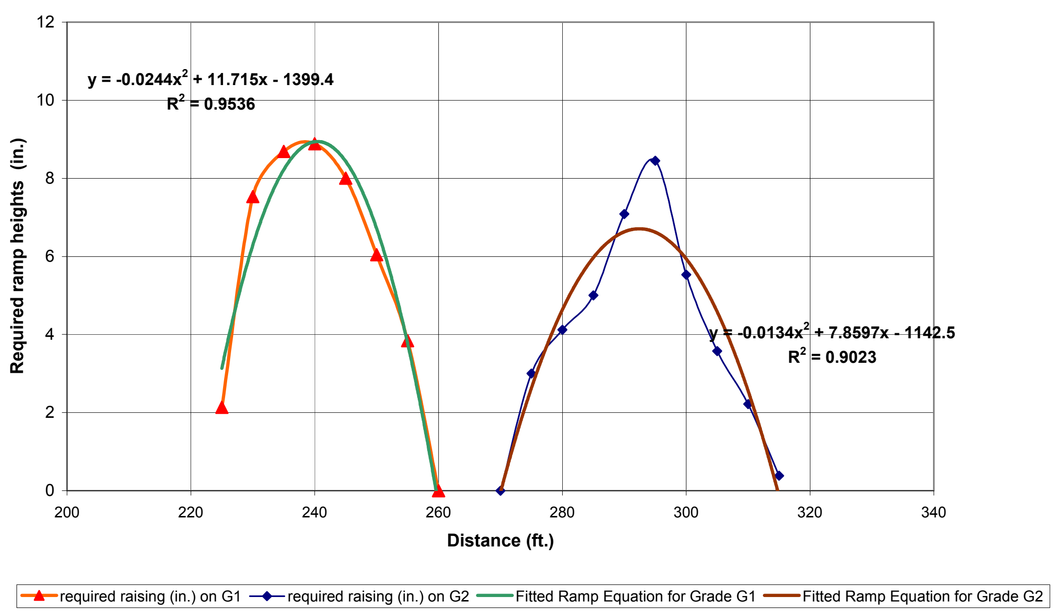


Figure 4.22. Hang-up Rehabilitation Evaluation: Ramp Height Requirements for Crossing No. 620928T, Clay County, Florida

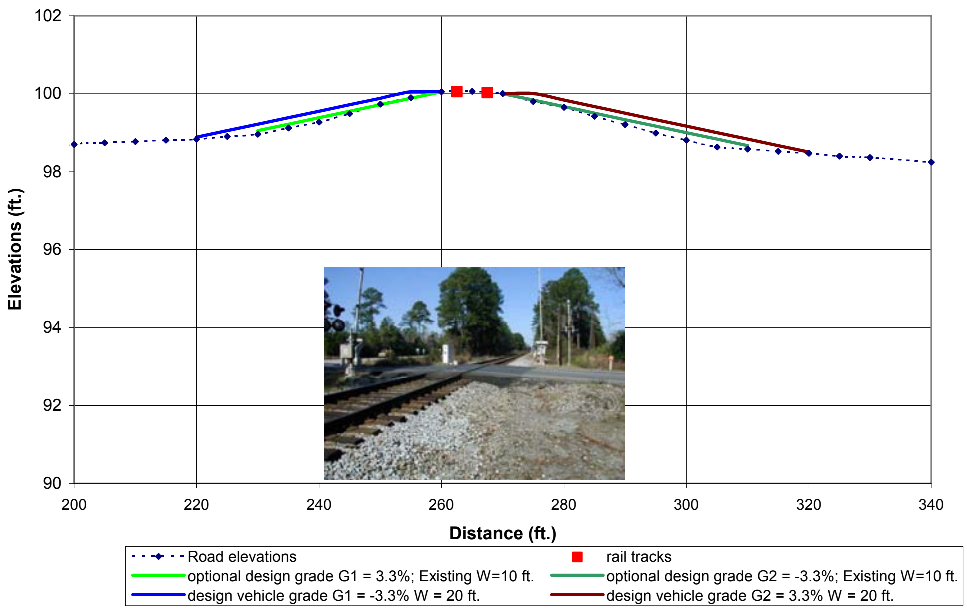


Figure 4.23. Closer View1: Hang-up Rehabilitation Evaluation for Crossing No. 620921V, Clay County, Florida

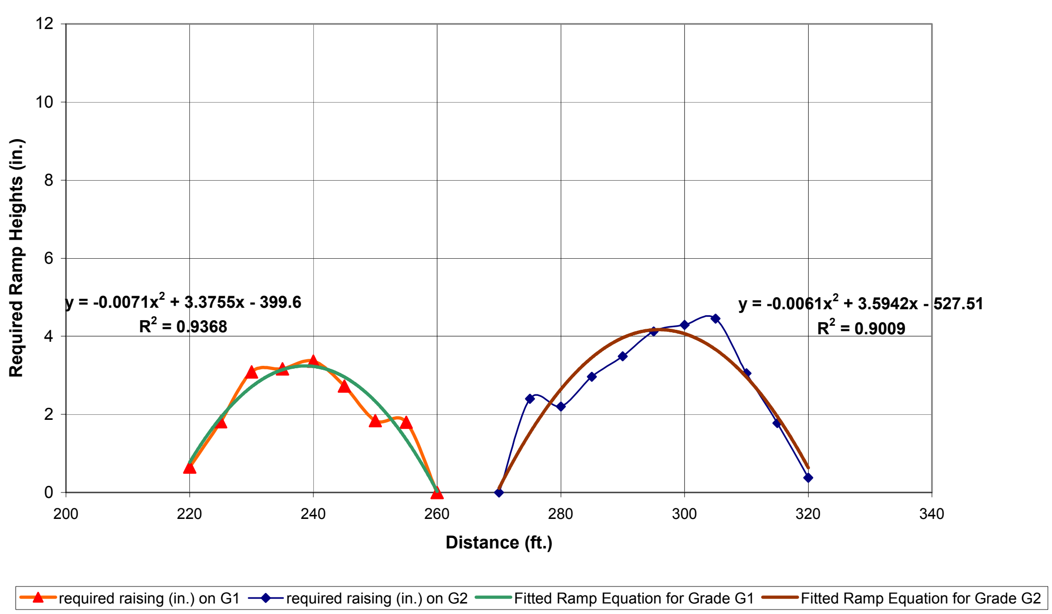


Figure 4.24. Hang-up Rehabilitation Evaluation: Ramp Heights Requirement for Crossing No. 620921V, Clay County, Florida

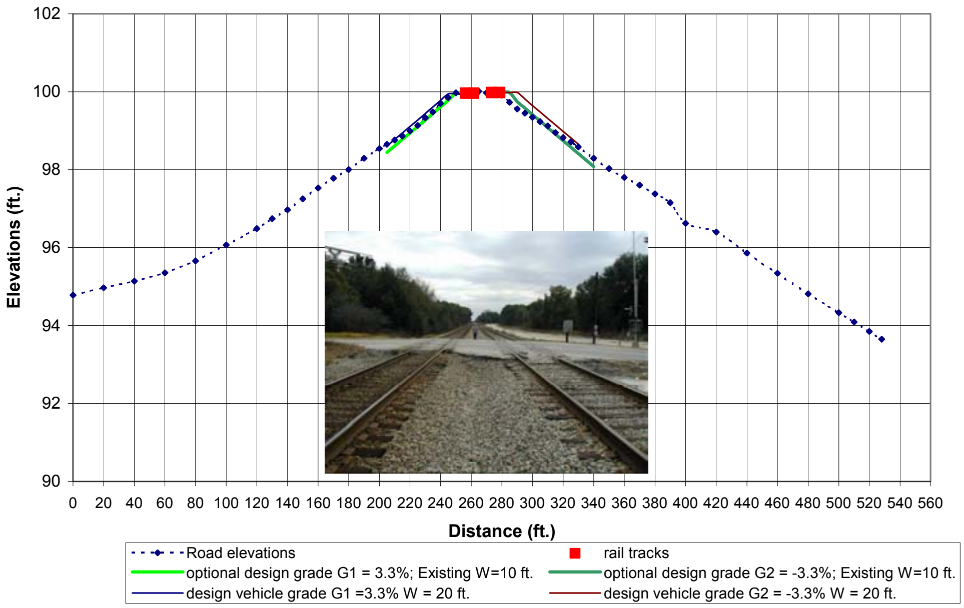


Figure 4.25. Hang-up Rehabilitation Evaluation for Crossing No. 621004S, Clay County, Florida, (Rdwy C/L elevations; RR Tracks C/L at approx. 265 ft., Elev. 100 ft.)

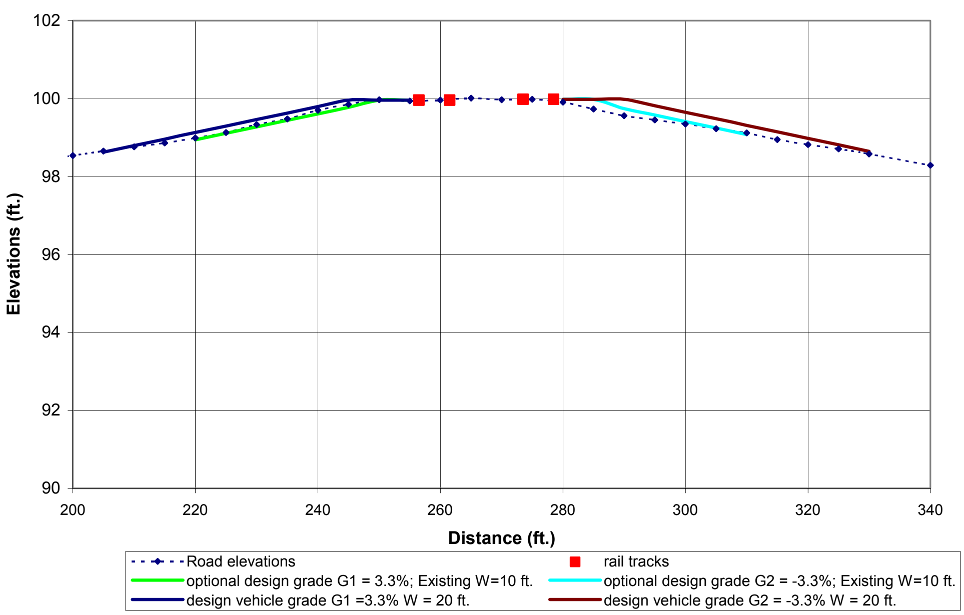


Figure 4.26. Closer View1: Hang-up Rehabilitation Evaluation for Crossing No. 621004S, Clay County, Florida

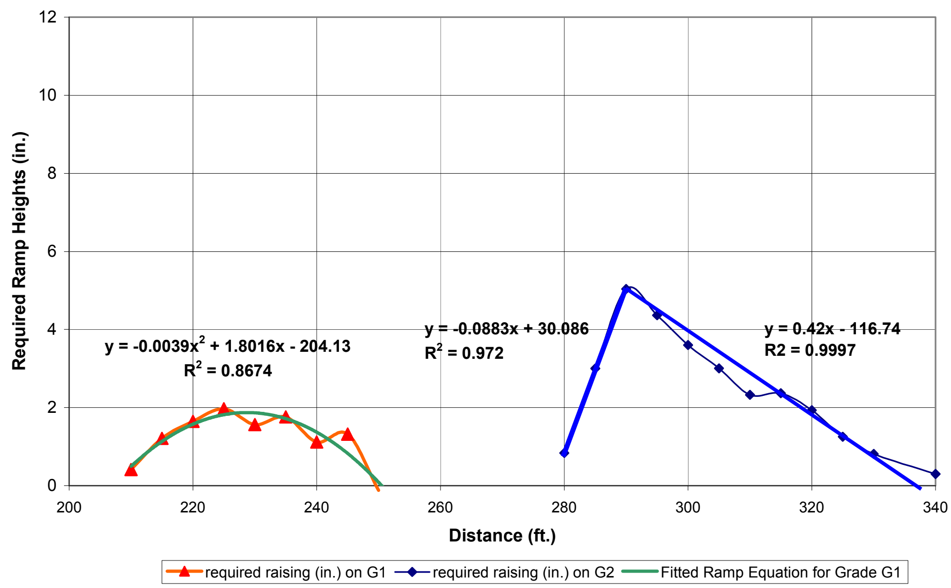


Figure 4.27. Hang-up Rehabilitation Evaluation: Ramp heights Requirement for Crossing No. 621004S, Clay County, Florida

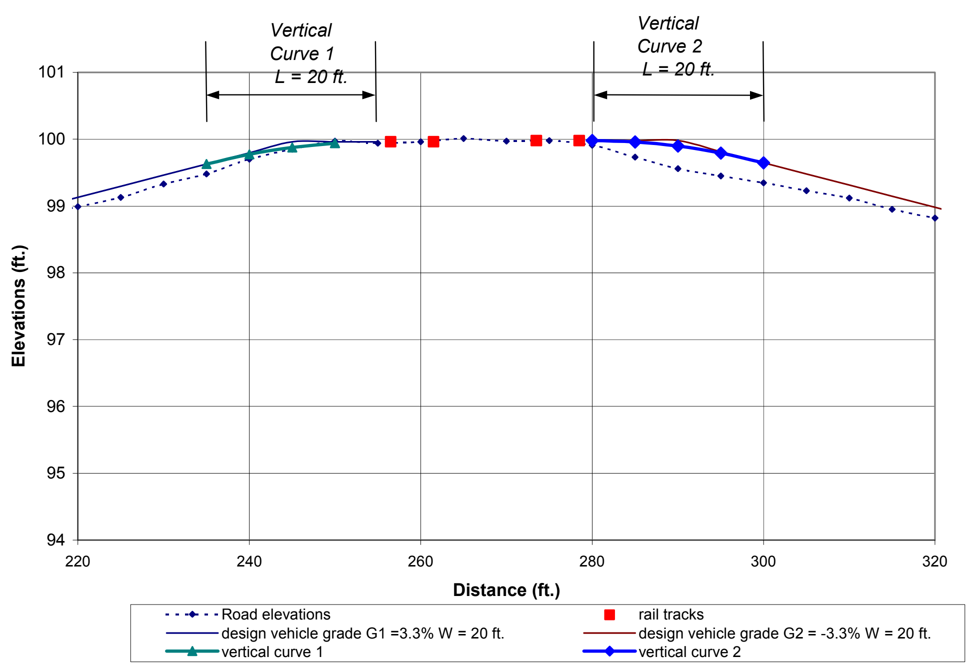


Figure 4.28. Hang-up Rehabilitation Evaluation: Vertical Curves for Crossing No. 621004S, Clay County, Florida,

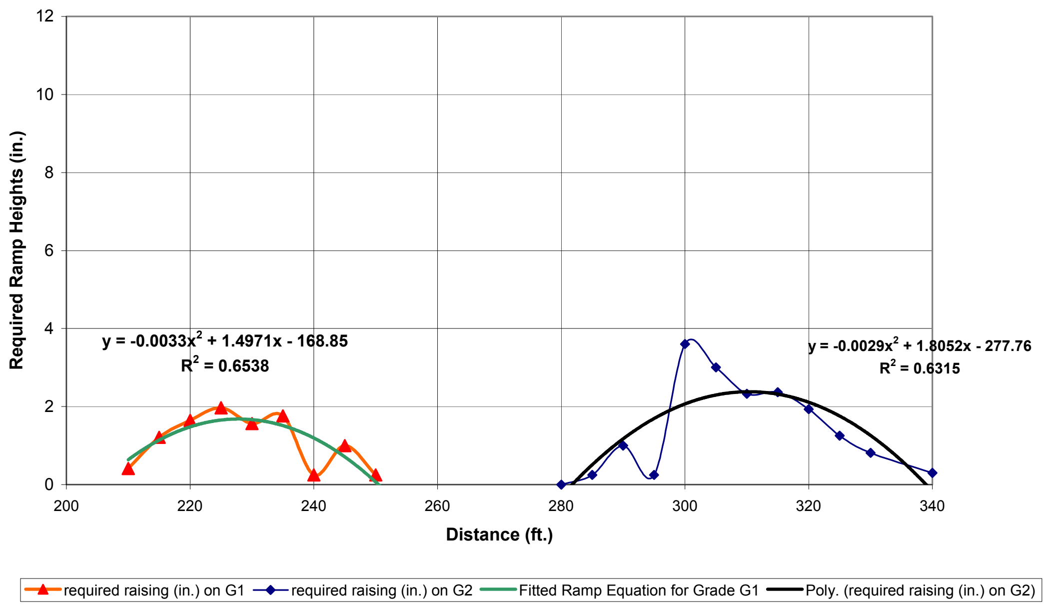


Figure 4.29. Hang-up Rehabilitation Evaluation: Ramp Heights Requirement for Crossing No. 621004S, Clay County, Florida,

Table 4.4. Hang-up Rehabilitation Evaluation: Vertical Curve Computations for Crossing No. 621004S, Clay County, Florida, (Rdwy C/L elevations; RR Tracks C/L at approx. 265 ft., Elev. 100 ft.)

Location	Offset (ft.)	Tangent Elevation (ft.)	Curve Elevation (ft.)
VERTICAL CURVE 1			
235	0.000	99.627	99.627
240	0.021	99.794	99.773
245	0.083	99.960	99.877
250	0.187	100.127	99.939
255	0.333	100.293	99.960
VERTICAL CURVE 2			
280	0.000	99.980	99.980
285	0.021	99.980	99.959
290	0.083	99.980	99.897
295	0.187	99.980	99.793
300	0.333	99.980	99.647

4.5 Profile Survey Documentation, Design Table, and Charts

For illustrative purposes, the Table 4.5 below and charts in Figures 4.30 to 4.32 were generated, as design aids for selecting maximum approach grades to highway railroad grade crossings, in evaluation for potential hang-up by low clearance vehicles. For tracks widths (W) of 10 ft., 15 ft., and 20 ft., critical approach grades are shown for various vehicle wheelbase lengths and ground clearances (c). A detailed geometric profile survey documentation form was also developed to aid inspectors in the field survey of grade crossings (Appendix D). The form describes inventory data of crossings, as well as checking the recorded ground elevations of approach grades, for the hang-up potential of low clearance vehicles. As mentioned earlier, Microsoft Excel tools were developed, as well as a comprehensive computer software program written and compiled in Microsoft Visual Basic 6.0, to serve as design and rehabilitation aids for evaluation of hang-up potential of low clearance vehicles at highway railroad grade crossings.

Table 4.5 Recommended Maximum Approach Grades for Highway Railroad Grade Crossings

Wheelbase (ft.)	Maximum Approach Grade, $G_{critical}$ (Tracks Width W = 10 ft.)			Maximum Approach Grade, $G_{critical}$ (Tracks Width W = 15 ft.)			Maximum Approach Grade, $G_{critical}$ (Tracks Width W = 20 ft.)		
	Ground Clearance, c = 4 in.	Ground Clearance, c = 6 in.	Ground Clearance, c = 8 in.	Ground Clearance, c = 4 in.	Ground Clearance, c = 6 in.	Ground Clearance, c = 8 in.	Ground Clearance, c = 4 in.	Ground Clearance, c = 6 in.	Ground Clearance, c = 8 in.
20	6.60%	10.00%	13.40%	13.20%	20.00%	26.80%			
22	5.50%	8.33%	11.17%	9.43%	14.29%	19.14%	33.00%	50.00%	67.00%
24	4.71%	7.14%	9.57%	7.33%	11.11%	14.89%	16.50%	25.00%	33.50%
26	4.13%	6.25%	8.38%	6.00%	9.09%	12.18%	11.00%	16.67%	22.33%
28	3.67%	5.56%	7.44%	5.08%	7.69%	10.31%	8.25%	12.50%	16.75%
30	3.30%	5.00%	6.70%	4.40%	6.67%	8.93%	6.60%	10.00%	13.40%
32	3.00%	4.55%	6.09%	3.88%	5.88%	7.88%	5.50%	8.33%	11.17%
34	2.75%	4.17%	5.58%	3.47%	5.26%	7.05%	4.71%	7.14%	9.57%
36	2.54%	3.85%	5.15%	3.14%	4.76%	6.38%	4.13%	6.25%	8.38%
38	2.36%	3.57%	4.79%	2.87%	4.35%	5.83%	3.67%	5.56%	7.44%
40	2.20%	3.33%	4.47%	2.64%	4.00%	5.36%	3.30%	5.00%	6.70%
42	2.06%	3.13%	4.19%	2.44%	3.70%	4.96%	3.00%	4.55%	6.09%
44	1.94%	2.94%	3.94%	2.28%	3.45%	4.62%	2.75%	4.17%	5.58%
46	1.83%	2.78%	3.72%	2.13%	3.23%	4.32%	2.54%	3.85%	5.15%
48	1.74%	2.63%	3.53%	2.00%	3.03%	4.06%	2.36%	3.57%	4.79%
50	1.65%	2.50%	3.35%	1.89%	2.86%	3.83%	2.20%	3.33%	4.47%
52	1.57%	2.38%	3.19%	1.78%	2.70%	3.62%	2.06%	3.13%	4.19%
54	1.50%	2.27%	3.05%	1.69%	2.56%	3.44%	1.94%	2.94%	3.94%
56	1.43%	2.17%	2.91%	1.61%	2.44%	3.27%	1.83%	2.78%	3.72%
58	1.38%	2.08%	2.79%	1.53%	2.33%	3.12%	1.74%	2.63%	3.53%
60	1.32%	2.00%	2.68%	1.47%	2.22%	2.98%	1.65%	2.50%	3.35%
62	1.27%	1.92%	2.58%	1.40%	2.13%	2.85%	1.57%	2.38%	3.19%
64	1.22%	1.85%	2.48%	1.35%	2.04%	2.73%	1.50%	2.27%	3.05%
66	1.18%	1.79%	2.39%	1.29%	1.96%	2.63%	1.43%	2.17%	2.91%
68	1.14%	1.72%	2.31%	1.25%	1.89%	2.53%	1.38%	2.08%	2.79%
70	1.10%	1.67%	2.23%	1.20%	1.82%	2.44%	1.32%	2.00%	2.68%
72	1.06%	1.61%	2.16%	1.16%	1.75%	2.35%	1.27%	1.92%	2.58%
74	1.03%	1.56%	2.09%	1.12%	1.69%	2.27%	1.22%	1.85%	2.48%
76	1.00%	1.52%	2.03%	1.08%	1.64%	2.20%	1.18%	1.79%	2.39%
78	0.97%	1.47%	1.97%	1.05%	1.59%	2.13%	1.14%	1.72%	2.31%
80	0.94%	1.43%	1.91%	1.02%	1.54%	2.06%	1.10%	1.67%	2.23%

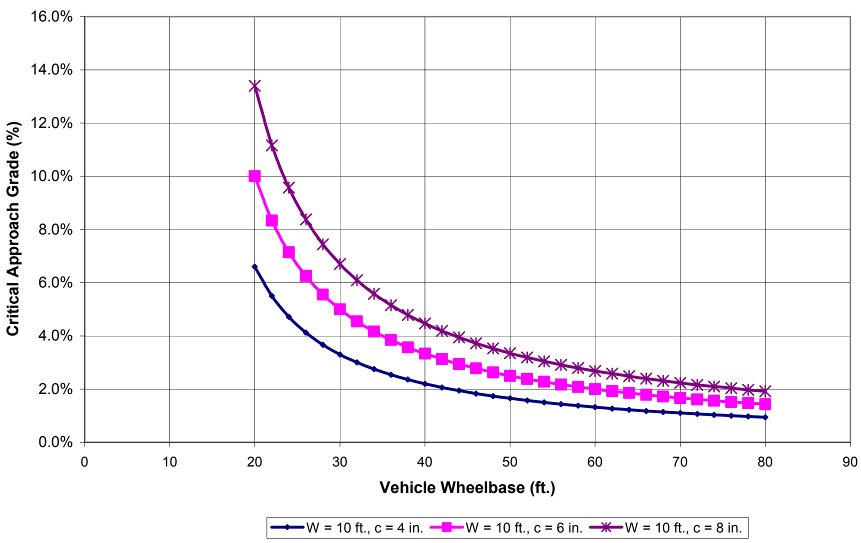


Figure 4.30. Variation in Critical Approach Grades for Highway Railroad Grade Crossings, Based on Vehicle Wheelbase and Ground Clearance (Track Width = 10 ft.)

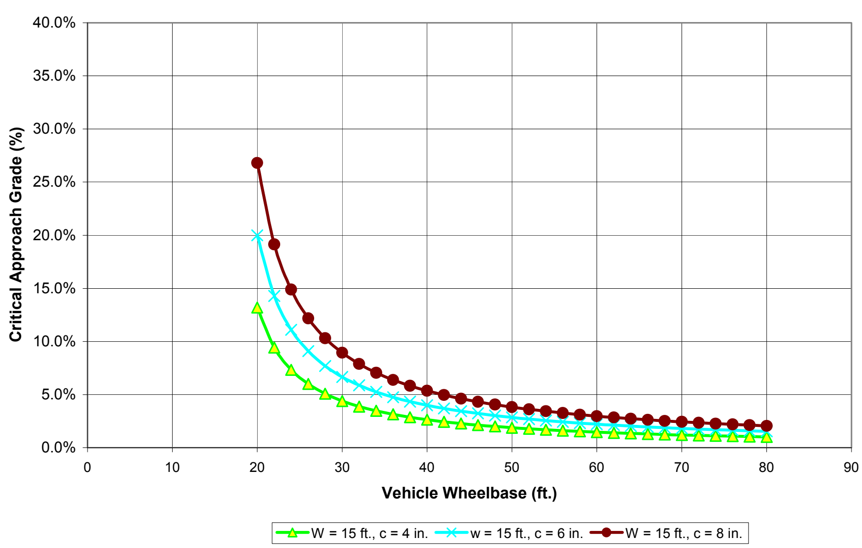


Figure 4.31. Variation in Critical Approach Grades for Highway Railroad Grade Crossings, Based on Vehicle Wheelbase and Ground Clearance (Track Width = 15 ft.)

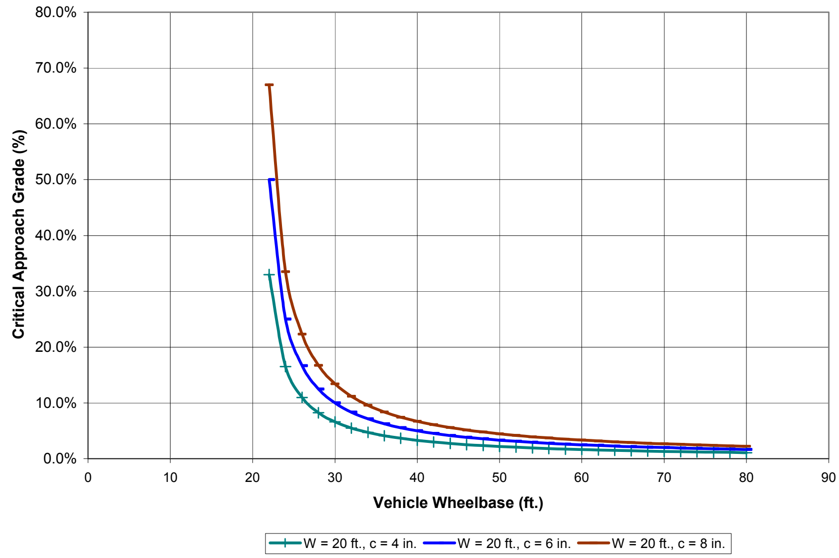


Figure 4.32. Variation in Critical Approach Grades for Highway Railroad Grade Crossings, Based on Vehicle Wheelbase and Ground Clearance (Track Width = 20 ft.)

4.6 Review of Critical Hump Crossings in Florida: Design Implications

In order to observe the overall pattern of properties of hump crossings on Florida roadways, a review was done of the crossings in the FDOT's RHCI database. The results are summarized in the following pages. A list of 44 crossings was generated from the database, to include the crossings identified in the records as being hump-signed or prone to low clearance vehicle hang-up, (e.g. located on vertical sag curves). Table 4.6 and Figure 4.33 summarize the findings from the overall review of the crossings in terms of the following attributes of each crossing: nearness to roadway intersections; nearness to roadway cures; asphalt buildup on rail tracks; vertical sag location; number of tracks; and superelevation of the tracks.

As seen in Figure 4.33, more than half of these grade crossings are located near a roadway intersection or a roadway curve, while one crossing is located near both. This could pose a serious design constraint in an effort to provide a suitable rehabilitation against potential hang-up by low clearance vehicles. All the identified crossings have asphalt buildup on the tracks, suggesting some maintenance work done by the railroad company, usually for tracks raising. In other words, tracks' raising by railroad companies or other forms of maintenance, may be responsible for creating all the hump crossings, and consequent potential for hang-up of low clearance vehicle at the crossings. Only three of the 44 crossings were located on vertical sag curve, suggesting a lower relative importance of the hang-up analyses of rear and front overhangs of low clearance vehicles, in comparison to the wheelbase analyses. Most of the crossings (about 90%) identified in this critical list, were single tracks, while about 30% were on superelevated tracks. The inventory photographs of some of these critical crossings are shown in Figures 4.34 to 4.47.

Table 4.6. Review of Highway Grade Crossings: Hump-Signed/ Prone To Low Clearance Vehicle Hang-up

	Crossing ID	Highway Street Name	Near Road Inter-section (< 50 ft.)?	Near Horiz. Road Curve?	Asphalt Buildup on Rail Tracks?	On Vertical Curve Sag Point?	Number of Tracks	Super-elevated Tracks?
1	272609N	NE 141st St., Miami, Fl.	YES	NO	YES	NO	1	YES
2	339724L	N 8th St., Pensacola, Fl.	YES	NO	YES	NO	1	NO
3	620904E	Moody St., Orange Park, Fl.	YES	NO	YES	NO	1	NO
4	620905L	Birchwood Dr., Orange Park, Fl.	YES	NO	YES	NO	1	NO
5	620906T	Woodland Dr., Orange Park, Fl.	YES	NO	YES	NO	1	YES
6	620908G	Greenridge Dr., Orange Park, Fl.	NO	NO	YES	NO	1	NO
7	620909N	Lakeside Villa., Orange Park, Fl	NO	NO	YES	NO	1	YES
8	620927L	Middlebug Ave., Greencove Sp, Fl	NO	NO	YES	NO	1	YES
9	620988C	CR 309, Pomona Park, Fl	YES	NO	YES	NO	1	NO
10	621286K	Lake Winona Rd., De Leon Sp, Fl	NO	NO	YES	NO	1	YES
11	622064E	Palmetto St., Lake Mary, Fl	YES	NO	YES	NO	1	NO
12	623002K	Lk Alfred Rd, Lake Alfred, Fl	NO	NO	YES	NO	1	NO
13	624155S	Interlachen Pkwy, Lakeland, Fl	YES	NO	YES	NO	1	YES
14	625103D	SE 180 St./ CR 10, Oxford, Fl	YES	NO	YES	NO	1	NO
15	625677T	Lipona Rd, Tallahassee	NO	NO	YES	NO	1	NO
16	625688F	Midway Rd., Quincy, Fl	NO	NO	YES	NO	2	YES
17	625689M	CR 268, Quincy, Fl.	YES	NO	YES	NO	2	YES
18	625692V	Ray Rd., Quincy, Fl	YES	NO	YES	NO	1	NO
19	625694J	Key Farms Rd., Quincy, Fl	NO	NO	YES	NO	1	NO
20	625695R	Dade Street., Quincy, Fl	NO	NO	YES	NO	1	NO
21	625700K	Shelfer St., Gretna, Fl	NO	NO	YES	NO	1	NO
22	625708P	Graded Rd., Gadsden, Fl	YES	YES	YES	NO	1	NO
23	625709W	Private Rd., Gadsden, Fl	YES	NO	YES	NO	1	NO
24	625710R	Private Rd., Gadsden, Fl	YES	NO	YES	YES	1	NO
25	625711X	Crystal Lane, Gretna, Fl	YES	NO	YES	NO	1	NO
26	625713L	CR 379, Gretna, Fl	NO	NO	YES	NO	1	NO
27	625714T	Atwater Rd., Gretna, Fl	NO	NO	YES	YES	1	YES
28	625715A	Crawfish Rd., Chattahoochee, Fl	NO	YES	YES	NO	1	NO
29	625716G	Lincoln Dr., Chattahoochee, Fl	NO	NO	YES	NO	2	NO
30	625727U	Crawfish Rd., Chattahoochee, Fl	NO	NO	YES	NO	1	NO
31	625735L	Tower Rd., Tallahassee, Fl	NO	NO	YES	NO	2	NO
32	625737A	SR 270, Havana, Fl	NO	YES	YES	YES	1	NO
33	625741P	Salem Rd., Havana, Fl	YES	NO	YES	NO	1	NO
34	625742W	Cutoff Rd., Havana, Fl	YES	NO	YES	NO	1	NO
35	625744K	SR 12, Havana, Fl	NO	NO	YES	NO	1	NO
36	625746Y	Country Club Dr, Havana, Fl	YES	NO	YES	NO	1	NO
37	625748M	Graded Rd., Havana, Fl	YES	NO	YES	NO	1	YES
38	625751V	Jamieson Rd., Havana, Fl	NO	NO	YES	NO	1	NO
39	625760U	W. Washington, Havana, Fl	NO	YES	YES	NO	1	NO
40	625761B	Franklin St., Quincy, Fl	YES	NO	YES	NO	1	NO
41	625762H	King St., Quincy, Fl	YES	NO	YES	NO	1	YES
42	625765D	Forest Dr., Quincy, Fl	YES	NO	YES	NO	1	YES
43	625766K	SR 267, Quincy, Fl	NO	NO	YES	NO	1	YES
44	625587U*	Adams St., Tallahassee, Fl	NO	NO	YES	NO	1	NO
		TOTALS	22	4	44	3	40	13
		%YES or Single Track	50.0%	9.1%	100.0%	6.8%	90.9%	29.5%

* Added by author based on observation; not listed as hump-signed or hang-up-prone in the FDOT inventory database.

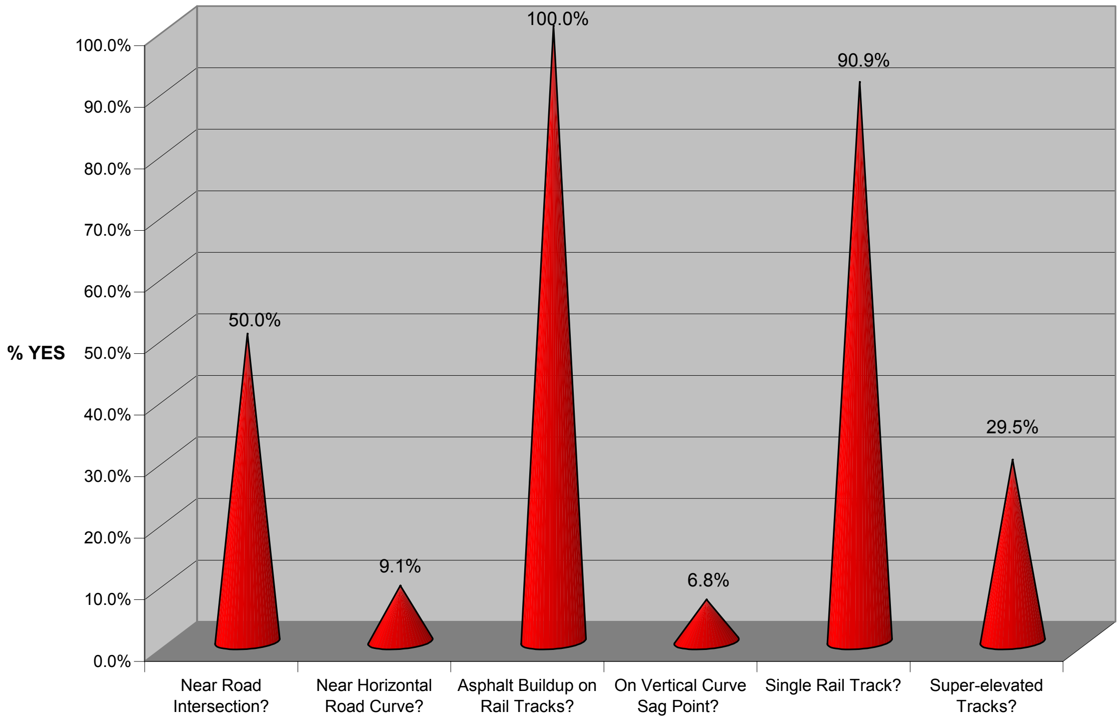


Figure 4.33. Attributes of Highway At-Grade Crossings In Florida: Hump-Signed Or Prone To Low Clearance Vehicle Hang-up (Total = 44)

Crossing ID: 272609N_Tracks North View;
NE 141st St., Miami, Florida

Crossing ID: 272609N_Tracks South View;
NE 141st St., Miami, Florida

Crossing ID: 339724L_Tracks West View;
N 8th St., Pensacola, Florida

Crossing ID: 339724L_Tracks East View;
N 8th St., Pensacola, Florida

Crossing ID: 620904E_Tracks Northeast View;
Moody St., Orange Park, Florida

Crossing ID: 620904E_Tracks Southwest View;
Moody St., Orange Park, Florida

Figure 4.34. Inventory Photographs of Crossing IDs 272609N, 339724L, and 620904E

 Crossing ID: 620905L_Tracks Northeast View; Birchwood Dr., Orange Park, Florida	 Crossing ID: 620905L_Tracks Southwest View; Birchwood Dr., Orange Park, Florida
 Crossing ID: 620906T_Tracks Northeast View; Woodland Dr., Orange Park, Florida	 Crossing ID: 620906T_Tracks Southwest View; Woodland Dr., Orange Park, Florida
 Crossing ID: 620908G_Tracks Northeast View; Greenridge Dr., Orange Park, Florida	 Crossing ID: 620908G_Tracks Southwest View; Greenridge Dr., Orange Park, Florida

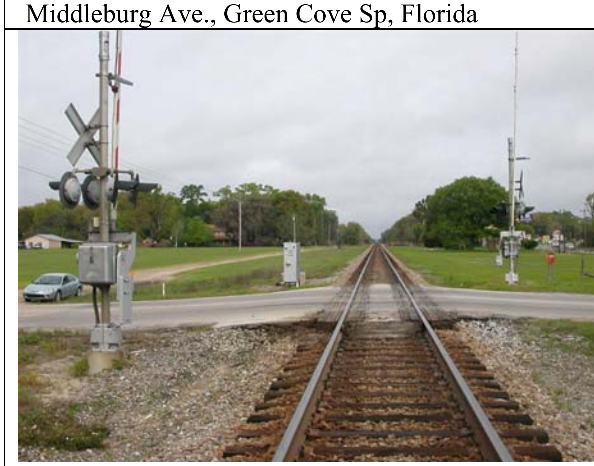
Figure 4.35. Inventory Photographs of Crossing IDs 620905L, 620906T, and 620908G

Crossing ID: 620909N_Tracks_ East View;
Lakeside Villa., Orange Park, Florida

Crossing ID: 620909N_Tracks_ West View;
Lakeside Villa., Orange Park, Florida

Crossing ID: 620927L_Tracks_Northwest View;
Middleburg Ave., Green Cove Sp, Florida

Crossing ID: 620927L_Tracks_Southeast View;
Middleburg Ave., Green Cove Sp, Florida



Crossing ID: 620988C_Tracks_North View;
CR 309, Pomona Park, Florida

Crossing ID: 620988C_Tracks_South View;
CR 309, Pomona Park, Florida

Figure 4.36. Inventory Photographs of Crossing IDs 620909N, 620927L, and 620988C


Crossing ID: 621286K_Tracks_ East View;
Lake Winona Rd., De Leon Spring, Florida


Crossing ID: 621286K_Tracks_ West View;
Lake Winona Rd., De Leon Spring, Florida


Crossing ID: 622064E_Tracks_East View;
Palmetto St., Lake Mary, Florida


Crossing ID: 622064E_Tracks_West View;
Palmetto St., Lake Mary, Florida


Crossing ID: 623002K_Tracks_East_View;
Lake Alfred Rd, Lake Alfred, Florida


Crossing ID: 623002K_Tracks_West_View;
Lake Alfred Rd, Lake Alfred, Florida

Figure 4.37. Inventory Photographs of Crossing IDs 621286K, 622064E, and 623002K

Crossing ID: 624155S_Tracks_ East View;
Interlachen Pkwy, Lakeland, Florida

Crossing ID: 624155S_Tracks_ West View;
Interlachen Pkwy, Lakeland, Florida

Crossing ID: 625103D_Tracks_North View;
SE 180 St./ CR 10, Oxford, Florida

Crossing ID: 625103D_Tracks_South View;
SE 180 St./ CR 10, Oxford, Florida

Crossing ID: 625677T_Tracks_Northwest_View;
Lipona Rd, Tallahassee, Florida

Crossing ID: 625677T_Tracks_Southeast_View;
Lipona Rd, Tallahassee, Florida

Figure 4.38. Inventory Photographs of Crossing IDs: 624155S, 625103D, and 625677T

 Crossing ID: 625688F_Tracks_ Northeast View; Midway Rd., Quincy, Florida	 Crossing ID: 625688F_Tracks_ Southwest View; Midway Rd., Quincy, Florida
 Crossing ID: 625689M_Tracks_East View; CR 268, Quincy, Florida	 Crossing ID: 625689M_Tracks_West View; CR 268, Quincy, Florida
 Crossing ID: 625692V_Tracks_East_View; Ray Rd., Quincy, Fl	 Crossing ID: 625692V_Tracks_West_View; Ray Rd., Quincy, Fl

Figure 4.39. Inventory Photographs of Crossing IDs 625688F, 625689M, and 625692V

Crossing ID: 625694J_Tracks_ Northeast View;
Key Farms Rd., Quincy, Florida

Crossing ID: 625694J_Tracks_ Southwest View;
Key Farms Rd., Quincy, Florida

Crossing ID: 625695R_Tracks_North View;
Dade Street, Quincy, Florida

Crossing ID: 625695R_Tracks_South View;
Dade Street, Quincy, Florida

Crossing ID: 625700K_Tracks_East_View;
Shelfer St., Gretna, Florida

Crossing ID: 625700K_Tracks_West_View;
Shelfer St., Gretna, Florida

Figure 4.40. Inventory Photographs of Crossing IDs 625694J, 625695R, and 625700K


Crossing ID: 625711X_Tracks_ North View;
Crystal Lane, Gretna, Florida


Crossing ID: 625711X_Tracks_ South View;
Crystal Lane, Gretna, Florida


Crossing ID: 625713L_Tracks_ Northeast View;
CR 379, Gretna, Florida


Crossing ID: 625713L_Tracks_ Southwest View;
CR 379, Gretna, Florida


Crossing ID: 625714T_Tracks_ East View;
Atwater Rd., Gretna, Florida


Crossing ID: 625714T_Tracks_ West View;
Atwater Rd., Gretna, Florida

Figure 4.41. Inventory Photographs of Crossing IDs 625711X, 625713L, and 625714T

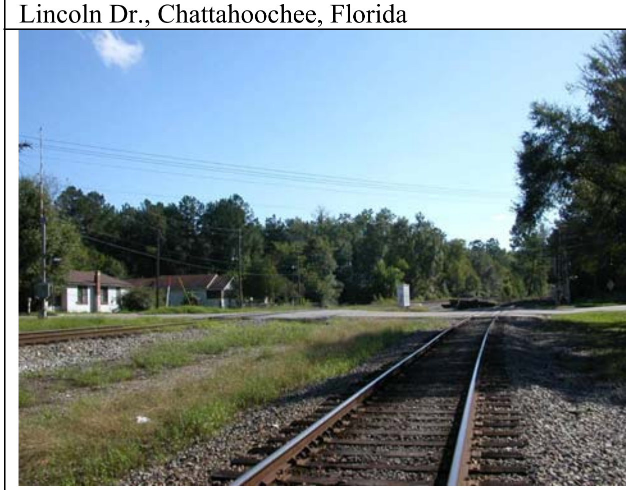
 Crossing ID: 625716G_Tracks_ East View 1; Lincoln Dr., Chattahoochee, Florida	 Crossing ID: 625716G_Tracks_ West View 1; Lincoln Dr., Chattahoochee, Florida
 Crossing ID: 625716G_Tracks_ East View2; Lincoln Dr., Chattahoochee, Florida	 Crossing ID: 625716G_Tracks_ West View2; Lincoln Dr., Chattahoochee, Florida

Figure 4.42. Inventory Photographs of Crossing IDs 625715A and 625716G

Crossing ID: 625727U_Tracks_ Northwest View;
Crawfish Rd., Chattahoochee, Florida

Crossing ID: 625727U_Tracks_ Southeast View;
Crawfish Rd., Chattahoochee, Florida

Crossing ID: 625735L_Tracks_ Northeast View;
Tower Rd., Tallahassee, Florida

Crossing ID: 625735L_Tracks_ Southwest View;
Tower Rd., Tallahassee, Florida

Crossing ID: 625737A_Tracks_ Northwest View;
SR 270, Havana, Florida

Crossing ID: 625737A_Tracks_ Southeast View;
SR 270, Havana, Florida

Figure 4.43. Inventory Photographs of Crossing IDs 625727U, 625735L, and 625737A

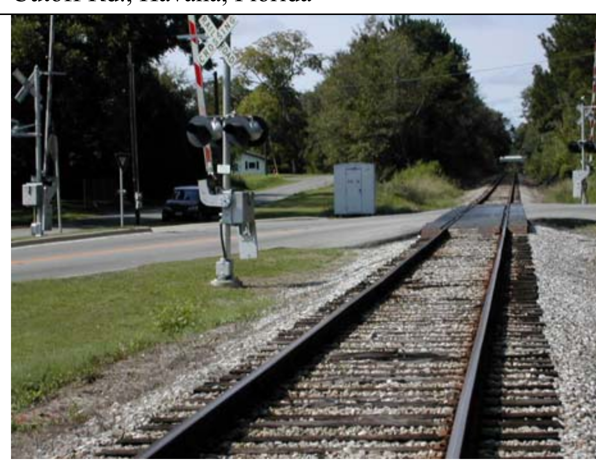
Crossing ID: 625741P_Tracks_ Northwest View;
Salem Rd., Havana, Florida

Crossing ID: 625741P_Tracks_ Southeast View;
Salem Rd., Havana, Florida

Crossing ID: 625742W_Tracks_Northeast_View;
Cutoff Rd., Havana, Florida

Crossing ID: 625742W_Tracks_Southwest_View;
Cutoff Rd., Havana, Florida

Crossing ID: 625744K_Tracks_Northeast_View;
SR 12, Havana, Florida



Crossing ID: 625744K_Tracks_Southwest_View;
SR 12, Havana, Florida

Figure 4.44. Inventory Photographs of Crossing IDs 625741P, 625742W, and 625744K

Crossing ID: 625746Y_Tracks_ Northeast View;
Country Club Dr, Havana, Florida

Crossing ID: 625746Y_Tracks_ Southwest View;
Country Club Dr, Havana, Florida

Crossing ID: 625748M_Tracks_North_View;
Graded Rd., Havana, Florida

Crossing ID: 625748M_Tracks_South_View;
Graded Rd., Havana, Florida

Crossing ID: 625751V_Tracks_East_View;
Jamieson Rd., Havana, Florida

Crossing ID: 625751V_Tracks_West_View;
Jamieson Rd., Havana, Florida

Figure 4.45. Inventory Photographs of Crossing IDs 625746Y, 625748M, and 625751V

Crossing ID: 625760U_Tracks_ Northeast View;
W. Washington, Quincy, Florida

Crossing ID: 625760U_Tracks_ Southwest View;
W. Washington, Quincy, Florida

Crossing ID: 625761B_Tracks_Northeast_View;
Franklin St., Quincy, Florida

Crossing ID: 625761B_Tracks_Southwest_View;
Franklin St., Quincy, Florida

Crossing ID: 625762H_Tracks_ Northeast _View;
King St., Quincy, Florida

Crossing ID: 625762H_Tracks_ Southwest _View;
King St., Quincy, Florida

Figure 4.46. Inventory Photographs of Crossing IDs 625760U, 625761B, and 625762H

Crossing ID: 625765D_Tracks_ Northeast View;
Forest Dr., Quincy, Florida

Crossing ID: 625765D_Tracks_ Southwest View;
Forest Dr., Quincy, Florida

Crossing ID: 625766K_Tracks_East_View;
SR 0267, Quincy, Florida

Crossing ID: 625766K_Tracks_West_View;
SR 0267, Quincy, Florida

Crossing ID: 625587U_Tracks_East _View;
Adams St., Tallahassee, Florida

Crossing ID: 625587U_Tracks_West _View;
Adams St., Tallahassee, Florida

Figure 4.47. Inventory Photographs of Crossing IDs 625765D, 625766K, and 625587U

4.7. Summary

Based primarily on ramp breakover angle due to design low clearance vehicles, a methodology was presented for evaluating highway railroad grade crossings. Vertical crest and sag curves were developed, to prevent hang-up of low clearance vehicles, based on the required approach tangents and the existing slope of the railway tracks plane. Recommendations on changes to existing FDOT design guidelines are presented along with illustrative geometric analyses of sample grade crossings in Florida, and some illustrative design aids in form of a table and charts. Using the methodology developed, the FDOT's inspection form was modified into a new more comprehensive profile documentation form to assist inspectors in performing field evaluations of grade crossings for the potential of hang-up. A comprehensive computer software program was written and compiled in Microsoft Visual Basic 6.0, to serve as design and rehabilitation aid for evaluation of hang-up potential of low clearance vehicles at highway railroad grade crossings. Also available are Microsoft Excel Tools for performing simple hang-up evaluations.

An overall review of hump crossings in Florida is presented, in terms of the following attributes: nearness to roadway intersections; nearness to roadway cures; asphalt buildup in the track area; vertical sag location; number of tracks; and superelevation of the tracks. It was observed that many of the critical crossings, in terms of potential hang-up by low clearance vehicles, are located near roadway intersections or a roadway curve with all these crossings indicating some rail maintenance resulting in asphalt buildup on the tracks.

5. Evaluation of Network Route Based on Crossing Profiles

Movement of vehicles in general and low-clearance vehicles in particular, may be hindered by location of certain obstacles on a highway network. For example highway bridges may have a load carrying capacity that would force the detour of certain heavy trucks. In the same light of thinking, the profiles at some highway railroads grade crossings may prevent the passage of certain low clearance vehicles because of the potential for hang-up at the crossing. To address this issue, this section of the study report presents the use of Geographic Information Systems (GIS) for routing low clearance vehicles though the safest route on a network to prevent hang-up at the grade crossings.

5.1 Railroad Grade Crossings in Tallahassee, Florida

Using the Federal Railroad's Administration (FRA)'s data, the following Table 5.1 was compiled for highway railroad grade crossings identified as being located in Tallahassee, Florida. The spatial coordinates of the crossings were extracted in ESRI's software (ArcView 8.3) with the display of FRA's basemap, superimposed on the Leon County's GIS roadway basemap. The coordinate projection for these locations is shown at the bottom of Table 5.1. As illustrated in the following Figures 5.1 through 5.7, location of highway railroad grade crossings can be easily shown and queried for pertinent information using GIS maps. A quantitative rating can also be established to represent the hang-up potential of highway railroad grade crossings for low clearance vehicles. As shown in Figure 5.2 for some crossings in east Tallahassee, feasible routing on the network of roadways is shown for a specified pair of origin and destination points. In this case, let us assume a car carrier is entering Tallahassee from Jacksonville, Florida (a commercial port). The shown origin point is the US 90 Exit off the Interstate 10, and the destination is a location of a car carrier on Apalachee Parkway. The different routes can be evaluated in terms of distance traveled, time of travel and more importantly, the hang-up potential of grade crossings to be encountered along each feasible route. It is assumed here that no grade separations exist on each of the routes indicated. In addition, use of a hyperlink to attach grade crossing photographs (Figure 5.1) and aerial photographs are demonstrated (Figures 5.6 and 5.7).

Table 5.1 Location Coordinates of Grade Crossings (from FRA and Leon County GIS)*

RECORD NO.	CROSSING ID	STREET INTERSECTED	X-COORD (FT)	Y-COORD (FT)
1a	625572E	CAPITOLA RD	2089751.36	522883.32
2	625573L	BAUM RD	2097433.39	528174.61
3	625574T	BENJAMIN CHAIRES RD	2092307.67	524561.26
4	625575A	CHAIRES CROSS RD	2088927.01	522500.29
5	625576G	ROAD TO THE LAKE	2086066.79	521609.33
6	625577N	WEEMS RD	2055959.55	528857.27
7	625580W	E CALL ST	2040681.87	524901.45
8	625584Y	MYERS PARK DR	**30.4343833	**84.2749333
9	625585F	GADSDEN ST	2038407.29	521256.64
10	625587U	ADAMS ST	2037214.49	521178.20
11	625588B	RAILROAD AVE	2034746.48	521352.24
12	625589H	SEABOARD ST	2035826.32	521227.38
13	625675E	STEARNS ST	2032226.23	520248.81
14	625678A	MABRY ST	2022176.74	520087.69
15	625679G	EISENHOWER ST	2020286.44	520151.77
16	625683W	AENON CHURCH RD	2008208.01	524823.93
17	625684D	BARINEAU RD/ C	2004258.06	526944.68
18	625685K	GEDDIS RD/ CR 1585	1998919.56	533311.79
19	625729H	THARPE ST (MAX?)	2014290.49	532677.53
20	625731J	GEARHART RD	2016854.45	538818.59
21	625732R	FRED GEORGE RD	2015395.21	542806.41
22	625734E	CAPITAL CIRCLE	2011019.14	553430.21
23	625735L	TOWER RD	2009432.25	556006.61
24	625782U	ATLAS ST	**30.4350233	**84.295228
25	625783B	MOSLEY ST	2032672.93	521516.75
26	625791T	PLANT ST	**30.4303000	**84.331350
27	627834R	HARTSFIELF RD	2016952.35	535963.67

**Basemap Projection: Basis for X-Y Coordinates*

Custom
Lambert_Conformal_Conic
False_Easting: 1968500.000000
False_Northing: 0.000000
Central_Meridian: -84.500000
Standard_Parallel_1: 29.583333
Standard_Parallel_2: 30.750000
Latitude_Of_Origin: 29.000000

***Latitude/Longitude Coordinates; Need to be Converted*

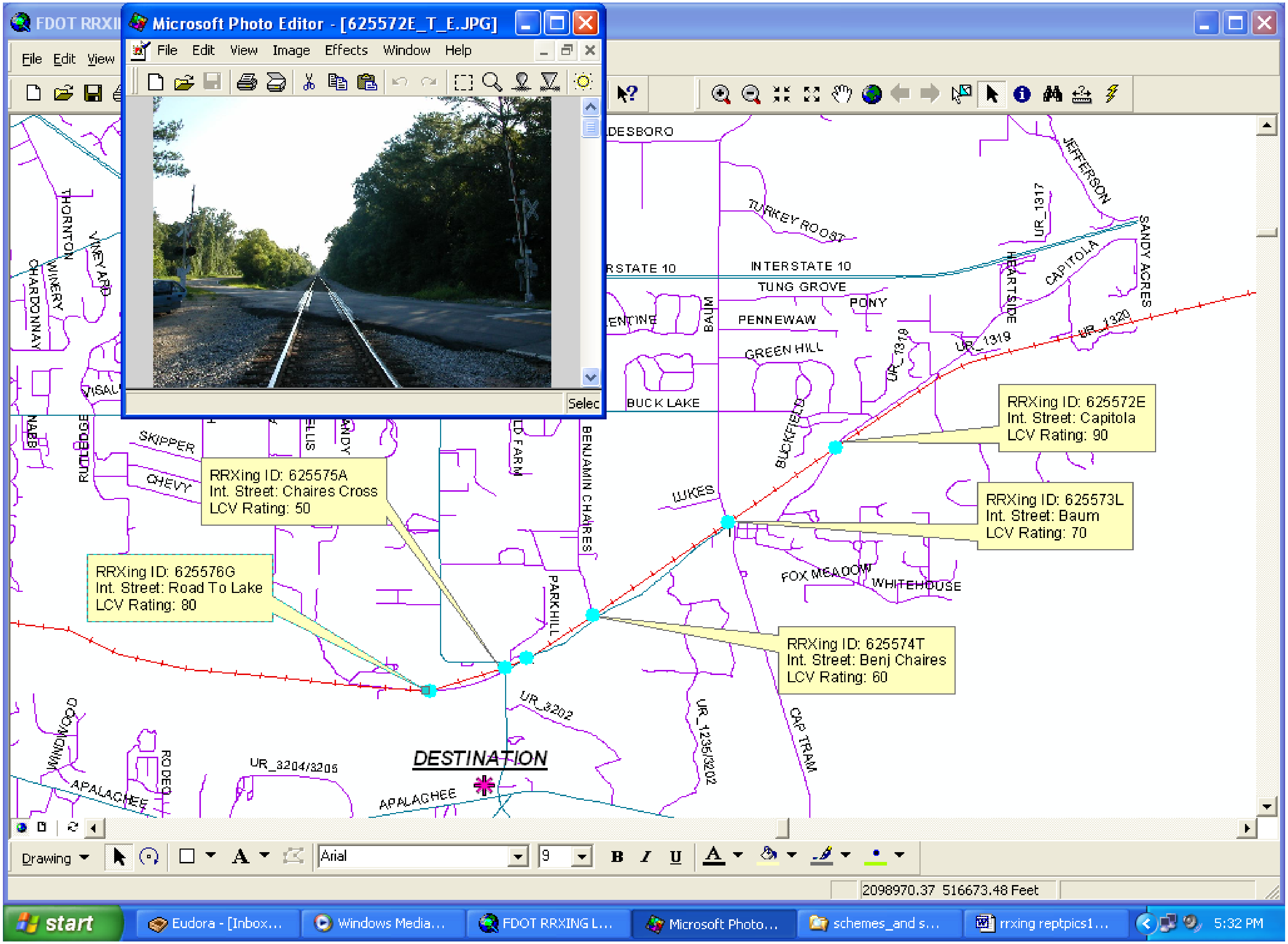
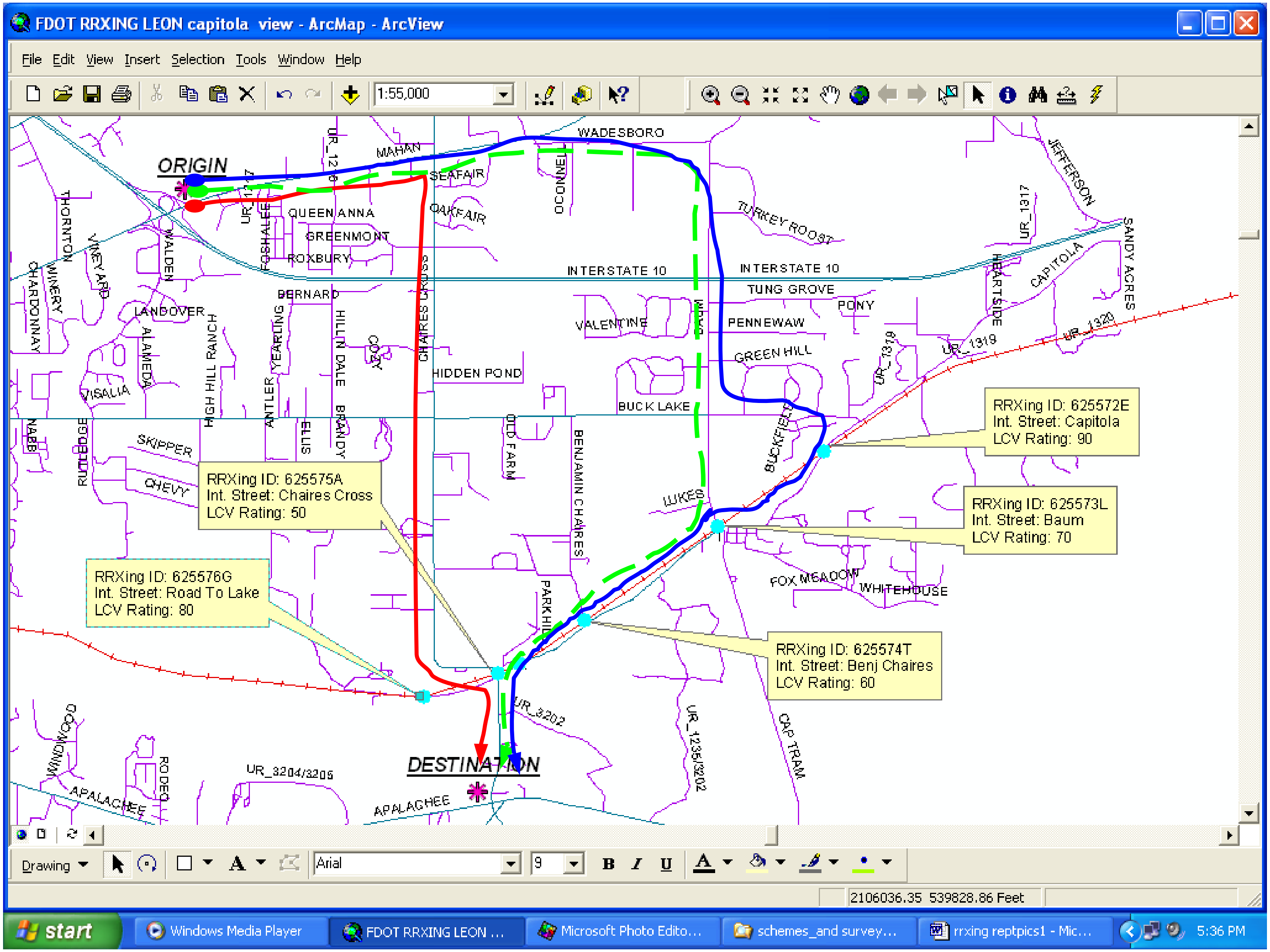


Figure 5.1 Network Locations of Crossings in East Tallahassee (with Hyperlinked Site Photograph)


FDOT RRXING LEON capitola view - ArcMap - ArcView
File Edit View Insert Selection Tools Window Help
1:55,000
ORIGIN
DESTINATION
WADESBORO
MAHAN
SEAFAIR
QUEEN ANNA
GREENMONT
ROXBURY
OAKFAIR
TURKEY ROOST
INTERSTATE 10
INTERSTATE 10
TUNG GROVE
PONY
PENNEWAW
GREEN HILL
VALENTINE
HIDDEN POND
BUCK LAKE
BERNARD
LANDOVER
VISALIA
SKIPPER
CHEVY
LUKES
FOX MEADOW
WHITEHOUSE
APALACHEE
APALACHEE
UR_3204/3205
UR_3202
CAPITOLA
JEFFERSON
SANDY ACRES
UR_1319
UR_1320
RRXing ID: 625572E
Int. Street: Capitola
LCV Rating: 90
RRXing ID: 625573L
Int. Street: Baum
LCV Rating: 70
RRXing ID: 625575A
Int. Street: Chaires Cross
LCV Rating: 50
RRXing ID: 625576G
Int. Street: Road To Lake
LCV Rating: 80
RRXing ID: 625574T
Int. Street: Benj Chaires
LCV Rating: 60
Drawing
Arial
2106036.35 539828.86 Feet
start
Windows Media Player
FDOT RRXING LEON ...
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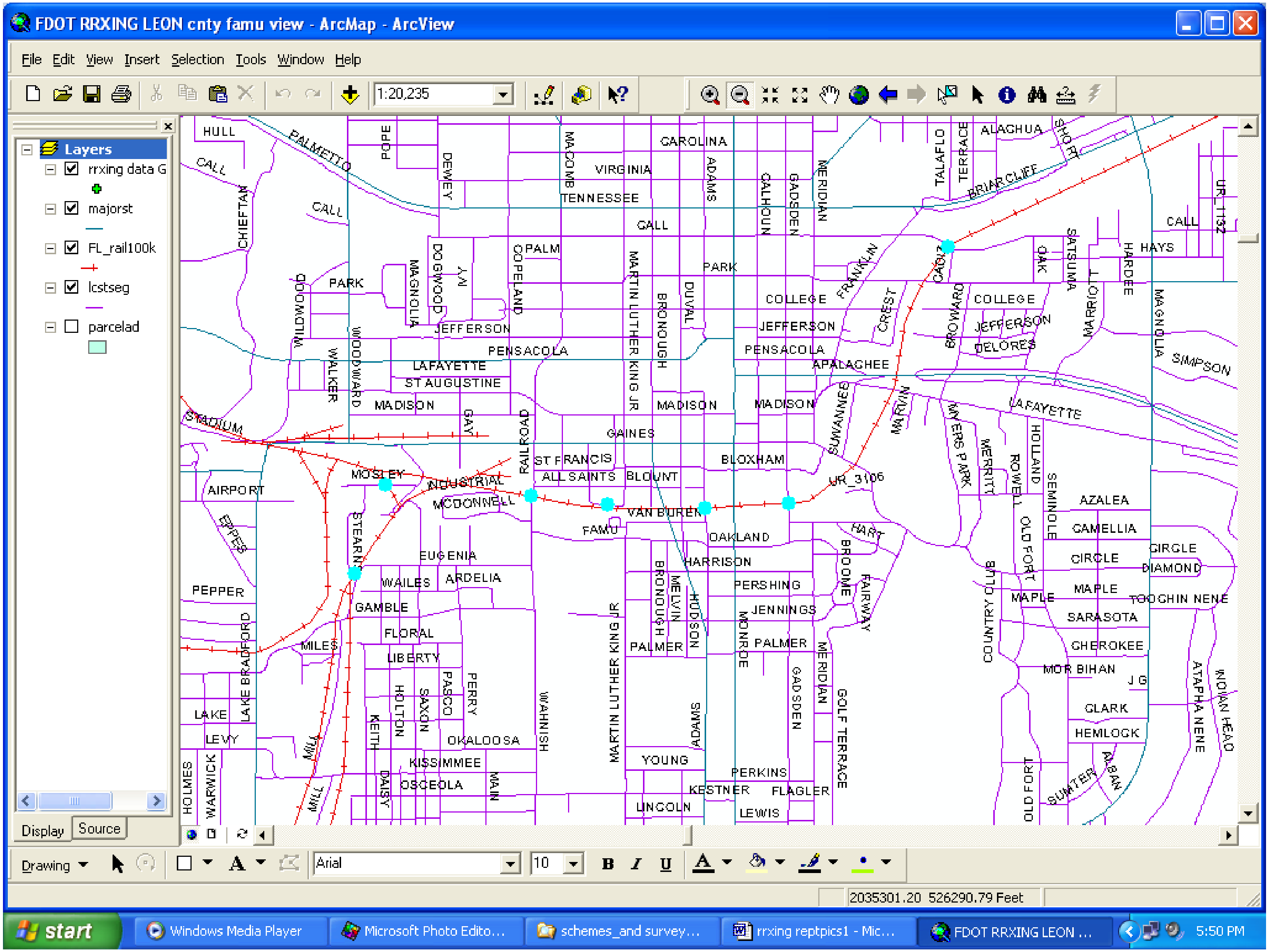
schemes_and survey...
rrxing reptpics1 - Mic...
5:36 PM


FDOT RRXING LEON cnty famu view - ArcMap - ArcView
File Edit View Insert Selection Tools Window Help
1:20,235
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Display Source
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Arial
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2035301.20 526290.79 Feet
start
Windows Media Player
Microsoft Photo Edito...
schemes_and survey...
rrxing reptpics1 - Mic...
FDOT RRXING LEON ...
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HULL
CALL
PALMETTO
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DEWEY
MACOMB
CAROLINA
VIRGINIA
TENNESSEE
ADAMS
CALHOUN
GADSDEN
MERIDIAN
TALAFLO
TERRACE
ALACHUA
BRIAR CLIFF
CHIEFTAN
PARK
MAGNOLIA
DOGWOOD
IVY
COPELAND
PALM
MARTIN LUTHER KING JR
BRONOUGH
DUVAL
COLLEGE
FRANKLIN
CREST
CADIZ
BROWARD
JEFFERSON
DELORES
OAK
SATSUMA
MARRIOTT
HARDEE
HAYS
SIMPSON
WILDWOOD
WALKER
WOODWARD
LAFAYETTE
ST AUGUSTINE
PENSACOLA
APALACHEE
MADISON
GAY
RAILROAD
GAINES
STADIUM
ST FRANCIS
ALL SAINTS
BLOUNT
BLOXHAM
SUWANNEE
MARVIN
MYERS PARK
MERRITT
ROWELL
HOLLAND
SEMINOLE
MOSLEY
INDUSTRIAL
MCDONNELL
AIRPORT
UR_3106
VAN BUREN
FAMU
OAKLAND
HART
AZALEA
CAMELLIA
CIRCLE
DIAMOND
EPPES
STEARNS
EUGENIA
HARRISON
BROOME
OLD FORT
MAPLE
TOOCHIN NENE
WAILES
ARDELIA
PERSHING
FAIRWAY
COUNTRY CLUB
SARASOTA
PEPPER
GAMBLE
MELVIN
HUDSON
JENNINGS
CHEROKEE
MILES
FLORAL
PALMER
MONROE
LIBERTY
MOR BIHAN
J G
LAKE BRADFORD
HOLTON
SAXON
PASCO
PERRY
WAHNISH
GOLF TERRACE
ATAPHA NENE
INDIAN HEAD
CLARK
LAKE
LEVY
KEITH
OKALOOSA
HEMLOCK
YOUNG
KISSIMMEE
PERKINS
ALBAN
HOLMES
WARWICK
DAISY
OSCEOLA
MAIN
KESTNER
FLAGLER
SUMTER
MILL
LINCOLN
LEWIS

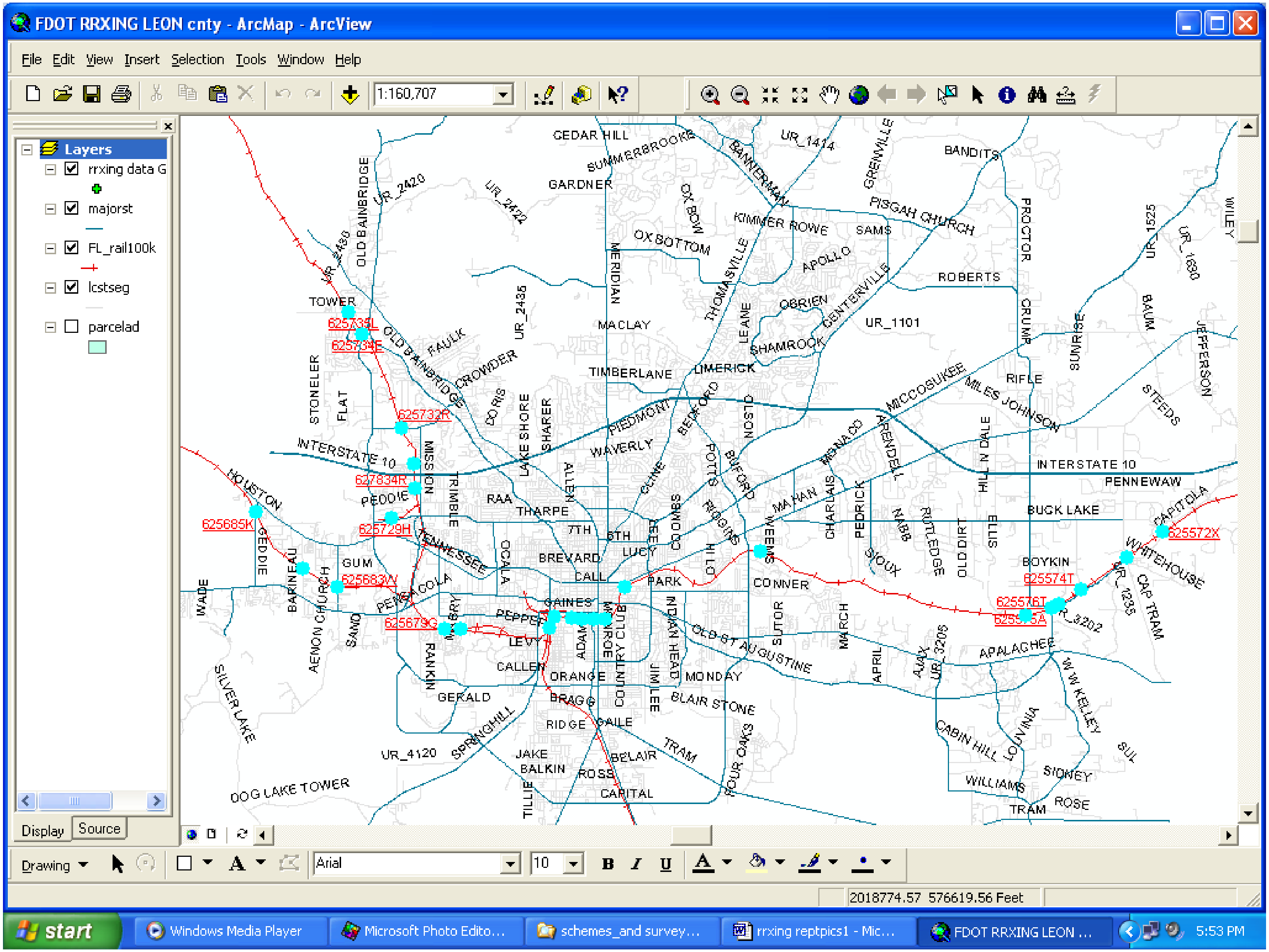
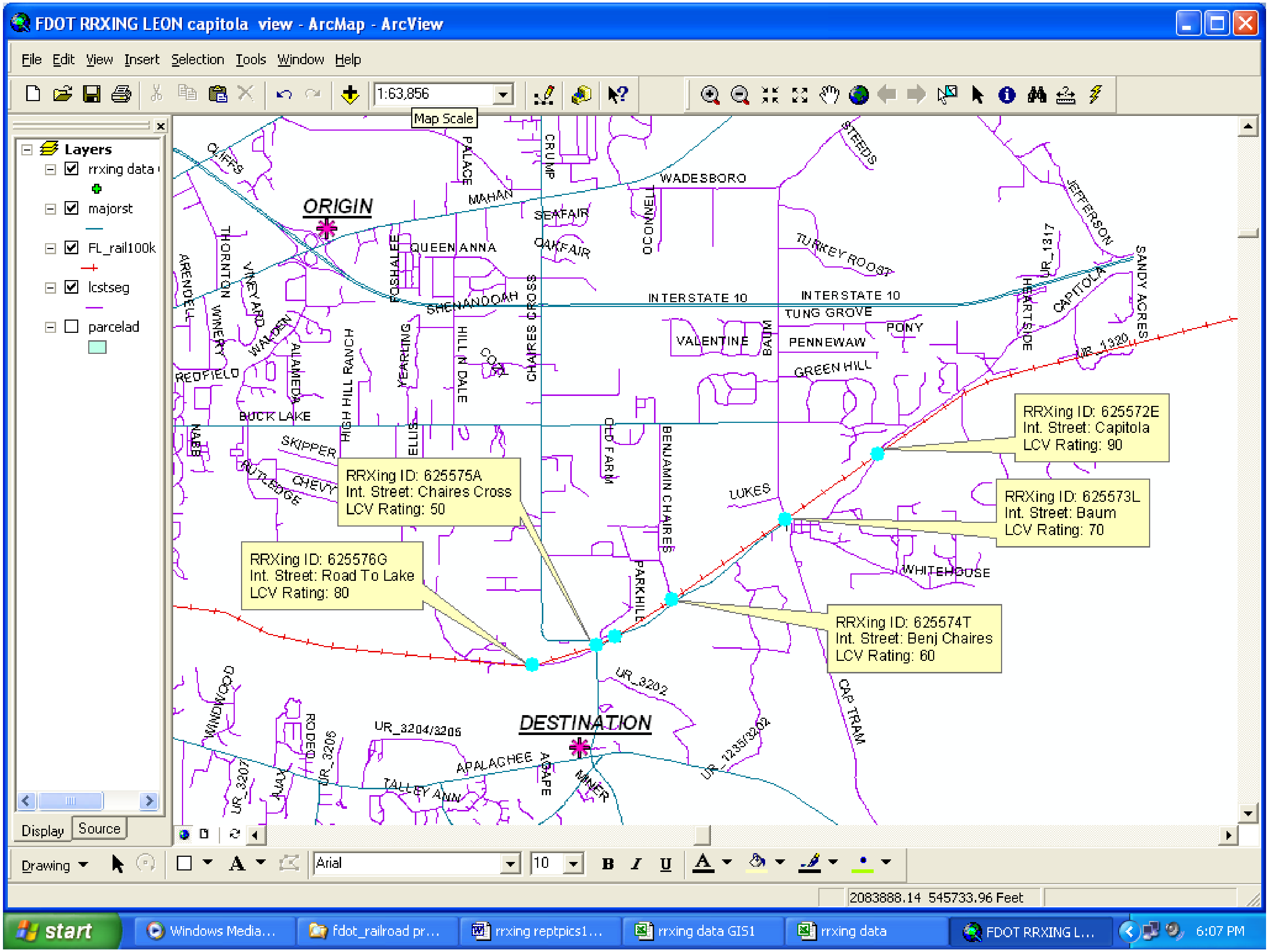


Figure 5.4 Network Locations of Crossings in Tallahassee.


FDOT RRXING LEON capitola view - ArcMap - ArcView
ORIGIN
DESTINATION
RRXing ID: 625572E
Int. Street: Capitola
LCV Rating: 90
RRXing ID: 625573L
Int. Street: Baum
LCV Rating: 70
RRXing ID: 625574T
Int. Street: Benj Chaires
LCV Rating: 60
RRXing ID: 625575A
Int. Street: Chaires Cross
LCV Rating: 50
RRXing ID: 625576G
Int. Street: Road To Lake
LCV Rating: 80
Layers
rrxing data
majorst
FL_rail100k
lcstseg
parcelad
1:63,856
2083888.14 545733.96 Feet

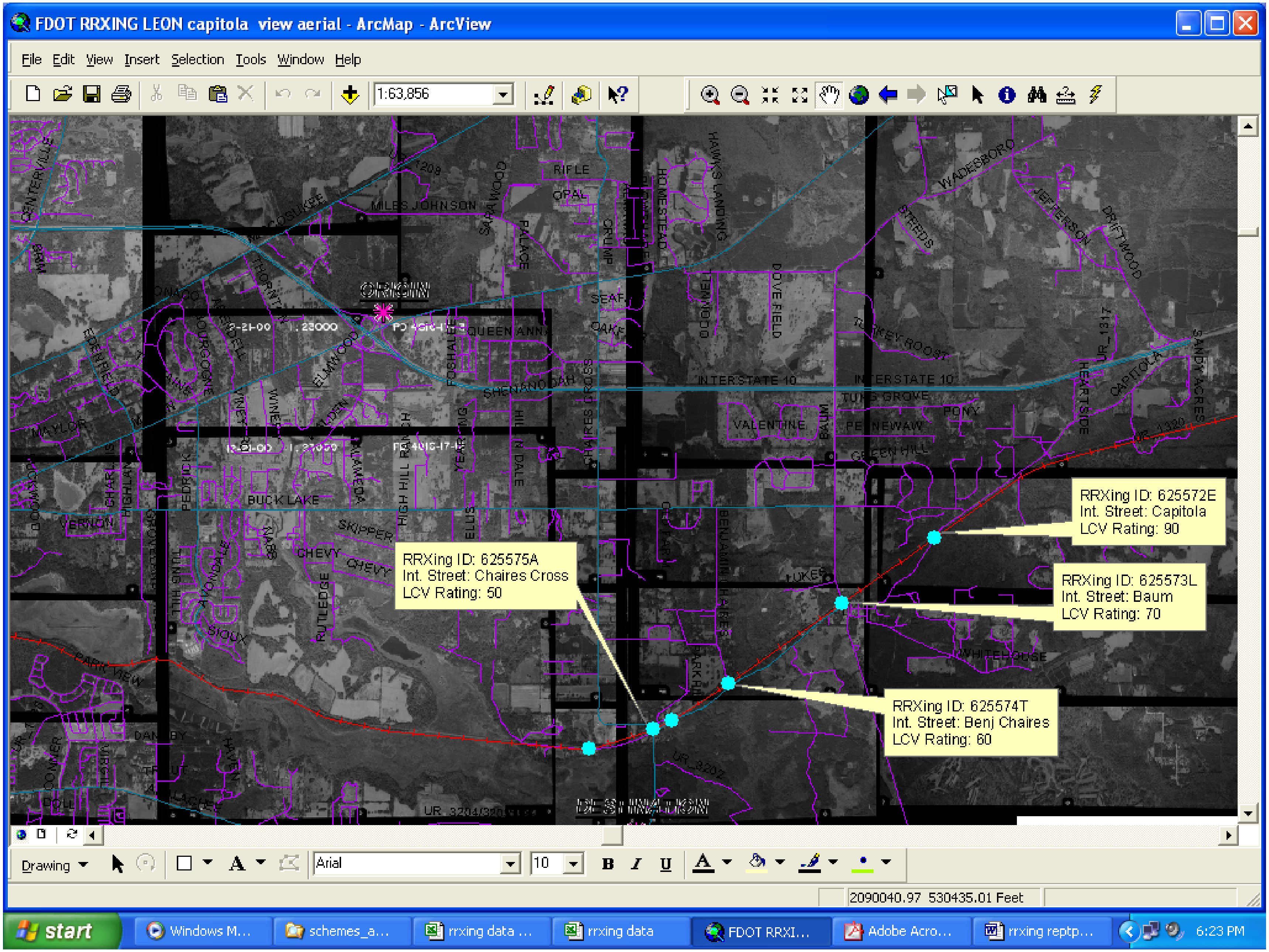


Figure 5.6 Network Location using Aerial Photos of Crossings in East Tallahassee.

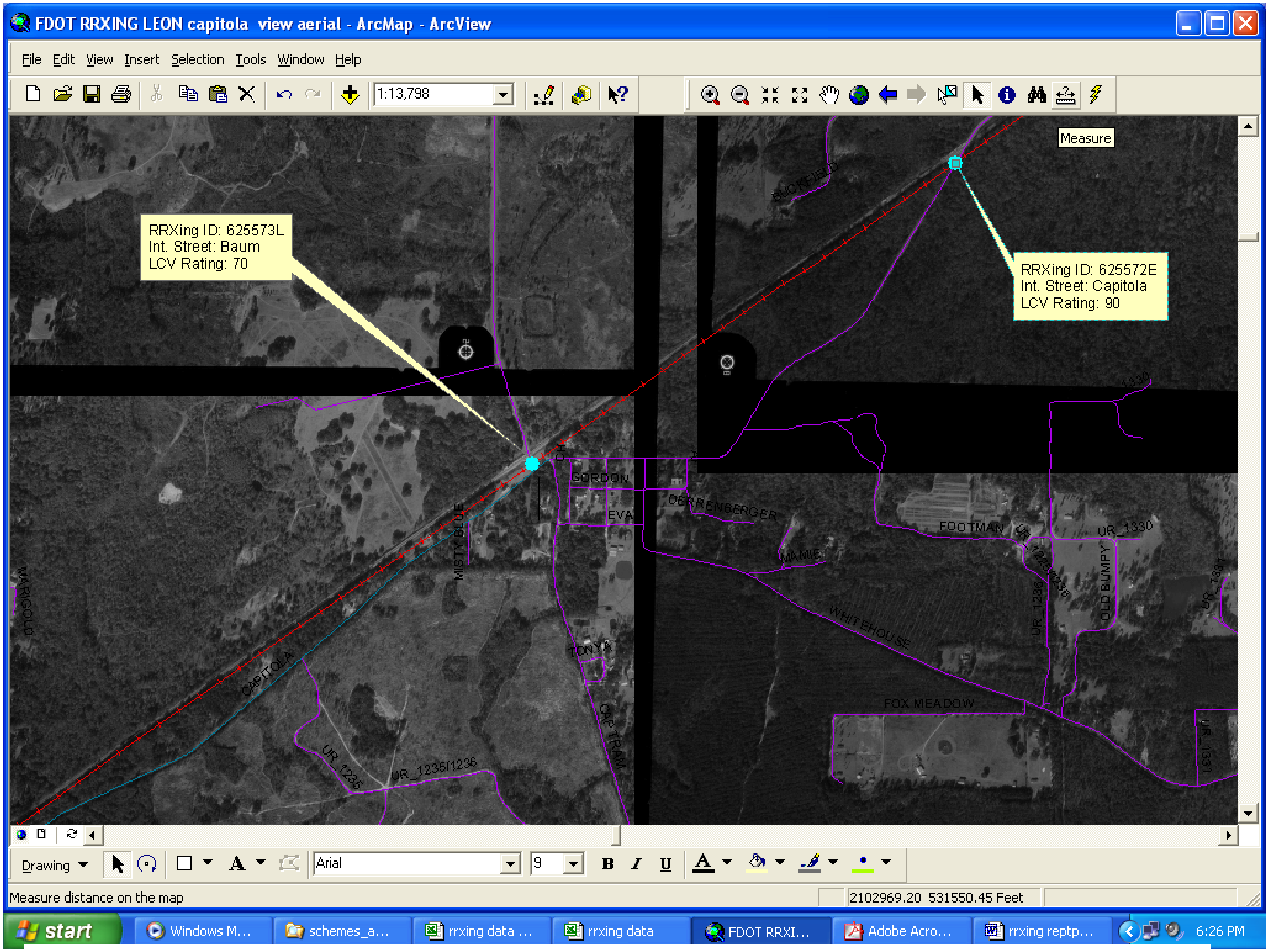


Figure 5.7 Network Location using Aerial Photos with Close View of Crossings in East Tallahassee.

5.2. Summary

A simple demonstration has been presented here on the use of GIS for network routing along roadways with grade crossings, using a suggested rating of hang-up potential and consideration of other roadway attributes such as time and distance of travel.

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APPENDIX A. References

FDOT, “Field and Office Manual for Profile Surveys of Highway - Rail At-Grade Crossings on Existing Paved Roadways, Bureau Of Roadway Design, Florida Department of Transportation, December 1984.

NTSB, “Rowland, North Carolina Collision Involving Amtrak 88 and Tractor Lowboy Semi-Trailer Combination Vehicle,” Washington D.C. Accident Report No. NTSB-84/01, 1984.

NTSB, “Jacksonville, Florida Collision Involving Amtrak Train P098 and Truck Semi-Trailer Combination Vehicle,” Washington D.C. Accident Report No. ATL-97-FR-004, 1997.

NTSB, “Intersection City, Florida Collision Involving Amtrak Train 97 and Truck Combination Vehicle,” Washington D.C. Report No. SB-02-23, 2002.

ITE Report, “Geometric Design Criteria for Highway-Rail Intersections (Grade Crossings), An Information Report Prepared by the Geometric Subcommittee,” Washington D.C. April 2001.

R. W. Eck, “Accommodating Low-Clearance Vehicles: An Emerging Issue for Highway Infrastructure,” Morgantown, Virginia, 1997.

R. W. Eck and S. K. Kang, “Low-Clearance Vehicles at Rail-Highway Grade Crossings: An Overview of the Problem and Potential Solutions,” Washington D.C., 1991.

Ronald. W. Eck and S. K. Kang, “Roadway Design Standards to Accommodate Low Clearance Vehicles,” Washington D.C., 1992.

M. W.A., “Passenger Car Overhang and Underclearance as related to Driveway Profile Design, Part I-Vehicle Data,” Washington D.C., 1958.

Bauer L.A., “Passenger Car Overhang and Underclearance as related to Driveway Profile Design, Part II-Street and Highway Design,” Washington D.C., 1958.

USDOT. Report, “Accidents that shouldn't happen: A Report of the Grade Crossing Safety Task Force to Secretary Federico Pena,” Washington D.C. 1996.

AASHTO, American Association of State Highway and Transportation Officials, A Policy on Geometric Design of Highways and Streets, Fourth Edition ed. Washington D.C., 2001.

NTSB, “Collision Between Metrolink Train 901 and Mercury Transportation, Inc., Tractor-Combination Vehicle at Highway-Railroad Grade Crossing in Glendale California, on January 28, 2000, safety Recommendation H-01-35, National Transportation Safety Board, Washington DC, 2001.

Mutabazi Madaniyo and Russel Eugene R, “Identification of Hump Highway / Rail Crossings in Kansas” Report No. K-TRAN: KSU-99-1, Final Report, Kansas State University, Manhattan, Kansas, July 2003.

Sayers, Michael W., and Karamihas, Steve M., “The Little Book of Profiling, Basic Information About Measuring and Interpreting Road Profiles,” The University of Michigan, Ann Arbor, September 1998.

APPENDIX B. Sample Survey Questionnaire and List of Agencies

Please use the box below to correct any information supplied in the label. Return the completed questionnaire by mail or fax to:
Dr. John O. Sobanjo, FAMU-FSU College of Engineering, Dept. of Civil and Environmental Engineering, 2525 Pottsdamer Street, Room 129, Tallahassee, FL 32310-6046. Fax: 850-410-6142

Survey On Highway Railroad Grade Crossings

Mailing Label Here

Contact Name		Agency Name
Address		City, State, Zip
Phone	E-mail	Type of Agency ☐ State ☐ Rail Company ☐ Other________

1. Does your agency consider the problem of low under vehicle clearance a major concern in the operational safety of vehicles on highway railroad grade crossings?
   ☐ Yes ☐ No

2. Have you conducted any study in the past, have an ongoing study, or immediate future plan to conduct a study, on the problem of low under vehicle clearance at highway railroad grade crossings?
   ☐ Yes ☐ No
   If YES, please indicate the dates of the study and availability of a report on your study.
   ____

3. Do you have any guidelines for design, construction and maintenance of highway railroad grade crossings (specifically addressing low under vehicle clearance issues) in your agency, other than the guidelines in the AASHTO design policy?
   ☐ Yes ☐ No
   If YES, please briefly summarize the guidelines.
   ____

4. Do you have a software program that is used for design and/or evaluation of highway railroad grade crossing profiles?
   ☐ Yes ☐ No
   If YES, please briefly describe the software program
   ____

5. What would you consider as major causes of hang-ups at highway railroad grade crossings due to low under vehicle clearance? Please select all that apply.
   ☐ Road Design ☐ Material ☐ Construction ☐ Maintenance ☐ Other _________

6. Does your agency have a regular maintenance program to establish a desirable roadway profile at highway railroad grade crossings?
   ☐ Yes ☐ No
   If YES, please briefly describe the program, including inspection and construction methods.
   ____
   ____

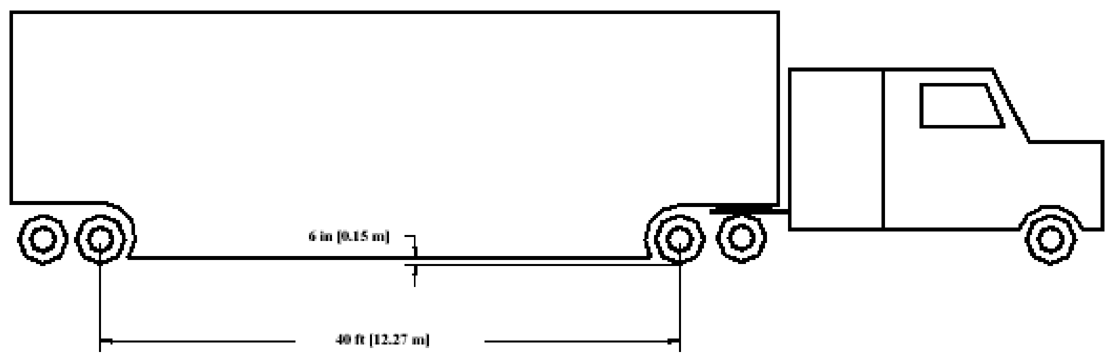
Please feel free to write additional comments on additional pages about your experience or suggestions, including potential solutions to the problem of vehicle hang-ups at highway railroad grade crossings due to low under vehicle clearance. Thank you very much for your help!

Table B.1. List of Responding Agencies

Organization	State	Phone
Alabama & Gulf Coast Railway, LLC	Alabama	(251) 575 5008
Maine DOT	Maine	(207) 624 3353
Bay line Railroad, LLC	Florida	
Seminole Gulf Railway (LP)	Florida	(239) 275 6060
Georgia DOT	Georgia	(404) 635 8120
AN Railway, LLC	Florida	(850) 229 7411
Massachusetts hw DOT	Massachusetts	
Pensylvania DOT	Pensylvania	(717) 787 8298
Idaho DOT	Idaho	
Ohio Rail Development Commission	Ohio	(614) 644 0286
North Carolina DOT	North Carolina	(919) 715 8740
Virginia DOT	Virginia	(804) 786 2532
Texas DOT	Texas	(512) 416 2200
North Carolina DOT, Rail Division	North Carolina	(919) 733 5564
Kansas DOT	Kansas	(785) 296 3529
Georgia-Florida Railnet, Inc	Georgia	
Florida West Coast Railroad Company	Florida	
South Central Florida Express	Florida	
Florida Midland, Central & Northern Railroads	Florida	
Alabama DOT	Alabama	(334) 242 6164
Arkansas DOT	Arkansas	
Connecticut DOT	Connecticut	
Iowa DOT	Iowa	(515) 239 1549
Kentucky DOT	Kentucky	
South Carolina DOT	South Carolina	(803) 737 1455
South Dakota DOT	South Dakota	(605) 773 3772
Montana DOT	Montana	(406) 444 6246
New York DOT	New York	(518) 457 8073
New Hampshire DOT	New Hampshire	(603) 271 2297
North Carolina	North Carolina	(919) 250 4016
Texas DOT	Texas	(512) 416 2673

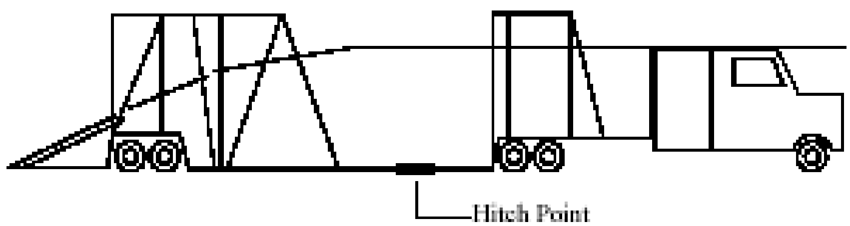
APPENDIX C. Low Clearance Design Vehicles (Eck et al. 2002)

Vehicle Type 1



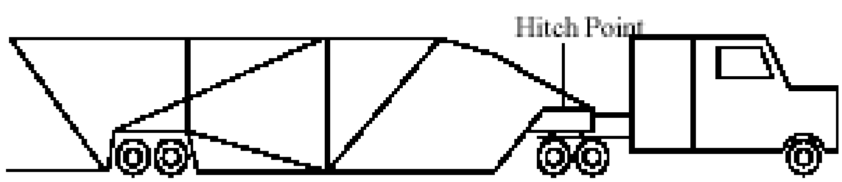
Double-drop trailer

Vehicle Type 2a



Stinger Mount Hitch

Vehicle Type 2b



High Mount Hitch

Figure C.1. Schematic Drawings of Double-drop Trailer, Stinger Mount Hitch and Stinger High Mount Hitch [Source: Eck et al. 2002]

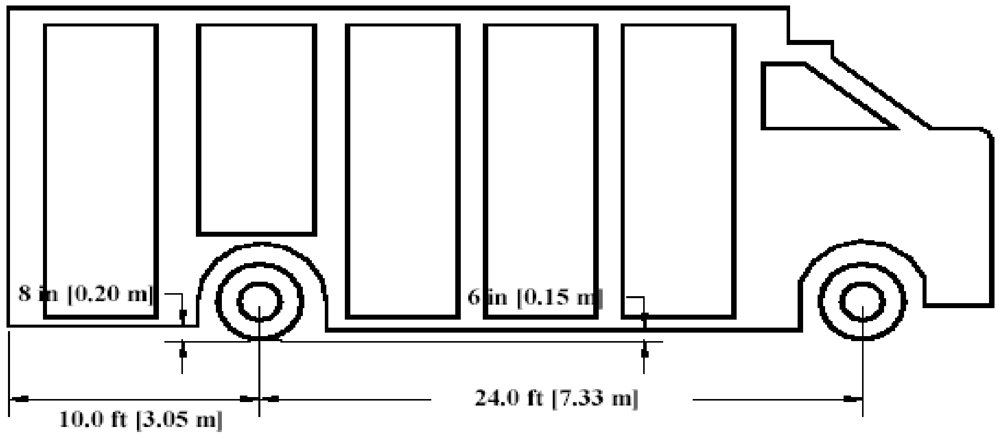
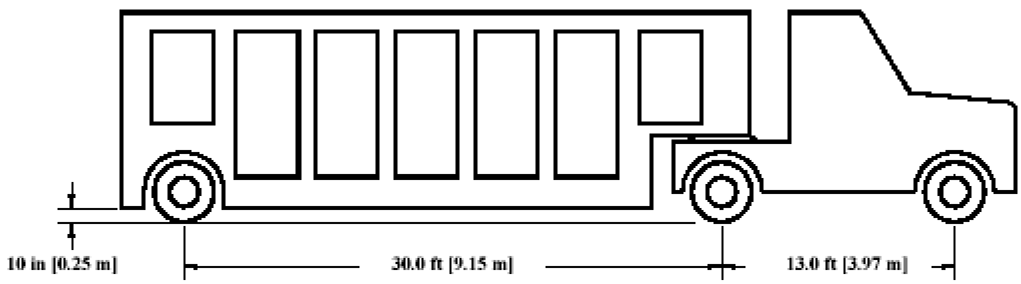
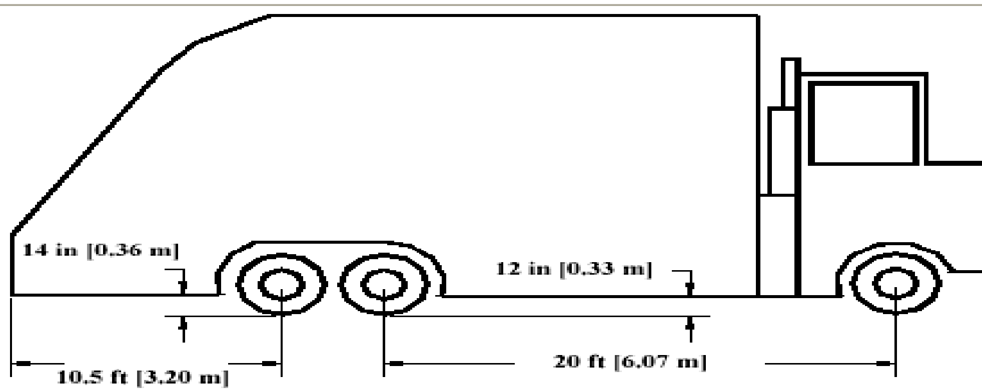
Vehicle Type 3	 Single Unit Beverage Truck
Vehicle Type 4	 Articulated Beverage Truck
Vehicle Type 5	 Rear-load Garbage Truck

Figure C.2. Schematic Drawings of Single Unit Beverage Truck, Articulated Beverage Truck, and Rear-load Garbage Truck [Source: Eck et al. 2002]

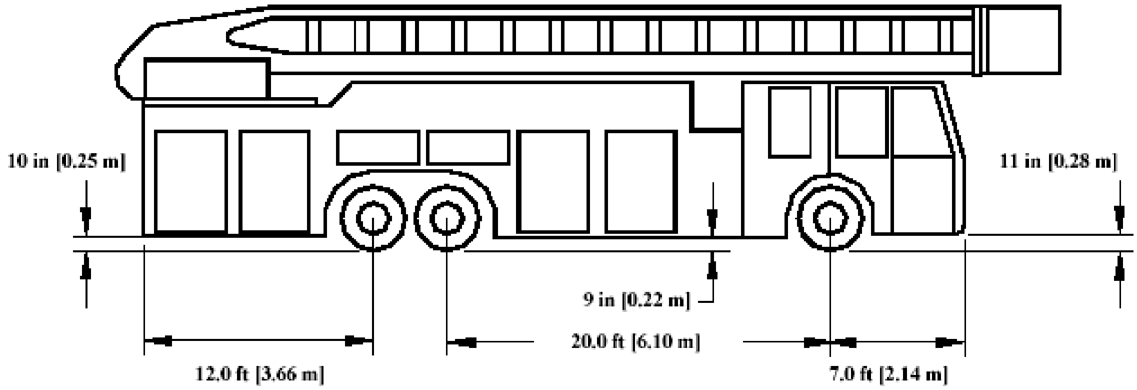
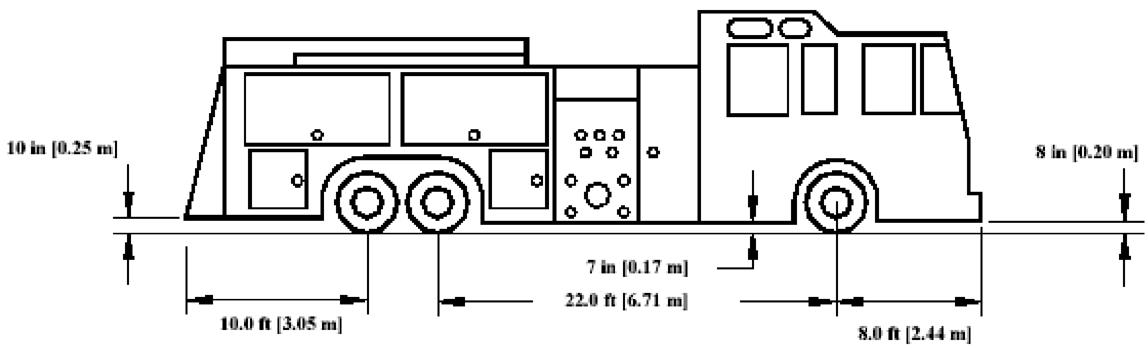
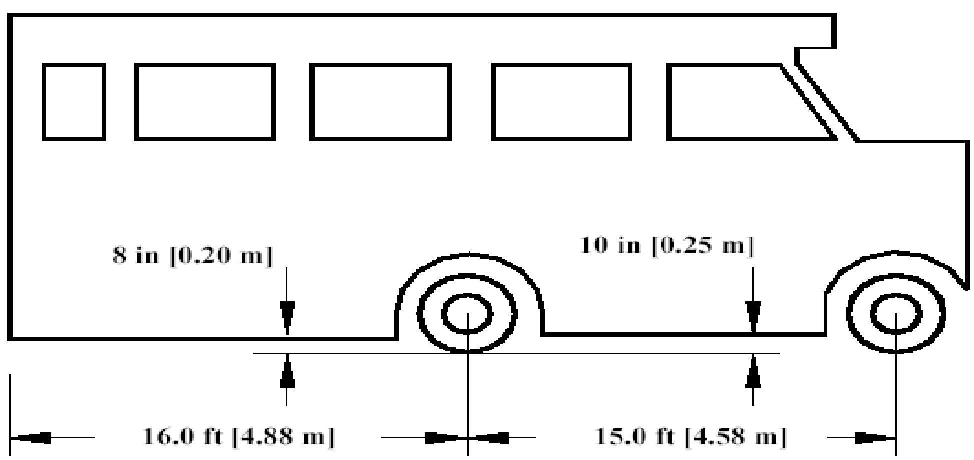
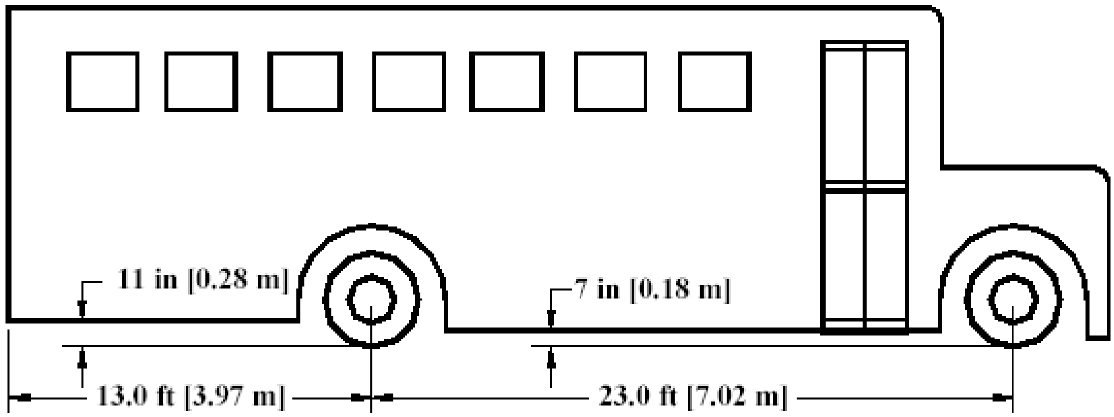
Vehicle Type 6	 Aerial Fire Truck
Vehicle Type 7	 Pumper Fire Truck
Vehicle Type 8	 Minibus

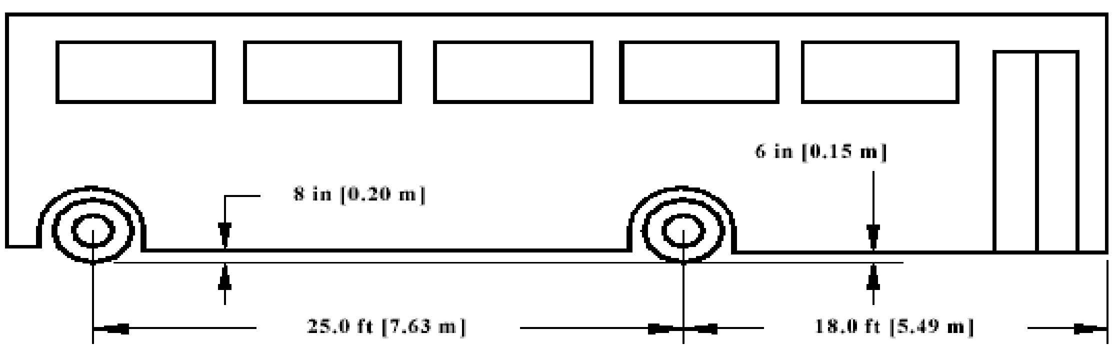
Figure C.3. Schematic Drawings of Aerial Fire Truck, Pumper Fire Truck, and Minibus [Source:

Vehicle Type 9



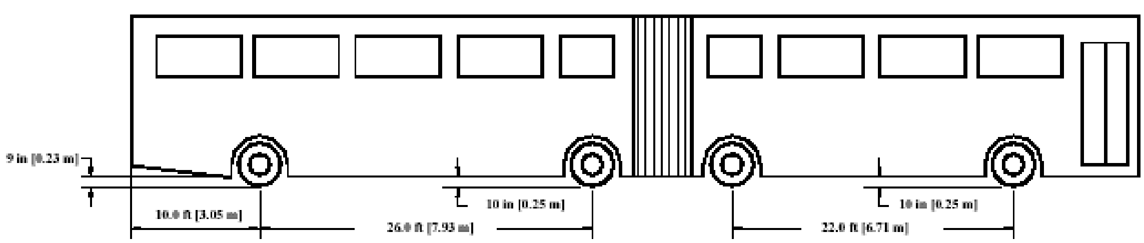
School Bus

Vehicle Type 10



Single Unit Transit Bus

Vehicle Type 11

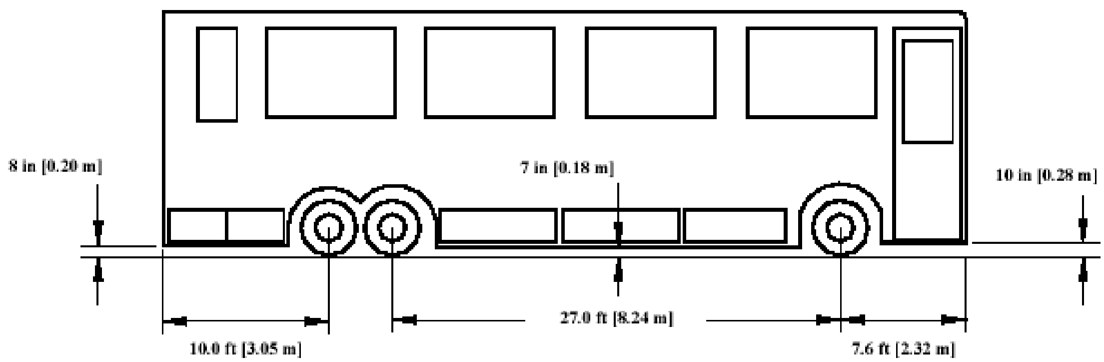


Articulated Transit Bus

Eck et al. 2002]

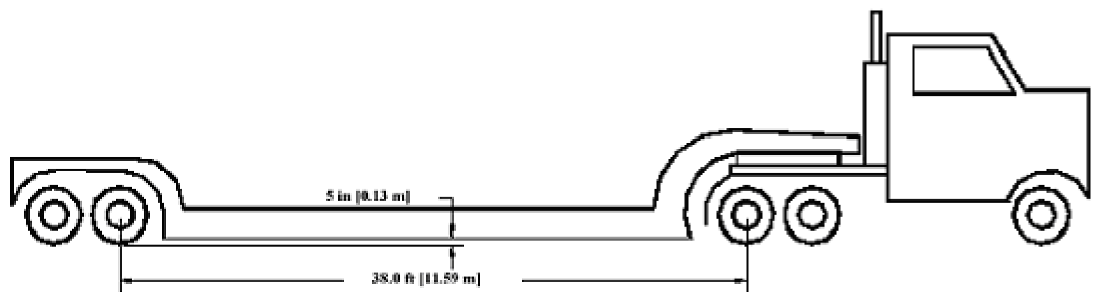
Figure C.4. Schematic Drawings of School Bus, Single Unit Transit Bus, and Articulated Transit Bus [Source: Eck et al. 2002]

Vehicle Type 12



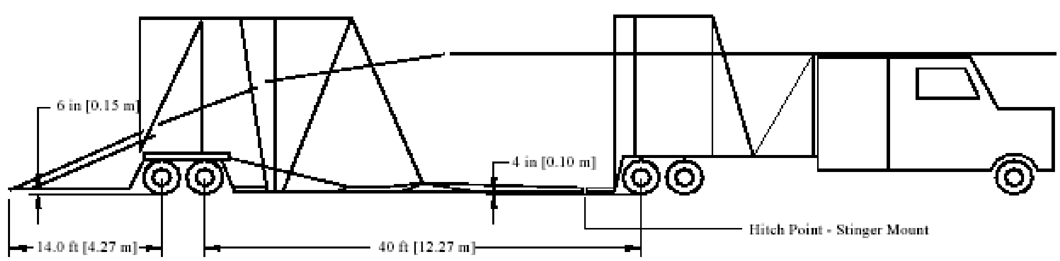
Motorcoach

Vehicle Type 13



Lowboy Trailers < 53 feet

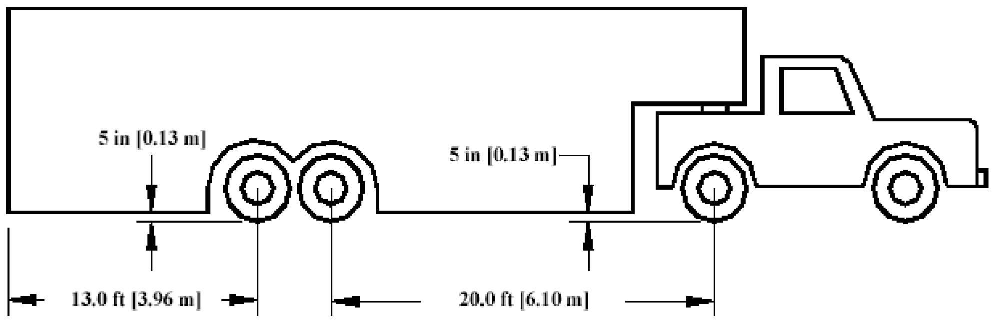
Vehicle Type 14



Car Carrier Trailer

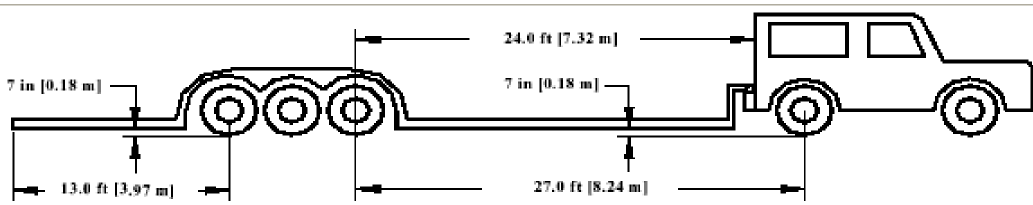
Figure C.5. Schematic Drawings of Motorcoach, Lowboy Trailers < 53 feet, and Car Carrier Trailer [Source: Eck et al. 2002]

Vehicle Type 15



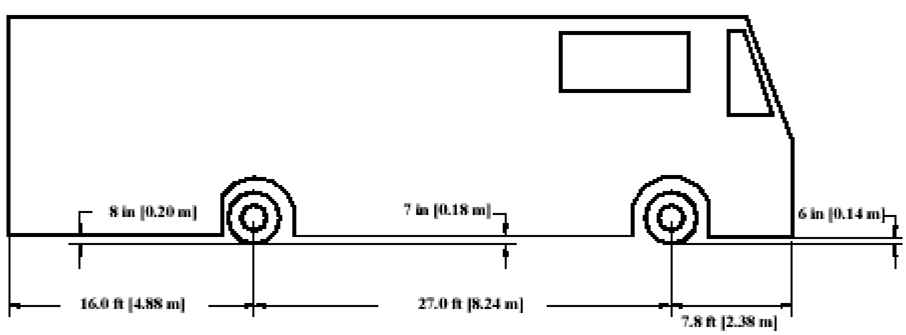
Passenger Vehicle & Trailer – Private use

Vehicle Type 16



Passenger Vehicle & Trailer – Commercial Use

Vehicle Type 17



Recreation Vehicles

Figure C.6. Schematic Drawings of Passenger Vehicle and Trailer – Private Use, Passenger Vehicle and Trailer – Commercial Use, and Recreational Vehicles [Source: Eck et al. 2002]

APPENDIX D. Geometric Survey Documentation At Crossings

Geometric Survey Documentation At Highway-Rail Grade Crossings

Sheet______of _______
Date________________

GENERAL DATA

Crossing Number____________________ Local Road Name________________________
City__________________________________ County____________________________________
FDOT Roadway ID___________________ State/US/County Route No._______________
FDOT Milepost______________________ Railroad Milepost________________________
GPS Location (Lat/Long deg.)
X-Coordinate ________________________ Y-Coordinate____________________________

Railroad Company____
Agency Conducting Survey____
Survey Party____

Crossing Status______________________ Public/Private___________________________
Crossing Condition___________________ Rideability______________________________
Skewed Tracks?_______________________ Hump Sign?_______________________________
Total No. of Roadway Lanes___________ No. of Tracks____________________________
FDOT Crossing Type (FDOT Old Index 560)____

SKETCH PLAN FOR CROSSING LOCATION

HORIZONTAL ALIGNMENT DATA

Approach Position 1 (Describe or Sketch on Plan):	
Angle of Intersection (deg.)	
Crossing Located on Highway Curve? (Yes/No)	
Tracks Superelevated? (Yes/No)	
Available Sight Distance Along Highway (Excellent/Very Good/Fair/Poor)	
Available Sight Distance Along Railroad Tracks (Excellent/Very Good/Fair/Poor)	
Tracks Parallel to Highway? (Yes/No)	
Approx. Distance to Nearest Highway Intersection (ft.)	
Approx. Distance to Nearest Highway Curve (ft.)	

Approach Position 2 (Describe or Sketch on Plan):	
Angle of Intersection (deg.)	
Crossing Located on Highway Curve? (Yes/No)	
Tracks Superelevated? (Yes/No)	
Available Sight Distance Along Highway (Excellent/Very Good/Fair/Poor)	
Available Sight Distance Along Railroad Tracks (Excellent/Very Good/Fair/Poor)	
Tracks Parallel to Highway? (Yes/No)	
Approx. Distance to Nearest Highway Intersection (ft.)	
Approx. Distance to Nearest Highway Curve (ft.)	

Approach Position 3 (Describe or Sketch on Plan):	
Angle of Intersection (deg.)	
Crossing Located on Highway Curve? (Yes/No)	
Tracks Superelevated? (Yes/No)	
Available Sight Distance Along Highway (Excellent/Very Good/Fair/Poor)	
Available Sight Distance Along Railroad Tracks (Excellent/Very Good/Fair/Poor)	
Tracks Parallel to Highway? (Yes/No)	
Approx. Distance to Nearest Highway Intersection (ft.)	
Approx. Distance to Nearest Highway Curve (ft.)	

General Remarks:

VERTICAL ALIGNMENT DATA

Approach Position 1 (Describe or Sketch on Plan) ______________________________
Grade of Tracks Plane or Superelevation (%) ______________________________
Tracks Gage (ft./ Default: 4.71 ft.) ______________________________
Length of Tracks Plane (ft./ Default: 10.00 ft.) ______________________________
Available Sight Distance Along Highway (Excellent/Very Good/Fair/Poor) ______________________________
Available Sight Distance Along Railroad Tracks (Excellent/Very Good/Fair/Poor) ______________________________
Profile Type ______________________________
Profile Scheme No. ______________________________

Profile Elevation Data: Crest Locations

Distance From Centerline of Nearest Tracks (ft.)	0.0	2.5	10.0	15.0	20.0	25.0	30.0	35.0	40.0	
Expected Relative* Elevation (in.) OPTION I	0.00	-0.06	-1.00	-2.25	-4.00	-6.24	-8.99	-12.24	-15.98	
Surveyed Relative Elevation (in.)										
Conflict (+/- in.)										
Expected Relative Elevation (in.) OPTION II**	-0.17	-0.37	-1.50	-2.66	-4.16	-5.99	-8.16	-10.66		
Surveyed Relative Elevation (in.)										
Conflict (+/- in.)										

*Based on 20 ft. vertical curves, using change A = 3.33% between tangents, assuming a 20 ft. plane at the tracks. Tracks gage assumed 5 ft.
**Based on 20 ft. vertical curves, using change A = 2.22% between tangents, assuming a 10 ft. plane at the tracks. Elevations relative to beginning of tie. Tracks gage assumed 5 ft.
With a track superelevation of e (%), use an initial tangent grade (%) of A + e.

Profile Elevation Data: Sag Locations

Distance From Centerline of Nearest Tracks (ft.)	0.0	5.0	10.0	15.0	20.0	25.0				
Expected Relative# Elevation (in.)	0.00	0.00	+0.38	+1.50	+3.38	+6.00				
Surveyed Relative Elevation (in.)										
Conflict (+/- in.)										

#Based on 20 ft. vertical curve on an initial 10 ft. long approach tangent, starting from 10 ft. beyond the nearest outer rail, with grade change A = 5.00% between tangents. Tracks gage assumed 5 ft.
With a track superelevation of e (%), use an initial tangent grade (%) of A + e.

General Remarks:

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APPENDIX D. User Manual for Computer Tools

HIGHWAY RAILROAD GRADE CROSSING EVALUATOR
XEVAL Version 1.0

USER MANUAL

1. INTRODUCTION

This computer program was written and compiled in Microsoft Visual Basic 6.0, in Microsoft Windows XP 2000 Environment, under a research grant at Florida State University, sponsored by the Florida Department of Transportation, to study the hang-up problems posed by low clearance vehicles when traversing highway railroad grade crossings, especially, hump crossings.
It is strongly recommended that the computer monitor's screen resolution be set to 1152 x 768 or more. Also, a subdirectory should be created (named c:\rail1) and the contents of the accompanying CD copied to this subdirectory. The user manual is provided here, with the use of sample screens to illustrate use of the computer program. First the basic operations of the computer program is described, then a brief description is provided for the data format required to run the program and also a simple overview of the vehicle simulation process.

2. COMPUTER PROGRAM OPERATION

With an initial login (Figure E.1), user can set protected user names and passwords. The main program is shown in Figure E.2 with several tab menus for various functions, as illustrated in Figures E.3 through E.29. The first tab option (Introduction) is just basic information about the program, seen by selecting the "About XEVAL" button. The next tab option is for The Profile Inventory option where users can look at profile database records, browse pictures, plot and review profiles. Currently, only two buttons are available – view crossing photos and plot profiles (Figures E.4 through E.12). The Network Evaluator tab option is shown in Figure E.13 but the operations for the buttons are not available at this time. The Profile Evaluator tab option for performing simulation runs of single or multiple vehicles traversing the grade crossings (Figures E.14 through E.21), considering wheelbase; the front and rear overhang evaluation are currently not available but they can be done using the inspection tools as describe later. The simulations are basically displayed in the following output formats: graphical profile plot of the entire 528 feet of roadway; a closer view of the 150 feet profile near the crossings; a planar view, i.e. no profile elevations indicated, just positions along the roadway, for 150 feet near the crossings, and the raw data of simulations results, stored in a data file that can be analyzed. The Design Analysis tab option are demonstrated in Figures E.22 and E.23 for reading the design manual (extracts of the research study methodology and user manual), and also the single vehicle simulation with the option of providing some rehabilitation such as planks or ramps or asphalt fill (Figures E.24 through E.25). The Field Inspection Tools tab options are demonstrated in Figures E.26 through E.29, for using survey point elevations at specific points to evaluate a crossing profile in the field for three vertical curve locations: 10-ft wide tracks planes on crest locations; 20-ft. wide tracks planes on crest locations; and sag locations.

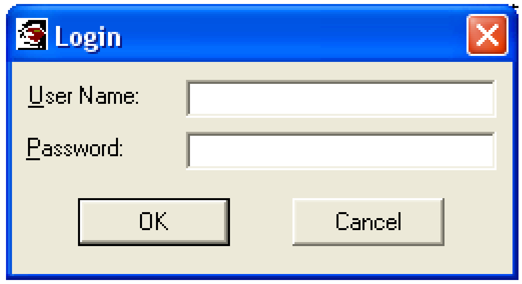


Figure E.1. User name and password screen

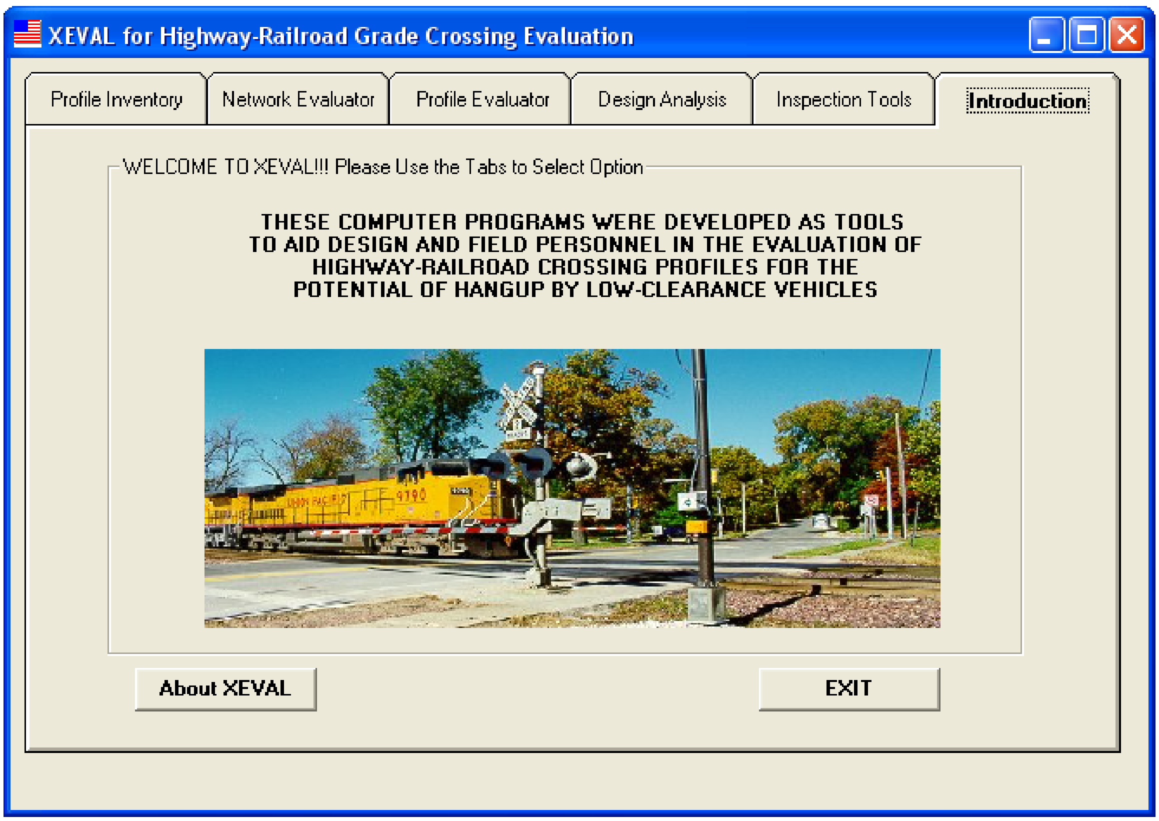


Figure E.2. Main Screen of the Program with Tab Menu Options

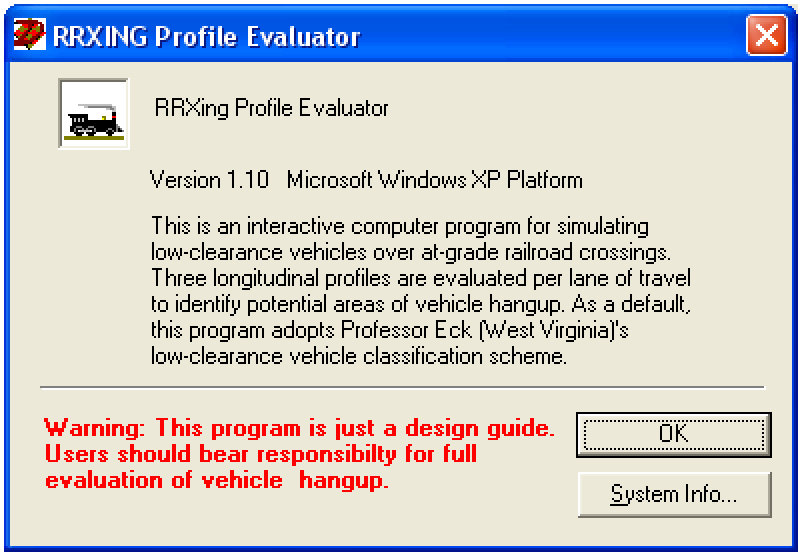


Figure E.3. General Information Computer Program (About XEVAL)

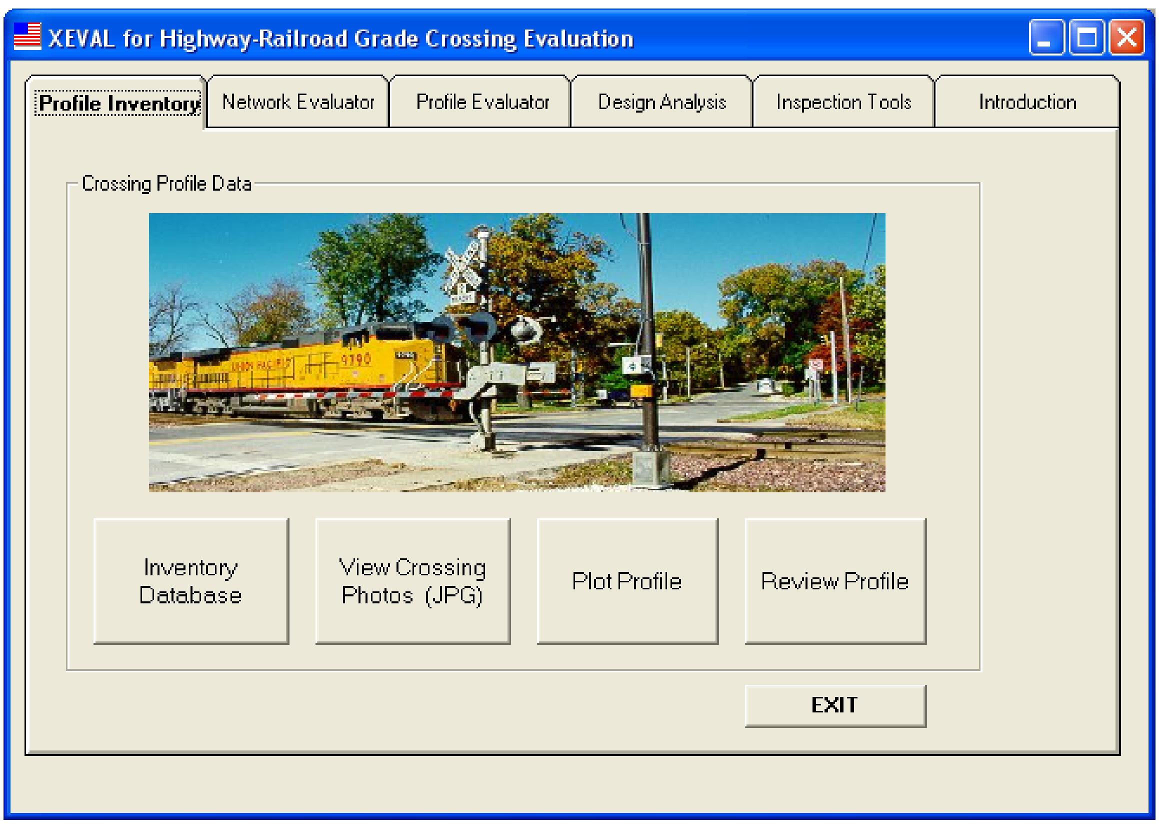


Figure E.4. Profile Inventory Options

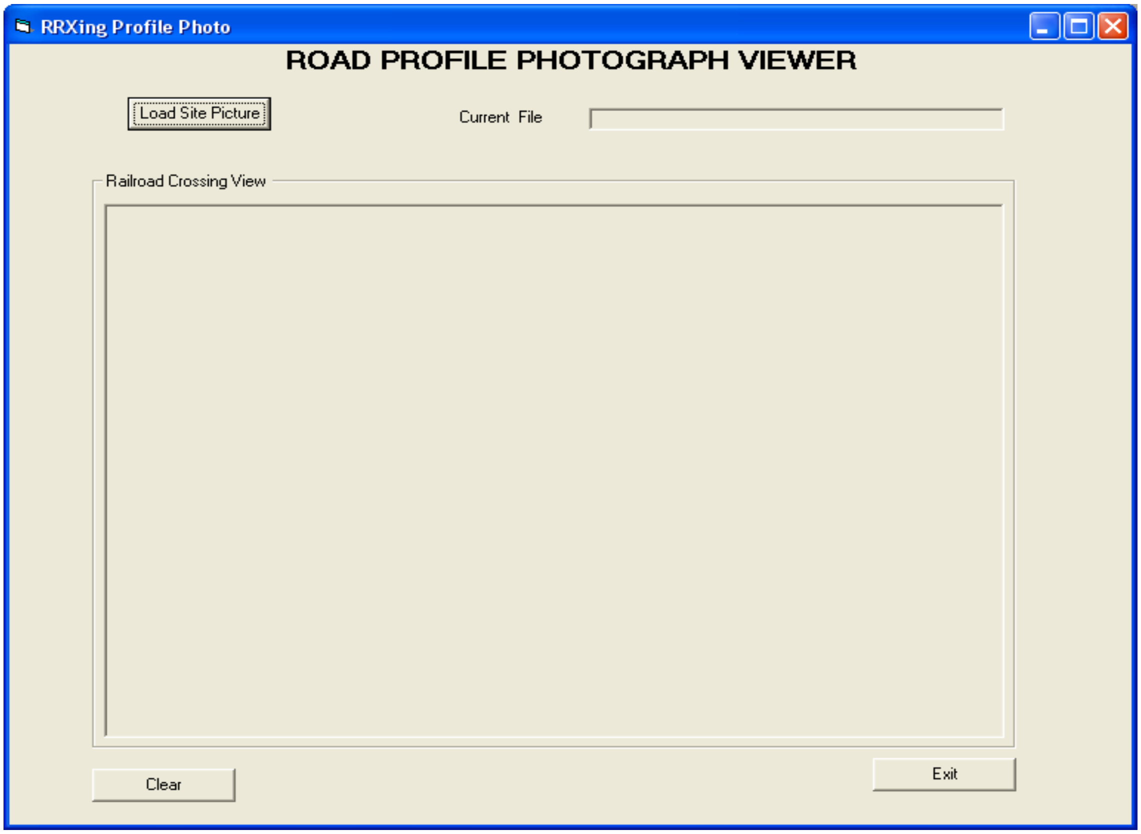


Figure E.5. Road Profile Photograph Viewer Option

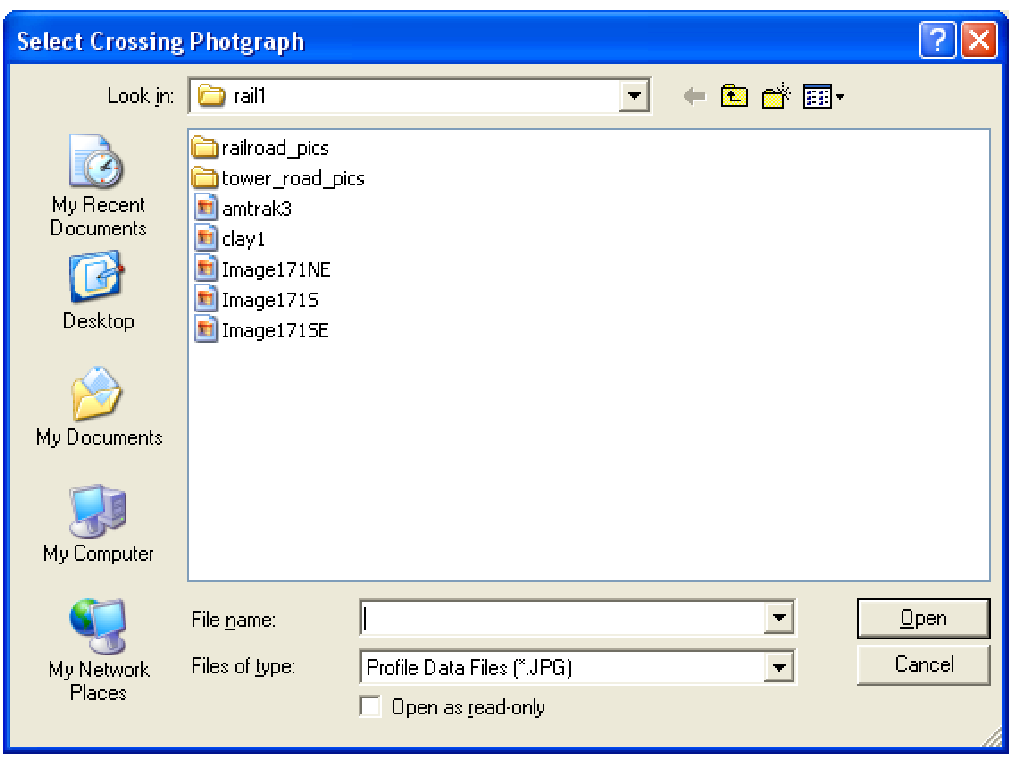


Figure E.6. Road Profile Photograph Viewer Option (Selecting File)

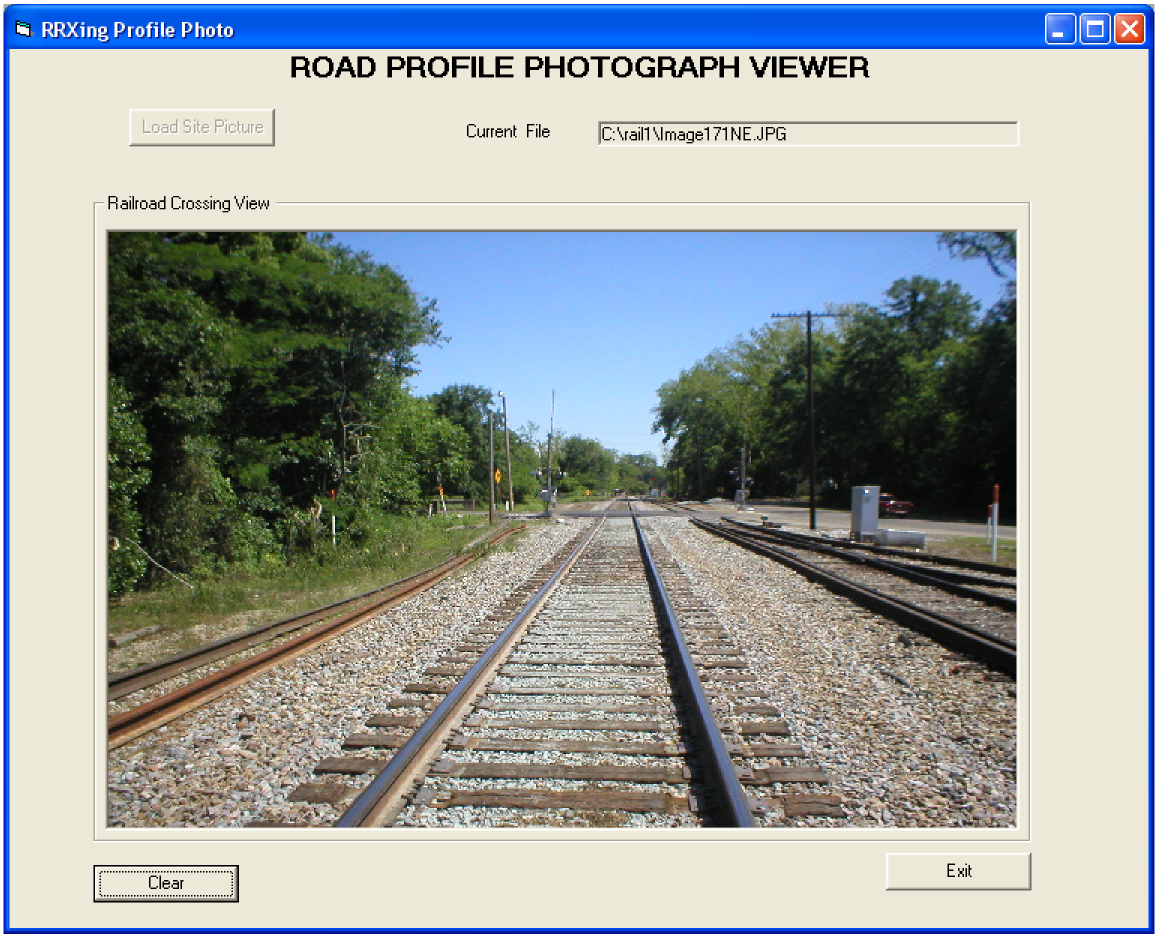


Figure E.7. Road Profile Photograph Viewer Option (Picture Inserted)

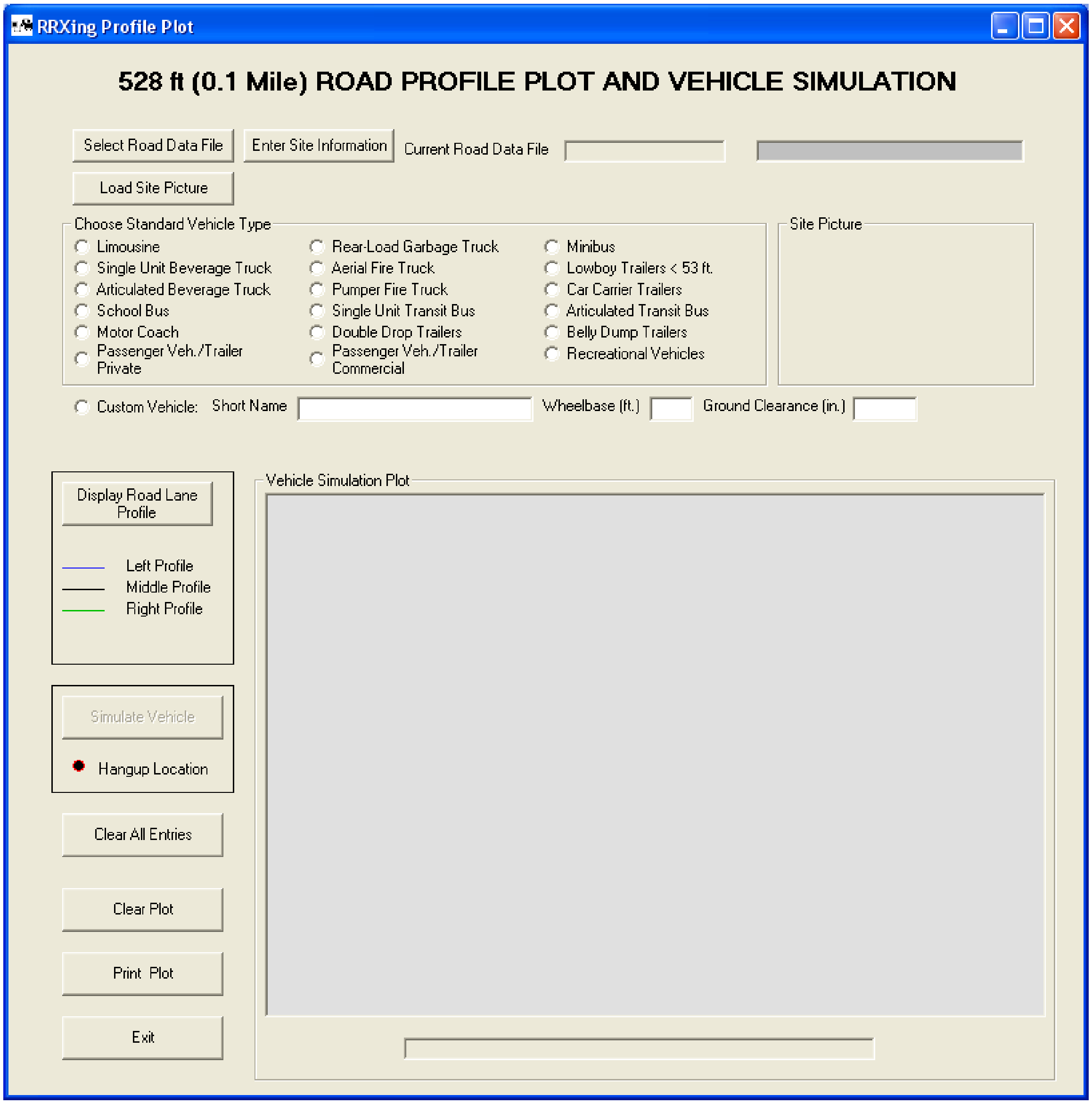


Figure E.8. Profile Plot Option

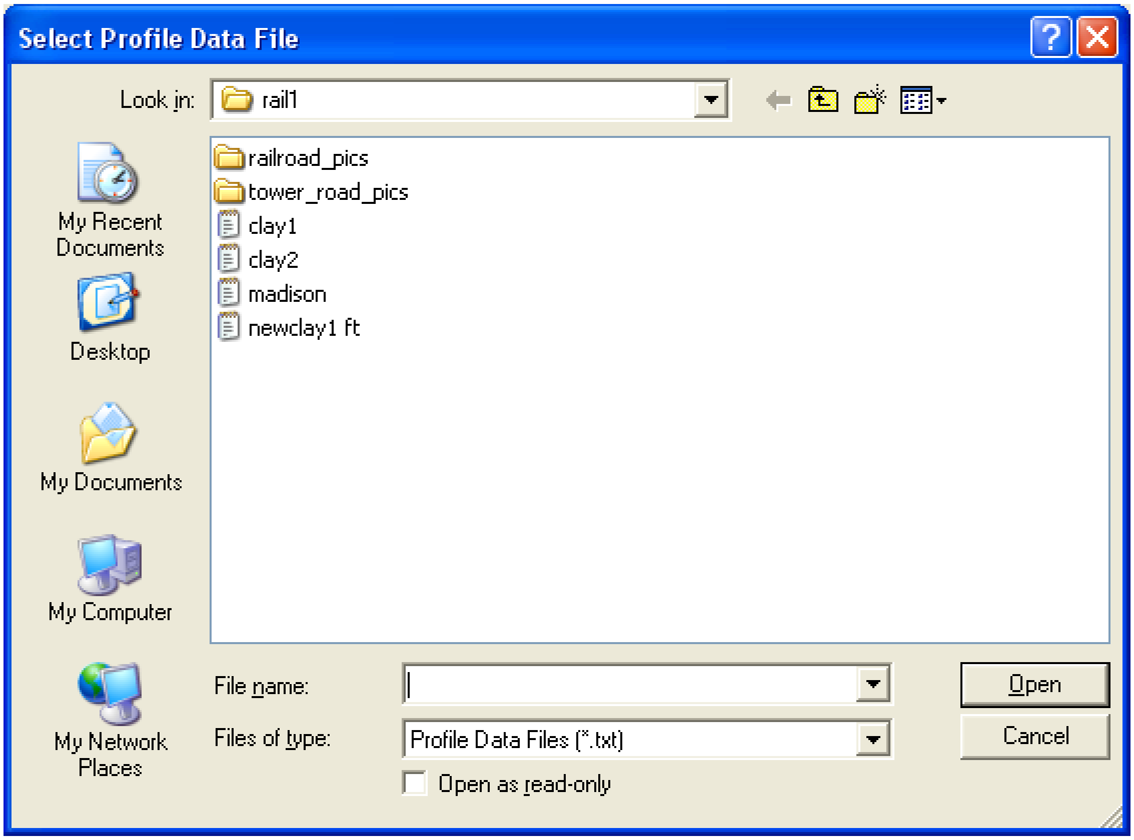


Figure E.9. Profile Plot Option (Selecting File)

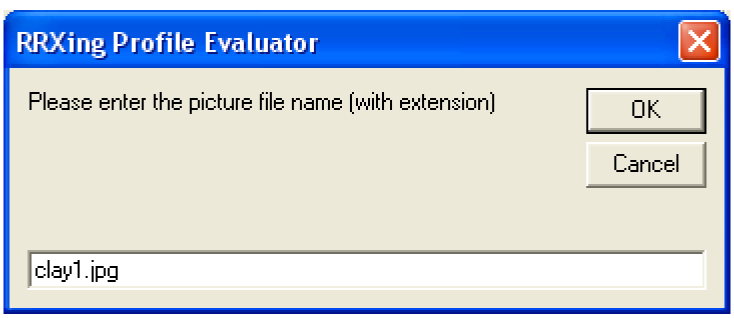


Figure E.10. Profile Plot Option (Picture Data Entry)

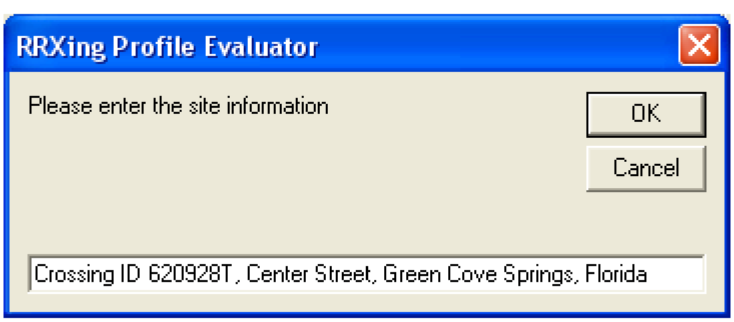


Figure E.11. Profile Plot Option (Site Data Entry)

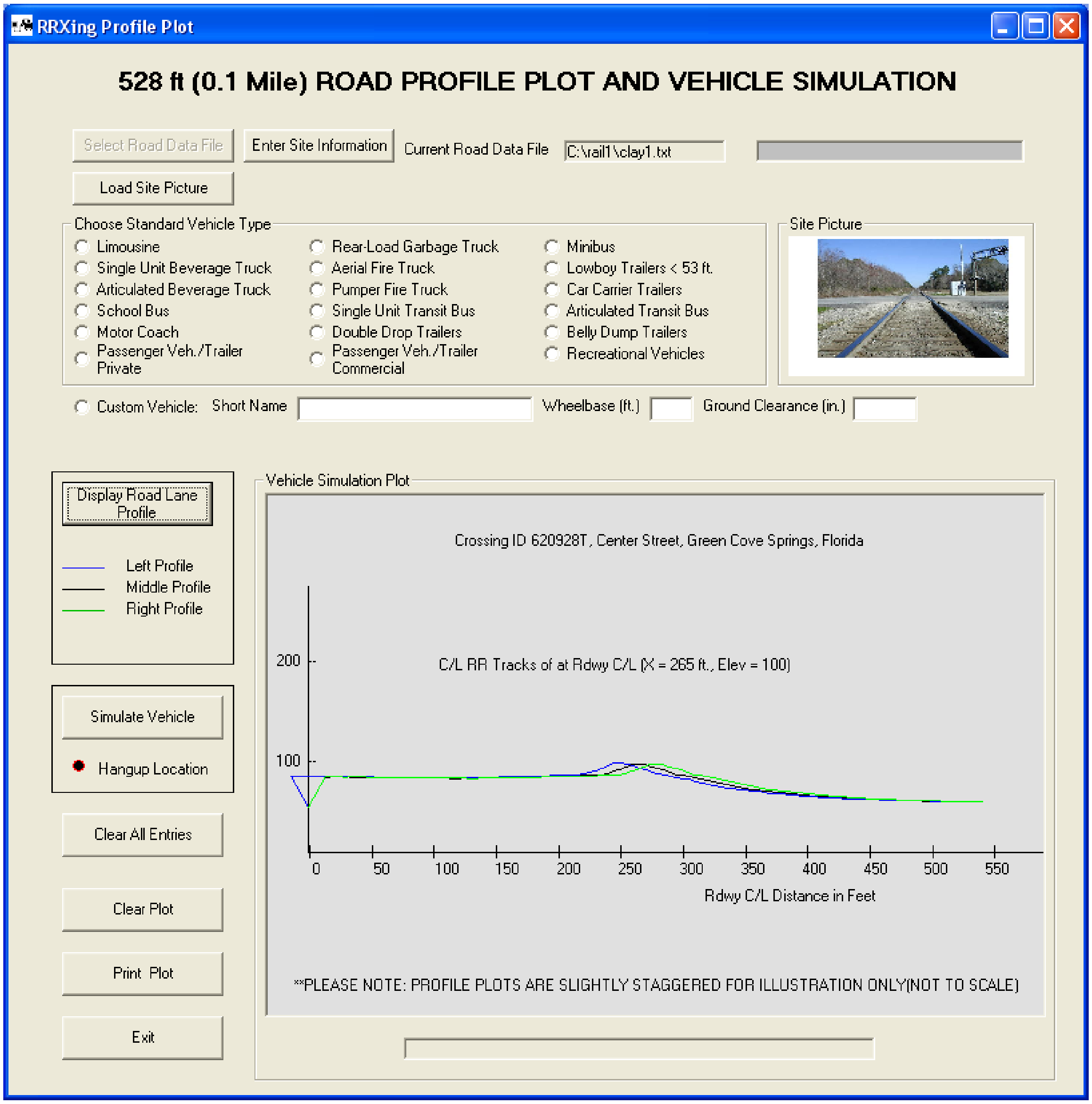


Figure E.12. Profile Plot Option for A Sample Crossing

Figure E.13. Network Evaluator Option

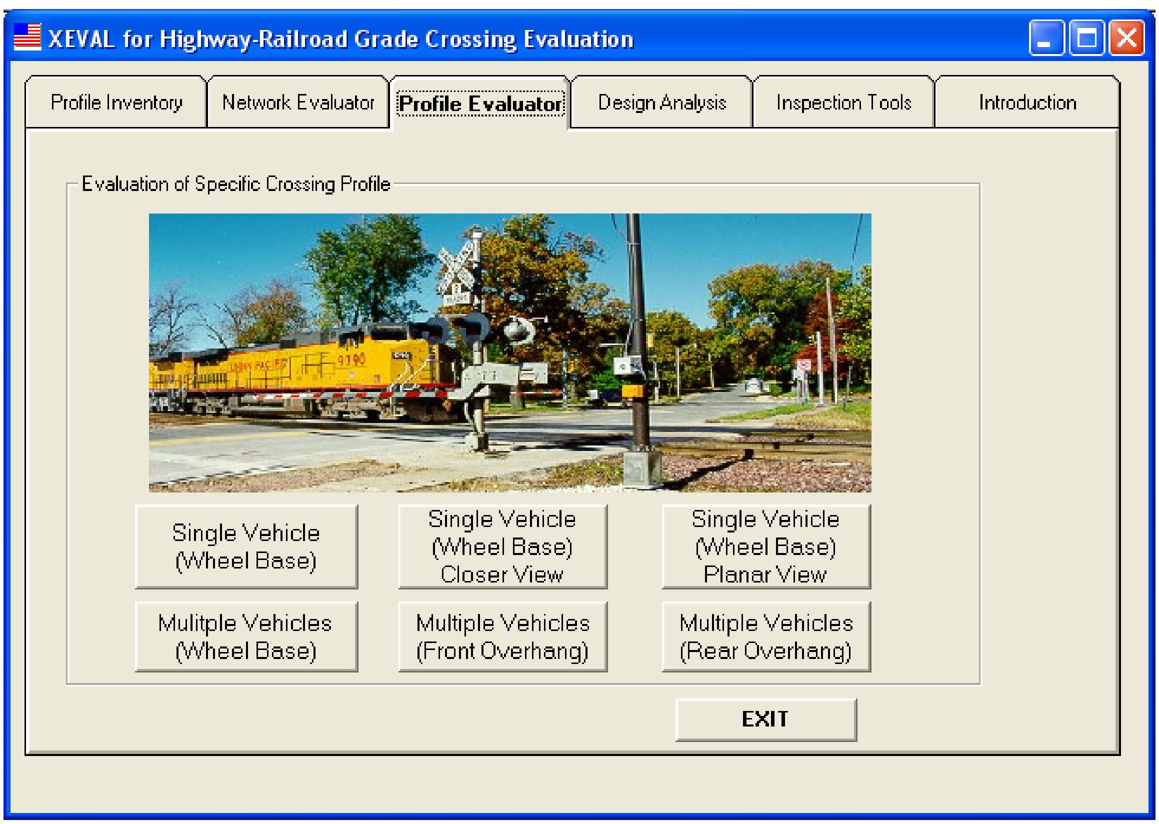


Figure E.14. Profile Evaluator Option

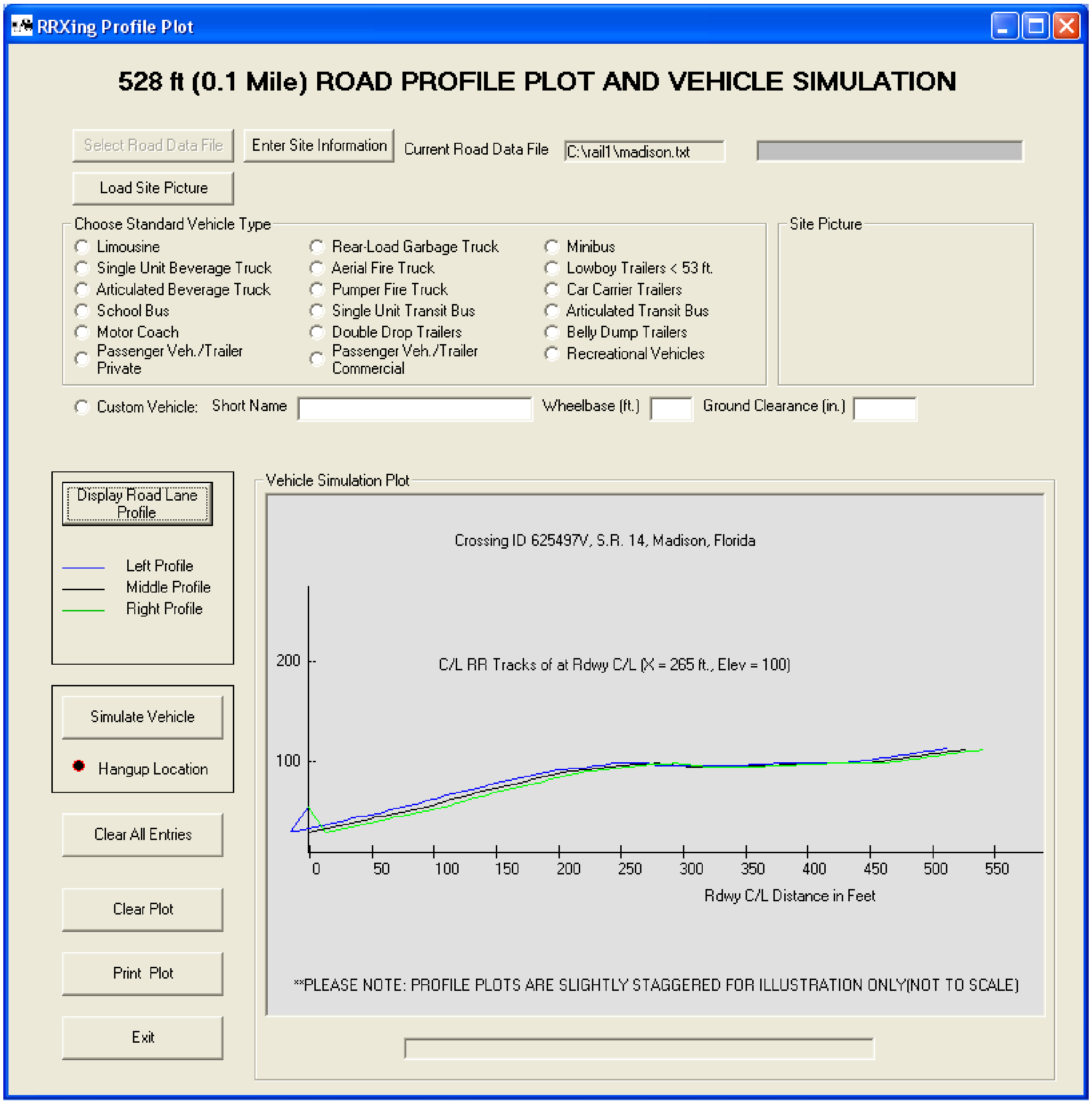


Figure E.15. Profile Evaluator Option (Single Vehicle – Wheel Base) Profile Plot Before Vehicle Simulation

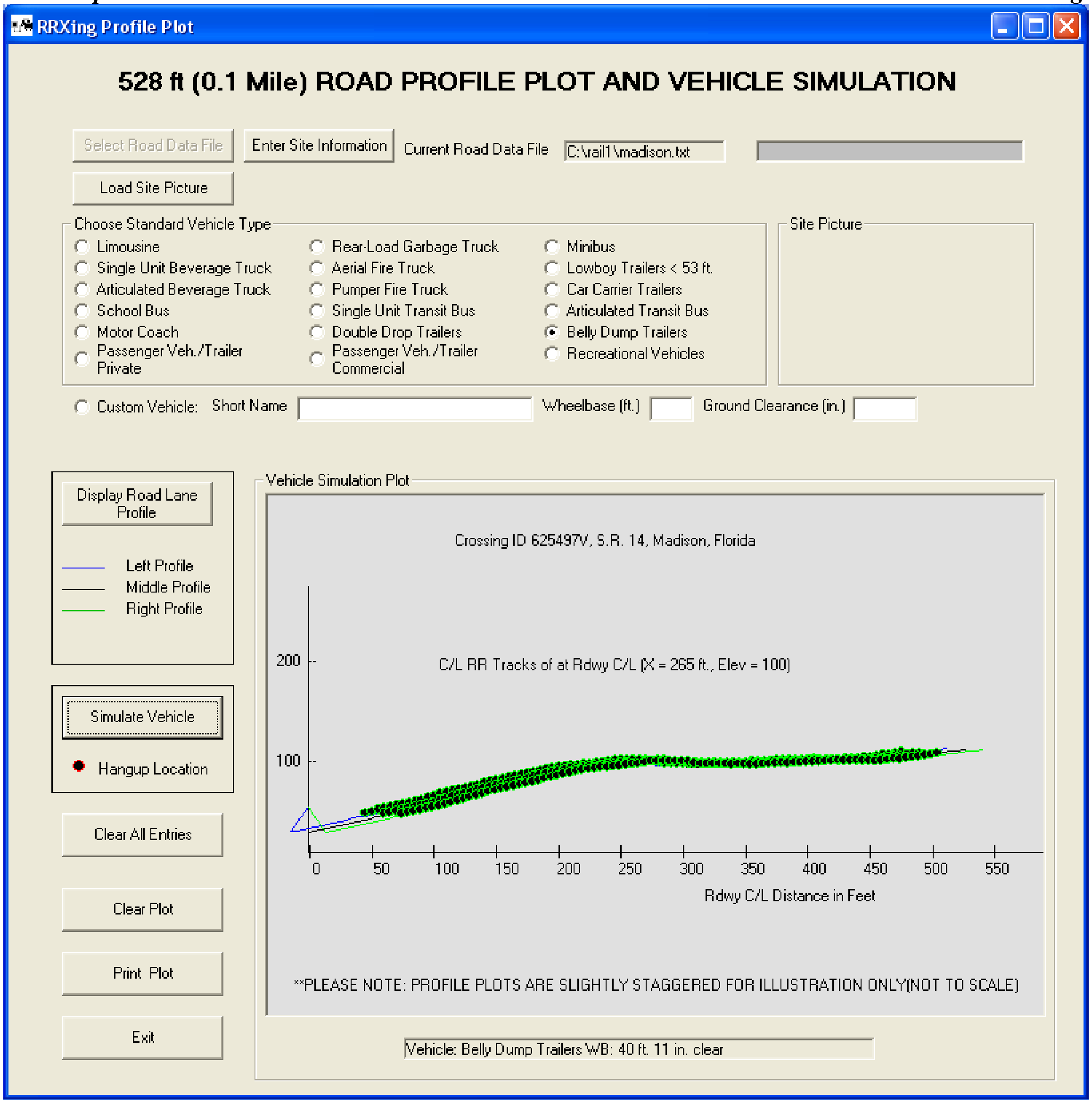


Figure E.16. Profile Evaluator Option (Single Vehicle – Wheel Base) Profile Plot After Vehicle Simulation

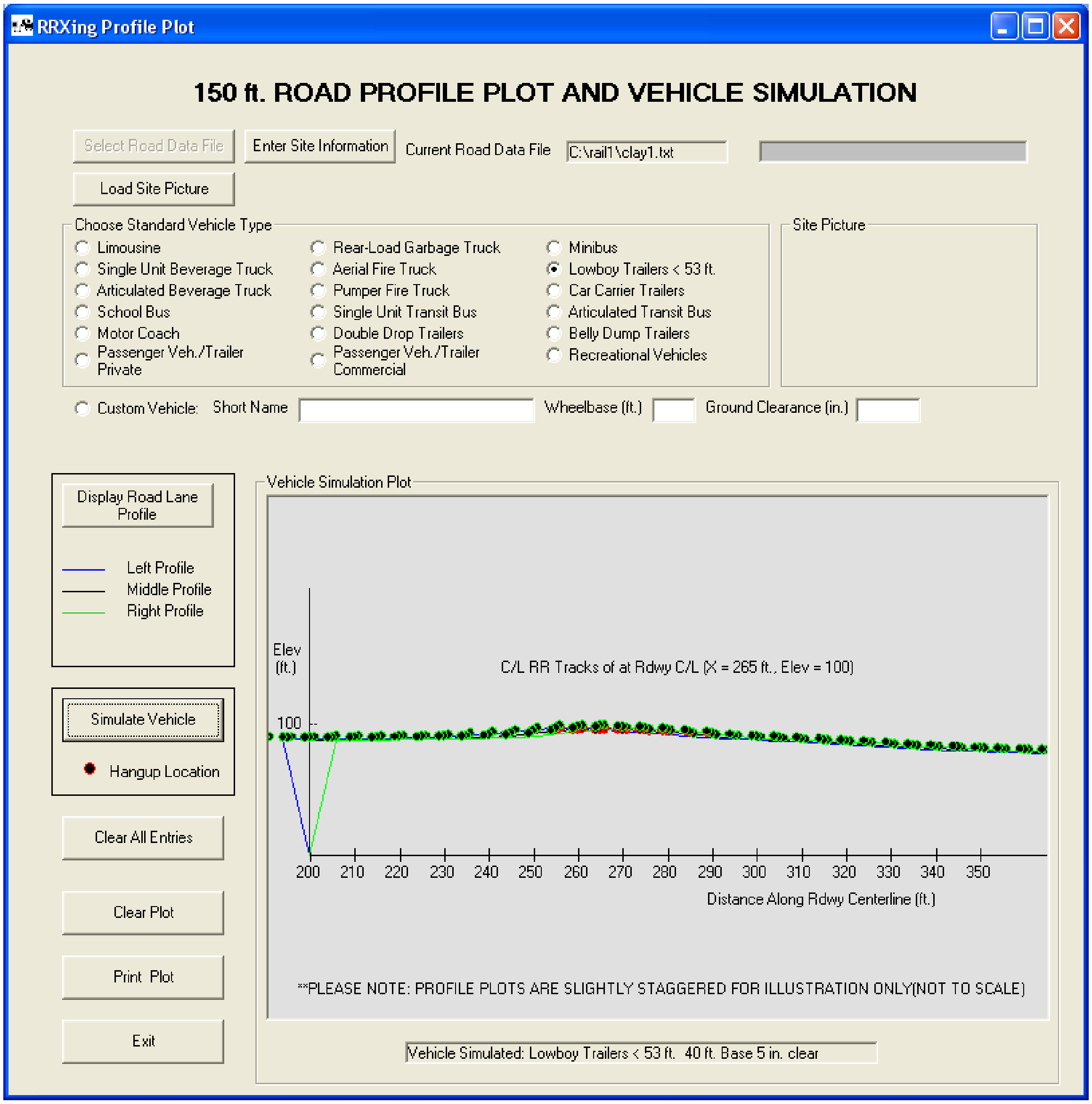


Figure E.17. Profile Evaluator Option (Single Vehicle – Wheel Base, Closer View of 150 ft.) Profile Plot After Vehicle Simulation

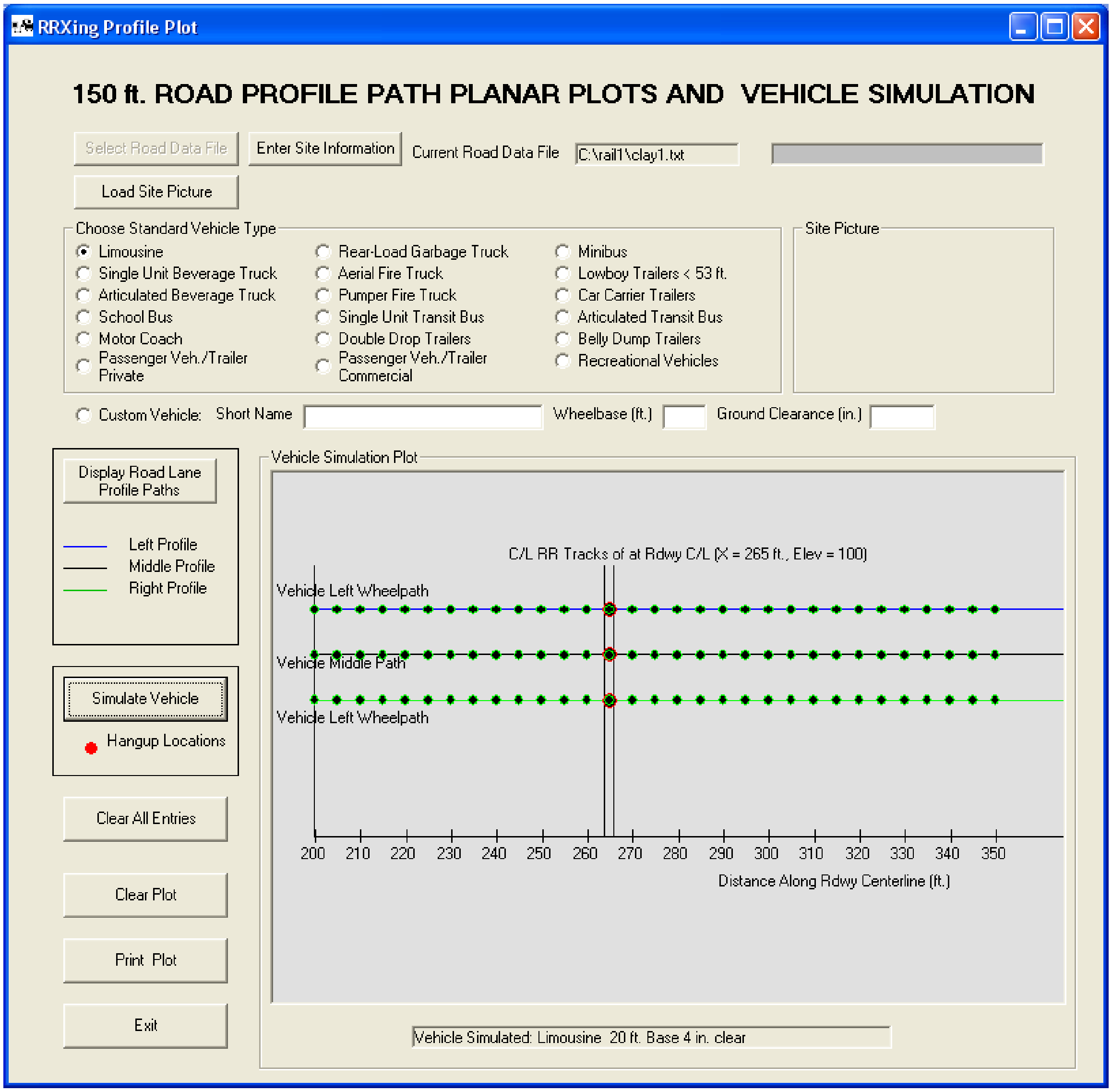


Figure E.18. Profile Evaluator Option (Single Vehicle – Wheel Base, Planar View of 150 ft.) Profile Plot After Vehicle Simulation

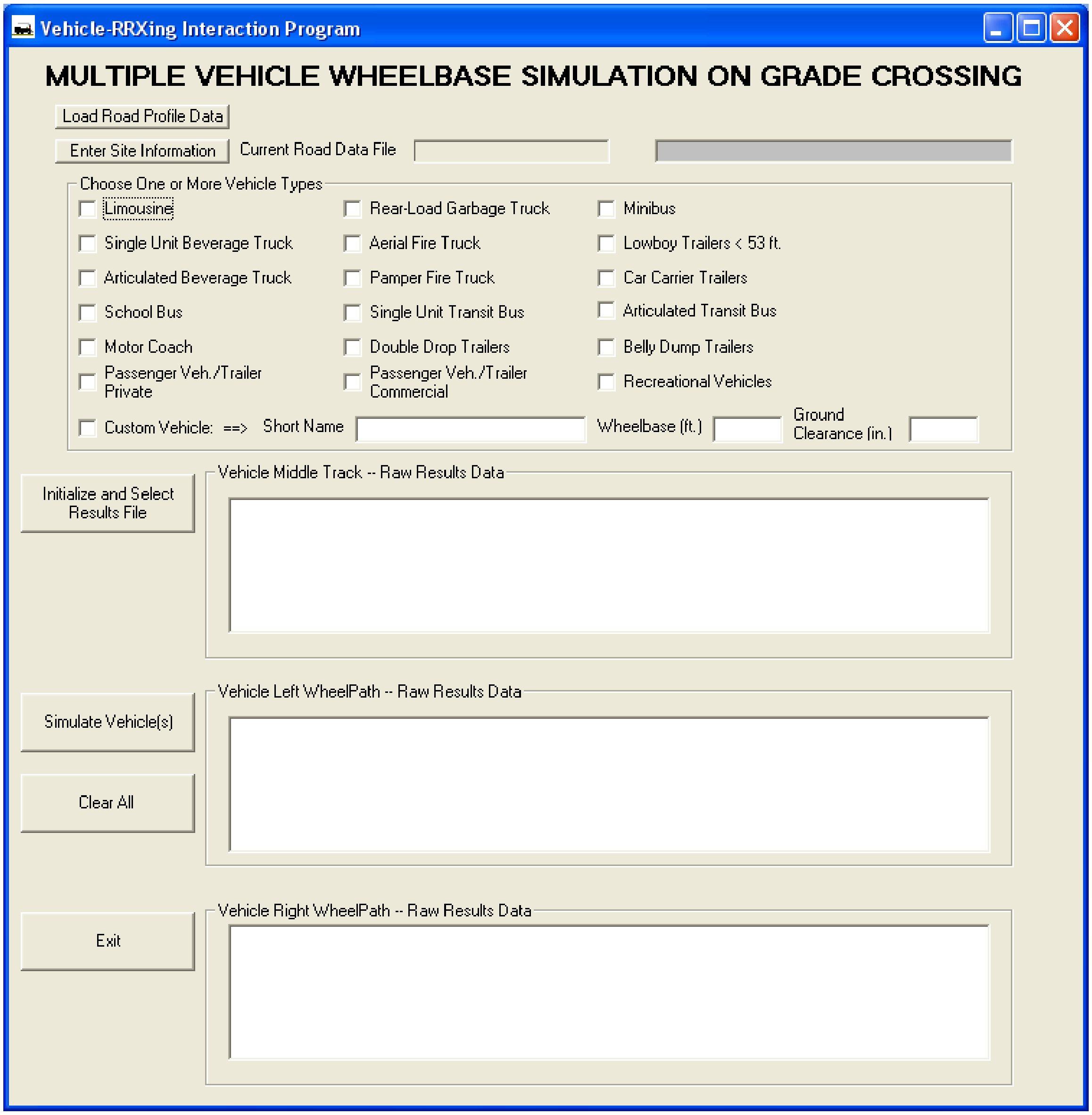


Figure E.19. Profile Evaluator Option (Multiple Vehicle – Wheel Base)

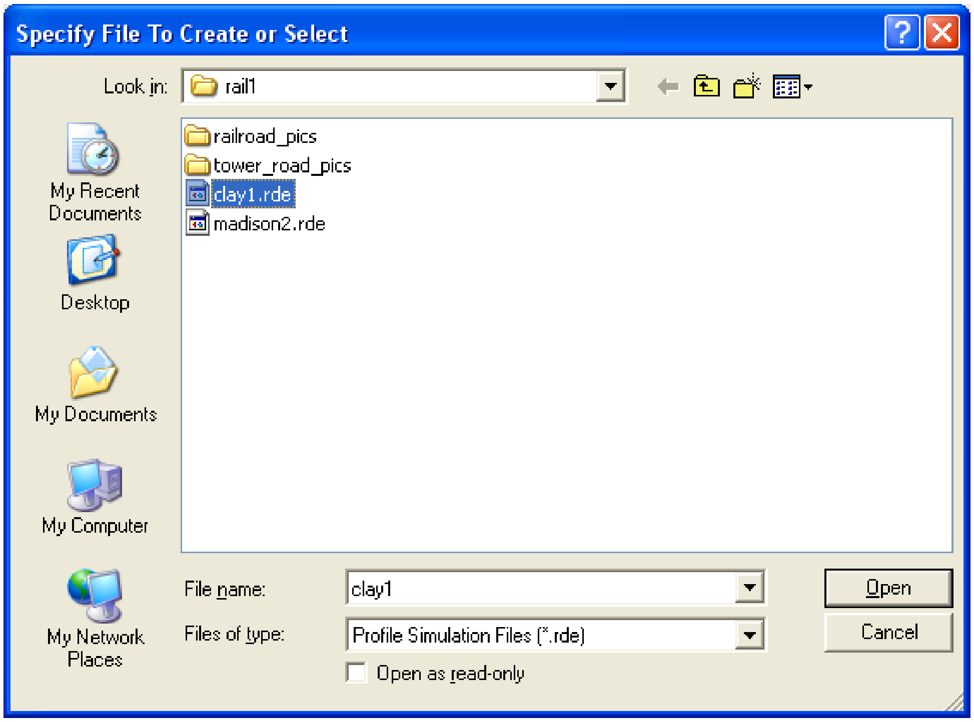


Figure E.20. Profile Evaluator Option (Multiple Vehicle – Wheel Base): Create or Select File to Store Simulation Results Raw Data

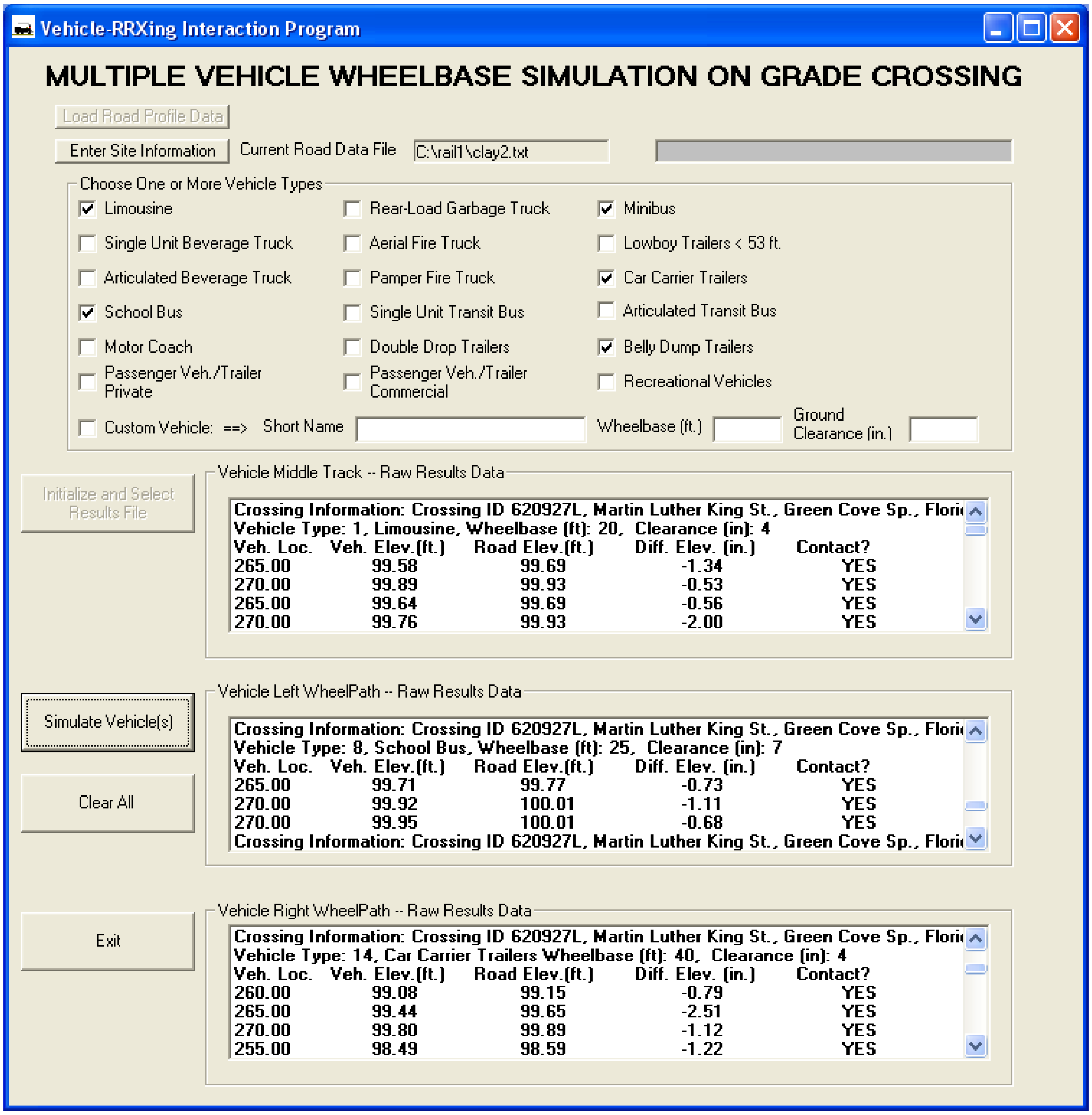


Figure E.21. Profile Evaluator Option (Multiple Vehicle – Wheel Base), with Raw Data Results After Vehicles' Simulation

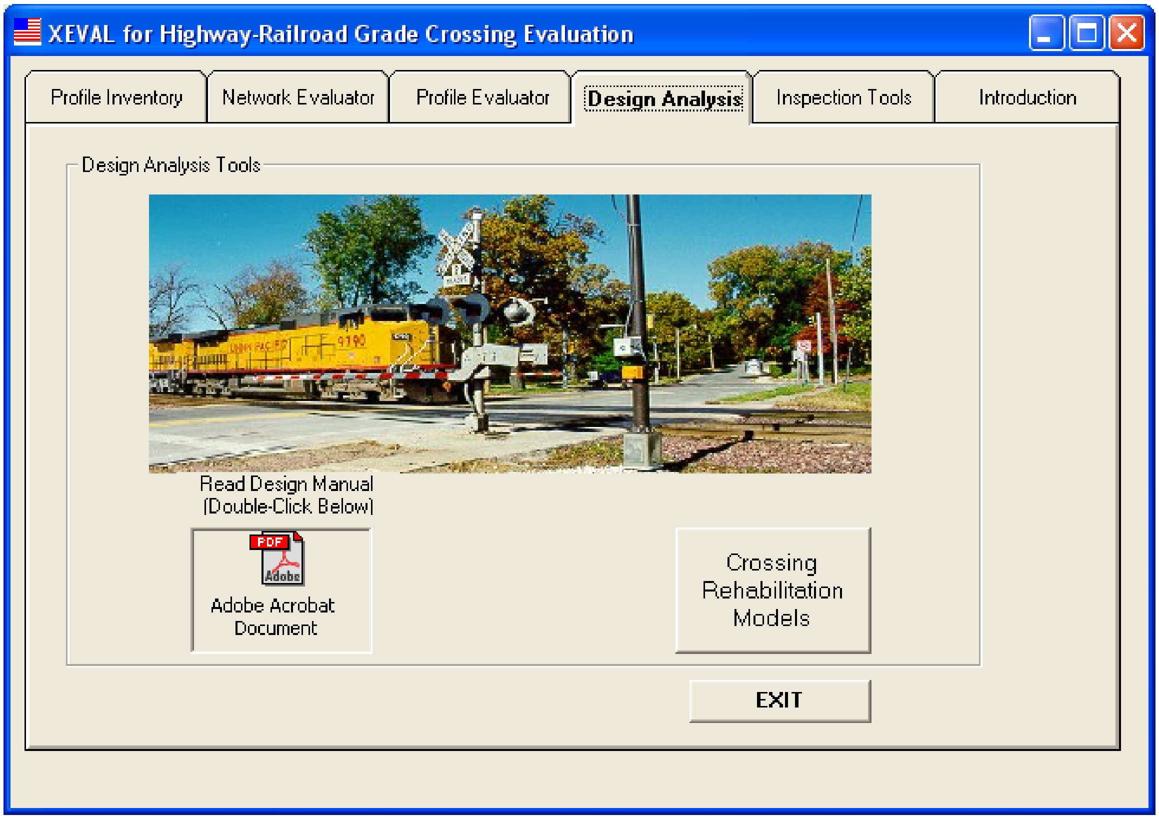
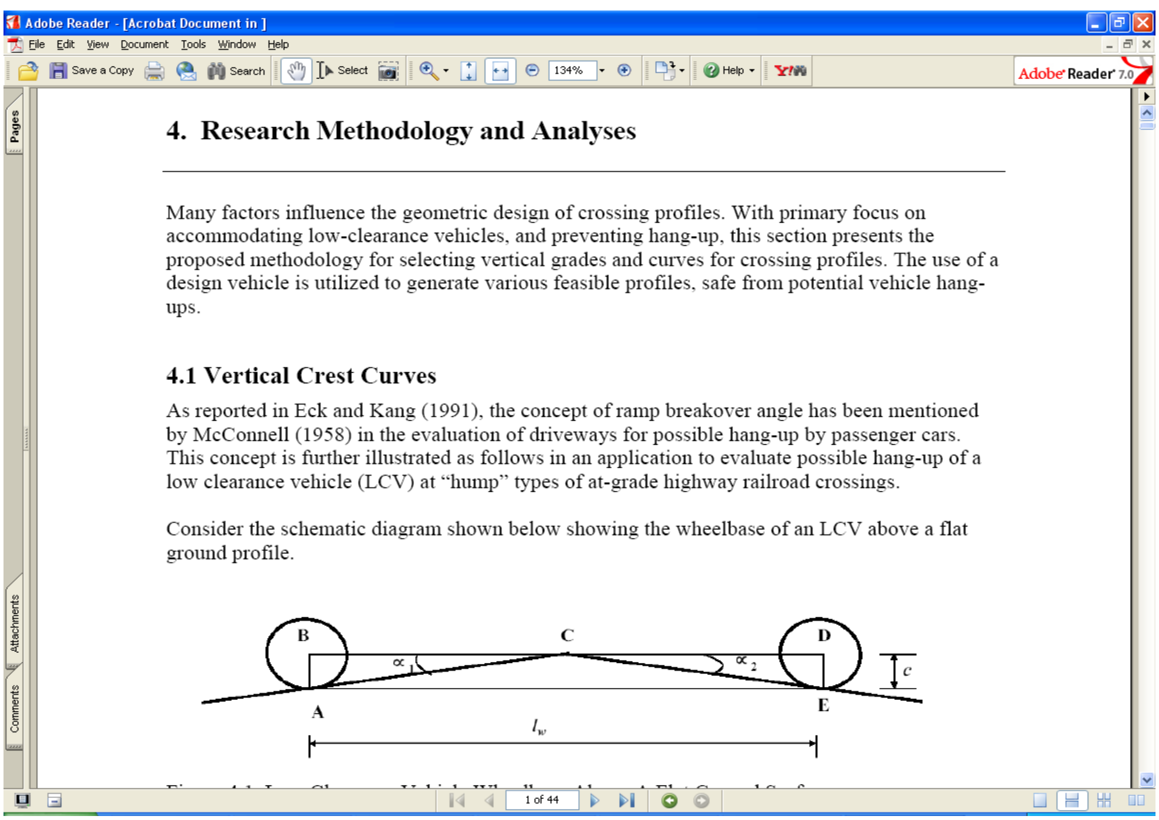


Figure E.22. Design Analysis Tools Option



4. Research Methodology and Analyses

Many factors influence the geometric design of crossing profiles. With primary focus on accommodating low-clearance vehicles, and preventing hang-up, this section presents the proposed methodology for selecting vertical grades and curves for crossing profiles. The use of a design vehicle is utilized to generate various feasible profiles, safe from potential vehicle hang-ups.

4.1 Vertical Crest Curves

As reported in Eck and Kang (1991), the concept of ramp breakover angle has been mentioned by McConnell (1958) in the evaluation of driveways for possible hang-up by passenger cars. This concept is further illustrated as follows in an application to evaluate possible hang-up of a low clearance vehicle (LCV) at "hump" types of at-grade highway railroad crossings.

Consider the schematic diagram shown below showing the wheelbase of an LCV above a flat ground profile.

Figure E.23. Design Analysis Tools Option (Design Manual – Research Report and Users Manual)

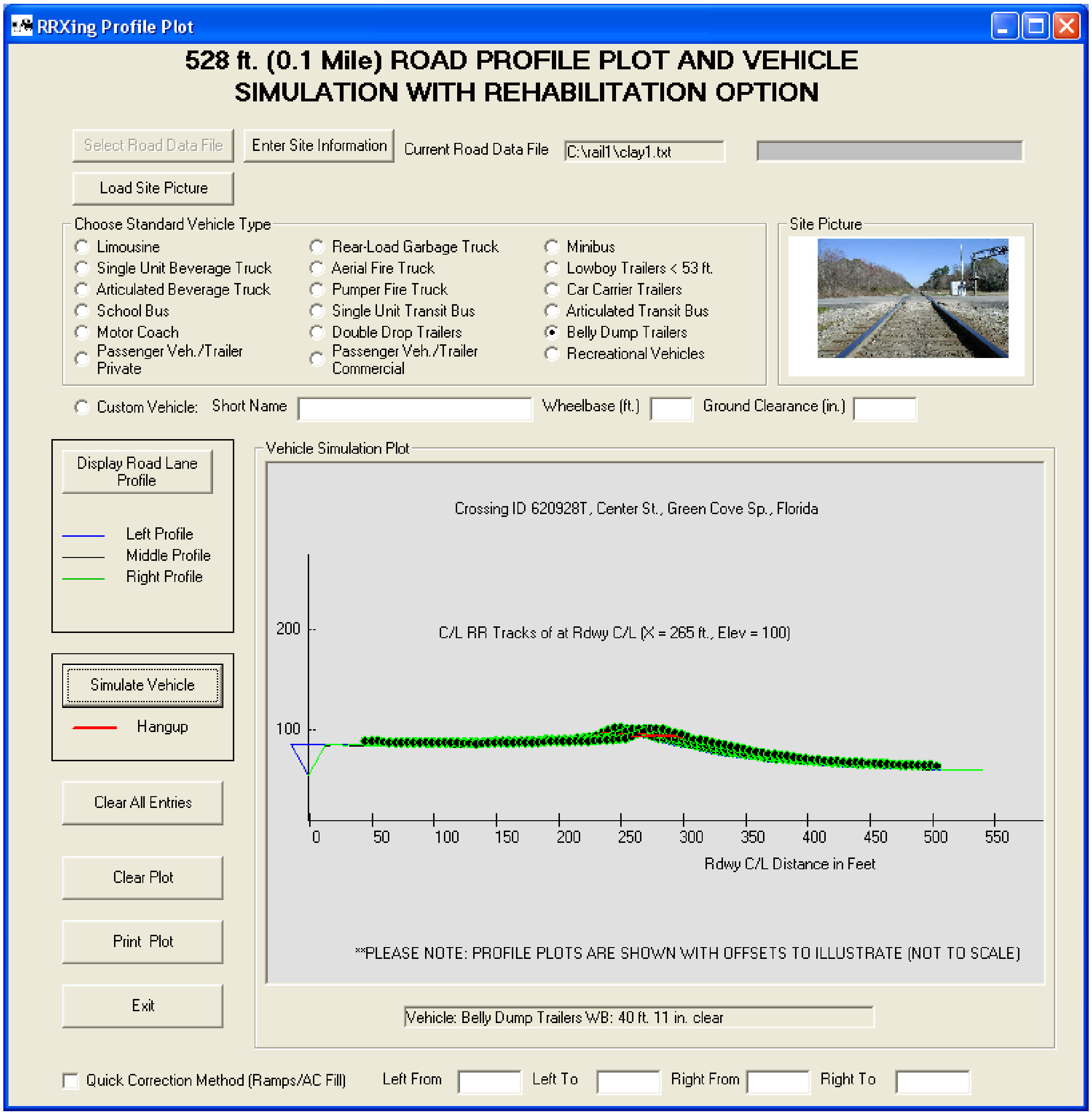


Figure E.24. Design Analysis Tools Option (Crossing Rehabilitation Models) After Single Vehicle Simulation with No Rehabilitation Provided

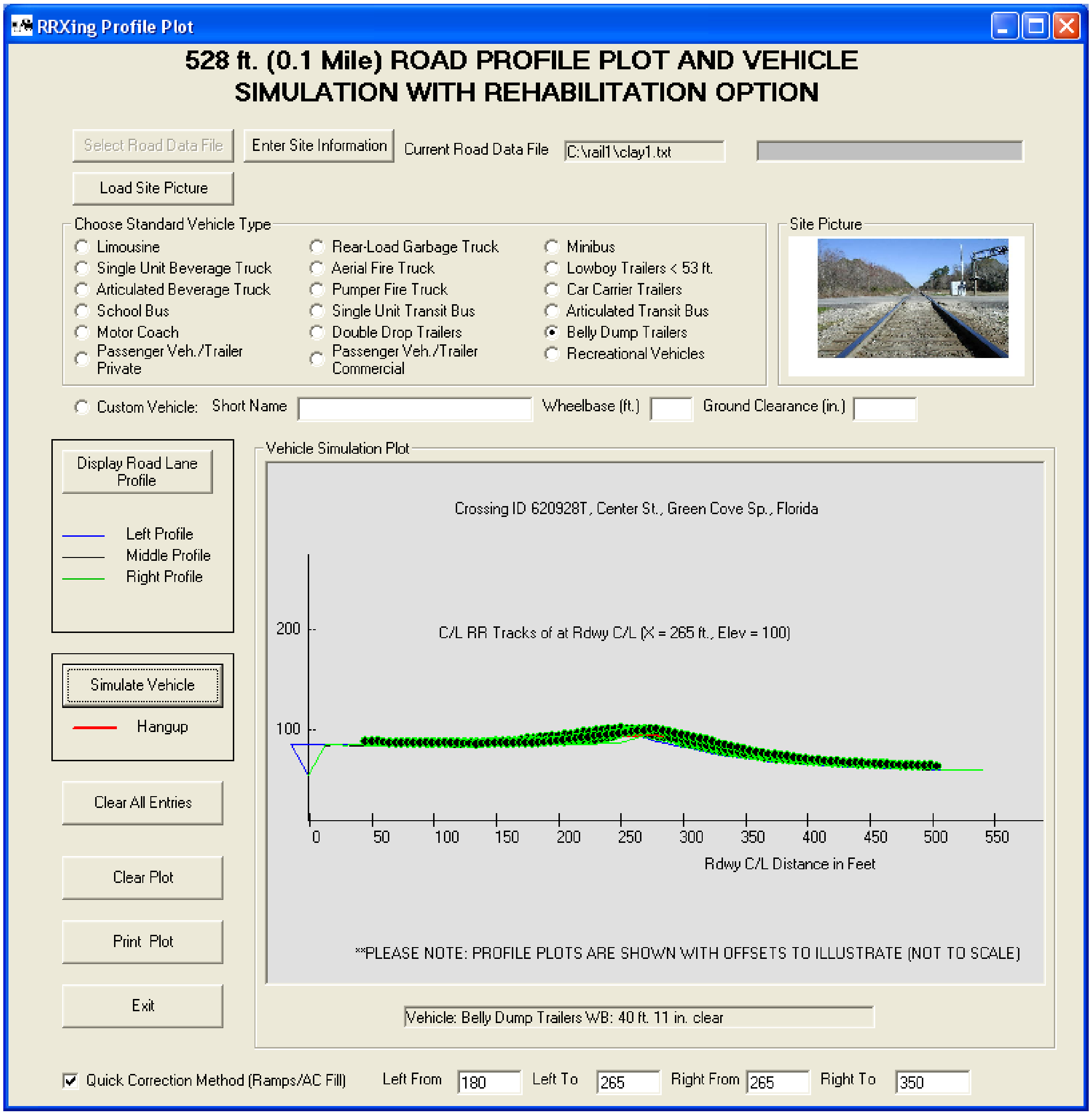


Figure E.25. Design Analysis Tools Option (Crossing Rehabilitation Models) After Single Vehicle Simulation with Ramps/AC Fill Rehabilitation Provided

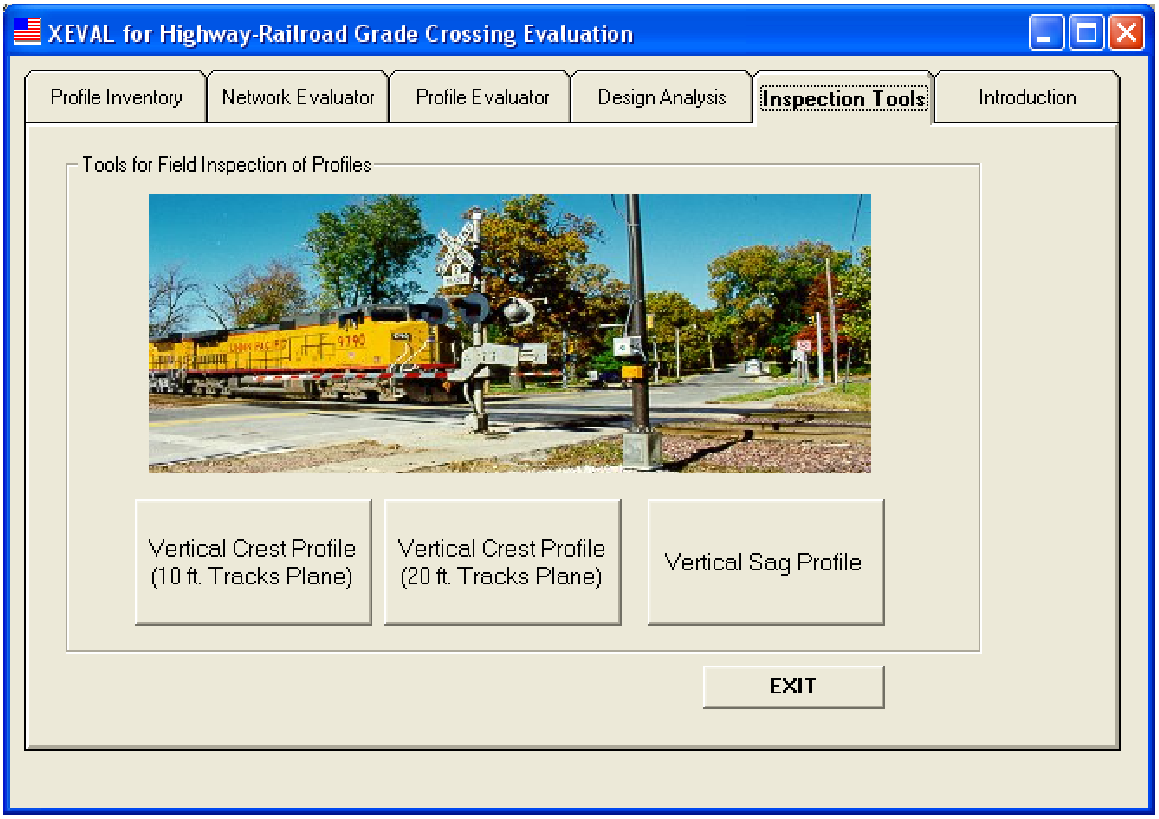


Figure E.26. Inspection Tools Option

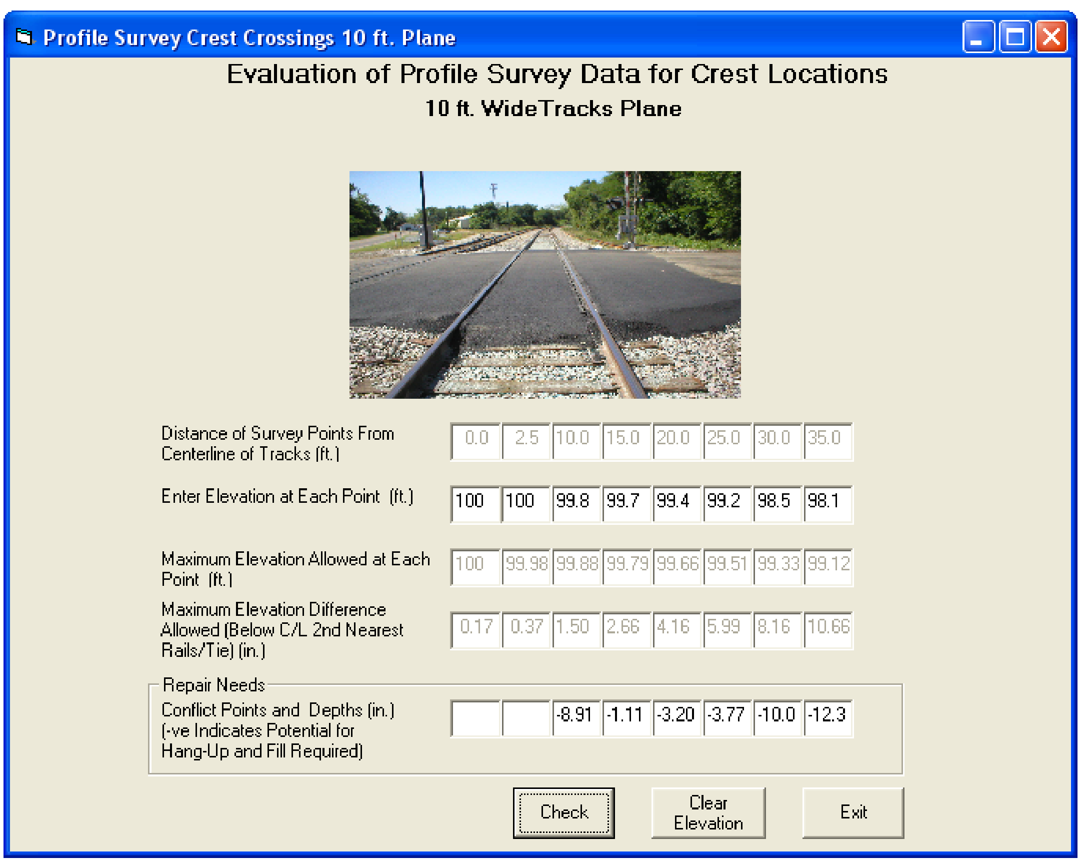


Figure E.27. Inspection Tools Option (Vertical Crest Profile – 10 ft. Tracks Plane)

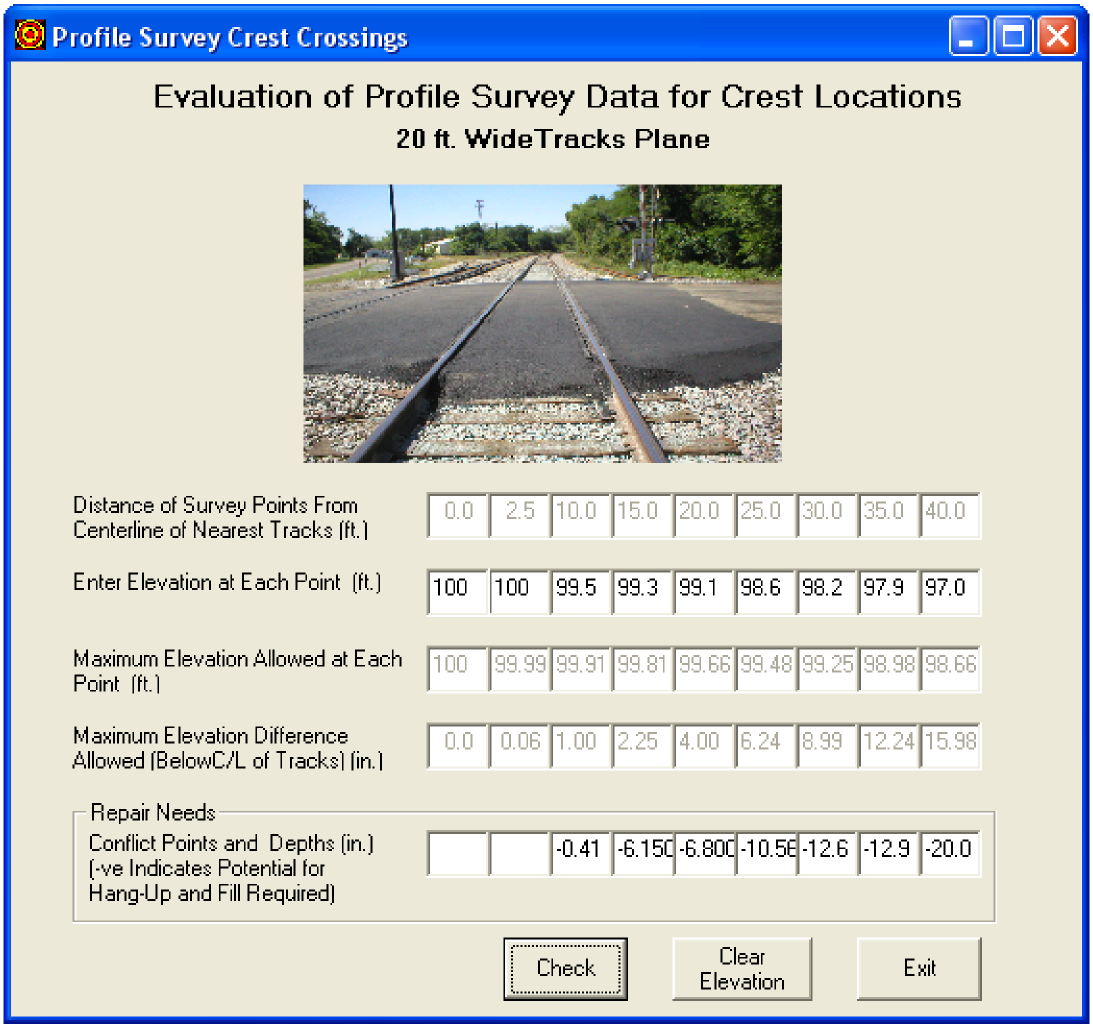


Figure E.28. Inspection Tools Option (Vertical Crest Profile – 20 ft. Tracks Plane)

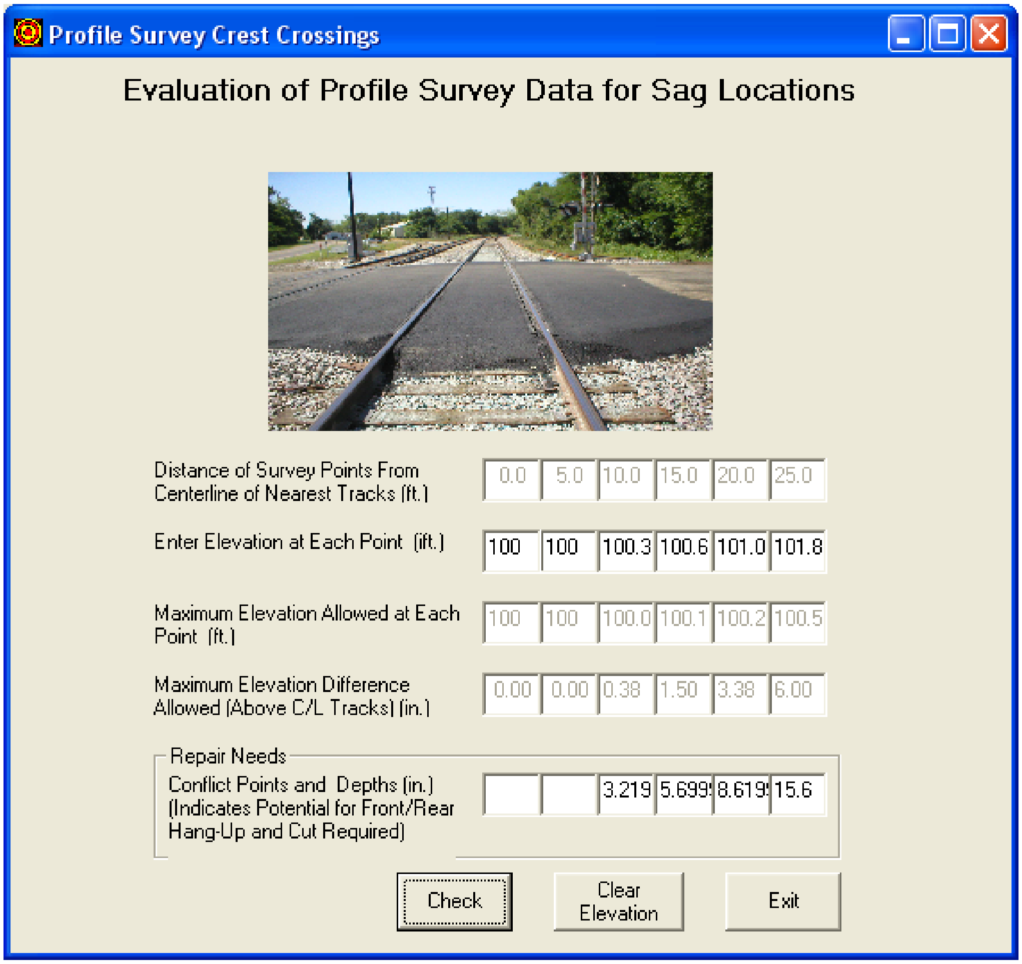


Figure E.29. Inspection Tools Option (Vertical Sag Profile)

3. OVERVIEW OF DATA INPUT AND VEHICLE SIMULATION

The survey data collected for the study was based on the roadway centerline for 528 ft. road length, with the elevation data obtained at 5 ft. intervals close to the crossing itself, but at 10 ft. intervals away from the crossings, and even at 20 ft. intervals on the far ends. To use this data, some interpolation had to be made to obtain elevations at 5 ft. intervals throughout the 528 ft. road length of data. Also, in order to generate the three road profiles (vehicle left wheel path, vehicle middle path, and the vehicle right wheel path), a roadway cross slope of 2% was assumed and utilized to estimate elevations at points two feet, 6 feet, and 10 feet respectively, from the roadway centerline (Figure E.30). It is assumed that these three points will correspond the three desired profile locations. Figure E.31 shows the sample data input for the road elevations (Crossing ID 60928T), with columns of data as follows: columns 1-10 for location along roadway (0 – 528 ft.); columns 11-20 for roadway elevation along vehicle left wheel path; columns 21-30 for roadway elevation along vehicle middle path; columns 31-40 for roadway elevation along vehicle right wheel path; columns 41-50 for roadway elevation along roadway centerline; and columns 51-53 indicating if data was from original survey or interpolated along the length of roadway.

The approach taken to simulate the vehicle along the profile is simply illustrated in Figure E.32 but the methodology for overall evaluation of the low clearance vehicles at crossing profiles, is described in the main body of this research report.

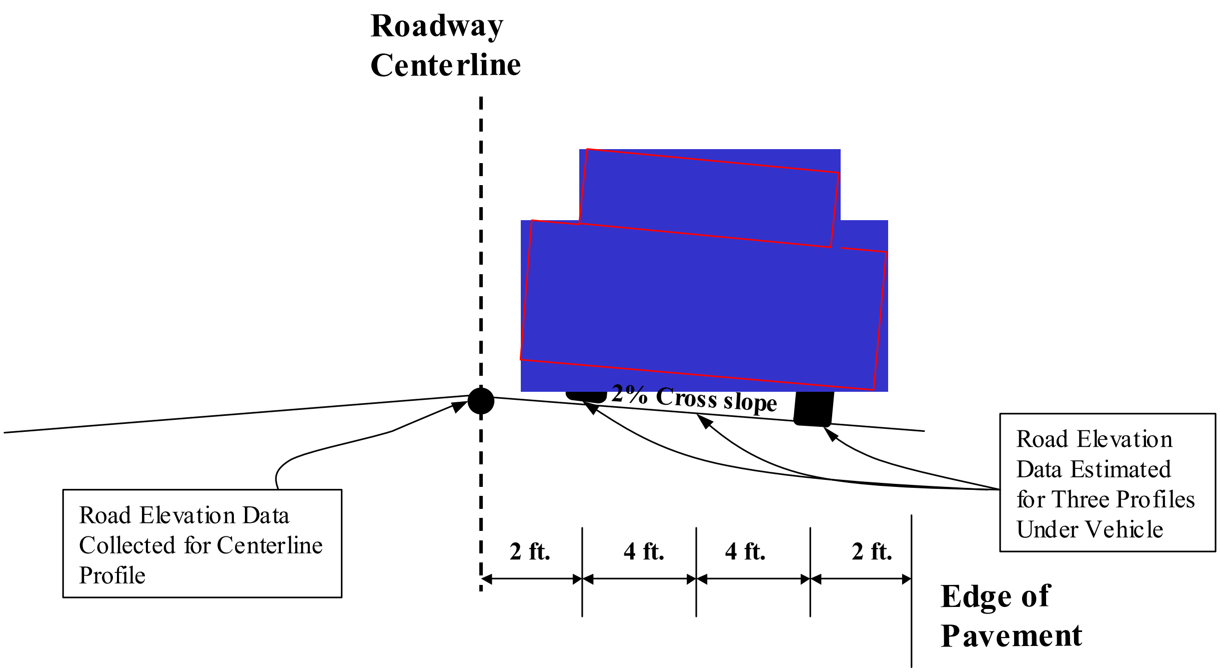


Figure E.30. Estimating Three Road Profiles Based on Cross Slope and Centerline Elevations clay1 - Notepad

File Edit Format View Help

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 10   98.19500  98.11500  98.07500  98.23500INT
 15   98.15000  98.07000  98.03000  98.19000INT
 20   98.18000  98.10000  98.06000  98.22000
 25   98.17750  98.09750  98.05750  98.21750INT
 30   98.17250  98.09250  98.05250  98.21250INT
 35   98.16500  98.08500  98.04500  98.20500INT
 40   98.17000  98.09000  98.05000  98.21000
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 50   98.14000  98.06000  98.02000  98.18000INT
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 70   98.08000  98.00000  97.96000  98.12000INT
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 80   98.05000  97.97000  97.93000  98.09000
 85   98.04750  97.96750  97.92750  98.08750INT
 90   98.04500  97.96500  97.92500  98.08500INT
 95   98.04250  97.96250  97.92250  98.08250INT
100   98.04000  97.96000  97.92000  98.08000
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115   97.97250  97.89250  97.85250  98.01250INT
120   97.95000  97.87000  97.83000  97.99000
125   98.00000  97.92000  97.88000  98.04000INT
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145   98.03000  97.95000  97.91000  98.07000INT
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205   98.26000  98.18000  98.14000  98.30000
210   98.30000  98.22000  98.18000  98.34000
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265   99.96000  99.88000  99.84000 100.00000
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a. Beginning Sections of Road Data

clay1 - Notepad

File Edit Format View Help

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410   95.51500  95.43500  95.39500  95.55500INT
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425   95.33500  95.25500  95.21500  95.37500INT
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475   94.98500  94.90500  94.86500  95.02500INT
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490   94.91500  94.83500  94.79500  94.95500INT
495   94.89250  94.81250  94.77250  94.93250INT
500   94.87000  94.79000  94.75000  94.91000
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510   94.83000  94.75000  94.71000  94.87000
515   94.81000  94.73000  94.69000  94.85000INT
520   94.79000  94.71000  94.67000  94.83000
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b. Ending Sections of Road Data

Figure E.31. Input Road Data File for Crossing ID 620928T

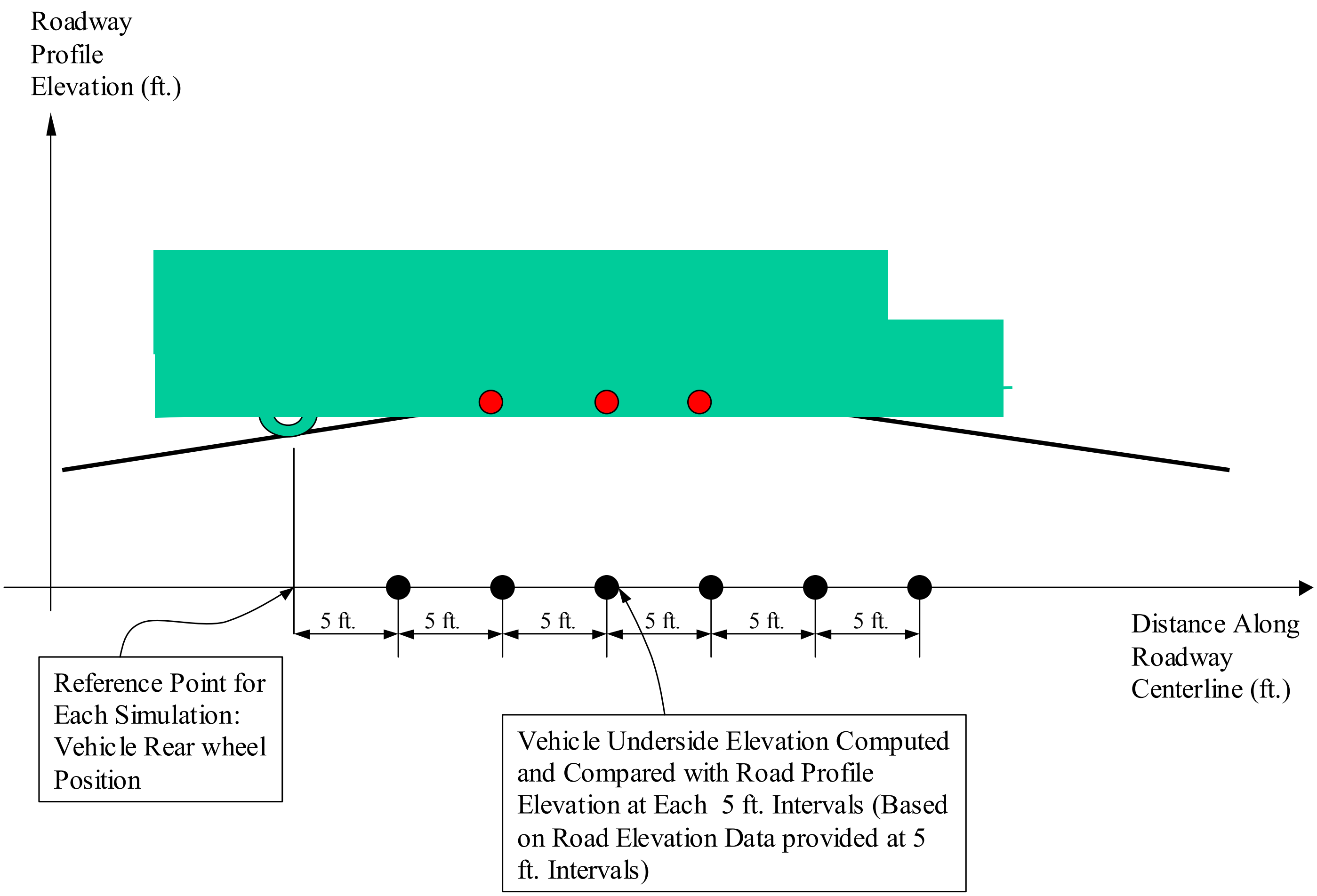

Figure E.32. Basic Steps in the Simulation of Vehicle Across Highway Railroad Crossing